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LOT 14: Domestic Washing Machines and Dishwashers

Final Report

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Tasks 6 - 7

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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.

0 Brief summary of the Study Tasks

A summary of the tasks included in this third part of the final report on the cold appliances study (tasks 6-7) is outlined in the following paragraphs

0.1 DESCRIPTION OF TASK 6

0.1.1 Subtask 6.1: Options, associated improvement, costs and impacts

First step is the identification of a list of design options to be applied to the base case models. To this end the information about possible options provided by the GEA 1995 study (for dishwashers and washing machines) and the WASH-2 study (for washing machines) will be analysed. Additional options will be defined through experts and stakeholders consultation and possibly further literature survey (mainly for the options not yet ready to be applied to the market).

The aim is to evaluate which of the already known options have been successfully applied to wash appliances and to what extent (i.e. to the overall amount of models or to a fraction of the production), and which new options can be added to the list. Each option will be described in detail. Should more than one base case be chosen, it is possible that not all the options can be applied to all base case models. Therefore, if necessary, the initial option list will be focused on each base case model.

After the consolidation of the options list(s), the associated environmental improvement (mainly decrease in energy/water consumption, but also noise decrease and detergent consumption) and the increase in consumer price (of the improved model) will be defined for each single option when applied to the base case. Environmental improvement and prices will be collected through the updating of the literature data and a large experts and stakeholders consultation.

The quantitative assessment of the environmental improvement per option will be performed using the EuP EcoReport methodology and software. Starting from the inventory improved data, a LCA using SimaPro6 will be also performed, taking advantage of the environmental balance data and the evaluation methods available in the software itself. Output, both for EuP-Ecoreport and for SimaPro6, will be presented in specific terms (per appliance and per functional unit), and compared by damage category and by Life Cycle Phase. Comparison between EuP-Ecoreport and SimaPro6 is possible only up to the characterization (list of environmental indicators) phase. The subsequent phases (up to damage evaluation), as explained in Subtask 5.2, implemented by SimaPro6 software, will be carried out in order to evaluate the whole environmental balance.

Improved model environmental performance will be compared with results of the best case LCA. This comparison will be carried out by analysing the results of the characterization phase (both with EuP-Ecoreport and SimaPro6) and then of the subsequent phases, in particular using the results provided by the damage evaluation. The aim of performing comparative life cycle analyses is to understand in depth the effects of the environmental performances of each design improvement. This means to understand not only if the whole performance of improved model is better than the base case one, but also to understand for which life cycle phase this improvement is relevant. Using specialised LCA software (like SimaPro6) it is moreover possible to underline and analyse each contribution of both the impact factors (characterization phase) and the damage indicators (damage evaluation), for each inventory data and for the life cycle phases.

0.1.2 Subtask 6.2: Analysis LLCC and BAT

The evaluation of the LLCC and the BAT will be achieved applying the Marginal Net Present Value approach. Through NPV analysis the net benefits of the technological options to consumers are estimated. At this stage, the manufacturing cost increases are assumed to be passed completely to consumers through price increase. Manufacturing price increase will be calculated according to and agreed amount of mark-up from purchasing price increase. The increase in consumer price will be then compared to the discounted annual economic savings (on the electricity) due to higher machine performance for the presumed lifetime of 15 years, resulting in the Net Present Value.

The NPV and LCC will be evaluated first for each (single) technological option referred to the base case models. Then the optimum combination of technological options will be defined. First, the single options are sorted according to the payback period (or the ratio of NPV/investment) with the higher return options first. Second, the savings are calculated for the combined options. Evidently the potential savings decrease as subsequent technological options are added, since less energy/water is available to be saved due to the impact of the previously added technological option(s).

Net Present Value is then calculated for the combined options. In order to see the impact of adding each subsequent option, the net present value of adding a specific option is calculated. This is known as the **Marginal Net Present Value** (MNPV) of adding a given option. Since the options are added in order of their potential economic contribution, we may add options until their marginal net present value is zero or negative. This determines the optimum design and is also the point in which the total net present value of the combined options is a maximum (or the LCC is at minimum). The BAT is represented by the latest option combination.

The NPV and Life Cycle Cost methods are equivalent. This is due to the fact that the life cycle cost is a constant value (the base case) minus the NPV of the improvements, thus the maximum NPV gives the minimum life cycle cost (LLCC). The output of the NPV analysis is the input in the LCC analysis where the constant values are added.

The main difference between the more traditional Life Cycle Cost analysis developed and reported in previous studies and the Marginal Net Present Value analysis (which both use the same design options input from the technical/economic analysis) lies in the fact that in traditional LCC design option impacts (savings and costs) are calculated one independent from another and then their effects are added, while the MNPV analysis calculates the effects of any option taking into account that a previous option has already been implemented and part of the savings has already been achieved. The other difference is that in the traditional LCC the options sequence is decided by "clustering" the options according to an engineering, not necessarily following their simple pay back time, while in the MNPV approach the options are applied mainly considering their economic feasibility for consumers (in terms simple payback time) and initial engineering considerations about their compatibility.

0.1.3 Subtask 6.3: Long-term targets (BNAT) and systems analysis

Long term technical potential for wash appliances, represented by the BNAT (Best Not yet Available Technologies) can be evaluated following the same approach used for the LCC. In fact, when the technological option list will be set, not only the available technologies will be collected, but also some options needing further applied and/or fundamental research. For these options stakeholders will be asked to estimate the possible price increase and environmental impact decrease. With this information a MNPV analysis could be developed, leading to the ranking of the

identified option and the evaluation of the long term potential. This analysis will involve options working within the same product archetype.

The long term potential on the basis of system changes will be attempted if such changes could be identified for this specific product. Possibly only the product-service substitution could be hypothesised for wash appliances.

In addition to the product system analysis developed in Task 4, some specific aspects will be dealt in this paragraph, mainly for washing machines:

1. the standby definition for washing machines and dishwashers
2. the trade-off between the amount of washed load and the nominal washing machine capacity
3. the indirect energy used in detergent production
4. the trade-off between high spin speed and the subsequent use of a (tumble) dryer (methodological analysis)

0.1.4 Subtask 6.4: Environmental assessment of the technological improvements

The quantitative assessment of the environmental improvements for the identified targets is developed in this subtask.

0.2 DESCRIPTION OF TASK 7

This task summarizes and totals the outcomes of all previous tasks. It looks at suitable policy means to achieve the potential improvement for wash appliances.

0.2.1 Subtask 7.1: Worldwide Scenarios for Wash Appliances

In this Subtask the main policy measures existing and planned worldwide for washing machines and dishwashers will be summarised and tentatively compared with those of the EU to evaluate the European position in the international context.

0.2.2 Subtask 7.2: Worldwide Compliance Assessment

In this Subtask, the different procedures followed worldwide for the declaration of the measured values, for the verification of the declared data and for the market compliance of policy measures will be described and tentatively compared, to evaluate the differences and the effectiveness of this fundamental aspect for an effective implementation of any mandatory or voluntary action.
Basic elements about statistics and measurement uncertainty will be also briefly described.

0.2.3 Subtask 7.3: EU Scenarios and Targets

The conclusions of the previous study Tasks will be the basis for the definition of a set of scenarios. Targets corresponding to the potential improvement resulting from the Life Cycle Analysis will be addressed, not only the LCCC and the BAT as requested by the eco-design approach, but also if necessary other points of the LCC.

The Use phase will be very likely the most addressed, since in general most of the environmental impact takes place during this phase, however should other life phases result in a real and proven significant environmental impact, they could be also addressed and further scenarios developed.

According to the clear indication of the Commission, the eco-design studies are intended to provide a factual basis to allow the Commission (assisted by the Forum and the Committee set in directive 2005/32/EC) to adopt implementing measures, if appropriate. The studies are supposed to identify options aiming at improving the environmental performance of the product under examination. **Policy proposals will be made by the Commission** and will be submitted for opinion of all Stakeholders in the Forum.

Nevertheless, during the kick-off meeting of the study the Commission asked to anyhow foresee some policy measure implementing the identified targets. For example, they could include the more traditional review of the labelling scheme (both in terms of declared parameters and thresholds of efficiency/performance classes) and the setting of energy/water requirements (energy/water consumption) to be achieved via a further round of the industry voluntary commitments or the setting of a specific legislation; a combination of mandatory and voluntary measures could also be envisaged; noise reduction could also be used as a scenario, alone or in combination of the other measures and targets; stand-by power/consumption reduction will be also discussed.

A stock model has been developed to evaluate the improvements that can be achieved within each scenario compared to the Business as Usual baseline. Energy savings are the most important parameter, but also the environmental impact reduction due to other aspects could contribute. The time horizon is 1990-2030.

0.2.4 Subtask 7.4: Manufacturers impact analysis

The impact analysis on manufacturers has been run using the E-GRIM model, developed by ISIS-ENEA in the framework of previous SAVE projects and already successfully applied in the analysis of the WASH-2 project.

Cost data used in the NPV and Life Cycle Cost methods is further disaggregated and used as input in E-GRIM model. Quantitative market data, industry structure, consumers' habits provided by previous phases of the study or by literature will be used to establish a framework to describe the linkages of the market and the technological improvement. E-GRIM model is expressly designed to allow the analysis of the effects of a single policy measure upon a single product. By combining multiple iterations it is also possible to analyse multiple products with policy measures taking effects over a period of time and/or multiple policy measures on the same product. The program simulates the sales, all main elements of cost and the cash flow, each year for fifteen years and then determines the present value of those cash flows without policy measure – the *Base case* – and with policy measure – the *Policy Measure case*. Output consists in the complete cash flow calculations, summary statistics, and graphs of major variables, including net cash flow for industry and for consumers (due to electricity savings), employment, investments required and impact on profits.

Average values to be used as input to E-GRIM model are presented at the sector level in terms of the "typical manufacturer".

0.2.5 Subtask 7.5: Sensitivity analysis

In the methodological approach chosen for the present study a sensitivity analysis is performed at each stage of data analysis. This applies to the economic and market analysis, to user defined

parameters, to product system analysis, to definition of the base case, product-specific inputs, to base case environmental impact assessment and to base case life cycle costs. Also for all other options concerning life cycle costs, the EU totals and the EU25 Total System Impact a sensitivity simulation will be run.

Again the technical analysis, and in particular the analysis of LLCC and BAT, include a very specific sensitivity analysis for the key parameters affecting the outcome (appliance life time, electricity price). The same is true of long term targets. For manufacturers' impact analysis a specific set of variables will be considered for sensitivity; this analysis includes an estimate of consumer behaviour for higher products purchasing prices and consumer net gains. The same is true for targets, scenarios and policy measures.

This final Subtask on sensitivity analysis the conclusion of sensitivity analysis performed in the study phases will be summarises and highlighted. For example, the sensitivity analysis for the LCC run considering (i) different lifetime (10, 12, 15 and 17 years) against a commonly agreed lifetime of, i.e., 15 years; (ii) different values of the energy price, where the EU average will be initially used and then the influence of the real prices in Member states will be evaluated; (iii) different numbers of annual washing cycles (for example 208, 220 and 280 cycle/year).

Contemporarily a sensitivity analysis will be performed on the most important parameters affecting the identified targets, scenarios and policy measures, trying also to describe the impact of possible key alternatives previously identified. The robustness of outcome and the sensitivity of certain market segments will be attempted and possibly discussed.

0.2.6 Subtask 7.6: Hypothesised policy measures for wash appliances

According to the last indication from the Commission, conclusions regarding possible policy measure scenarios for wash appliance will be drawn in this Subtask which will close the project.

6 Task 6: Technical Analysis

6.1 SUBTASK 6.1: OPTIONS, ASSOCIATED IMPROVEMENT, COSTS AND IMPACTS

Washing cycle in a dishwasher can be divided in the following phases:
1. Regeneration of the water softener (with a salt)
2. Cold pre-rinse
3. Hot wash (+ detergent), temperature ranging from 75°C to 45°C; cold wash is also possible is special cycles
4. Cold rinse
5. Hot rinse (+ rinsing agent), temperature: 65°C (75-77°C in special cycles)
6. Drying.

The sequence is fixed a part from the regeneration phase which can be performed before or after any rinsing phase including the wash phase.

Main technical characteristics of the dishwashers on the market in 2005 dealing with energy/water consumption and noise are:
1. Heating system:
   - Instantaneous water heater (electric resistance with water flowing)
   - Tubular electric resistance (electric resistance with storage)
- Drying system:
   - Condensation: humidity freely condensate on the colder internal walls of the cabinet
   - Ventilation: a fan is added to drain humidity from inside the machine
   - Condensation and ventilation: a combination of the two systems
- Insulation materials:
   - Bitumen: to reduce the noise of the water sprayed against the metallic walls of the tub
   - Phono-absorber material: to further reduce the noise (especially for machines to be used during the night)
- Control system:
   - Program clock, electro-mechanical or electronic
   - Temperature control: on/off or electronic thermostat
   - Water level control: mechanical or electronic sensor
- Washing cycle time:
   - Standard cycle, used for the energy labelling, is declared at 140-150 minutes, shorter cycles, down to a 30 minute rapid cycle, are also available in almost all the machines.

The technological trends can be summarised as:
- water consumption is about 13-14 litres, with values going down to 9-10 litres;
- improvements in mechanical and hydraulic aspects (alternating water spraying and higher pressure water spraying);
- introduction of intelligent sensors (substituting the older and less precise ones), evaluating the degree/type of dirtiness on the dishes and in the water, the detergent type, the tableware weight and adapting consequently the washing cycle phases (temperature, amount of water, detergent an time);
- new enzymatic detergents, active at 45°C allow the washing cycle at 45°C: some machines use a reference cycle temperature at 50°C, some at 45°C;

- increased number of place settings to 15, for larger families or higher use: this aspect allows theoretically to reach a higher energy efficiency class with the same machine, due to the inclusion of the place settings in the formula for the calculation of the energy efficiency index E_I, on the other side, more place settings means additional load weight to be heated). If the standard 12 ps load has an estimated weight of 3kg cutlery and 22 kg dishes, plates and glasses, 3 place settings more mean 6,25kg of additional load weight. On the other side, the index $E_I = C/C_R$ where $C_R = 1,35 + 0,025$ x ps, that is $C_R = 1,65$ for the 12ps model. If the number of place settings is increased to 15, $C_R = 1,73$, the new larger machine is allowed to consume 105 Wh more to fulfil the "A class" requirement $E_I \leq 0,64$. If the additional energy input needed to compensate the additional load weight is lower than 105 Wh, the residual energy can be used for other purposes (better drying, for example) or to improve the energy efficiency of the machine;
- attention to noise (for night washing cycles and reduced noise pollution);
- increase in the number of washing cycles designed for specific purposes: glasses, crystals, rapid cycle for very low dirty dishes, longer and stronger cycle for pottery, etc, and very recently plastic toys and dishes (building bricks, rattles and other toys are cleaned gently by the Lego 40°C cycle)[1];
- increase time control: "delay start" option, to delay the start of the washing cycle (for example to use the night electricity tariffs) or on the contrary "time to end the cycle" to end the cycle at a set time independently (up to certain degree) from the starting moment (cycle type, temperature and water to be adjusted consequently taking into consideration the allowed time to wash)
- increased attention to hygiene problems: specific "hygiene cycle" added or an "hygiene phase" added to an already existing washing cycle. Micro-organisms reduction is achieved mainly through high temperature (very hot programme or hotter rinse at 75-77°C) sometime complemented by other physical means, such as UV irradiation at the end of the hygiene cycle.

6.1.1 Option collection

A *Technological Option List* will be created through the consultation of the previous European studies on household appliances, the specialised literature and the discussion with manufacturers and other stakeholders. Not only the presently available technologies will be collected, but also options needing further applied and/or fundamental research.

For all the identified options, the possible price increase and environmental impact, energy /water consumption decrease when applied to the base case(s) will be evaluated (for already applicable options) or estimated (for BNAT options), along with the percentage of their application to the market.

A specific *Technological Option Data Collection form* (an electronic sheet) will be used to facilitate the data collection and the collected information systematisation.

6.1.2 Options, associated improvement, costs and impacts for Dishwashers

6.1.2.1 The hypothesised technological options for dishwashers

[1] Source: "Cutting Edge Washing from BSH", October 2006, Appliance Magazine, Europe Report.

Since no other studied on dishwashers were performed at European level after 1995 (GEA), all the technological options starting from that year have been looked for, even if some have been completely applied to go from the 1995 base case to the 2005 base case.

The GEA study, the specialised literature, the discussion with manufacturers and stakeholders lead to define the following list of technological options:

- **Option No 1 - weight reduction of heated parts** (5% = 2,5kg out of a 50kg machine): heat loss through radiation and convection from the heating up of the machine occurs during the washing cycle. Savings can be achieved through (i) improving thermal insulation or (ii) reducing the cabinet energy storage. In the second case, a weight reduction of the components heated to 65°C can lead to the same result as using new materials with a lower heat capacity, since no better material than the already used stainless steel can be easily found. A 2,5% reduction or 2,5kg is considered as in previous GEA study. This option is already applied to all the dishwasher models on the market.
- **Option No 2 - reduced thermal bridging between inside and outside**: an improvement of the thermal insulation is achieved by reducing the thermal bridging effect of inner and outer casing. This reduction can be obtained either by eliminating the some of the steel flanges surrounding the inner casing or by using some foam (insulating material) securing the outside shell to the inside. Both systems are possible, depending of the design of the specific dishwasher models. This option was already proposed in GEA study. This option is already applied to all the dishwasher models on the market.
- **Option No 3 - improved pump and motor efficiency**: the 1995 base case dishwasher is equipped with two electric pumps (one for re-circulation and one for draining) with motors. The running time of the draining pump is negligible as its energy consumption, therefore only the re-circulation pump improvement is considered. A 10% overall improvement of the motor and pump system efficiency is considered, from 20% to 30%, as already considered in the GEA study. A comment was made on the fact that this option improves the efficiency of the system, but also the running time, resulting in a lower energy saving. This option is already applied to all the models on the market.
- **Option No 4.1 - lower wash temperature (55°C) and longer time (+ 25 minutes)**: in 1995 the standard base case machines had a normal cycle at 65°C. At that time manufacturers started to propose as alternative a normal cycle with the temperature of the wash phase reduced at 55°C and a longer duration (estimated in 25 minutes). It should be noted that the hot rinse phase was still run at 65°C to reach a good drying of the dishes. This option was applied to all the models on the market and was already considered in the GEA study. In the today dishwashers this option is totally replaced by options 4.2 and 4.3.
- **Option No 4.2 - lower wash temperature (50°C) and longer time**: a further improvement was the reduction of the washing temperature at 50°C, with an increase of the cycle duration to 1,5 hours (90 minutes). The hot rinse phase is still 65°C. This option is still applied to about 30% of the models on the market (the other 70% of the models using Option 4.3). It is applied to 9ps and 12ps base cases.
- **Option No 4.3 - lower wash temperature (45°C) and longer time**: a further improvement was the reduction of the washing temperature at 45°C, with a further increase of the cycle duration. The hot rinse phase is still at 65°C. Although this option is applied to 70% of the models on the market, it decreases the cleaning efficiency on specific "difficult" stains (especially tea and coffee), because present detergents work better at 50°C or higher temperatures. This option is less applicable with detergents whose bleaching action starts at 50°C. Possibly, detergents active at a lower temperature should be introduced.
- **Option No 4.4 - lower wash temperature (40°C) and longer time**: a further possible improvement is the reduction of the washing temperature at 40°C, with a further increase of the

cycle duration. The hot rinse phase is still at 65°C. This option has been recently made possible by new 7-in-one tablet detergent, marketed under the name of "Somat 7" by the detergent manufacturer Henkel. It is claimed that *with the help of a low-temperature activator, dishes become sparkling at just 40°C. The new detergent booster with washing active enzymes removes stubborn stains, such as egg and sauce residues, so that they can be rinsed off at only 40°C. The bleaching agents completely remove even tea stains*[2]. A further research is needed to evaluate if this low-temperature detergent is available on the overall EU market and if the claimed washing performance at lower temperature is confirmed.

- **Option No 5 - improved accuracy of water level**: accuracy of water levels can be improved by the use of more accurate mechanical or electronic sensors. At present electronic sensors are widely available, which can give better results compared to mechanical ones. This option was already considered in the GEA study and is currently applied to all the models on the market.
- **Option No 6 - alternating spraying of water**: dishwashers are equipped with two or more water arms, which work alternatively or in combination. If the water is alternatively sprayed (from for example the upper and the lower arms alternatively) a water saving can be achieved. A different (patented) technique is used by some manufacturers with the same final effect. This option was already considered in the GEA study and is currently applied to about 40% of the models on the market.
- **Option No 7 - (partly) reuse of last rinsing water**: an apparently simple way to reduce the water consumption is to store water from the last rinse phase and (re)use it in the pre-rinse phase of the following cycle. The last rinse water should in fact be sufficiently clean to be reused. This option requires the addition of a water storage tank, which is already forecast is some of the described options. However, due to the already achieved reduction of the water use in the present dishwashers, the last rinse water in considered by manufacturers too soiled to be stored for many hours without hygiene problems. Although this option was taken into consideration in 1995 in GEA study, no machines are today equipped with this system and its application is considered highly critical, nevertheless it could be studied for future applications (BNAT). For some manufacturers it affects only the water consumption reduction of pre-wash phase and has no impact on the reduction of the energy consumption; for others, also some energy savings can be achieved. This Option is an alternative to Option 15.1.
- **Option No 8 - heat exchanger (with storage tank)**: defined as "heat buffer" in the GEA study, this option forecast the addition of a water storage tank to be used as heat buffer. At the end of the washing phase the tank is filled with fresh water and - due to the difference in temperature - heat flows from the tub to the stored water, which is then used in the so called cold rinse phase after the hot wash. Less energy (heat) is therefore necessary during the hot rinse to reach the necessary load temperature for drying. This option is at present applied to 15% of the models on the market.
- **Option No 9 - cross flow heat exchanger** (with storage tank): another way to recover waste heat from the hot wash is the use of a cross flow heat exchanger between the incoming fresh water and the drained hot water. The heated fresh water is then stored in the storage tank described in the previous option. Already considered in the GEA study this option is not used at present, but it is under study. It is worth noting that GEA study considered the use of the *cross flow heat exchanger* as an alternative to the *water storage tank*, while today the exchanger is seen - and studied - as an improvement of previous Option 8, although this option is still not applied. This option is not applicable to 9ps machine due to lack of space to accommodate the exchanger.
- **Option No 10 - elimination of heating element for drying**: this option was initially applied in 1995. The heating elements used for heating the load for the drying phase were removed and heat was provided during the hot rinse phase. This option was applied to all the models on the

[2] Source: Henkel, Sustainability Report 2006, pag. 19 (English version).

markets and lead to an increase of 20 minutes of the drying phase. At present it is estimated that the system is still used by 5% of the models. Possible ways to shorten the drying phase or to achieve better drying performance are to provide an extra aid in the form of a condensation system or the ventilation of the moist air, described in Options 11.1, 11.2 and 11.3.

- **Option No 11.1 – condensing system for drying without additional heat**: the hot load is left to dry "naturally" by condensation of the (hot) water vapour on the inner walls of the cabinet. This option is presently applied to 45% of the models and to the 9ps and 12ps base cases. The possible improvement is to use Options 11.2 and 11.3.
- **Option No 11.2 – (water tank) condenser for drying**: the condensing system might use an amount of fresh water to act as a condensing coolant. Different designs are possible, but GEA proposed the use of a water storage tank bordering the tub and filled with fresh water at the beginning of the drying cycle just after the draining of the hot rinse water. The moist hot air coming from the load condensates at the surface of the tub walls cooled by the stored cold water and creates also air circulation by natural convection. The condensed water is drained. The clean stored water is (or can be) used in the pre-rinse phase of the following cycle. As alternative, a fan can be used to cool down the condenser surface instead of the water. At present this option is applied to 25% models on the market and was already considered in the GEA study.
- **Option No 11.3 – condenser plus fan for drying**: to achieve a better drying performance a fan is combined to the condenser (in about 25% of the models on the market). A condensing system is equipped with a fan to create what is today referred as "turbo dry system": the air flow from the fan improves the drying performance and can reduce the drying time.
- **Option No 12 - hot rinse at 55°C**: this option was described in GEA study as one way to reduce energy consumption. However, it was never used in dishwashers. Its application requires a total re-design of the drying phase and the development of a drying aid. In addition it could cause problems of drying spots (water re-deposition on dry load). No rinse aid is currently available on the market working at 55°C and more energy is needed if no rinse aid is used. Also the rinse aid used in the EN standard is active at 65°C. This option could be considered for future application (BNAT) even if it is considered critical by manufacturers.
- **Option No 13 - differentiation of water levels**: the total amount of water needed in a cycle is given mainly by the water that is travelling through air or running down the load, which in turn depends on the recirculation flow. If a reduction of water flow is possible in certain phases the total amount of used water can be reduced. Described in GEA study, this option is already applied to all the models on the market.
- **Option No 14 - insulated water tank**: a further saving could be achieved if the storage tank described in Option 8 is insulated and used to store the hot water from the last hot rinse. This option was mentioned as a possible future long-term development in GEA study but it is still not applied to dishwashers as considered not feasible due to hygiene problems deriving from the long storage time of the water, especially when one or less washing cycle per day is run in households. In addition, the energy savings can occur only if the interval between to successive washing cycles is short, otherwise the water temperature inside the insulated tank will decrease to ambient temperature. This option is technically not applicable to 9ps machines due to the lack of space to accommodate the tank in compact machines.
- **Option No 15.1 - avoidance/reduction of the cold pre-rinse**: the cold pre-rinse (= pre-wash) is generally used to prepare the load for the following hot wash by starting to remove the dried soil. Water used for the cold pre-rinse can be reduced (or even the phase deleted) if the following hot wash phase is sufficient to reach a good washing performance. This options can cause drawbacks of cleaning performance, but is nevertheless already used by 40% of the market. It is in alternative to Option 7. It is applied to the 9ps and the 12ps base cases.
- **Option No 15.2 – partly draining and re-filling (of water):** there is the possibility to drain only part of the soiled water and re-fill the machine with the same amount of fresh clean water.

This option can be applied mainly to the cold rinses and main wash, but not in the final rinse. It is at present applied to 20% of the market.

- **Option No 16 - avoidance/reduction of the intermediate cold rinse**: the water consumption for this phase could be decreased (or even the phase deleted) if the rinsing performance of the following hot rinse phase guarantees an good rinsing of the load. Due to the reduction of the water for rinsing it can cause drawbacks of drying spots and severe soil re-deposition. For some manufacturers the drawbacks can be avoided by adding a second pre-wash, which in turn increases again the water demand of the same amount thus neutralising the effect of this option on water savings, leaving just an energy savings. The application of this option has been reduced (due to the re-deposition problems and consequent low washing performance class) to 5% of the present models on the market, and it is expected to disappear soon.
- **Option No 17 - direct heating of the load (avoid last hot rinse)**: it could be possible to perform the last rinse without additional heating and instead heat up directly the load to 65°C after the last rinse water has been drained. In a normal cycle in fact the last hot rinse is usually needed to heat up the load to a suitable temperature for the following drying phase. Despite the fact that this option was mentioned in the GEA study as a potential long term option, it is at present considered not feasible due to the lack of suitable technology. Microwave heating of the load has bees studied but without acceptable results. The energy used in the alternative way of heating the load should be taken into consideration. To be addressed as BNAT.
- **Option No 18 - DC brushless motor and reciprocating pump**: mentioned in GEA study as further improvement of pump and motor system, the DC brushless motor entered into market around 2003 as option, and is at present used by 5% of the models. The use of the reciprocating pump not feasible due to noise problem, a different type of pump is used.
- **Option No 19 - Dual speed motor (HPS system)**: mentioned in recent specialised journals as a way to save energy (and water) through the use of a dual speed pump which is claimed to increase the pressure of the water flow in the spray arms, doubling the (cleaning) power and thus allowing a temperature reduction with a possible energy savings. This option is considered not leading to the claimed savings in the “normal cycle”, but it could be used for more intensive cycles.
- **Option No 20 - optimized hydraulic system with less water**: optimisation of the hydraulic system can lead to a reduction in water consumption by saving the water filling the system itself, which is not used for the pure washing/rinsing activity. This option is already applied to all the models on the market.
- **Option No 21 - optimized regeneration of softener**: soft water system regeneration with a salt can be performed before or after any rinsing phase including the wash phase. Its optimisation through the use of an electronic system can lead to significant saving of water (and salt) since the regeneration is run only when really necessary and not after each washing cycle or phase. An electronic sensor measures the water hardness and starts the regeneration consequently. This option is already applied to all the models on the market.
- **Option No 22 - accuracy of temperature in main wash and hot rinse**: a better accuracy of the temperature levels can be achieved with better sensors. Electronic sensor are widely available and used today. This option is already applied to all the models on the market.
- **Option No 23.1 - noise reduction, level 1: 50 dB(A)**: noise level is today considered an important element of the profile of an appliance. Can be achieved through a combination of factors: better insulation, redesign of the hydraulic system, dampers for the tub and the pumps, motor placed on insulated supports, etc.. Here a better insulation is especially taken into consideration, since the other possibilities are generally used to achieve improvements other than noise reduction (the redesign of the hydraulic system for the optimisation of water levels and dampers for the tub and the pumps to reduce the overall appliance vibrations). The increase in insulation improves the machine weight and therefore the energy consumption. This option is

applied to most of the models on the market, and to the 9ps and 12ps base cases. Other models having a lower noise level apply Options 22.2 and 22.3.

- **Option No 23.2 - noise reduction, level 2:** the same as Option 23.1 but to a level of 44dB(A), which is today applied to 20% of the models on the market.
- **Option No 23.3 - noise reduction, level 3:** the same as Option 23.1 but to a level of 41dB(A), which is the lowest available on the market today in some models. This reduction is applied to 5% of the models on the market.
- **Option No 24 - increase the temperature of the last rinse to 70-75°C (hygiene considerations)**: in most of the recently advertised machines the hygiene problem of the dirty tableware (left in the machine before being washed) and the consequent machine contamination are addressed. High temperature and UV (see following option) have an antimicrobial effect on micro-organisms reducing their presence. Hygiene is claimed to be achieved through a very hot final rinse at 70-75°C (in some models the temperature could reach 77°C[3]) used at the end of the washing programme or as and independent hygiene high temperature cycle.
  In general there are three, increasing, micro-organisms reduction levels: 99% or "hygiene" level, 99,9% or "sanitisation" level and 99,999% or the "sterilisation" level. The first and second levels are claimed to be reached by manufacturers in advertising their dishwashers, the third one deals with public health and should not be addressed when dealing with simple household appliances. The final very hot rinse option is today applied to about 20% of the models on the market.
  It should be discussed if this option, which implies an increase in the energy consumption for a washing cycle (from the energy point of view it is exactly the opposite of Options 4.1, 4.2 and 4.3) has to be considered a special cycle or consumer-behaviour dependent, or if - on the contrary - the hygiene could shortly become part of a "normal" washing cycle as other Options. Should this the case, further consideration is needed about the contradiction between the 'policy-driven' efforts to decrease the dishwashers energy consumption by reducing the washing/rinsing/drying temperature and the 'consumer-driven' increase in energy consumption due to (real or perceived) hygiene problems.
- **Option No 24.1 - UV irradiation** (after the increase of the temperature of the last rinse to high temperature): in some machines the very hot last rinse is followed by a (20 minute) UV irradiation[4]. The UV irradiation is applied by one manufacturer, but is considered by other manufacturers as having no hygiene effect due to the shadows created by one piece of tableware on the others and therefore not considered as an effective option.
- **Option No 25 - electronic sensors for the detection of the load weight**: there are two possibilities:
  - a soil sensor detects the actual load soiling and adjusts consequently the best programme (amount of water, length of the washing programme and temperature) to be used;
  - a sensor (indirectly) detects the actual weight of the load and adjust consequently the best programme characteristics.

  The first option is already applied to 40% of the models on the market, using software intelligence with existing sensor technology; more advanced sensors will not give better results. In real-life conditions, the savings are proportional to the soil reduction (compared to the standard load soiling). The second option is already applied to 20% of the models on the market, and is referred to the decrease of the standard place settings in real life washing cycles.
  Since the energy consumption, washing and drying performance are at present measured for the standardised programme operating at full load and standard soiling, these options have no impact on the overall water/energy consumption nor to the energy labelling rating, at least for the moment; they can save energy and water in the real-life base cases.

[3] Source: model LG Inverter Direct Drive, Trade Bianco, September 2006, pag. 114.
[4] Source: model LG Inverter Direct Drive, Trade Bianco, September 2006, pag. 114.

- **Option No 26 - delay start**: the washing cycle can be delayed to the decided time, leaving the machine loaded and ready for start. Delaying the machine start, this option allows to use the off-peak tariffs (thus decreasing the cost of the used energy) or to have the washing cycle at different moment during the day selected by the consumer. There is no effect on energy and water consumption per washing cycle, and not affect on the energy efficiency class of the present energy labelling scheme. The machine is turned "on" and ready to start at the given time (at the end of the delay), therefore at least a certain power consumption is needed for the timer and the associated electronics to function. This is more to be dealt in the framework of stand-by considerations and system analysis and within real-life base cases. Nevertheless, this option is already applied to 30% of the machines on the market. The definition of "delay start" mode in the IEC/EN standards is the pre-requisite to allow the measurement of the power consumption (in W) of this mode.
- **Option No 27 - electronic update of the programmes/diagnostics**: update of the software managing the different washing cycles can be done by connecting the machine to the assistance PC. This option could be also used for machine diagnostic[5]. There is no immediate impact on energy/water consumption, but by updating the software a better washing cycle management could be achieved (if and when a better software is developed) in case of change in external conditions such as the development of a new detergent, with potential consumption reduction. 20% of machine on the market already have this option.
- **Option No 28 - Internet connectivity**: this option enables remote diagnostics and programmes update, in this sense it is an evolution of Option 27. When connected to Internet the unit is linked to the company's (or assistance's) servers and automatically reports service issues and orders replacement parts and repair. An added benefit is the user's ability to start or stop the machine when outside home via the Internet connection. It is applied to none or very few models on the market (0,1%). A machine with this feature can not have an hard-switch, and will remain in a WOL state thus increasing the energy consumption in non-on mode (standby or low power modes). The same considerations of Option 26 apply. To be considered for long term development (BNAT).
- **Option No 29 - voice controlled appliances**: as appliance control become more capable and precise, one of the challenges facing designers is how to keep controls from getting too complicated while giving choices to users. One approach, little used in the appliance industry, is voice technology, allowing for example to program a machine to follow a customised programme with just a few spoken words. Voice controls can add a bit of differentiation and give personality to an appliance, not to mention the advantages for the aged and disabled users, because of the hands- and eyes-free approach, even if the loading and unloading of the machine requires the use of both hands and eyes. Not applied for the moment, but to be considered for long term development (BNAT).

6.1.2.2 The Technological Option List for dishwashers in 2005

Considerations about the applicability of the hypothesised options led to the definition of a Technological Option List for dishwashers, including some long term/BNAT options. The selected set of options has been rearranged and renumbered as:

- **Option a.1** (Option 4.3): Lower wash temperature (45°C) with longer time
- **Option a.2** (Option 4.4): Lower wash temperature (40°C) with longer time (note: to be further investigated for global applicability)
- **Option b** (Option 6.1): alternating spraying of water
- **Option c** (Option 8): heat exchanger (with storage tank)

[5] Source: model MIELE 1000G, Trade Bianco, September 2006, pag. 117.

- **Option d** (Option 9): cross flow heat exchanger – **not applicable to 9ps dishwasher**
- **Option e.1** (Option 11.2): (water tank) condenser for drying
- **Option e.2** (Option 11.3): condenser with fan for drying
- **Option f.1** (Option 15.1): avoidance/reduction of the cold pre-rinse
- **Option f.2** (Option 15.2): partly draining and re-filling (of water)
- **Option g** (Option 18): DC brushless motor
- **Option h.1** (Option 23.2): noise reduction (through better insulation), level 44 dB(A)
- **Option h.2** (Option 23.3): noise reduction (through better insulation), level 41 dB(A)
- **Option i** (Option 24): hot rinse at 70-75°C <for real life base case only>
- **Option j.1** (Option 25): electronic sensors for the load soiling <for real life base case only>
- **Option j.2** (Option 25): electronic sensors for the load weight <for real life base case only>
- **Option k** (Option 26): delay start <for real life base case only>
- **Option BNAT 1** (Option 7): (Partly) reuse of last rinsing water
- **Option BNAT 2** (Option 12): Hot rinse at 55°C
- **Option BNAT 3** (Option 14): insulated water tank **- not applicable to 9ps dishwasher**
- **Option BNAT 4** (Option 17): Direct heating of the load (avoid last hot rinse)
- **Option BNAT 5** (Option 28): Internet connectivity
- **Option BNAT 6** (Option 29): Voice controlled appliances.

All Options will be applied to the standard base cases with the exception of where it is indicated that options will be applied to real life base-case only since they will have no effect on the standard base case, due to for example the measurement method used in the standard (which does not take into account that specific aspect). All options will be applied to the real-life base case.

6.1.2.3 Costs and impacts for dishwashers technological options

The selected technological options are shown in Table 6.1 for the 9ps and in Table 6.2 for the 12ps dishwasher, along with the average rate of application, the improvement in manufacturing cost/price and consumer price and the associated energy/water savings when each option is applied to the relevant standard base case. Shown data have been gathered through a data collection exercise with manufacturers and were validated through a discussion with experts and stakeholders.

Main cost/price parameters shown in Tables 6.1-6.2 are:

- **Unit production costs** (manufacturing costs): directly related to production including materials, energy, components, labour, any allocated overhead costs and annual investment cost per unit. Annual investment cost per unit is equal to the total investment cost for the technological improvement divided by 10 (years of depreciation) divided by the capacity or units produced annually. The reference capacity is one million units/year. Unit costs directly related to production of that unit/technical option are: materials, components, energy, labour, R&D related to the development of that unit/technical option, overhead costs that can be allocated to that unit/technical option, investment that can be related to that unit/technical option.
  For example, if total investment cost is 5 million Euro, the capacity is 1 000 000 units/yr with 10 years depreciation, the annual investment cost per unit is 0,50 Euro. This is summed with the other unit costs of materials, energy, component, labour and any allocated overhead costs.
- **Unit production price** (manufacturing price): unit production costs plus all other costs that are not directly related to that unit/technical option: sales and marketing, general and administrative costs, general R&D expenses, profit before taxes, any other general overhead cost. In the past, the product price at the factory was approximately 1,3 times the unit production cost.

- **Consumer price**: is the price paid by the consumer at the retailing place including transport costs, profit of retailer, advertising of product from retailer, etc. Consumer price was estimated by the product price at the factory plus the mark-up. A mark-up value of 2,75 was used in WASH-2 study for washing machines.

Table 6.1: Technological Option List, improvement in cost/price and energy/water savings for the 9ps dishwasher

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
a.1	Lower wash temperature (45°C) longer time	70	2,7	3,51	+30	+0,0362	0	0	+30	10,53	standard base case washing temperature is 50°C
a.2	Lower wash temperature (40°C) longer time	0	2,7	3,51	+30	+0,0362	0	0	+30	10,53	option to be further investigated, at present to be applied only to the **real-life** base case
b	Alternating spraying of water	40	7	9,1	+50	+0,0604	+2,5	+0,1825	+20	27,3	
c	Heat exchanger (with storage tank)	15	7	9,1	+30	+0,0362	0	0	--	27,3	
d	Cross flow heat exchanger										not feasible for 9ps
e.1	Condenser for drying	25	10	13	+15	+0,0181	0	0	-10	39	
e.2	Condenser with fan for drying	25	10	13	+15	+0,0181	0	0	-10	39	
f.1	Avoidance/reduction of the cold pre-rinse = prewash	60	0	0	+10	+0,0121	+2,5	+0,1825	-5	0	alternative to Option BNAT1
f.2	partly draining and re-filling (of water)	20	1	1,3	+5	+0,0060	+1,5	+0,1095	--	3,9	
g	DC brushless motor	0	20	26	+20	+0,0242	+0,5	+0,0365	--	78	reciprocating pump not usable due to noise
h.1	Noise reduction (better insulation), level 44dB(A)	20	8	10,4	-70	-0,0845	0	0	+10	31,2	base case 50 dB(A)
h.2	Noise reduction (better insulation), level 41dB(A)	3	18	23,4	-90	-0,1087	0	0	+10	70,2	base case 50 dB(A)

Table 6.1: Technological Option List, improvement in cost/price and energy/water savings for the 9ps dishwasher – continued

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
i	Hot rinse at 70-75°C	20	2	2,6	-230	-0,2778	0	0	+10	7,8	consequences of use by consumers to be investigated, to be applied to the **real-life** base case
j.1	Electronic sensors for the load soling (50% soiled)	40	5	6,5	+80	0,1208	+0,8	+0,058	-10	19,5	applied to **real-life** base case, 50% of the standard soiling
j.2	Electronic sensors for the load weight (50% mass)	20	4	5,2	+100	0,1449	+1,0	+0,073	-10	15,6	applied to **real-life** base case, 50% of the standard place settings
k	Delay start (results form Task3 indicated in parenthesis)	30 (used by 10%)	0	0	-(0,0105 at 3,5 W)	-0,000013	0	0	(3h = average time in this mode)	0	applied to **real-life** base case, and to be considered together with standby within system analysis

*standby power

Table 6.2: Technological Option List, improvement in cost/price and energy/water savings for the 12ps dishwasher

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
a.1	Lower wash temperature (45°C) longer time	70	2,7	3,51	+40	+0,0374	0	0	+30	10,53	standard base case washing temperature is 50°C
a.2	Lower wash temperature (40°C) longer time	0	2,7	3,51	+40	+0,0374	0	0	+30	10,53	option to be further investigated, at present to be applied only to the **real-life** base case
b	Alternating spraying of water	40	7	9,1	+70	+0,0654	+3,0	+0,1974	+20	27,3	
c	Heat exchanger (with storage tank)	15	7	9,1	+30	+0,0280	0	0	--	27,3	
d	Cross flow heat exchanger	0	16	20,8	+40	+0,0374	0	0	+10	62,4	improvement of Option c
e.1	Condenser for drying	25	10	13	+15	+0,0140	0	0	-10	39	
e.2	Condenser with fan for drying	25	10	13	+15	+0,0140	0	0	-10	39	
f.1	Avoidance/reduction of the cold pre-rinse = prewash	60	0	0	+10	+0,0093	+3,0	+0,1974	-5	0	alternative to Option BNAT1
f.2	partly draining and re-filling (of water)	20	1	1,3	+5	+0,0047	+2,0	+0,1316	--	3,9	
g	DC brushless motor	5	20	26	+20	+0,0187	+0,5	+0,0329	--	78	
h.1	Noise reduction (better insulation), level 44dB(A)	20	10	13	-95	-0,0888	0	0	+10	39	base case 50 dB(A)
h.2	Noise reduction (better insulation), level 41dB(A)	5	20	26	-120	-0,1121	0	0	+10	78	base case 50 dB(A)

Table 6.2: Technological Option List, improvement in cost/price and energy/water savings for the 12ps dishwasher - continued

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
i	Hot rinse at 70-75°C	20	2	2,6	-250	-0,2336	0	0	+10	7,8	consequences of use by consumers to be investigated to be applied to the **real-life** base case
j.1	Electronic sensors for the load soling (50% soiled)	40	5	6,5	+100	+0,0935	+1,0	+0,0658	-10	19,5	applied to **real-life** base case, 50% of the standard soiling
j.2	Electronic sensors for the load weight (50% mass)	20	4	5,2	+120	+0,1121	+1,5	+0,0987	-10	15,6	applied to **real-life** base case, 50% of the standard place settings
k	Delay start (results form Task3 indicated in parenthesis)	30 (used by 10%)	0	0	-(0,0105 at 3,5 W)	-0,000010	0	0	(3h = average time in this mode)	0	applied to **real-life** base case, and to be considered together with standby within system analysis

Starting from collected unit production costs, the manufacturing price has been calculated from by multiplying them by 1,3. Consumer price increase has been calculated using a mark-up value of 3,0. The electric energy price is 0,17 €cent/kWh in real terms. The standard and real-life base-cases annual energy consumption (see Task 5 report) are reported in Table 6.3:

Table 6.3: Standard and real-life base-cases annual energy consumption and noise

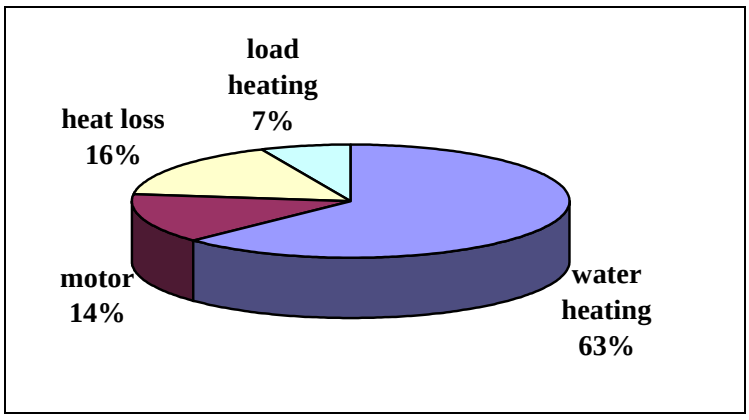
Machine type	Electricity consumption (kWh/cycle)	Water consumption (litre/cycle)	Noise (dBA)
STBC 9ps	0,828	13,7	50
STBC 12ps	1,070	15,2	50
RLBC 9ps	0,903	13,9	50
RLBC 12ps	1,167	15,4	50

6.1.3 Options, improvements, costs and impacts for Washing Machines

6.1.3.1 Introduction

The washing process uses energy, which can be subdivided into heating, mechanical action and pumping. The amount of energy used for heating is influenced by the amount of water (the suds level), the wash load, the temperature of the cold water inlet and the temperature to be reached (i.e. the final ΔT). The energy used for mechanical action depends on the total wash time. The energy use for pumping is in general fixed in the wash programme, and is not influenced substantially by any of the process variables. All the different phases of the washing process use a portion of the energy consumption of the wash cycle. During the washing process the energy used to heat the water also flows to other parts of the machine, for example the steel drum, the glass door and the wash load, and part is lost to the environment. The amount of energy that is lost to the environment depends on a number of variables, among which the insulation of the machine, the duration of the cycle, the ambient temperature and the temperature of the heated water. Figure 6.1[6] shows the relative share of the components of the energy consumption of a 60°C cotton cycle in 1993.

Figure 6.1: Relative energy consumption for the different components of the washing cycle in 1993.



[6] Source: GEA 1993.

Washing cycle in a washing machines can be divided in the following phases:

1. Water intake (+ detergent) for load wetting
2. Heating (to the set water temperature)
3. Main wash phase (ending with the drain of the wash phase liquor)
4. Post wash: cold water intake, rinse, drain
5. Rinsing phase, with intermediate spinning between rinses (+ softener in the final rinse)
6. Final spinning phase.

Main technical characteristics of the washing machines on the market in 2005 dealing with energy/water consumption and noise are:

- Heating system:
  - Instantaneous water heater (electric resistance with water flowing)
- Insulation materials:
  - phono-absorber material: to further reduce the noise (especially for machines to be used during the night)
- Control system:
  - Program clock, electro-mechanical or electronic
  - Temperature control: on/off thermostat or electronic sensor
  - Water level control: mechanical or electronic pressostat
  - Load weight control: electronic sensor
- Washing cycle time:
  - 60°C cotton cycle, used for the energy labelling, is declared at 110-130 minutes, shorter and longer cycles and different temperatures are also available in all the machines
- Washing water (sud volume) and ΔTemperature:
  - the low cost washing machines are assumed to have suds level (at rated capacity) of 20 litres in the main wash, this is 16 litres for medium cost machines and 14 litres for high cost machines equipped with electronics. Lower volumes are achieved in more recent machines, up to 12-13 litre due to 100% electronics and sensor use
  - in all machines the ΔT was assumed to be 40°C to 45°C for the 60°C cotton cycle (cold water intake at 15-20°C)
- Rinsing phase: rinsing changed over the year:
  - reference type around 1985: 4 rinses without intermediate spins with 22 l of water per rinse (total 88 litre of water)
  - program type around 1993: 3 rinses with intermediate spins., 15 l of water per rinse (total 45 litre of water)
  - low consumption program type: 2 rinses with intermediate spin, 15 l of water per rinse (total 30 litre of water)
  - 2005 machines: have 3 rinses with intermediate spin, 8-10 l water per rinse (total 24-30 litre of water).

6.1.3.2 The reviewed technological options in 1998 (WASH-2 study)

The presented options were revised in the WASH-2 study, taking into consideration that in the period 1993-1998 the industry addressed most of the issued described in the GEA study and added a few new design options, and through an extensive discussion with industry and non-industry experts. Updated technological options and related estimated energy/water savings and additional cost in 1998 were:

- **Option 1 - *motor efficiency***: an estimate of motor efficiency options is shown in Table 6.4.

Table 6.4: Estimated motor efficiency options in WASH-2 study

Motor options	relative costs (Euro)	market share 1998 (%)	motor efficiency (%)	contribution to average efficiency (%)
Asynchronous motor 50-500 rpm	-25	25,0	20,0	5,0
AC phase controlled 60-1400 rpm	0	70,0	30,0	21,0
DC phase controlled 40-1600 rpm	5	3,4	36,0	1,2
Chopper motor	18	1,5	38,0	0,6
Brushless DC (+ control)	50*	0,1	50,0	0,1
Brushless DC Direct Drive (+ control)	90**	0,01	50,0	0,0
Total		100,0		27,8

*10 Euro motor + 40 Euro control; **40 Euro motor + 50 Euro control

Apart from the motor efficiency, a better motor enables the engineers to enter other efficient design options. The improvement in motor efficiency alone causes a reduction of around 30Wh/cycle (chopped) to 50 Wh/cycle (brushless DC or Switched Reluctance). The additional benefit of the more (brushless DC, SR motor) or less (chopper motor) sophisticated variable speed drive will help the reduction of the sud volume;

- **Option 2 - *time-temperature trade-off***: the total cycle time between 1993 and 1998 has increased by some 10 to 20%, whilst at the same time the number of rinses has on average diminished. A total cycle time of 120 to 130 minutes was common in 1998, whereas in 1993 the cycle time was 100 to 110 minutes. Manufacturers claim that there is zero benefit from time-temperature trade-off referring to the situation from 1998 onwards. It is concluded that, although in the period 1993-1998 the optimisation of time, temperature and other parameters will have played a role, for the immediate future it will be a saving option only for low-range machines.
- **Option 3 - *mechanical action***: one of the most important *new* design options, not mentioned in the GEA study, is the introduction of complex mechanical action and even spinning action during the wetting phase to reduce the sud volume by 2 to 3 litres. In terms of energy this is a saving in the range of 100 to 150 Wh/cycle (including a sophisticated control, see next option).
- **Option 4 - *full electronic and controls***: apart from suitable variable speed motors, the previous option also needs a sophisticated water level and process control. This option creates the methodological problem of re-clustering all the design options, as it makes no sense to add a variable speed drive motor without the sophisticated controls that go with it.
- **Option 5 - *thermal efficiency***: the total energy consumption for machine-heat up, heat-up of the glass door, radiation and convection losses has been reduced from 276 Wh/cycle in 1993 to 175Wh/cycle in 1998. Yet, the industry indicates that a further reduction of thermal losses is possible by some 50 Wh/cycle at an expense of 12 Euro.
- **Option 6 - *tub-drum geometry***: diminishing the tub-drum clearances and increasing the drum volume (volume to load ratio), thus reducing the required sud volume and, because of the better wash performance, being able to save energy by reducing the cycle time (alternatively reducing the temperature). Manufacturers expect only little improvement from a reduction of tub-drum tolerances (25 Wh/cycle and 0,5 litre of water) and no benefits at all of increasing the drum volume versus the load capacity. This is debatable as many highly efficient washing machines were recently presented with drum volumes of 48, 52 and even 60 litres. The claimed capacity of these machines is 5,5, 6 or even 7 kg, but often the test load (for the energy label) is 5 kg. This means at a volume to load ratio of almost 10:1, whereas in the past even ratios of 8:1 were not uncommon. The dimension of the outer casing is the same as with a "normal" machine,

therefore the clearances between tub and drum or tub and outer casing must have been reduced; probably both. The water consumption of these machines can be as low as 39 litres/cycle and the sud volume during washing is only 12,5 to 13 litres. It is disputed whether at such low sud levels a satisfactory wash performance is possible: industry and some test-house experts claim that a minimum of 13 litres sud volume (at 5 kg load) is required. With respect to 1993 the volume-to-load ratio of the average washing machine has increased by around 10 to 15% (from a 42-44 litre drum at 5 kg load in 1993 to 48 litre drum at 5 kg load in 1998, while the rated capacity has not been changed). The tub-drum clearances have been reduced significantly with values found as low as 10 mm. Both these factors have lead to an improved wash performance (trade-off with energy through e.g. lower temperatures) and a reduction in sud volume (translates directly into less energy).

- **Option 7 - *rinsing optimisation***: improved rinsing efficiency using only 3 rinses and increasing the intermediate spinning action, saving water. This saves some 13 litres per cycle. There is a general acceptance of 3 rinse cycles instead of 4 or 5, with a higher number of intermediate spins. The cost of this option, which was introduced in the 1993-1998 period, is estimated at 7 Euro (instead of the estimated 11,8 Euro mentioned in the GEA study).
- **Option 8 - *water level and temperature control***: improved water level control, reducing the sud volume. Manufacturers claim that 80% of all machines now have a sophisticated mechanical water level control. The suds volume of the base case was set at 16,6 litres, which means a saving potential of 30 Wh/cycle (6 Wh/kg) to be expected for the future at an average cost of 1,5 Euro.
  The electronic thermostat is clearly a more expensive and more sophisticated item, saving by itself through better control of the temperature curve. With a price of 20 Euro however it is believed to be applicable in only a limited number of machines.
- **Option 9 - *Sophisticated electronic controls***: introduction of "fuzzy" or other type of sophisticated control enables the machine to determine a large part of the program by itself. This option (or rather this set of options) optimises the consumer behaviour regarding programme settings, thus saving considerable amounts of energy and water. Since this option does not affect energy and water consumption in the standard base case it was not included in the LCC analysis.

The most important element emerging from the description of the technological option was that more and more, the design of a washing machine is a systems design requiring specific combinations of sensor, central intelligence and motors rather than the addition of extra features to an already existing design. The clustering of design options, which is a necessity in order to apply the LCC methodology, is therefore a somewhat arbitrary process. Discussion and refining of the options costs and savings lead to the creation of the LCC input Table 6.5, including 8 options, which were later reduced creating Option (1+2) as the combination of the two single motor improvements (that were assumed to be applied contemporarily with a ratio of 70:30 and an overall price of 24,75 Euro). Option 8 about better rinses in applied only to 25% of the market. A mark-up of 2,75 was used to calculate the consumer price increase from the manufacturing cost increase. The Net Present Value for the single technological options is presented in Table 6.6.

Conclusions from the technical/economic analysis in 1998 were:

- Between 1993 and 1998 there has been no breakthrough in washing machine technology. Nor can we foresee basic new insights from laboratory experiments running today. The technical economic analysis by GEA in 1993 estimated that an electricity consumption of 0,165 kWh/cycle was possible and this still is roughly the best that can be expect for the coming years (for the 60 ºC cotton cycle);
- Various technological options have matured since 1993 and have been implemented. Mass production of previously seen as more “experimental” features has started and prices have

dropped. Notably this is true for motor technology, where DC motors will probably soon be the new standard for all top-range washing machines. This also applies to evolution of electronics in washing machines, which will affect both energy and water consumption for the 1998 standard base case but probably even more appliances in real life. As a consequence, many design options identified have become more 'economical' to the consumer in terms of LCC and payback time;

- What also changed between 1993 and 1998 is that the machines are designed more and more as a total concept. The basically electro-mechanical concept has evolved to an electronically controlled machine with sophisticated sensors as inputs and sophisticated motors (and heating element controls) as outputs. This evolution makes the identification of single, "add-on" design options (and their costs) more difficult.

Table 6.5: Base-case values and technical options energy/water savings and costs in 1998 (WASH-2 study)

Option	Technological options	Energy savings over the base case		Water savings over the base case		Costs	Price
(No)	(description)	(Wh)	(%)	(litre)	(%)	(EURO)	(EURO)
1	DC motor phase control	50	4,35	0	0	5	13,75
2	DC chopper motor	70	6,09	0	0	18	49,5
3	Time temperature trade-off	50	4,35	0	0	1	2,75
4	Mechanical action	50	4,35	0	0	5	13,75
5	T, W sensors, full electronic and 100% AC phase control	100	8,70	12,5	19,841	10	27,5
6	Thermal efficiency	50	4,35	0	0	4	11
7	Tub-drum clearance	25	2,17	0,5	0,794	3	8,25
8	Rinses	0	0	2,5	3,97	0,5	1,375

Table 6.6: Net Present Value results for single technological option in 1998 (WASH-2 study)

Single options (No)	Option price (EURO)	Energy saving for option (%)	Water saving for option (%)	Payback time EU (years)	NPV lifetime 10 y	NPV lifetime 12 y	NPV lifetime 15 y	NPV lifetime 17 y
1+2	24,75	4,88	0	16,56	-13,75	-12,21	-10,24	-9,06
3	2,75	4,35	0	2,06	7,05	8,43	10,18	11,24
4	13,75	4,35	0	10,32	-3,95	-2,57	-0,82	0,24
5	27,5	8,70	19,841	3,73	26,76	34,35	44,08	49,90
6	11	4,35	0	8,26	-1,20	0,18	1,93	2,99
7	8,25	2,17	0,794	9,65	-1,96	-1,08	0,05	0,72
8	1,375	0	3,97	1,46	5,57	6,54	7,79	8,53

The LCC analysis led to the following *conclusions for a 60ºC cotton cycle standard base case*:

- the average energy consumption of a washing machine is at 0,24 kWh/kg (1998 situation);
- the lowest LCC point is at 0,188 kWh/kg for the standard base case, but at a rather long pay-back period of 8,3 years;
- the best technically feasible is at 0,17 kWh/kg, which is some 10% higher than the present "A" level. At this point the LCC is still below the level of the base case scenario for 1998, but the calculated pay back period (of 16,9 years) is longer than the average appliance life time (of 15 years).

6.1.3.3 Technological options for washing machines in 2005

The review of WASH-2 study options, the consultation of specialised magazines and an extensive discussion with industry and non-industry experts lead to the definition of the following list of possible technological options to be applied to the improvement of the 2005 base case:

- **Option No 1.1 – increased motor efficiency**: an estimate of possible motor efficiency improvement is presented in Table 6.7.

Table 6.7: An estimate of possible motor efficiency improvement in 2005

Motor options	market share in 2005 (%)	motor efficiency (compared to the AC phase motor)
Brushless DC (+ control)	0,5	+6%
Brushless DC direct drive (+ control)	0,5	+6%
Three-phase (+control)	5	+6%

Improvement in motor efficiency alone causes a reduction of around 50 Wh/cycle (brushless DC or Switched Reluctance). The additional benefit of the more sophisticated variable speed drive will help the reduction of the suds volume. The brushless DC motor eliminates the heat losses and time needed to make the motor cool down; when the Direct Drive system (the motor is mounted directly on the axis of the drum, without the traditional belt drive with low energy losses and better control) is also added the machine vibrations and noise are reduced; the three-phase motor is more used at present (5% of the market); the direct drive and the three-phase motor allow the reduction of the washing cycle noise to 48dB(A). Apart from the motor efficiency, a better motor enables the engineers to enter other efficient design options. The three motor types are alternative systems.

The different motor options are alternatives of the same technological innovation

- **Option No 1.2 - optimised materials in motors**: motor can be optimised also by optimising the amount of construction material; less iron and copper have no impact on energy/water consumption but reduce the material composition of the machine and the costs for manufacturers which can compensate the raw materials price increase; 5% less material can be used at present with no modification of the other motor characteristics. Apparently this option is still not applied to models on the market.
- **Option No 2 - time-temperature trade-off**: the savings due to this options have been already applied to all the market and not further improvement is considered possible.
- **Option No 3 - optimised mechanical action**: improvements in mechanical laundry agitation properties possible with the new motors and sophisticated controls (see next option); the effect on energy/water consumption is unclear, especially in the standardised cycle used for the Energy Labelling scheme, but some saving is still considered possible through a further optimisation.
- **Option No 4 - full electronic and controls**: electronic controls can be applied to different elements of the washing machine and washing cycle phases:
  - **Option No 4.1 - unbalance control:** control is achieved by the use of sensors for the motor, shock absorbers and machine mechanical construction. Shock absorbers can be mechanical (frictional) or high pressure (filled with gas or oil). Some sort of simple unbalance control is included in about 90% of the machines (see Option 4.2). A more sophisticated unbalance control, achieved by the use of special methods which detect the unbalance, is already applied to 5% of the market.

- **Option No 4.2 - load/water/temperature sensors**: about 90% of the machines on the market have at least partial electronic control. Sensors evaluate the load weight and the degree of dirtiness of the laundry, adapting consequently the washing cycle phases (temperature, amount of water, detergent and time); other sensors avoid the presence of too much water in the drum and stop the heating in case of overheating, thus improving the textile protection against thermal shocks. A simple unbalance control is also included.
  Load sensors: weight sensor can be used for optimal energy and water consumption with some reduction possible, but not detected with the present test method. This option has to be applied to real life base case for partial load detection and addressed in the new standard when dealing with partial load.
  Water sensors: analogue water sensor is applied only to 5% of the machines.
  Temperature sensors: the electronic thermostat, considered too expensive by the WASH-2 study, is now implemented in 80% the machines on the market together a simple unbalance control system. Some energy can still be saved when compared to electromecanical switch.
- **Option No 4.3 - sophisticated electronic controls:** introduction of "fuzzy" or other type of sophisticated control enables the machine to determine a large part of the program by itself. This option (or rather this set of options), already applied to 50% of the market, optimises the consumer behaviour regarding programme settings, thus could save energy and water. Since this option does not affect energy and water consumption in the standard base case it will be applied to the real-life base case, when the "reduced load" option is evaluated. Fuzzy logic is applied to produce more "sophisticate" machines.

- **Option No 5 - thermal efficiency**: the total energy consumption for machine-heat up, heat-up of the glass door, radiation and convection losses have been optimised. No further reduction is considered possible.
- **Option No 6 - tub-drum geometry**: considered fully optimised in the machine on the market.
- **Option No 7 - decrease in washing temperature**: new detergents and bleaching active at low temperature allow washing at lower temperature with decrease of energy consumption; however, contemporarily, an increase in detergent dosage is needed to maintain the same washing performance (all the other conditions being the same), but additional detergent might imply an increase in water consumption to achieve an acceptable rinsing performance, or to maintain the same performance of today at 60°C;. Not detectable at present with current EN standard and cotton cycle at 60°C. To be addressed in a new EN standard, where a lower temperature wash (40°C cycle) and rinsing performance considerations could be included. Both issues are addressed in the new edition of the IEC 60456 (5th edition).
- **Option No 8 - rinsing phase optimisation**: a better rinsing efficiency, with a decrease of the water needed to rinse, can be achieved through different improvements (for example: optimised drum shape, spinning speed, water flow through the laundry, etc.). The rinsing performance (amount of detergent residual in the washed laundry) not addressed in the present standard (see before). Applied to about 20% of the market.
- **Option No 9 - noise reduction**: noise in washing machine is caused by the motor and the water circulation during washing phase and by the spin during spinning. Noise reduction (to 48 dB(A)) in the wash phase can be achieved with the use of the direct drive and the three-phase motor (see before) plus the optimisation of the drain pump. Spinning noise to be reduced to 68-65 dB(A) by unbalance control (see before).
- **Option 10: increased time control (start delay)**: the use of "delay start" feature allows to start the washing cycle at a decided time, leaving the machine loaded and ready for start. Delaying the machine start could allow to use the off-peak tariffs (thus decreasing the cost of the used energy) or to have the washing cycle at different moment during the day selected by the consumer. The machine is turned 'on' and ready for the start at the given time (at the end of the delay), therefore at least a certain power consumption is needed for the timer and the associated electronics to function. This is more to be dealt in the framework of stand-by considerations

within system analysis and real-life base cases. Nevertheless, this option is already applied to 30% of the machines on the market. The "delay start" mode is not included in the revision of IEC 60456, nor in any of the present or planned policy measures around the world (see Task 1). Another new function for washing machines is the "time to end of the cycle" to end the cycle at a set time independent from the starting (cycle type, temperature and water to be adjusted consequently taking into consideration the allowed time to wash);

- **Option 11: increased amount of load** (for larger families, less frequent cycles or large laundry items): allows to reach a higher energy efficiency class with the same machine. If an class A machine of 5kg is allowed to consume 0,19 kWh/kg or 0,950 kWh for the cotton 60°C cycle, a 6kg machine of the same dimensions is allowed to consume 1,14 kWh/cycle (or 190 Wh for the extra 1 kg load). If the additional energy input needed to compensate the additional load weight is lower than 190 Wh, the residual energy can be used for other purposes or alternatively to improve the efficiency. "Big size" models (washing from 8 to 10 kg load) are introduced on the market today; the declared target is large families or small communities (restaurants, sport clubs, agritourisms, beauty centres, etc.) but also to wash very large laundry items (blankets, etc.) home or to make only one washing cycle per week in a 'normal' household. However, there is another reason at the basis of this marketing (and technological) choice: market globalisation and increased competition requires manufacturer to rationalised and optimise the production, by reducing the product platforms. Global market allows consumer to know, understand and appreciate the features of appliances sold in – once – far markets. Traditionally, the European market of washing machines was focussed on 5kg, front loading, horizontal axis machines, while the American (Canada, US, Mexico and other Latin American countries) market was focussed on larger, top loading, vertical axis machines. Increasing the load of European washing machines, and contemporarily reducing the load of the vertical axis machines to improve efficiency, could be also interpreted as an attempt by industry towards platforms harmonisation (or at least increased compatibility). Which in turn is the pre-requisite for international standard harmonisation and shared policy measures.
  Whether this effort will be successful depends in the end on changes in consumers behaviour and perception of own needs, which can be – to a certain extent – guided/matched through the introduction of appliances with new characteristics such as a larger capacity.
- **Option 12 – laundry and machine hygiene**: increased attention is registered to hygiene problems: micro-organisms reduction in the laundry and in the machine (drum and detergent dispenser) is achieved mainly through high temperature (the old boiling water 90-95°C cycle used for a different purpose, steam cycle), Ag+ ions release (through a silver bar positioned outside the drum or silver nano particles mixed with the gaskets and the internal coating material); high temperature (77°C) water intake at the beginning of the washing cycle for few minutes (typically 3 min, claimed to saturate the laundry with hot water long enough to kill most of the of the common household bacteria but not long enough to damage the fibres). Silver ion system is considered more a marketing tool than an effective mean to reduce micro-organisms contamination. The same results can be achieved using chemicals: traditional bleaching and more modern oxidising agents, specific detergents.
  It should be discussed if the increase in washing temperature, which implies an increase in the energy consumption for a washing cycle (just the opposite of other options) has to be considered a special cycle, and therefore not included in the evaluation of the machine energy consumption in standardised conditions, or if 'hygiene' should become part of a "normal" washing cycle and therefore considered in the overall evaluation of a machine consumption.
- **Option No 13 – single stain removal system**: presented in Munich in June 2006 by BSGH[7] a washing machines with a new stain removal system for different stains. The stain removal system allows the washer to be set to one of 14 different stain types, and the wash cycle will be

[7] Source: "Cutting Edge Washing from BSH", October 2006, Appliance Magazine, Europe Report.

adapted accordingly. Bloodstains, for example, are treated with a long, cold pre-wash. The user is expected not to mix differently stained items (as it is done at present for the normal laundry), but to collect all items with the same fabric and stain and wash lighter loads separately. The washer control adjusts water usage accordingly and provides detergent-use guidance to the consumer.

- **Option No 14 – drum construction**: (patented) integrated fibreglass housing with a counterbalance moulded directly into the shell of the outer drum (instead of the concrete or other materials counterbalance mounted to the outside). This option could decrease the manufacturing costs but the environmental impact of fibreglass, compared to the material used for the more traditional stand-alone counterbalance, has to be evaluated. No effect on energy/water consumption foreseen.
- **Option No 15 – automatic detergent dispensing** with sensor at the end of the reservoir. More typical for US machines, can be applied to European models[8] especially if liquid detergents will become the first choice due to the washing temperature decrease. However, the reservoir should be integrated in the external case, where available space is less and less due to the larger drum and used in parallel with the more traditional detergent dispenser (to allow the use of powder/tablet detergents). Positive effects of optimised (reduced) detergent dosage only in case the detergent is dosed according to the real load and programme type. It should be noted that washing machine and detergent manufacturers give generally extensive information to the customers about detergent use/dosage.
- **Option No 16 – increase of the spinning speed**: an improvement of the spinning speed increases the energy consumption of the washing cycle (higher consumption of the motor) and in general improves the spin drying efficiency by decreasing the remaining moisture content of the washed load. This in turn improves the overall efficiency of the washing-drying system, when a dryer is used. According to the German Agency Dena[9], a high-speed spinning, above 1 200 rpm, requires between 5% (at 60°C) and 10% (at 40°C) more energy than lower spin speeds.
- **Option No 17 – electronic update of the programmes/diagnostics**: update of the software managing the different washing cycles can be done by connecting the machine to the assistance PC. This option could be also used for machine diagnostic. There is no immediate impact with the energy/water consumption, but by updating the software a better washing cycle management could be achieved (if and when a better software is developed) in case of change in external conditions such as the development of a new detergent, with potential consumption reduction. 20% of machine on the market already have this option, to be used by an authorized after sale service.
- **Option No 18 – Internet connectivity**: this option enables remote diagnostics and programmes update. When connected to Internet the unit is linked to the company's (or assistance's) servers and automatically reports service issues and orders replacement parts and repair. An added benefit is the user's ability to start or stop the machine when outside home via the Internet connection. It is applied to none or very few models on the market (0,1%). A machine with this feature can not have an hard-switch, and will remain in a WOL state thus increasing the energy consumption in non-on mode (standby or low power modes). The same considerations of Option 10 apply. To be considered for long term development (BNAT).
- **Option No 19: LCD with actual load indication**: the indication of the actual load in LCD displays (possible due to the new load sensors, see before) could be a good system to address consumer behaviour towards full (or higher) loading of the machine. To be dealt for real life

[8] MIELE W 4449 WPS Liquid Washing Machine sold in UK, see:
http://www.miele.co.uk/Products/Features.aspx?pid=105% 20Miele%20W4449%20-%20liquid%20detergent%20dispensing.

[9] source: Revision of the Energy Labelling System, Final Report, 2006, Deutsche Energie-Agentur GmbH (Dena)

base case. At present no machines have this feature. The LCD display is present in some high end-range machines (0,5-1% of the market), and also the sensors for load weight, but not necessarily the load is displayed. It could be a good system to address consumer behaviour towards full (or higher) loading of the machine.

- **Option No 20 – voice controlled appliances**: (user-friendly interfaces in multiple languages and vocal interfaces) as appliance control become more capable and precise, one of the challenges facing designers is how to keep controls from getting too complicated while giving choices to users. One approach, little used in the appliance industry, is voice technology allowing for example to program a machine to follow a customised programme with just a few spoken words. Voice controls can add a bit of differentiation and give personality to an appliance, not to mention the advantages for the aged and disabled users, because of the hands- and eyes-free approach, even if the loading and unloading of the machine requires the use of both hands and eyes. Not applied for the moment, but to be considered for long term development (BNAT).
- **Option No 21 – mixed appliances**: a combination Washer/Dryer/Air-Conditioner has been presented in November 2006 by Toshiba Consumer Marketing: the Air Conditioning Cycle Drum TW-2500 VC/2000 VC is said to be the world's first washer/dryer with an air-conditioning function[10]. It sends out cool air, which is designed to improve the comfort in the room where the laundry appliance is used. The unit is designed with an air-conditioning cycle engine with dehumidifying and cooling functions, similar to an air-conditioner with a compressor. This allows the unit to dispense with the use of a heater when drying or water for cooling. Optimizing drying starts in the wash cycle, where the unit uses the S-DD Engine Plus 3, designed to give the machine the ability to perform powerful dehydration at a very high spin speed (1.500 rpm). In the drying cycles, the air-conditioning cycle engine accomplishes dehumidification using a 1 horsepower compressor and large-air-volume fan. The unit is a drum-type washer/dryer with a 9 kg laundry capacity. Electric power consumed for washing and drying a 6 kg load of laundry has been reduced to 1 600 Wh using 6 to 4 litre of water. Users choose from three modes of operation: "Standard" mode, "Speedy" mode (said to cut 40 minutes off the total washing/drying cycle) and the "Good Sleep" mode, designed to have a noise level as low as that of a library. The air-conditioning function is designed to have about 800 W of cooling capability, so that it can lower the temperature of about a 3,3 m^2 room from 30°C to 25°C in about 15 minutes. Integration of different functions to be addressed in system analysis and BNAT.
- **Option No 22 – Hot-fill feature**: several producers no longer offer it in the UK, where the application is declining. It is offered in no other of the EU27 country. The main reasons for the decreasing use are that as more water is saved by other measures the savings due to hot fill are reduced proportionately and also the fact that less hot water is needed makes the impact of pipe losses even greater as it is the initial volume of water that is lukewarm. Since the option is not expanding in the UK and not used elsewhere, the option can be considered not further usable. Recently, the UK consumer body "Which?" advised consumers that as long as most of the washing are at 40 °C there is little advantage to using a combination of hot and cold fill[11].
- **Option No 23 – "New and alternative" washing systems**: some new alternative washing systems are advertised and sold, mostly outside Europe, which do not use water or which try to re-use water or use in any case less water. These include: ozone treatment of the wash liquor, ultrasonic agitation, high performance osmosis/filtration and steam cleaning[12]. Although

[10] Source: November 2006 APPLIANCE Magazine.
[11] Source: Which? report : Washing machines, 28 June 2007, see:
http://www.which.co.uk/reports_and_campaigns/house_and_home/Reports/cleaning/Cleaning%20appliances/Washing%20machines/washing_machines_essential_guides_574_73738_9.jsp
[12] Source: MTP Briefing Note: IBNW23: Innovation briefing note on domestic laundry washing products and services.

available on some markets, most of these systems are considered not attractive for the European market as it stands now. Nevertheless, since in the long term there may be environmental benefits to be gained from some of these alternatives a description for some of them is given in Subtask 6.3 dealing with long term targets.

6.1.3.4 The technological Option List for washing machines in 2005

The considerations about the applicability of the hypothesised options lead to the definition of a set of technological options for washing machines including some long term/BNAT options. The selected set of options has been rearranged and renumbered as:

- **Option a.1** (Option 1): Brushless DC motor (+ control), or as alternative
- **Option a.2** (Option 1): Brushless DC direct drive motor (+ control), or as alternative
- **Option a.3** (Option 1): Three-phase motor
- **Option a.4** (Option 1.2): Optimised motor composition
- **Option b** (Option 3): Optimised mechanical action
- **Option c.1** (Option 4.1): Unbalance control (with separate sensors)
- **Option c.2** (Option 4.2): Analogue water sensor
- **Option c.3** (Option 4.2): Temperature control sensor
- **Option d** (Option 8): Rinsing phase optimisation
- **Option e** (Option 11): Increased load capacity (from 5kg to 6kg load) in the same machine
- **Option f.1**(Option 12): high temperature (77°C) water intake <for real-life base case only>
- **Option f.2** (Option 12): Boiling water or steam cycle <for real-life base case only>
- **Option g** (Option 4.2): weight sensors (load control) <for real-life base case only>
- **Option h** (Option 4.3): sophisticated electronic controls (fuzzy logic) <for real-life base case only>
- **Option i** (Option 10): increased time control: delay start <for real-life base case only>
- **Option j** (Option 19): LCD with actual load display <for real-life base case only>
- Option k (Option 16): Increase spin speed (from 1 200 to 1 600 rpm)
- **Option BNAT 1** (Option 18):Internet connectivity
- **Option BNAT 2** (Option 20): Voice controlled appliances
- **Option BNAT 3** (Option 21): Mixed appliances
- **Option BNAT 4** (Option 23): Alternative washing systems

All Options will be applied to the standard base case, with the exception of where it is indicated that options will be applied to real life base-case only since they will have no effect on the standard base case, due to for example the measurement method used in the standard (which does not take into account that specific aspect). All options will be applies to the real-life base case.

6.1.3.5 Costs and impacts for washing machine technological options

The selected technological options are shown in Table 6.8, along with the average rate of application, the improvement in manufacturing cost/price and consumer price and the associated energy/water savings when each option is applied to the base case machine. Shown data have been gathered through a data collection exercise with manufacturers and were validated through the discussion with experts and stakeholders.

Main cost/price parameters shown in Table 6.8 are:

- **Unit production costs** (manufacturing costs): directly related to production including materials, energy, components, labour, any allocated overhead costs and annual investment cost per unit. Annual investment cost per unit is equal to the total investment cost for the technological

Table 6.8: Technological Option List, improvement in price/costs and energy/water savings for the 5kg washing machine

Options		Application to the market	Unit production		Savings				Noise	Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water					
(No)	(description)	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(dBA)	(± min)	(€)	
a.1	Brushless DC motor (+ control)	0,5	15,4	20	+50	+0,0501	0	0	-2/3	-10	60	300-800 W motor, alternative to Options a.2 and a.3
a.2	Brushless DC direct drive motor (+ control)	0,5	50,0	65	+40	+0,0401	0	0	-2/3	-10	195	300-800 W motor, alternative to Options a.1 and a.3
a.3	Three-phase motor	5	23,1	30	+50	+0,0501	0	0	-6	-10	90	300-800 W motor, alternative to Options a.1 and a.2
a.4	Optimised motor composition	0	-0,8	-1	--	-	--	--	--	--	-3	compensation of material cost increase
b	Optimised mechanical action	20	0,4	0,50	+100	0,1002	2	0,0394	0	--	1,5	
c.1	Unbalance control (with separate sensors)	5	5,8	7,5	0	0	0	0	-5	--	22,5	noise reduction in spinning at 1200 rpm
c.2	Analogue water sensor	5	1,5	1,5-3	+10	+0,0100	+5,07	+10	--	--	6	
c.3	Temperature control sensor	80	0,4	0,50	+50	+0,0501	0	+0,0592	--	--	1,5	includes a simple unbalance control
d	Rinsing phase optimisation	20	3,8	5	0	0	+7,5	+0,1479	--	-15	15	Improves rinsing and allows water savings
e	Increased load capacity in the same machine	30	0,08	0,1	-80	-0,0802	-3	-0,0592	--	+15	0,3	from 5kg to 6kg load

Table 6.8: Technological Option List, improvement in price/costs and energy/water savings for the 5kg washing machine – continued

Options		Application to the market	Unit production		Savings				Noise	Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water					
(No)	(description)	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(dBA)	(± min)	(€)	
f.1	high temperature 77°C 8 litre water intake	0,5	0,4	0,5	-215	-0,2154	0	0	--	+3	1,5	frequency of usage to be evaluated, to be applied to **real-life** base case
f.2	Boiling water/steam cycle (4 litre)	0,5	0,4	0,5	-370	-0,3707	0	0	--	+10	1,5	
g	Weight sensors (load control)	2	5,8	7,5	+90	0,0902	+4,5	0,0888	--	0	22,5	applied to **real-life** base case, load reduced to 5kg to 3,4kg (see Task 3); needs new standard for evaluation
h	sophisticated electronic controls (fuzzy logic)	50	9,6	12,5	+15	+0,0209	+1	0,0216	0	0	37,5	Lead to a more "sophisticate" machine; applied to **real-life** base case
i	increased time control: delay start (results form Task3 indicated in parenthesis)	30 (used by 8%)	3,8	5	-(0,0105 at 3,5 W)	-0,000015	0	0	0	(3h = average time in this mode)	15	applied to **real-life** base case, and to be considered together with standby within system analysis
j	LCD with actual load display	0,5-1	7,7	10	the same values as Option g in absolute terms, but increases both energy and water consumption				--	0	30	to be applied to **real-life** base case; allows to go from 3,4kg to 5kg load
k	Increase spin speed (to ≥ 1 600)	15	7,7	10	-49,9	-0,05	0	0		+5	30	noise increase in spinning

improvement divided by 10 (years of depreciation) divided by the capacity or units produced annually. The reference capacity is one million units/year. Unit costs directly related to production of that unit/technical option are: materials, components, energy, labour, R&D related to the development of that unit/technical option, overhead costs that can be allocated to that unit/technical option, investment that can be related to that unit/technical option. For example, if total investment cost is 5 million Euro, the capacity is 1 000 000 units/yr with 10 years depreciation, the annual investment cost per unit is 0,50 Euro. This is summed with the other unit costs of materials, energy, component, labour and any allocated overhead costs.

- **Unit production price** (manufacturing price): unit production costs plus all other costs that are not directly related to that unit/technical option: sales and marketing, general and administrative costs, general R&D expenses, profit before taxes, any other general overhead cost. In the past, the product price at the factory was approximately 1,3 times the unit production cost.
- **Consumer price**: is the price paid by the consumer at the retailing place including transport costs, profit of retailer, advertising of product from retailer, etc. Consumer price was estimated by the product price at the factory plus the mark-up. A mark-up value of 2,75 was used in WASH-2 study for washing machines.

Starting from collected unit production prices, the manufacturing costs have been calculated from by dividing them by 1,3. Consumer price increase has been calculated using a mark-up value of 3,0. The electric energy price is 0,17 €cent/kWh in real terms.

The standard and real-life base-cases annual energy consumption (Task 5) are given in Table 6.9.

Table 6.9: Standard and real-life base-cases annual energy consumption and noise

Machine type	Electricity consumption (Wh/cycle)	Water consumption (litre/cycle)	Noise (dBA)
STBC 5kg	0,998	50,7	53/70
RLBC 5kg	0,719	46,3	53/70

6.2 SUBTASK 6.2: ANALYSIS LLCC AND BAT

6.2.1 The NPV/MNPV Approach

As stated in the TREN/D1/40-2005 Call for Tender, the assessment of monetary Life Cycle Costs is relevant to indicate whether design solutions might negatively or positively impact the total EU consumer's expenditure over the total product life (purchase, running costs, etc.). The distance between the LLCC and the BAT indicates - in a case a LLCC solution is set as a minimum target - the remaining space for product-differentiation (competition). The BAT indicates a medium-term target that would probably more subject to promotion measures than restrictive action. The BNAT (= Best Not yet Available Technologies) indicates long-term possibilities and helps to define the exact scope and nature of possible measures.

The evaluation of the Least Life Cycle Cost and the BAT is achieved applying the Marginal Net Present Value (MNPV) approach: through Net Present Value (NPV) analysis the net benefits of the technological options to consumers are estimated; at this stage, the manufacturing cost increases are assumed to be passed completely to consumers through price increase; manufacturing price increase are calculated according to an agreed amount of mark-up from purchasing price increase. The increase in consumer price will be then compared to the discounted annual economic savings (on

the electricity) due to higher machine performance for the presumed lifetime of 15 years, resulting in the Net Present Value.

The NPV and LCC are evaluated first for each (single) technological option referred to the base case models. Then the optimum combination of technological options will be defined. First, the single options are sorted according to the payback period (or the ratio of NPV/investment) with the higher return options first. Second, the savings are calculated for the combined options. Evidently the potential savings decrease as subsequent technological options are added, since less energy/water is available to be saved due to the impact of the previously added technological option(s). This approach has been already followed in previous studies, for example the GEA study for dishwashers[13].

Net Present Value is then calculated for the combined options. In order to see the impact of adding each subsequent option, the net present value of adding a specific option is calculated. This is known as the **Marginal Net Present Value** of adding a given option. Since the options are added in order of their potential economic contribution, we may add options until their marginal net present value is zero or negative. This determines the optimum design and is also the point in which the total net present value of the combined options is a maximum (or the LCC is at minimum). The BAT is represented by the latest option combination. The NPV and Life Cycle Cost methods are equivalent. This is due to the fact that the life cycle cost is a constant value (the base case) minus the NPV of the improvements, thus the maximum NPV gives the minimum life cycle cost (LLCC). The output of the NPV analysis is the input in the LCC analysis where the constant values are added.

The main difference between the more traditional Life Cycle Cost analysis developed and reported in previous studies and the Marginal Net Present Value analysis (which both use the same design options input from the technical/economic analysis) lies in the fact that in traditional LCC design option impacts (savings and costs) are calculated one independent from another and then their effects are added, while the MNPV analysis calculates the effects of any option taking into account that a previous option has already been implemented and part of the savings has already been achieved. The other difference is that in the traditional LCC the options sequence is decided by "clustering" the options according to an engineering analysis or their simple pay back time, while in the NPV/MNPV approach the options are applied considering their economic return for consumers (in terms of net present value) after initial engineering considerations about their feasibility and compatibility.

6.2.1.1 The MNPV approach limits

The described method of adding percentage savings is completely correct if all options give a fix percentage of improvement, but in reality some of the identified options could results in a fix absolute savings: for these options, the absolute savings value should be subtracted as fix amount from the residual energy consumption; if not, the saving is systematically underestimated and the introduced error is proportional to the option application sequence, being higher the later the option is used, and the amount of savings.
Compared to the previous studies, a more sophisticated mixed system including percentage and fixed saving has been developed in the case options with fixed absolute savings are identified. The

[13] "The saving potential of the combined options can not be found by simply adding the savings of the single options. In the first place with most options savings are not a fixed number but a fixed percentage of the initial consumption. So with a machine that already has a lower energy consumption that the base case savings of most options are lower too. In the second place some options can not be combined at all…." (GEA2 study, page 14.47)

energy-consumption implications of various higher-efficiency design options are evaluated using a simple software - an ad-hoc excel sheet - initially developed for use in the previous SAVE studies for household appliances in which ENEA was partner, but now improved.

6.2.2 The NPV/MNPV and LCC Analysis for Dishwashers

6.2.2.1 The key technical, economic and financial assumption

The key technical, common economic and financial assumptions (see Task 5) are:

- Product life 15 years
- Cycles per year 280
- Discount rate 5%/year (PWF = 10,38 for 15years)
- Electricity price 0,17 Euro/kWh
- Water price 3,7 Euro/m^3
- Detergent, softener, rinsing agent: 2,34[14] Euro/kg, 0,6 Euro/kg and 2,4 Euro/kg
- Maintenance & repairs 5,5 Euro/year
- Disposal & recycling 61 Euro/life (at the end of life)
- Average 12ps machine price 548,4 Euro
- Average 9ps machine price 520 Euro.

In particular:

- number of washing cycles per year: 280 cycle/year was found in a German study made by STIWA in 2003. In addition, also 208 cycle/year (kept for sake of comparison with previous results) and 220 cycle/year (used is the labelling directive) will be used in the sensitivity analysis;
- chemicals: the use of detergent is 30g/cycle, for softener (salt) 20g/cycle and for rinsing agent 4g/cycle;
- the sales weighted average price of the dishwashers sold in 2004 according GfK was on average of 548,4 Euro for the 13 EU member stated where GfK collected the market data, with 552 Euro in West EU countries and 464 Euro in East EU countries which will be used in the sensitivity analysis. The 9ps machine price is estimated in 520 Euro.

6.2.2.2 The Simple Payback Time and Net Present Value analysis for the standard base cases

The first step of the analysis is the evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the relevant standard base cases, which have been defined as the average 9ps and 12ps of the machines in 2005. The results are presented in Table 6.10. NPV is calculated for a lifetime of 15 years and 280 washing cycles. The same data are ordered in Table 6.11 by simple payback time for each base case: in general there is a good agreement between the SPB and the NPV values, where the former increases the latter decreases. Some Options increase the energy/water consumption, and therefore the calculated payback time will be negative. The NPV is positive for four options for both the 9ps and the 12ps machine. The first two options achieve water savings: “avoidance/reduction of the cold pre-rinse” (*Option f.1*) and “partly draining and re-filling of water” (*Option f.2*), followed by “alternating spraying of water (*Option b*) and by the reduction of the wash temperature to 45°C (*Option a.1*). The following options have SPB longer that the average appliance lifetime (15 years) and significantly negative net present values.

[14] Low alkaline compact powder with enzymes.

Table 6.10: Simple payback time and net present value (at 15 years, for 280 cycles/year) for the identified technological options applied to the standard base cases for dishwashers

Dishwashers categories		9ps machine		12ps machine	
Options (n)	**Technology** (description)	SPB (years)	NPV (€)	SPB (years)	NPV (€)
a.1	Lower wash temperature (45°C) longer time	7,37	4,29	5,53	9,23
b	Alternating spraying of water	5,49	24,29	4,24	39,54
c	Heat exchanger (with storage tank)	19,12	-12,48	19,12	-12,48
d	Cross flow heat exchanger			32,77	-42,64
e.1	condenser for drying	54,62	-31,59	54,62	-31,59
e.2	Condenser with fan for drying	54,62	-31,59	54,62	-31,59
f.1	Avoidance/reduction of the cold pre-rinse	0,00	31,82	0,00	37,20
f.2	partly draining and re-filling (of water)	2,18	14,70	1,69	20,08
g	DC brushless motor	53,06	-62,74	53,06	-62,74
h.1	Noise reduction to 44 dB(A) (through better insulation)	-9,36	-65,79	-8,62	-85,94
h.2	Noise reduction to 41 dB(A) (through better insulation)	-16,39	-114, 7	-13,66	-137,3

Table 6.11: Technological options ordered by simple payback time (SPB) and net present value (NPV) at 15 years and 280 cycle/year for dishwasher standard base cases

Options (n)	9ps dishwasher SPB (years)	9ps dishwasher NPV (€)	Options (n)	12ps dishwasher SPB (years)	12ps dishwasher NPV (€)
f.1	0	31,82	**f.1**	0	37,2
f.2	2,18	14,7	**f.2**	1,69	20,08
b	5,49	24,29	**b**	4,24	39,54
a.1	7,37	4,29	**a.1**	5,53	9,23
c	19,12	-12,48	**c**	19,12	-12,48
g	53,06	-62,74	**d**	32,77	-42,64
e.1	54,62	-31,59	**g**	53,06	-62,74
e.2	54,62	-31,59	**e.1**	54,62	-31,59
h.1	-9,36	-65,79	**i**	-0,66	-131,3
h.2	-16,39	-114, 7	**h.1**	-8,62	-85,94
d			**h.2**	-13,66	-137,3

6.2.2.3 The Marginal Net Present Value and the aggregated option LCC analysis

To evaluate the improvement potential of the single options, the aggregated option analysis is developed. This LCC analysis was run for the average standard base-case appliances and for the standard base case models. The former represents the average of the reference year and takes into consideration the percentage of application of each technological option on the market, or better the percentage of each option still available for application on the market. For the latter a technological level is specified for the base cases and then all the available technological options are applied.

In the first case the possible average improvement of the overall appliance category are predicted. The second analysis allows to predict the best available technology models an can be also considered a sort of inner validation of the previous scenario and more in general of the overall calculation model: if the calculation can predict in a technically and economically sound way the

development from the base case model to the to the best available models on the market in 2005, then the overall simulation is coherent with the reality.

In Table 6.12 the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption for a 15 year lifetime and 280 cycles per year are presented for the average standard base cases and the standard base case models. For the former also the cycle time is presented.

Table 6.12: Technological options and marginal net present value (MNPV) at 15 years for the aggregated option analysis for dishwasher average standard base cases and standard base case models

Average standard base case		Consumption			Standard base case model		Consumption	
Options (n)	$MNPV_{av}$ (€)	energy (kWh/cycle)	water (litre/cycle)	time (min)	Options (n)	MNPV (€)	energy (kWh/cycle)	water (litre/cycle)
9ps dishwasher								
+b	14,57	0,798	12,20	102	**+b**	24,29	0,778	11,20
+f.1	11,48	0,794	11,31	100	**+f.2**	11,61	0,773	9,97
+f.2	9,43	0,790	10,32	100	**+a.1**	3,31	0,745	9,97
+a.1	1,09	0,782	10,32	109	**+c**	-13,96	0,718	9,97
+c	-11,31	0,758	10,32	109	**+e.1**	-32,57	0,705	9,97
+e.1	-16,11	0,751	10,32	104	**+e.2**	-32,69	0,692	9,97
+e.2	-24,21	0,741	10,32	97	**+g**	-69,74	0,676	9,61
+g	-64,54	0,723	9,94	97	**+h.1**	-55,51	0,733	9,61
+h.1	-47,84	0,770	9,94	104	**+h.2**	-109,56	0,813	9,61
+h.2	-108,19	0,851	9,94	114				
12ps dishwasher								
+b	23,73	1,028	13,40	102	**+b**	39,54	1,000	12,20
+f.1	13,27	1,024	12,34	100	**+f.2**	15,67	0,995	10,59
+f.2	12,74	1,020	11,04	100	**+a.1**	7,85	0,958	10,59
+a.1	2,49	1,009	11,04	109	**+c**	-14,03	0,931	10,59
+c	-11,33	0,985	11,04	109	**+e.1**	-32,55	0,918	10,59
+e.1	-16,09	0,978	11,04	104	**+e.2**	-32,64	0,905	10,59
+e.2	-24,17	0,968	11,04	97	**+d**	-45,68	0,871	10,59
+d	-44,53	0,931	11,04	107	**+g**	-65,56	0,855	10,25
+g	-65,56	0,914	10,64	107	**+h.1**	-76,46	0,937	10,25
+h.1	-55,62	0,975	10,64	114	**+h.2**	-129,51	1,042	10,25
+h.2	-125,43	1,079	10,64	124				

The optimum option combination varies with the base case and whether the LCC analysis was run for the average standard base-case appliances or for the standard base case models. Nevertheless some common elements can be drawn from the data presented in Table 6.12:

- the use of alternating spraying of water is always the most cost-effective design option for the
- average standard base cases and standard base case models;
- options saving water were always cost-effective;
- lower wash temperature was always cost-effective;
- the use of a heat exchanger was always the first of the non cost-effective options
- the improvement of the drying phase by adding a condenser and a fan was always non-cost effective

- the same happens for the DC brushless motor;

the decrease of the noise through a better insulation improves the energy consumption and has therefore always a negative effect on the energy efficiency.

a) The results for the average standard base cases

The resulting energy consumption and incremental purchase price for Base Case and average LLCC ($LLCC_{av}$) case for the two standard base cases are presented in Table 6.13. Also the energy efficiency index (E_I) is shown, calculated according to the algorithms of directive 97/17/EC (described in Task 1). The energy and water consumption for the 9ps machine is reduced by 46 Wh/cycle (or 5,6%) and 3,4 litre/cycle (or 24,8%); for the 12ps machine the energy and water consumption is reduced by 61 Wh/cycle (or 5,7%) and 4,2 litre/cycle (or 27,6%). The average E_I at $LLCC_{av}$ of the two products are below the threshold of the class A, with an improvement of 5,6% for the 9ps machine and of 5,7% for the 12ps machine. The forecast increase in purchase price at $LLCC_{av}$ is 4,4% for the 9ps dishwasher and 4,1% for the 12ps machine. The ratio between the predicted increase in purchase price and the efficiency improvement is:

Appliance	Ratio
9ps	0,79
12ps	0,72

The LCC is also presented in Figure 6.2 for the two average standard base cases. It is worth noting that *Option h.1* and *Option h.2* have been added as the last ones, despite their MNPV, due to the associated increase in the energy consumption of the machines. In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding the energy consuming options.

The lowest predictable energy consumption after all options have been added, or the average Best Available Technology (BAT_{av}) to the base cases is presented in Table 6.14. For dishwashers, three BAT_{av} levels can be predicted, due to the fact the options applied to reduce the noise are also increasing the overall energy consumption of the dish-washing cycle. In particular an average machine with a noise level of 41dB(A) consumes about the same as the average machine in 2005, but need the contemporary implementation of several technological options to balance the consumption increase due to the added insulation. The energy consumption for the 9ps machine is reduced by 105 Wh/cycle (or 12,7%) and that of the 12ps machine by 156 Wh/cycle (or 14,6%). The water saving is 3,76 litre/cycle (or 27,4%) for the 9ps category, with a minimum of slightly less that 10 litres; for the 12ps machine the savings is 4,56 litre/cycle (or 30,0%) with a minimum of 10,64 litres.

When the Life Cycle Cost (lifetime=15 years, 280 cycles/year) is shown as a function of the energy consumption (in kWh/cycle) and the Energy Efficiency Index (E_I) in directive 97/17/EC the curves in Figures 6.3 and 6.4 result.

Table 6.13: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and LLCCav for average standard base cases

Standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case E_I	$LLCC_{av}$ E_I	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)
9ps dishwashers	0,828	0,782	13,7	10,3	0,657	0,620	5,6	520,0	542,7	4,4	1.409	1.373
12ps dishwashers	1,070	1,009	15,2	11,0	0,648	0,611	5,7	548,4	571,1	4,1	1.594	1.542

Table 6.14: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and BATav for average standard base cases

Standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case E_I	BAT_{av} E_I	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)
9ps dishwashers	0,828	0,723	13,7	9,9	0,657	0,574	12,7	520,0	692,6	33,2	1.409	1.489
		0,770				0,611	7,0		716,6	37,8		1.537
		0,851				0,675	-2,8		784,7	50,9		1.645
12ps dishwashers	1,070	0,914	15,2	10,6	0,648	0,554	14,6	548,4	779,5	42,1	1.594	1.699
		0,975				0,591	8,9		808,8	47,5		1.758
		1,079				0,654	-0,8		882,9	61,0		1.884

Figure 6.2: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the applied technological options for 9ps and 12ps dishwasher average standard base cases.

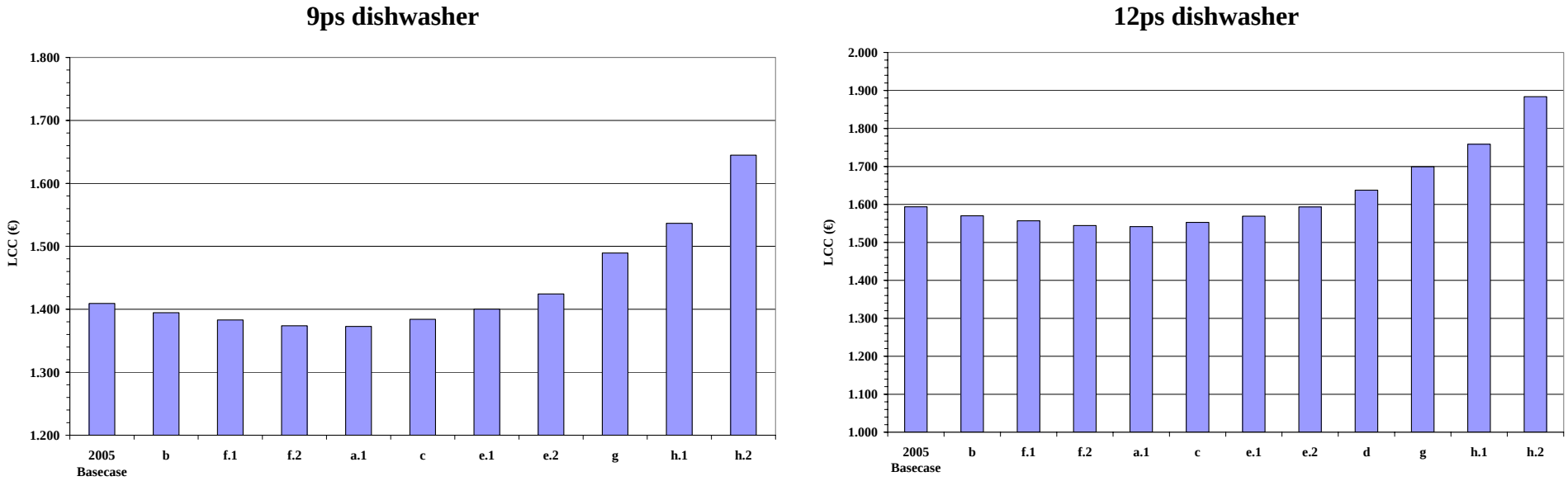


Figure 6.3: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the energy consumption for each dishwasher standard base cases. Average standard base cases are the red point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 12ps machine curve only) show the option application sequence.

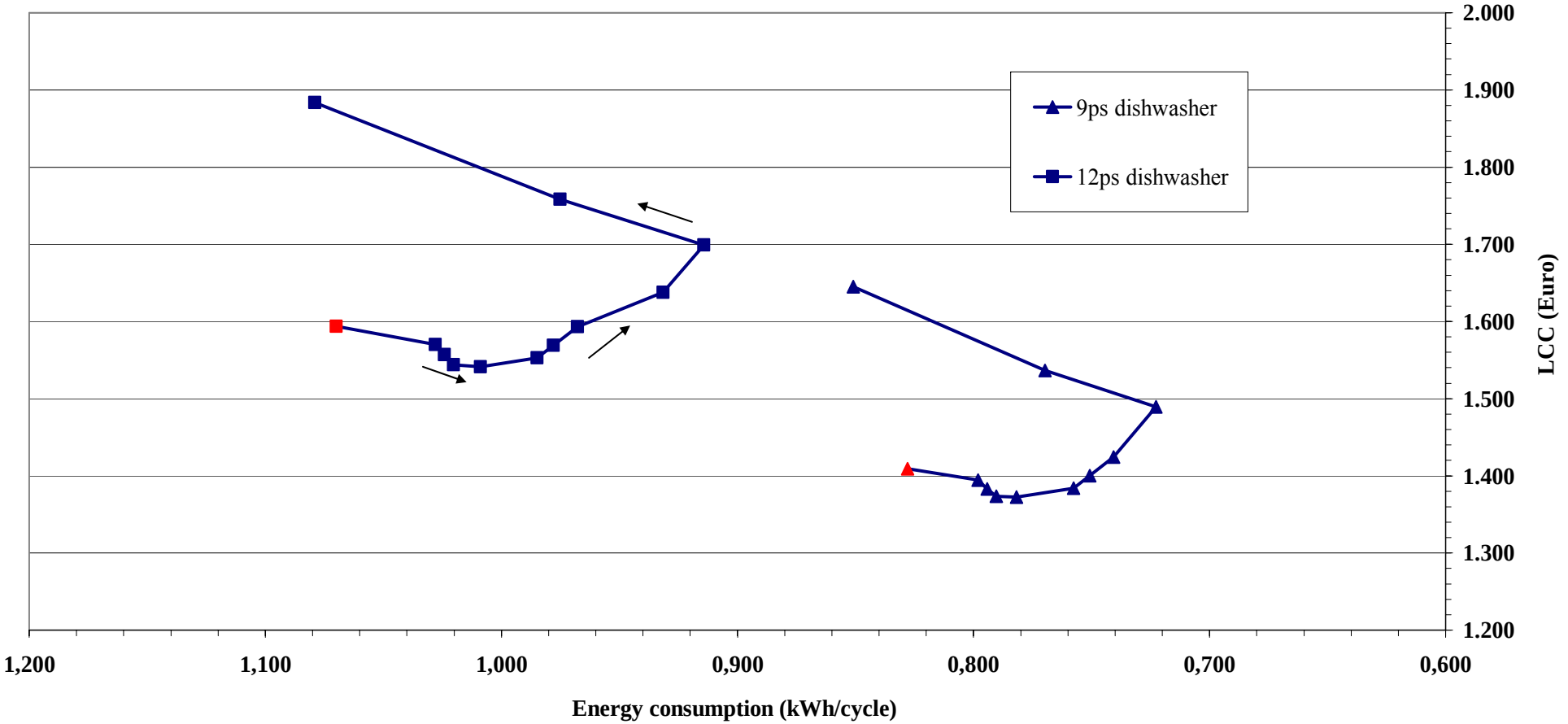
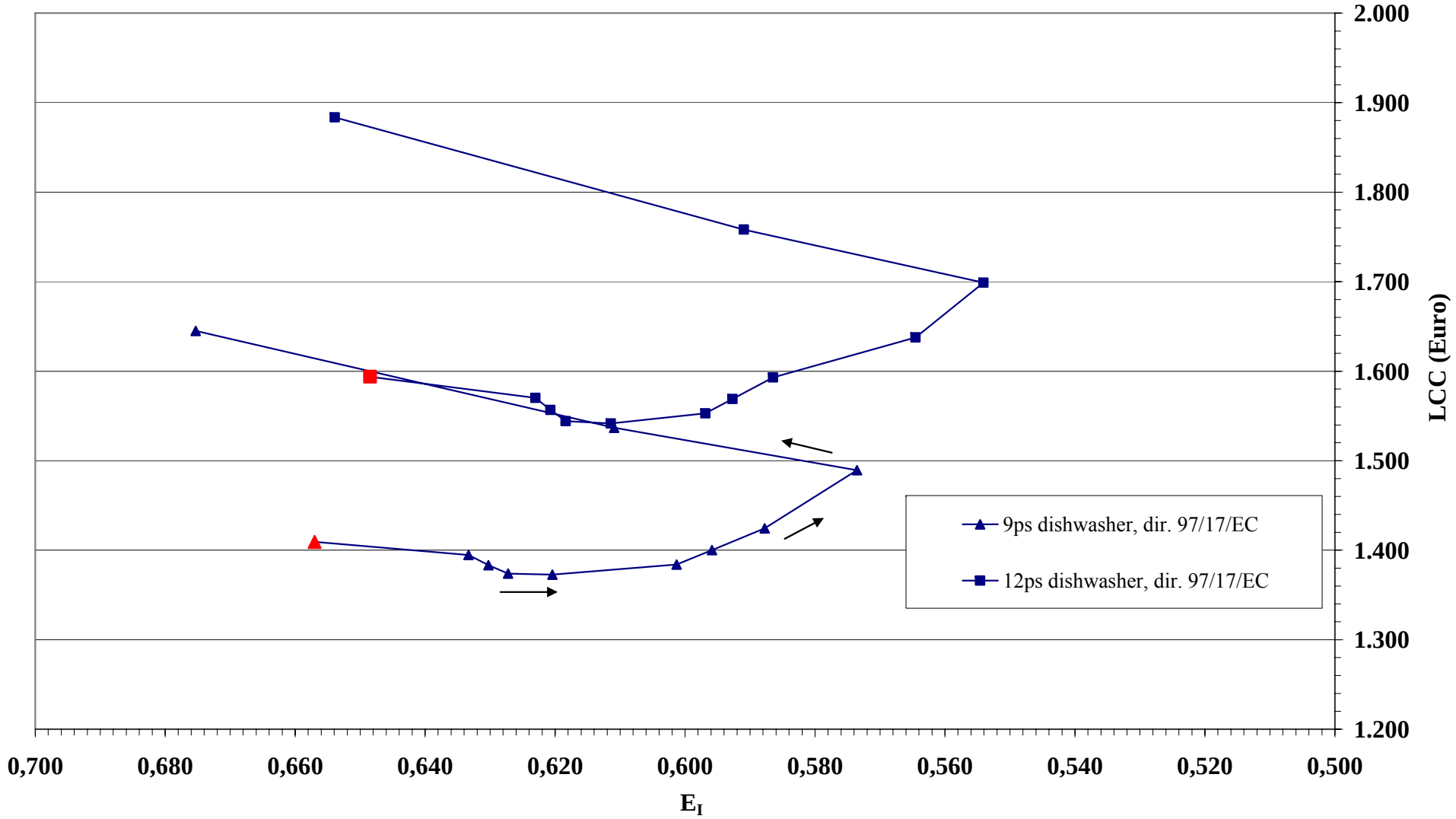


Figure 6.4: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the Energy Efficiency Index (EI) in directive 97/17/EC for each dishwasher standard base case. Average standard base cases are the red point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 9ps machine curve only) show the option application sequence.



b) The results for the standard base case model

When the more traditional LCC analysis is applied, the technological options already applied to the base cases are identified, allowing therefore to define the options which are totally available for application among those included in the initial Technological Option List. The LCC analysis is then run. The resulting predicted improvement in energy/water consumption, energy efficiency and purchasing price are presented in Table 6.15 for each base case model.

The energy and water consumption for the 9ps machine is reduced by 83 Wh/cycle (or 10,0%) and 3,7 litre/cycle (or 27,2%); for the 12ps machine the energy and water consumption is reduced by 112 Wh/cycle (or 10,5%) and 4,6 litre/cycle (or 30,3%). The average E_I at LLCC of the two products are below the threshold of the class A, with an improvement of 10% for the 9ps machine and of 10,5% for the 12ps machine.

The predicted increase in purchase price at LLCC is 8% for the 9ps dishwasher and 7,60% for the 12ps machine. The ratio between the increase in purchase price and the efficiency improvement becomes is:

Appliance	Ratio
9ps	0,80
12ps	0,72

The LCC is also presented in Figure 6.5 for the two base case models. It is worth noting that *Option h.1* and *Option h.2* have been added as the last ones, despite their MNPV, due to the associated increase in the energy consumption of the machines. In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding the energy consuming options.

The lowest predictable energy consumption for after all options have been added, or the Best Available Technology (BAT) to the base cases is presented in Table 6.16. For dishwashers, three BAT levels can be predicted, due to the fact the options applied to reduce the noise are also increasing the overall energy consumption of the dish-washing cycle. In particular an average machine with a noise level of 41dB(A) consumes about the same as the average machine in 2005, but need the contemporary implementation of several technological options to balance the energy consumption increase due to the added insulation. The options to reduce noise could be applied to any model and at any stage of the technological development pathway, here they are applied as last option to the best available technology model to show more clearly the tradeoffs between energy consumption and noise reduction

The energy consumption for the 9ps machine is reduced by 152 Wh/cycle (or 18,4%) and that of the 12ps machine by 215 Wh/cycle (or 20,1%). The water saving is 4,1 litre/cycle (or 29,9%) for the 9ps category, with a minimum close to 9,5litres; for the 12ps machine the savings is 5 litre/cycle (or 32,6%) with a minimum of 10,2 litres.

When the Life Cycle Cost (lifetime = 15 years, 280 cycles/year) is shown as a function of the energy consumption (kWh/cycle) and the Energy Efficiency Index (E_I) in directive 97/17/EC the curves in Figures 6.6 and 6.7 result.

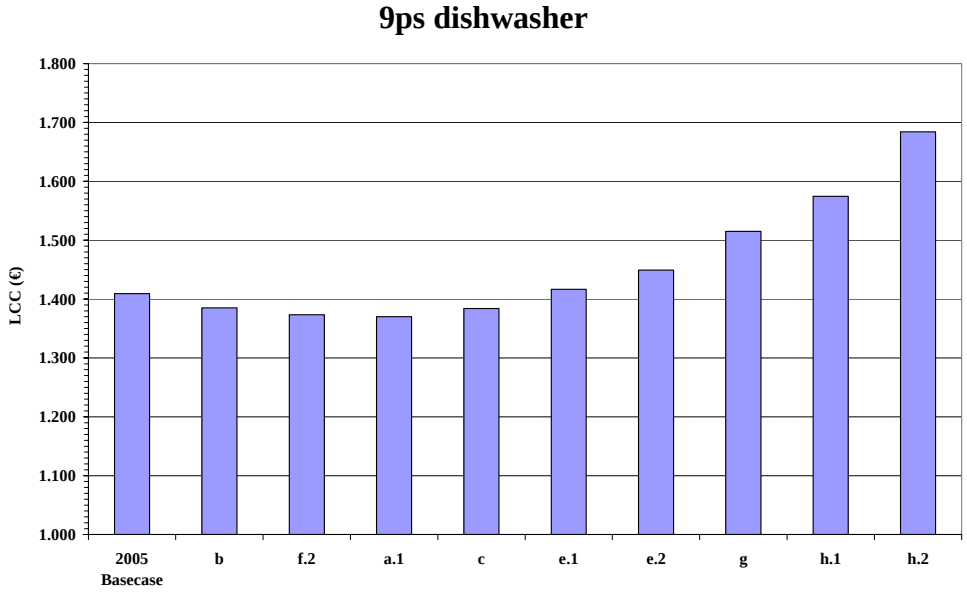
Table 6.15: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and LLCC for standard base case models

Standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	LLCC (kWh/cycle)	Base case (litre/cycle)	LLCC (litre/cycle)	Base case E_I	LLCC E_I	difference (%)	Base case (Euro)	LLCC (Euro)	Increase (%)	Base case (€)	LLCC (€)
9ps dishwashers	0,828	0,745	13,7	9,97	0,657	0,591	10,0	520,0	561,7	8,0	1.409	1.370
12ps dishwashers	1,070	0,958	15,2	10,6	0,648	0,581	10,5	548,4	590,1	7,6	1.594	1.531

Table 6.16: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and BAT for standard base case models

Standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	BAT (kWh/cycle)	Base case (litre/cycle)	BAT (litre/cycle)	Base case E_I	BAT E_I	difference (%)	Base case (Euro)	BAT (Euro)	Increase (%)	Base case (€)	BAT (€)
9ps dishwashers	0,828	0,676	13,7	9,61	0,657	0,536	18,4	520,0	745,0	43,3	1.409	1.515
		0,733		9,61		0,582	11,5		776,2	49,3		1.575
		0,813		9,61		0,645	1,9		846,4	62,8		1.684
12ps dishwashers	1,070	0,855	15,2	10,25	0,648	0,518	20,1	548,4	835,8	52,4	1.594	1.772
		0,937		10,25		0,568	12,4		874,8	59,5		1.801
		1,042		10,25		0,632	2,6		952,8	73,7		1.931

Figure 6.5: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the applied technological options for 9ps and 12ps dishwasher standard base case models.



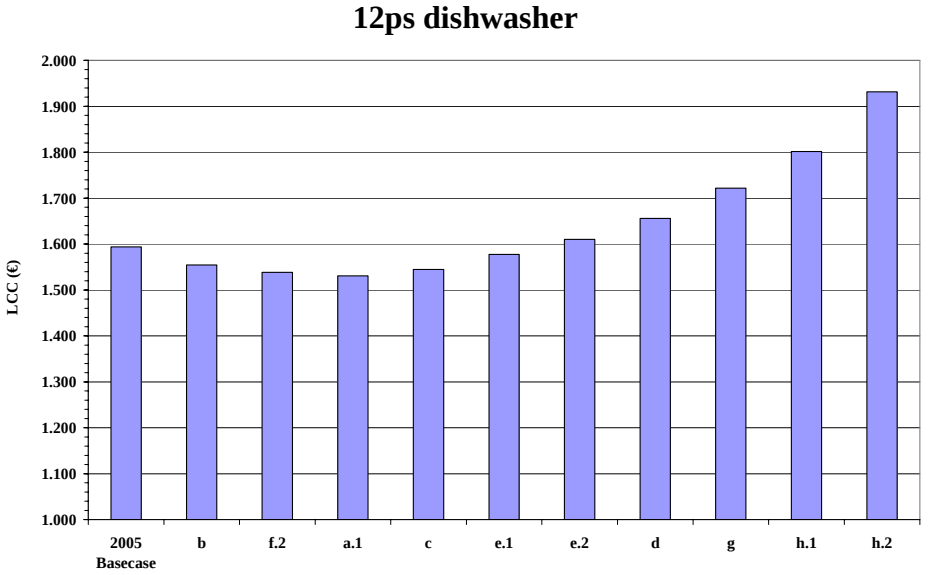


Figure 6.6: Life Cycle Cost (lifetime = 15 years) as a function of the energy consumption for each of the dishwasher standard base case model. Standard base case models are the red point on each curve, the Best Available Technology (BAT), at noise=50 dB(A), in the reference year (2005) is the most right point on each curve (highlighted in pink). Appliance base cases are identified by place settings number. Arrows (on the 12ps machine curve only) show the option application sequence.

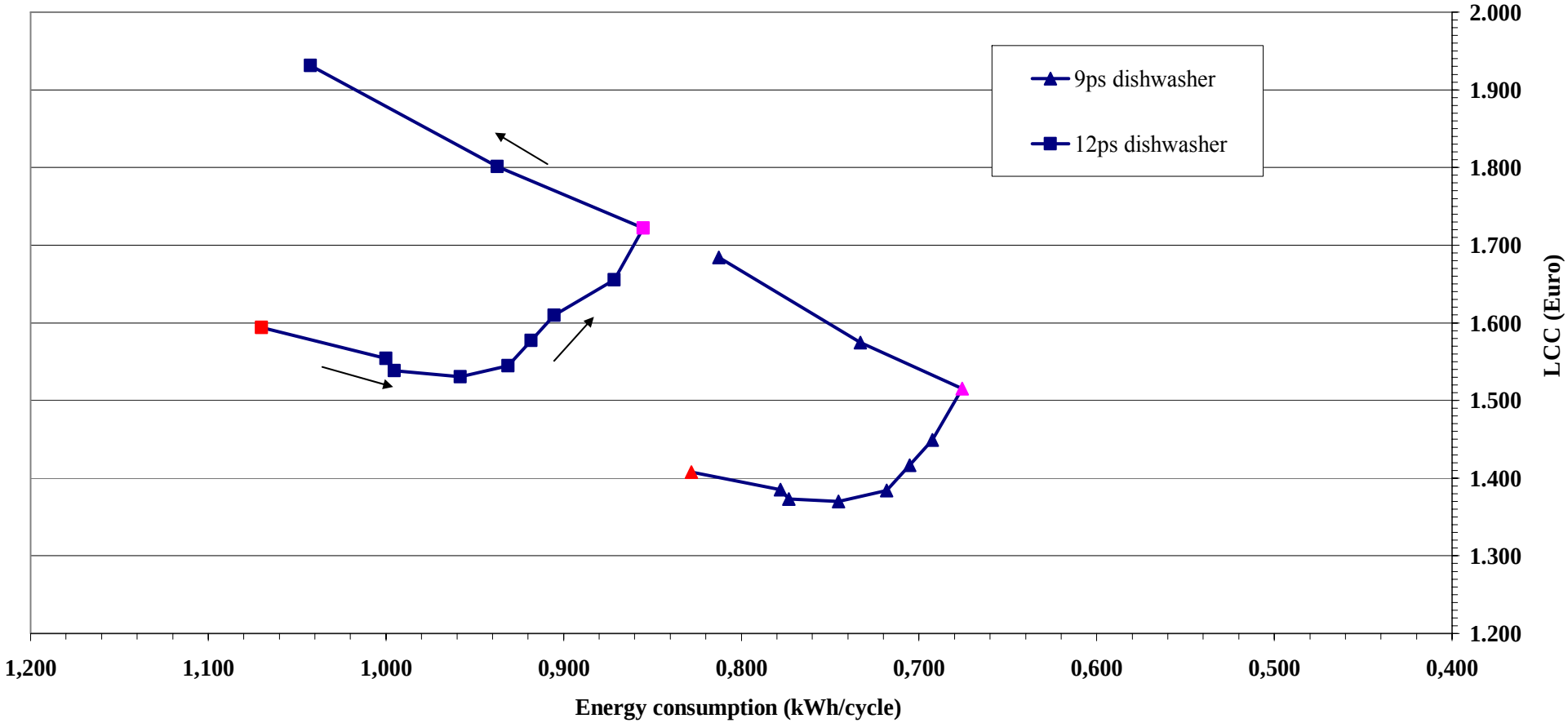
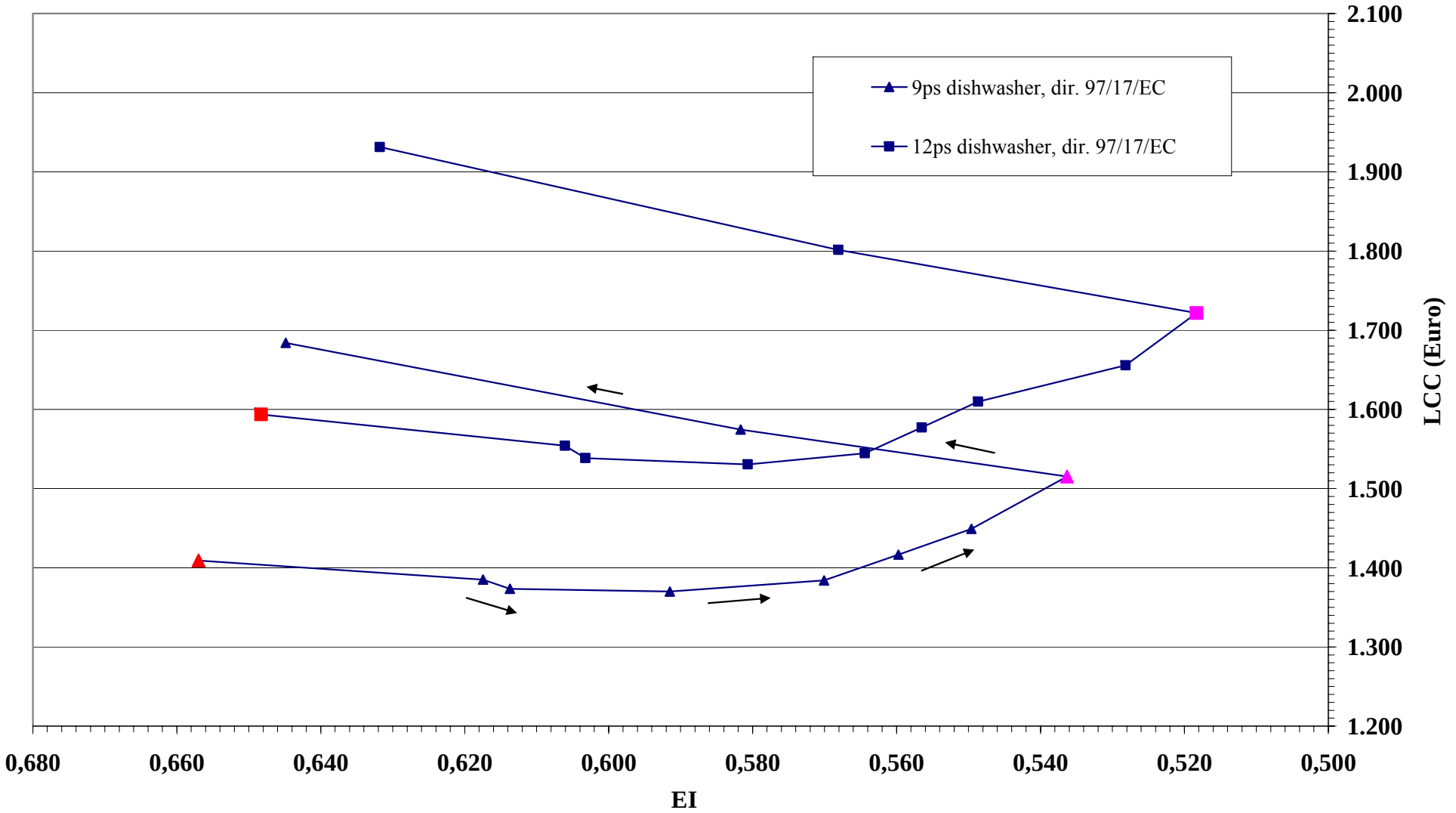


Figure 6.7: Life Cycle Cost (lifetime = 15 years) as a function of the Energy Efficiency Index (EI) in directives 97/17/EC for each of the dishwasher standard base case models. Standard base case models are the red point on each curve, the Best Available Technology (BAT), at noise=50 dB(A), in the reference year (2005) is the most right point on each curve (highlighted in pink). Appliance base cases are identified by place settings number. Arrows (on the 9ps machine curve only) show the option application sequence.



A close agreement can be seen between the results the predicted BAT energy consumption and efficiency index and the actual minimum values of the dishwasher models on the market in 2005/2006 in terms of minimum energy and water consumption for the 12ps machine and the best model in CECED 2005 technical database for the 9ps machine (see Task 5) as shown in Table 6.17.

Table 6.17: Comparison of the minimum energy and water consumption for dishwasher models in 2005/2006 and the results of the LCC for the standard base case models

Category	Min. energy consumption (kWh/cycle)		Min. water consumption (litre/cycle)	
	CECED 2005	LCC	CECED 2005	LCC
9ps dishwasher	0,800	0,813 (41dBA)	10	9,6
12ps dishwasher	0,950 (45dBA) 1,050 (41dBA)	0,937 (44dBA) 1,042 (41dBA)	9	10,3

6.2.2.4 The analysis for the real-life base cases

The real-life base case LCC analysis will be run by applying the technological options identified for the standard base case to the real-life base cases defined in Task 5 on the basis of the consumer analysis described in Task 3. The expected outcome is the evaluation of the savings achievable under real life conditions from the technological improvement of the standard machines.

The evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the relevant real-life base cases was run. The results are presented in Table 6.18 for the 9ps and the 12ps machines. NPV is calculated for a lifetime of 15 years and 280 washing cycles.

Table 6.18: Simple payback time and net present value (at 15 years, for 280 cycles/year) for the identified technological options applied to the real-life base cases for dishwashers

Dishwashers categories		9ps machine		12ps machine	
Options (n)	**Technology** (description)	SPB (years)	NPV (€)	SPB (years)	NPV (€)
a.1	Lower wash temperature (54,3°C) longer time	7,37	4,29	5,53	9,23
b	Alternating spraying of water	5,49	24,29	4,24	39,54
c	Heat exchanger (with storage tank)	19,12	-12,48	19,12	-12,48
d	Cross flow heat exchanger			32,77	-42,64
e.1	condenser for drying	54,62	-31,59	54,62	-31,59
e.2	Condenser with fan for drying	54,62	-31,59	54,62	-31,59
f.1	Avoidance/reduction of the cold pre-rinse	0,00	31,82	0,00	31,82
f.2	partly draining and re-filling (of water)	2,18	14,70	1,69	20,08
g	DC brushless motor	53,06	-62,74	53,06	-62,74
h.1	Noise reduction to 44 dB(A) (through better insulation)	-9,36	-65,79	-8,62	-85,94
h.2	Noise reduction to 41 dB(A) (through better insulation)	-16,39	-114,67	-13,66	-137,29

In particular, for *Option a.1* the decrease (i.e. the ΔT) in the washing temperature is kept constant compared to the standard base case. In other words, if the average standard 12ps machine has a wash temperature of 50°C whereof the average real life 12ps machine has an actual washing temperature of 59,3°C (ΔT = +9,3 K), when *Option a.1* is applied the new actual wash temperature

under real life conditions is 45+9,3 = 54,3 °C. The energy savings associated with the option application remains the same as in the standard base case simulation.

The results of the aggregated option analysis are presented in Table 6.19, where the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption values for a 15 year lifetime and 280 cycles per year are given for the average real life base cases.

Table 6.19: Technological options and marginal net present value (MNPV) at 15 years for the aggregated option analysis for average dishwasher real life base cases

9ps dishwasher		Consumption		**12ps dishwasher**		Consumption	
Options (n)	$MNPV_{av}$ (€)	energy (kWh/cycle)	water (litre/cycle)	Options (n)	MNPV (€)	energy (kWh/cycle)	water (litre/cycle)
+b	14,57	0,873	12,40	**+b**	23,73	1,125	13,60
+f.1	11,50	0,869	11,51	**+f.1**	11,40	1,121	12,72
+f.2	9,47	0,865	10,51	**+f.2**	12,99	1,117	11,40
+a.1	1,10	0,857	10,51	**+a.1**	2,52	1,106	11,40
+c	-11,25	0,832	10,51	**+c**	-11,27	1,082	11,40
+e.1	-16,08	0,826	10,51	**+e.1**	-16,07	1,075	11,40
+e.2	-24,17	0,815	10,51	**+e.2**	-24,13	1,064	11,40
+g	-65,01	0,797	10,14	**+d**	-44,38	1,028	11,40
+h.1	-47,53	0,845	10,14	**+g**	-61,12	1,010	10,99
+h.2	-108,45	0,926	10,14	**+h.1**	-59,73	1,072	10,99
				+h.2	-125,85	1,177	10,99

The resulting energy consumption and incremental purchase price for Base Case and average LLCC ($LLCC_{av}$) case when the technological options are applied to the two real-life base cases are presented in Table 6.20. The energy and water consumption for the 9ps machine is reduced by 46 Wh/cycle (or 5,1%) and 3,2 litre/cycle (or 23,4%); for the 12ps machine the energy and water consumption is reduced by 61 Wh/cycle (or 5,2%) and 4,0 litre/cycle (or 26,0%).

The LCC is also presented in Figure 6.8 for the two real-life base cases. It is worth noting that the options increasing the energy consumption have been added as the last ones, despite their MNPV, due to the associated increase in the energy consumption of the machines. In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding the energy consuming options.

The lowest predictable energy consumption values after all options have been added, or the average Best Available Technology (BAT_{av}) to the base cases are presented in Table 6.21. For dishwashers, three BAT_{av} levels can be predicted due to the fact that some options, as already mentioned, are also increasing the overall energy consumption of the dish-washing cycle. In particular, a machine with a noise level of 41dB(A) consumes more than the average machine in 2005 under real life conditions. When the noise remain unchanged at the average value of 50d(B)A, the energy consumption for the 9ps machine is reduced by 46 Wh/cycle (or 5,1%) with a minimum of 0,857 kWh/cycle and that of the 12ps machine by 61 Wh/cycle (or 5,2%) with a minimum of 1,106 kWh/cycle. The water saving is 3,4 litre/cycle (or 24,5%) for the 9ps category, with a minimum of 10,5 litres; for the 12ps machine the savings is 4 litre/cycle (or 26%) with a minimum of 11,4 litres.

When the Life Cycle Cost (lifetime = 15 years, 280 cycles/year) is shown as a function of the energy consumption (in kWh/cycle) and the Energy Efficiency Index (E_I) in directive 97/17/EC the curves in Figures 6.9 and 6.10 result.

Table 6.20: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and LLCCav for real-life base cases

Real life base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case E_I	$LLCC_{av}$ E_I	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)
9ps dishwashers	0,903	0,857	13,9	10,5	0,717	0,680	5,1	520,0	542,7	4,4	1.448	1.412
12ps dishwashers	1,167	1,106	15,4	11,4	0,707	0,670	5,2	548,4	571,1	4,1	1.644	1.593

Table 6.21: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and BATav for real-life base cases

Real life base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case E_I	BAT_{av} E_I	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)
9ps dishwashers	0,903	0,797	13,9	10,1	0,717	0,633	11,7	520,0	692,6	33,2	1.448	1.528
		0,845				0,670	6,4		716,6	37,8		1.576
		0,926				0,735	-2,6		784,7	50,9		1.684
12ps dishwashers	1,167	1,010	15,4	11,0	0,707	0,612	13,4	548,4	779,5	42,1	1.644	1.750
		1,072				0,650	8,1		808,8	47,5		1.810
		1,177				0,713	-0,8		882,9	61,0		1.936

Figure 6.8: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the applied technological options for 9ps and 12ps dishwasher real-life base cases

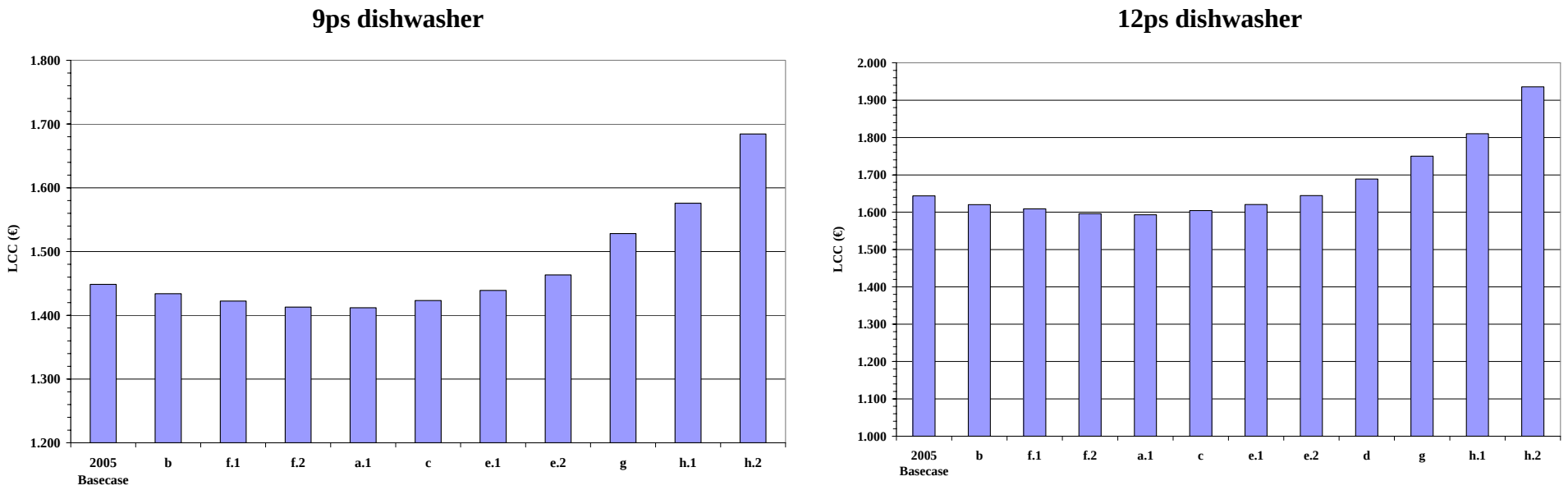


Figure 6.9: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the energy consumption for each dishwasher real-life base cases. Real-life base cases are the red point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 12ps machine curve only) show the option application sequence.

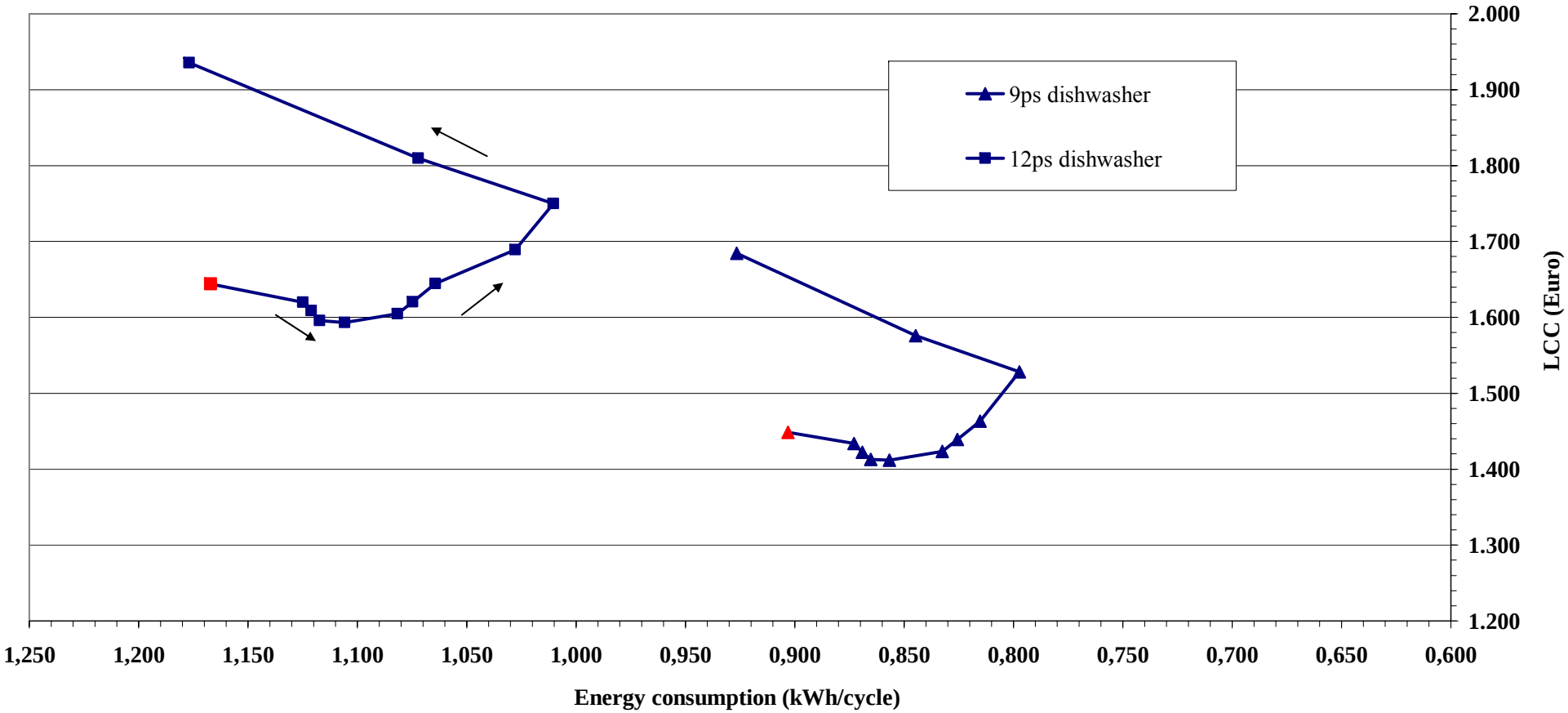
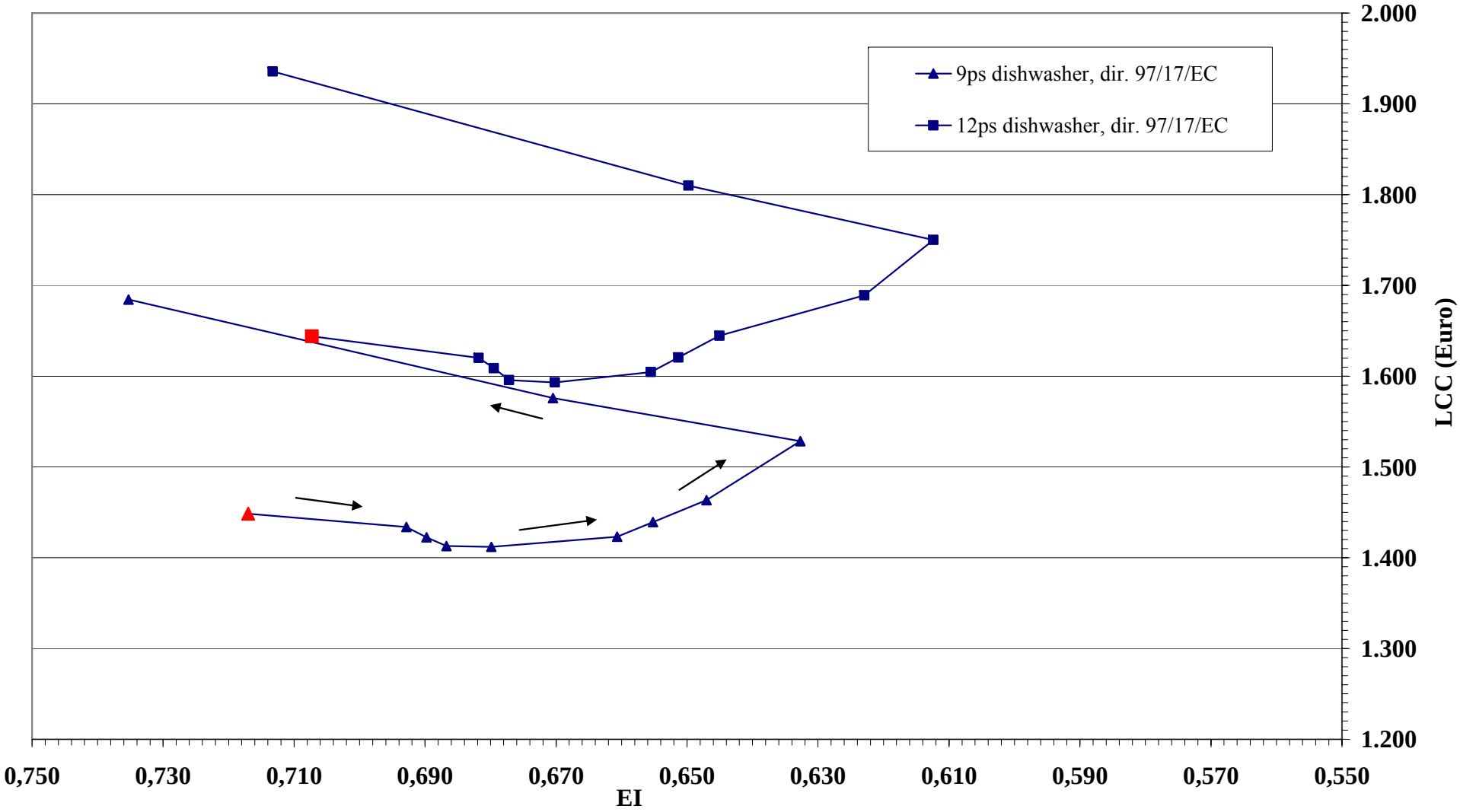


Figure 6.10: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the Energy Efficiency Index (EI) in directive 97/17/EC for each dishwasher real-life base cases. Real-life base cases are the red point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 9ps machine curve only) show the option application sequence.



6.2.2.5 The analysis for the standard base cases with an extended option set

In this analysis, the technological options identified in previous Tables 6.1-6.2 as suitable for the real life will be applied to the standard base cases together with the options already identified as applicable for the standard base cases to evaluate the overall modification of the energy/water consumption when the average machine is used under real-life conditions. This exercise, although simplified through some potentially questionable assumptions, will give indications on the energy/water consumption measured according to a possible revised standard, more adherent to the real life.
Again the evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the relevant standard base cases was developed. The results are presented in Table 6.22 for the 9ps and the 12ps machines. NPV is calculated for a lifetime of 15 years and 280 washing cycles.

The results of the aggregated option analysis are presented in Table 6.23, where the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption values for a 15 year lifetime and 280 cycles per year are given. In particular in the previous analysis *Option a.1* and *Option a.2* have been combined, so that the actual wash temperature drops from 50°C to 40°C in one step; *Option h.1*, *Option h.2* and *Option i* have been added as the last ones, despite their MNPV, due to the associated increase in the energy consumption of the machines. In particular the decision to apply *Option i* (encompassing a hot rinse at 70-75°C) to 20% of the cycles is questionable, but has been included as the last option to evaluate the potential increase in energy consumption in case a final hot rinse would become part of a future standard washing cycle (to solve the hygiene problems). In addition, *Option j.1- electronic sensors for the load soling (50% soiled)* and *Option j.2 - Electronic sensors for the load weight (50% mass)* have been added together (to avoid the need of a separate further LCC analysis), thus simulating a wash cycle with a half load of half soiled tableware, but not necessarily this will happen contemporarily in real life.

Table 6.22: Simple payback time and net present value (at 15 years, for 280 cycles/year) for the extended technological options applied to the average standard base cases for dishwashers

Dishwashers categories		9ps machine		12ps machine	
Options (n)	**Technology** (description)	SPB (years)	NPV (€)	SPB (years)	NPV (€)
a.1	Lower wash temperature (45°C) + longer time	7,37	4,29	5,53	9,23
a.2	Lower wash temperature (40 °C) + longer time	7,37	4,29	5,53	9,23
b	Alternating spraying of water	5,49	24,29	4,24	39,54
c	Heat exchanger (with storage tank)	19,12	-12,48	19,12	-12,48
d	Cross flow heat exchanger			32,77	-42,64
e.1	condenser for drying	54,62	-31,59	54,62	-31,59
e.2	Condenser with fan for drying	54,62	-31,59	54,62	-31,59
f.1	Avoidance/reduction of the cold pre-rinse	0,00	31,82	0,00	37,20
f.2	partly draining and re-filling (of water)	2,18	14,70	1,69	20,08
g	DC brushless motor	53,06	-62,74	53,06	-62,74
h.1	Noise reduction to 44 dB(A) (through better insulation)	-9,36	-65,79	-8,62	-85,94
h.2	Noise reduction to 41 dB(A) (through better insulation)	-16,39	-114,67	-13,66	-137,29
i	Hot rinse at 70-75°C (20% of the cycles)	-0,71	-121,44	-1,04	-85,37
j.1	Electronic sensors for the load soling (50% soiled)	3,49	38,51	3,36	40,66
j.2	Electronic sensors for the load weight (50% mass)	2,31	54,44	2,15	59,82
k	Delay start (3,5 W average power level)	0,00	-0,01	0,00	-0,01

Table 6.23: Marginal net present value (MNPV, 15years) for the aggregated option analysis for the extended technological options applied to the average standard base cases for dishwashers

9ps dishwasher		Consumption		**12ps dishwasher**		Consumption	
Options (n)	$MNPV_{av}$ (€)	energy (kWh/cycle)	water (litre/cycle)	Options (n)	MNPV (€)	energy (kWh/cycle)	water (litre/cycle)
+j.2	43,55	0,732	12,90	**+j.2**	47,85	0,974	14,00
+j.1	19,37	0,679	12,45	**+j.1**	21,23	0,919	13,45
+f.1	10,43	0,654	11,09	**+f.1**	18,57	0,883	11,85
+b	10,26	0,651	10,28	**+b**	11,70	0,880	10,92
+f.2	8,11	0,648	9,38	**+f.2**	10,86	0,877	9,77
+a.1 & a.2	1,39	0,618	9,38	**+a.1 & a.2**	7,36	0,834	9,77
+k	0,00	0,618	9,38	**+k**	0,00	0,834	9,77
+c	-13,81	0,599	9,38	**+c**	-13,38	0,814	9,77
+e.1	-16,39	0,592	9,38	**+e.1**	-16,35	0,808	9,77
+e.2	-25,27	0,584	9,38	**+e.2**	-25,05	0,799	9,77
+g	-67,35	0,570	9,03	**+d**	-47,64	0,769	9,77
+h.1	-42,36	0,607	9,03	**+g**	-64,07	0,756	9,46
+h.2	-99,72	0,671	9,03	**+h.1**	-54,12	0,806	9,46
+i	-25,51	0,720	9,03	**+h.2**	-116,53	0,892	9,46
				+i	-18,37	0,926	9,46

The resulting energy consumption and incremental purchase price for Base Case and average LLCC ($LLCC_{av}$) case when the technological options are applied to the two real-life base cases are presented in Table 6.24. The energy and water consumption for the 9ps machine is reduced by 210 Wh/cycle (or 25,4%) and 4,3 litre/cycle (or 31,4%); for the 12ps machine the energy and water consumption is reduced by 236 Wh/cycle (or 22,1%) and 5,4 litre/cycle (or 31,5%). This significant savings is mainly due to the half load (*Option j.1*) and half soil (*Option j.2*) options. On the other side these results can be presented on the basis of a constant weight and soiled load, where the energy and water consumption should be at least doubled to reach 1,236 kWh/cycle/18,8 litre cycle for the 9ps machine and 1,668 kWh/cycle/19,6 litre/cycle for the 12ps machine. The LCC is also presented in Figure 6.11 for the two average standard base cases. It is worth noting that the options increasing the energy consumption have been added as the last ones, despite their MNPV, due to the associated increase in the energy consumption of the machines. In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding the energy consuming options.

The lowest predictable energy consumption values after all options have been added, or the average Best Available Technology (BAT_{av}) to the base cases are presented in Table 6.25. For dishwashers, four BAT_{av} levels can be predicted due to the fact that some options, as already mentioned, are also increasing the overall energy consumption of the dish-washing cycle (*Options h.1, h.2, i* and *k*). In particular, the predicted energy consumption for a machine with a noise level of 41dB(A) (third row of each base case) is 0,671 kWh/cycle, still lower than the average standard 9ps machine in 2005, but after the application of a series of consumption reduction options. For the 12ps machine, the consumption is 0,892 kWh/cycle when the noise is reduced to of 41dB(A). When the noise remain unchanged at the average value of 50d(B)A, the energy consumption for the 9ps machine is reduced by 258 Wh/cycle (or 31,2%) with a minimum of 0,570 kWh/cycle and that of the 12ps machine by 178 Wh/cycle (or 16,6%) with a minimum of 0,756 kWh/cycle. The water saving is 4,7 litre/cycle (or 34,3%) for the 9ps category, with a minimum of 9 litres; for the 12ps machine the savings is 5,7 litre/cycle (or 37,5%) with a minimum of 9,5 litres.

When the Life Cycle Cost (lifetime = 15 years, 280 cycles/year) is shown as a function of the energy consumption (in kWh/cycle) and the Energy Efficiency Index (E_I) in directive 97/17/EC the curves in Figures 6.12 and 6.13 result.

Table 6.24: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and LLCCav for the extended standard base case analysis

Extended standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case E_I	$LLCC_{av}$ E_I	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)
9ps dishwashers	0,828	0,618	13,7	9,4	0,657	0,473	28,0	520,0	577,4	11,0	1.430	1.337
12ps dishwashers	1,070	0,834	15,2	9,8	0,648	0,506	22,0	548,4	605,8	10,5	1.594	1.476

Table 6.25: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for dishwasher Base Case and BATav for the extended standard base case analysis

Extended standard base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)	
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case E_I	BAT_{av} E_I	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)
9ps dishwashers	0,828	0,570	13,7	9,0	0,657	0,437	33,5	520,0	727,3	39,9	1.430	1.459
		0,607				0,465	29,2		751,3	44,5		1.502
		0,671				0,514	21,7		819,4	57,6		1.601
		0,720				0,551	16,1		821,0	57,9		1.627
12ps dishwashers	1,070	0,756	15,2	9,5	0,648	0,458	29,4	548,4	814,2	48,5	1.594	1.646
		0,806				0,489	24,7		843,5	53,8		1.700
		0,892				0,541	16,6		917,6	67,3		1.817
		0,926				0,561	13,5		919,1	67,6		1.835

Figure 6.11: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the applied technological options for 9ps and 12ps dishwasher extended standard base case analysis

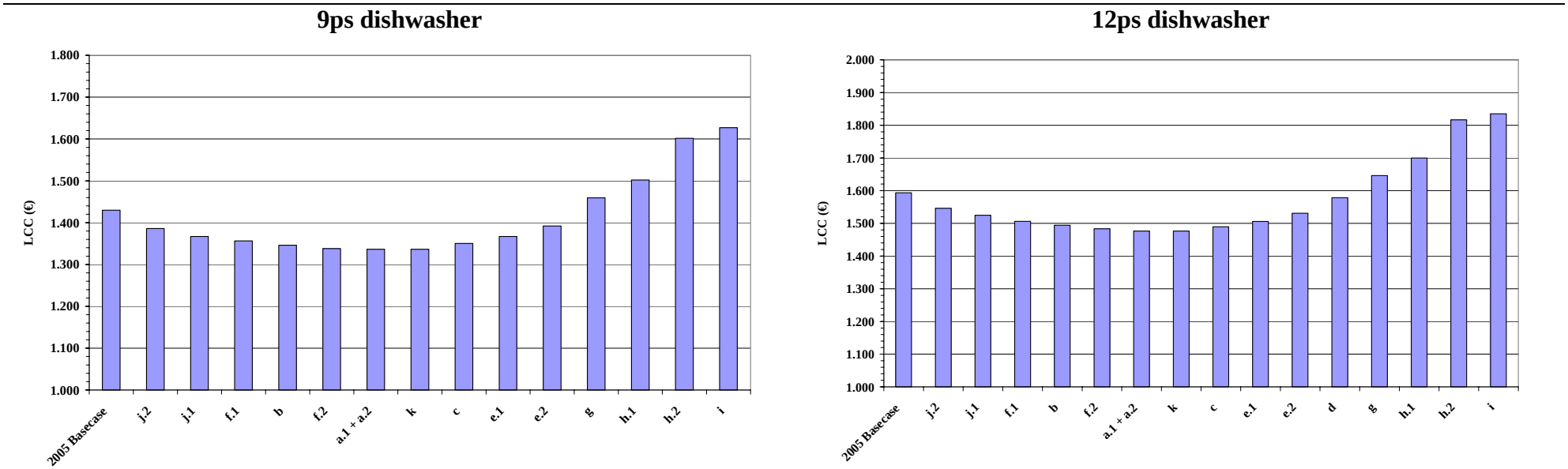


Figure 6.12: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the energy consumption for dishwasher extended standard base case analysis. Average standard base cases are the red point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 12ps machine curve only) show the option application sequence.

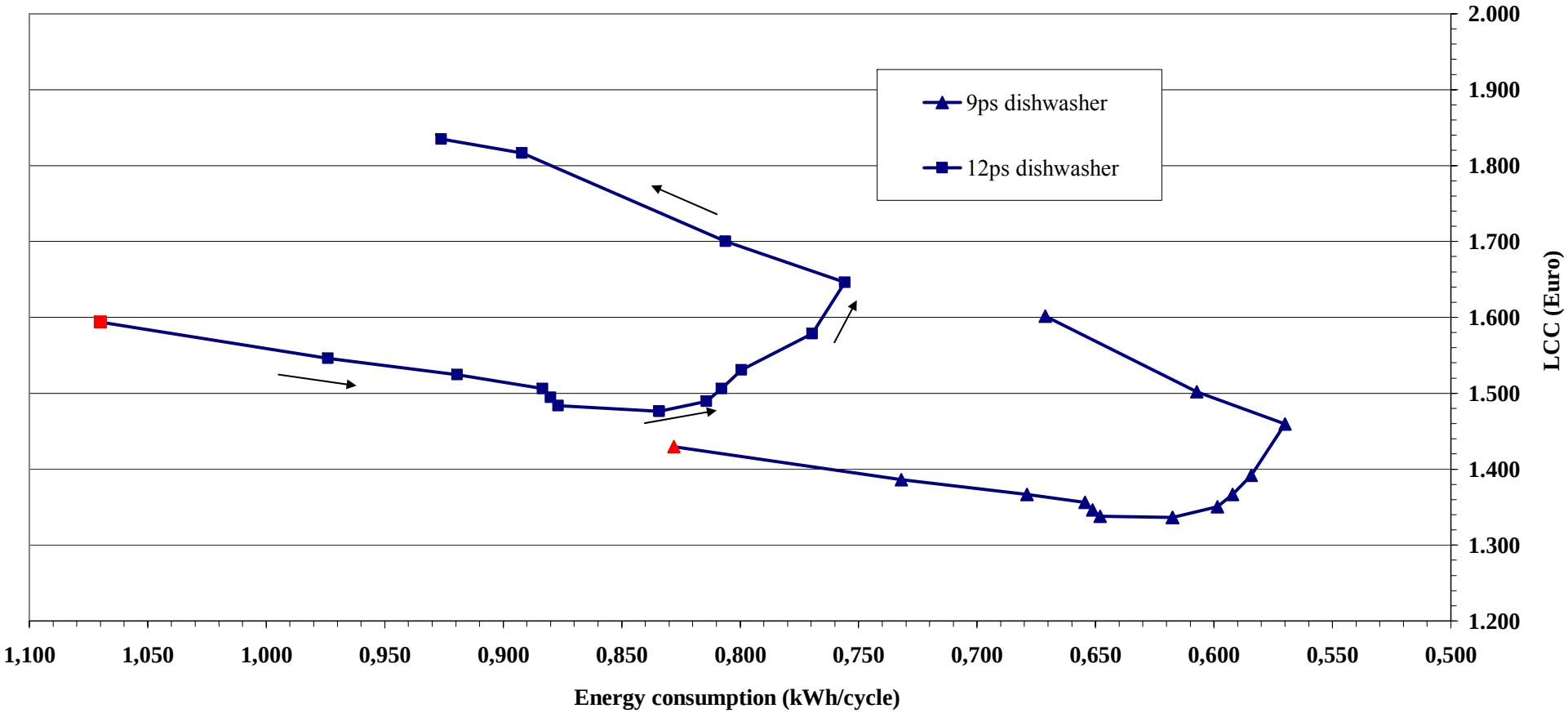
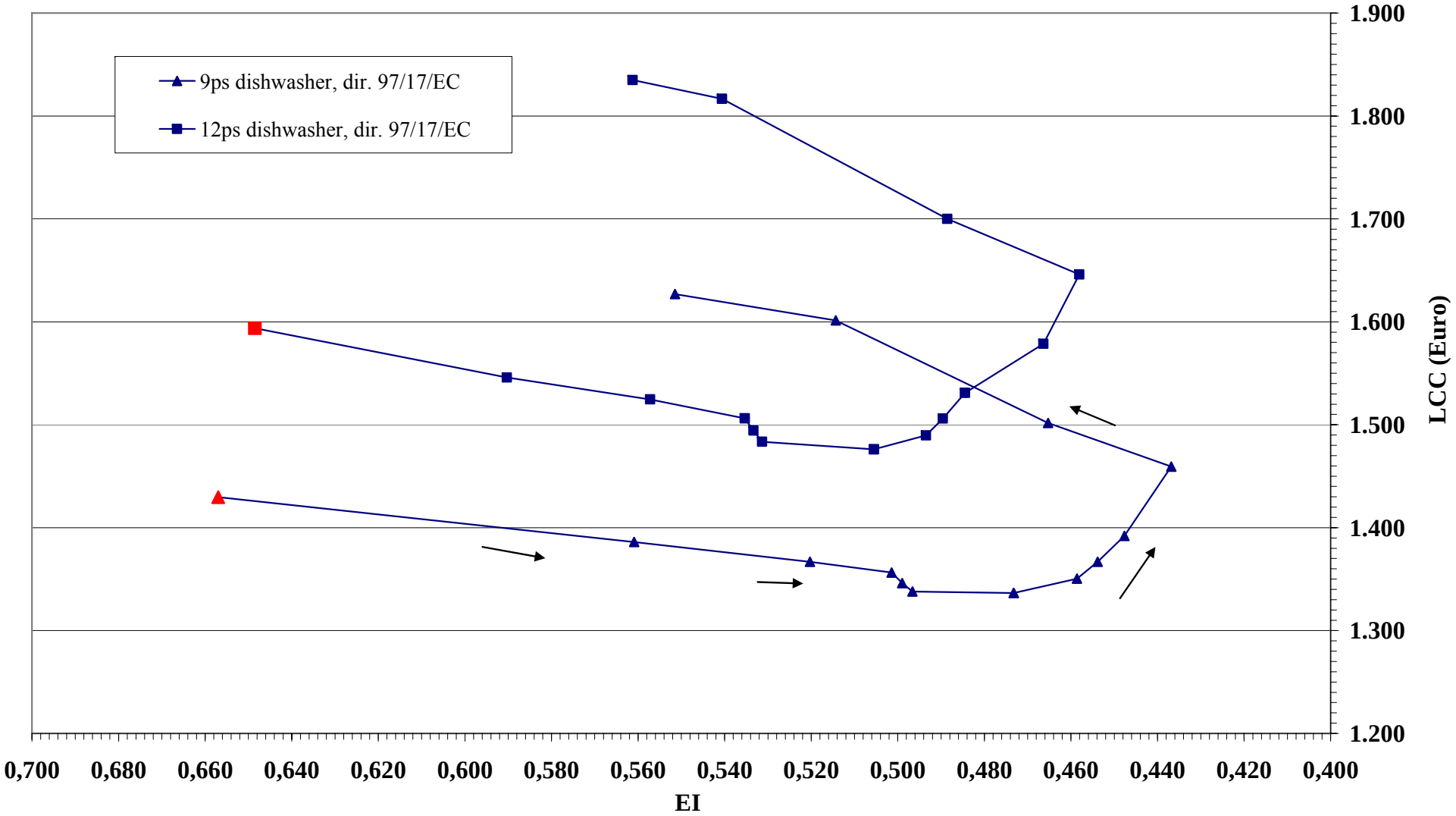


Figure 6.13: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the Energy Efficiency Index (EI) in directive 97/17/EC for each dishwasher real-life base cases. Real-life base cases is the first point on each curve. Appliance base cases are identified by their place setting number. Arrows (on the 9ps machine curve only) show the option application sequence.



6.2.2.6 Conclusions of the LCC analysis and results comparison for dishwashers

The LCC is a means of expressing the overall cost of the appliance from the owner's perspective. It includes both the initial purchase price, the operating expenses for electricity, water and chemicals consumption and the other costs (maintenance, repairs, disposal) amortised to the present. In this approach, the net present value of the operating expenses and other costs decrease from one year to the next due to discounting of their current value. Due to the time and budget constraints of the present study, and supported by the analysis of the last available technical database of the dishwasher appliance models produced or imported in the EU market in 2005, only free-standing base cases were simulated.
A summary of the LCC analyses is presented in Table 6.26 for the $LLCC_{av}$ values and in Table 6.27 where the BAT_{av} values are compared. In the two Tables also the values for the Marginal Payback Time (MPB) have been calculated and are shown. Main results are:

a) The **LCC analysis for the standard base cases** shows that:

- for the two average standard base cases the least life cycle cost occurs for appliances that are rated A class (for energy efficiency) with an $E_I = 0,62$ for the 9ps machine and $E_I = 0,61$ for the 12ps dishwasher (the threshold for class A is $E_I \leq 0,64$) and an energy consumption of 0,782 kWh/cycle and 1,009 kWh/cycle respectively; the water consumption is 10,3 and 11,0 litre/cycle respectively; the standard base cases energy consumption is 0,828 kWh/cycle for the 9ps machine and 1,070 kWh/cycle for the 12ps machine.
- the water consumption at LLCC point is 9,4 litre/cycle for the 9ps dishwasher and 9,8 litre/cycle for the 12ps dishwasher, against a standard base case consumption of 13,7 litre/cycle and 15,2 litre/cycle respectively;
- the payback time at LLCC is quite short: 4 years for the 9ps machine and even lower, at 3,1 years for the 12ps dishwasher;
- the LCC analysis for the standard base case models predicts the energy and water consumption of the best available models on the market in 2005/2006 for the 12ps machine and the best model available in CECED 2005 technical database for the 9ps dishwasher (no data on best models on the market were found for this machine category). The energy efficiency index values for the BAT are respectively $E_I=0,536$ for the 9ps machine and $E_I=0,518$ for the 12ps dishwasher when the noise remains at 50d(B)A, corresponding to 0,676 kWh/cycle and 0,855 kWh/cycle; the water consumption decreases to 9,6 and 10,3 litre/cycle respectively. The E_I increases to $E_I=0,645$ for the 9ps machine and $E_I=0,632$ for the 12ps machine when the noise is decreased to 41d(B)A, which is the lowest declared value on the market in both 2005 and 2007, with a corresponding energy consumption of 0,813 and 1,042 kWh/cycle;
- the payback time at BAT is longer than the estimated appliance lifetime, being 19,4 years for the 9ps machine and 19,3 years for the 12ps machine when the noise is maintained at 50 dB(A). When the noise decreases to 41 dB(A) the payback time reaches 94,4 years for both machines;
- options aimed at decreasing noise increase the machine energy consumption is all cases. These options are shown as applied at the end to the best available technology models to better illustrate the energy/noise tradeoffs, they could be applied to any model and at any point of the technological development pathway.

b) The **LCC analysis for the real-life base cases** shows that:

- the average real life 12ps machine has an actual washing temperature of 59,3°C, compared to the average standard machine with 50°C;
- for the two average real-life base cases, the least life cycle cost occurs at an energy consumption of 0,857 kWh/cycle and 1,106 kWh/cycle respectively with a water consumption of 10,5 and 11,4 litre/cycle respectively;
- the payback time at LLCC is again 3-4 years for the two dishwasher categories;

- the analysis predicts also an energy and water consumption of the best available models at 0,797 kWh/cycle for the 9ps dishwasher and 1,010 kWh/cycle for the 12ps dishwasher, with a corresponding water consumption of 10,1 and 11 litre/cycle;
- options aimed at decreasing noise increase the machine energy consumption is all cases. These options are shown as applied at the end to the best available technology models to better illustrate the energy/noise tradeoffs, they could be applied to any model and at any point of the technological development pathway;
- the payback time increases to about 19 years (longer than the estimated appliance lifetime) for both dishwashers when noise remains at 50dB(A), and increases rapidly when noise decreases.

c) The **LCC analysis for the extended standard base cases** shows that:

- in this analysis the technological options suitable for the real life will be applied to the standard base cases together with the options already identified for the standard base cases, to evaluate the changes in energy/water consumption when the average machine is used under real-life conditions. A wash cycle with a half load of half soiled tableware has been simulated, but not necessarily this will happen contemporarily in real life;
- for the two extended standard base cases the least life cycle cost occurs at an energy consumption of 0,618 kWh/cycle and 0,834 kWh/cycle respectively with a water consumption of 9,4 and 9,8 litre/cycle respectively, mainly due to the half load/half soiled tableware presence. These results can be presented also on the basis of a constant weight and soiled load, where the energy and water consumption should be at least doubled to reach 1,236 kWh & 18,8 litre per cycle for the 9ps machine and 1,668 kWh & 19,6 litre per cycle for the 12ps machine;
- payback time is the same as for the other cases: 3-4 years for the two machine categories;
- the analysis predicts also an energy and water consumption of the average BAT models (with noise remaining at base case level or 50 dB(A)) at 0,570 kWh/cycle for the 9ps dishwasher and 0,720 kWh/cycle for the 12ps dishwasher, with a water consumption of 9 and 9,5 litre/cycle;
- the payback time is now 12,1 years for the 9ps machine and 12,7 years for the 12ps dishwashers, shorter than the appliance lifetime
- options aimed at decreasing noise increase the machine energy consumption is all cases. These options are shown as applied at the end to the best available technology models to better illustrate the energy/noise tradeoffs, they could be applied to any model and at any point of the technological development pathway. Payback time increases accordingly, but remains at the level of the appliances lifetime when the noise is decreased to 44 dB(A); when noise is further decreased or the high temperature (hygienising) rinse is allowed then the payback time increases to 30 years.

6.2.3 The NPV/MNPV and LCC Analysis for Washing Machines

6.2.3.1 The key technical, economic and financial assumption

The key technical, common economic and financial assumptions (see Task 5) are:

- Product life: 15 years
- Cycles per year: 220
- Discount rate: 5%/year (PWF = 10,38 for 15years)
- Electricity price: 0,17 Euro/kWh
- Water price: 3,7 Euro/m^3
- detergent costs: 0,22 Euro/wash for 139,76 g/wash
- Maintenance & repairs: 5,5 Euro/year
- Disposal & recycling 61 Euro/life (at end of life)
- Machine price: 443,5 Euro.

Table 6.26: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for the dishwasher Base Case and LLCC Case

Base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)		
	Base case (kWh/cycle)	LLCC (kWh/cycle)	Base case (litre/cycle)	LLCC (litre/cycle)	Base case E_I	LLCC E_I	difference (%)	Base case (Euro)	LLCC (Euro)	Increase (%)	Base case (€)	LLCC (€)	MPB (years)
9 place settings dishwasher													
Average standard	0,828	0,782	13,7	10,3	0,657	0,620	5,6	520,0	542,7	4,4	1.409	1.373	4,0
Real life	0,903	0,857	13,9	10,5	0,717	0,680	5,1	520,0	542,7	4,4	1.448	1.412	4,0
Extended standard	0,828	0,618	13,7	9,4	0,657	0,473	28,0	520,0	577,4	11,0	1.430	1.337	4,0
12 place settings dishwasher													
Average standard	1,070	1,009	15,2	11,0	0,648	0,611	5,7	548,4	571,1	4,1	1.594	1.542	3,1
Real life	1,167	1,106	15,4	11,4	0,707	0,670	5,2	548,4	571,1	4,1	1.644	1.593	3,2
Extended standard	1,070	0,834	15,2	9,8	0,648	0,506	22,0	548,4	605,8	10,5	1.594	1.476	3,4

Table 6.27: Energy efficiency index (EEI), energy & water consumption and incremental purchase price for the dishwashers Base Case and BAT Case

Base case	Energy consumption		Water consumption		Energy efficiency Index (dir. 97/17/EC)			Purchase price			LCC (15 years, 280 cycles)		
	Base case (kWh/cycle)	BAT (kWh/cycle)	Base case (litre/cycle)	BAT (litre/cycle)	Base case E_I	BAT E_I	difference (%)	Base case (Euro)	BAT (Euro)	Increase (%)	Base case (€)	BAT (€)	MPB (years)
9 place settings dishwasher													
Average standard	0,828	0,723	13,7	9,9	0,657	0,574	12,7	520,0	692,6	33,2	1.409	1.489	19,4
		0,770				0,611	7,0		716,6	37,8		1.537	29,5
		0,851				0,675	-2,8		784,7	50,9		1.645	94,4
Real life	0,903	0,797	13,9	10,1	0,717	0,633	11,7	520,0	692,6	33,2	1.448	1.528	19,3
		0,845				0,670	6,4		716,6	37,8		1.576	29,5
		0,926				0,735	-2,6		784,7	50,9		1.684	94,4
Extended standard	0,828	0,570	13,7	9,0	0,657	0,437	33,5	520,0	727,3	39,9	1.430	1.459	12,1
		0,607				0,465	29,2		751,3	44,5		1.502	15,1
		0,671				0,514	21,7		819,4	57,6		1.601	24,3
		0,720				0,551	16,1		821,0	57,9		1.627	30,1
12 place settings dishwasher													
Average standard	1,070	0,914	15,2	10,6	0,648	0,554	14,6	548,4	779,5	42,1	1.594	1.699	19,0
		0,975				0,591	8,9		808,8	47,5		1.758	28,2
		1,079				0,654	-0,8		882,9	61,0		1.884	77,9
Real life	1,167	1,010	15,4	11,0	0,707	0,612	13,4	548,4	779,5	42,1	1.644	1.750	19,2
		1,072				0,650	8,1		808,8	47,5		1.810	28,7
		1,177				0,713	-0,8		882,9	61,0		1.936	81,6
Extended standard	1,070	0,756	15,2	9,5	0,648	0,458	29,4	548,4	814,2	48,5	1.594	1.646	12,7
		0,806				0,489	24,7		843,5	53,8		1.700	15,9
		0,892				0,541	16,6		917,6	67,3		1.817	25,6
		0,926				0,561	13,5		919,1	67,6		1.835	29,0

In particular:

- number of cycles per year: 200 is the number of washing cycles considered in the energy labelling directive for a four-person household and forecast for 2010 in the WASH-II study. In addition, 220 cycles (the average number of cycles used in the WASH-II study) and 245 cycles (the average number of cycles used in the GEA study) will be considered for the sensitivity analysis;
- the sales weighted average price of the washing machines sold in 2004 according GfK was on average of 443,5 Euro for the 13 EU member stated where GfK collected the market data. In addition the values of 562 Euro in West EU countries and 326 Euro in East EU countries will be considered for the sensitivity analysis;
- temperature setting: standard base case 60°C cotton (40°C cotton cycle will be estimated within the sensitivity analysis).

6.2.3.2 The Simple Payback Time and Net Present Value analysis for the standard base cases

The first step of the analysis is the evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the standard base case for washing machines. The results are presented in Table 6.28. NPV is calculated for a lifetime of 15 years and 220 washing cycles.

The same data are ordered in Table 6.29 by simple payback time. In general there is a good agreement between the SPB and the NPV values, where the former increases the latter decreases. Some Options increase the energy/water consumption, and therefore the calculated payback time will be negative. The NPV is positive for four options: the first option tends to better control the temperature (*Option c.3*), the second to the optimisation of the mechanical action (*Option b*) , while the other two are relevant with the water consumption optimisation through a sensor (*Option c.2*) the optimisation of the rinsing phase (*Option d*). The following options have SPB much longer that the average appliance lifetime (15 years) and significantly negative net present values. *Option a.4 - Optimised motor composition* decrease slightly the purchase price of the machine through the optimisation of the composition and the decrease in the motor price.

Table 6.28: Simple payback time and net present value (at 15 years, for 220 cycles/year) for the identified technological options applied to the standard base case for washing machines

Options (n)	**Technology** (description)	**SPB** (years)	**NPV** (€)
a.1	Brushless DC motor (+ control)	32,1	-40,6
a.2	Brushless DC direct drive motor (+ control)	130,3	-179,5
a.3	Three-phase motor	48,1	-70,6
a.4	Optimised motor composition	--	3,0
b	Mechanical action optimisation	0,3	54,2
c.1	Sophisticated unbalance control (+ separate sensors)	--	-22,5
c.2	Analogue water sensor	1,3	40,7
c.3	Temperature control sensor (+ simple unbalance control)	0,3	43,3
d	Rinsing phase optimisation	2,5	48,4
e	Increased load capacity in the same machine	--	-56,7
k	Higher spinning speed (to ≥ 1 600 rpm)	--	-49,37

Table 6.29: Technological options ordered by simple payback time (SPB) and net present value (at 15 years, for 220 cycles/year) for the identified technological options applied to the standard base case for washing machines

Options (n)	**Technology** (description)	**SPB** (years)	**NPV** (€)
b	Mechanical action optimisation	0,3	54,2
c.3	Temperature control sensor (+ simple unbalance control)	0,3	43,26
c.2	Analogue water sensor	1,3	40,72
d	Rinsing phase optimisation	2,5	48,37
a.1	Brushless DC motor (+ control)	32,1	-40,59
a.3	Three-phase motor	48,1	-70,59
a.2	Brushless DC direct drive motor (+ control)	130,3	-179,47
a.4	Optimised motor composition	--	3
c.1	Sophisticated unbalance control (+ separate sensors)	--	-22,5
k	Higher spinning speed (to ≥1 600 rpm)	--	-49,37
e	Increased load capacity in the same machine	--	-56,7

6.2.3.3 The Marginal Net Present Value and the aggregated option LCC analysis

To evaluate the improvement potential of the standard base case, the aggregated option analysis is developed. Also in the case of washing machines this LCC analysis was run for the average standard base-case appliance and for the standard base case model. The former represents the average machine of the reference year and takes into consideration the percentage of application of each technological option to the market, or better the percentage of each option still available for application to the market; for the latter a technological level is specified for the base case and then all the available technological options are applied.

In the first case, the possible average improvement of the overall appliance category is predicted. The second analysis allows to predict the best available technology model, and can be also considered a sort of inner validation of the previous scenario and more in general of the overall calculation model: if the simulation can predict in a technically and economically sound way the development from the base case model to the to the best available model(s) on the market in 2005, then the overall simulation is not only inherently coherent, but also in agreement with the reality.
In addition, an analysis with and without *Option e - increased load capacity in the same machine* will be developed, to evaluate the influence of the an increased load capacity over a technological development pathway.

In Table 6.30 the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption for a 15 year lifetime and 220 cycles per year are presented for the average standard base cases and the standard base case models. The reasons for the selection of the specific technological pathways (out of the Technological Option List) and the detailed Life Cycle Cost results and calculations for each base case are presented in Annex 1.

The optimum option combination varies whether the LCC analysis was run for the average standard base-case appliance or for the standard base case model, nevertheless some common elements can be drawn from the data presented in Table 6.30:

- the use of the optimised mechanical action is always the most cost-effective design option;
- the same occurs for the optimisation of the rinsing phase and the addition of analogue water sensors;
- the optimised motor composition is slightly cost-effective in both cases;

- the temperature control sensor is cost-effective only for the standard base case;
- any motor improvement is not cost-effective, the less cost-ineffective is the brushless direct drive DC motor (plus the relevant control);
- a more sophisticate unbalance control is the last of the cost-effective options or the first of the non cost-effective depending on the case;
- the increase in spinning speed is also not cost-effective (when the washing machine alone is considered[15]);
- the increase in the load capacity (from 5 to 6 kg) is not cost-effective at the overall machine (energy and water consumption) level, but becomes a positive technological development when evaluate considering the energy and water consumption per unit of load weight.

The resulting energy and water consumption and incremental purchase price for Base Case and LLCC for the average standard base case and the standard base case model are presented in Table 6.31. Also the energy consumption "C" for kg of washed load for the standard 60°C cotton cycle is shown, calculated according to the algorithms of directive 95/12/EC (described in Task 1). The energy and water consumption for the average machine are reduced by 98 Wh/cycle (or 9,8%) and 12 litre/cycle (or 23,7%); the consumption per kg of washed load for the LLCC is 0,168 corresponding to the commercially defined A+ energy efficiency class (A class according to the mentioned directive). For the standard base case model the LLCC model has an energy consumption of 0,889 kWh/cycle (with a savings of 109 Wh or 10,9%) an a water consumption of 37,4 litre/cycle (with a savings of 13,3 litre or 26,2%). The energy efficiency class achievable is again A+ (A class according to the EU labelling directive).

The forecast increase in purchase price is 3,8% for the average standard base case and 4,4% for the standard base case model. The ratio between the predicted increase in purchase price and the efficiency improvement is:

Base case	Ratio
Average standard base case	0,38
Standard base case model	0,44

The LCC is also presented in Figure 6.14 for the two standard base cases. It is worth noting that *Option k* and *Option e* have been added as the last ones, due to the associated increase in the spinning speed (for the former) and in the machine load capacity (for the latter). In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding this option which modifies the machine technical characteristics.

The lowest predictable energy consumption for after all options have been added, or the Best Available Technology (BAT) to the base case is presented in Table 6.32. For washing machines, three BAT levels can be predicted, due to the fact the last two added options increase the overall energy consumption of the laundry-washing cycle by increasing the spinning speed and the load capacity. The energy consumption for the average standard base case is reduced by 143 Wh/cycle (or 14,3%) to 0,855 kWh/cycle; the water consumption of 12 litre/cycle (or 23,7%), with a minimum of 38,7 litres.
When the Life Cycle Cost (lifetime=15 years, 220 cycles/year) is shown as a function of the energy consumption (kWh/cycle) the curves in Figure 6.15 result.

A close agreement can be seen between the results the predicted BAT energy consumption and energy efficiency class and the actual minimum values of the washing machine models on the

[15] The interaction of the washing machine and the dryer will be briefly analysed in paragraph 1.5.3 System Analysis.

market in 2005/2006 in terms of minimum energy and water consumption and the best model in CECED 2005 technical database (see Task 5) as shown in Table 33.

Table 6.30: Technological options and marginal net present value (MNPV) at 15 years for the aggregated option analysis for washing machine average standard base case and standard base case model

Average standard base case				Consumption		Standard base case model				Consumption	
Options (n)	$MNPV_{av}$ (€)	Noise* (dBA)	Cycle time (min)	energy (kWh/cycle)	water (litre/cycle)	Options (n)	MNPV (€)	Noise* (dBA)	Cycle time (min)	energy (kWh/cycle)	water (litre/cycle)
+b	54,22	53	110	0,918	49,10	**+b**	54,22	53	110	0,898	48,70
+d	37,09	53	98	0,918	43,29	**+d**	45,87	53	95	0,898	41,50
+c.2	32,44	53	98	0,909	39,18	**+c.2**	32,55	53	95	0,889	37,35
+c.3	7,15	53	98	0,900	38,71	**+a.4**	3,00	53	95	0,889	37,35
+a.4	3,00	53	98	0,900	38,71	**+c.1**	-22,50	48	95	0,889	37,35
+c.1	-21,38	53	98	0,900	38,71	**+a.1**	-42,71	45	85	0,844	37,35
+a.1	-42,28	50	88	0,855	38,71	**+k**	-46,39	45	90	0,887	37,35
+k	-23,30	50	92	0,892	38,71	**+e**	-46,56	45	105	0,958	39,56
+e	-23,47	50	103	0,942**	40,32**						

*during the washing cycle;
**for an increased load of 6kg

Table 6.30: Technological options and marginal net present value (MNPV) at 15 years for the aggregated option analysis for washing machine standard base case model – continued

Options	Consumption per cycle				Specific consumption				EE class
	energy (kWh/cycle)		water (litre/cycle)		energy (kWh/kg cycle)		water (litre/kg cycle)		
(n)	5kg	6kg	5kg	6kg	5kg	6kg	5kg	6kg	
+b	0,838	--	45,4	--	0,168	--	9,1	--	A+
+d	0,838	--	38,7	--	0,168	--	7,7	--	A+
+c.2	0,829	--	34,8	--	0,166	--	7,0	--	A+
+a.4	0,829	--	34,8	--	0,166	--	7,0	--	A+
+c.1	0,829	--	34,8	--	0,166	--	7,0	--	A+
+a.1	0,788	--	34,8	--	0,158	--	7,0	--	A+
+k	0,827	--	34,8	--	0,165	--	7,0	--	A+
+e	--	0,958	--	39,6	--	0,160	--	6,6	A+

Table 6.31: Energy and water consumption and incremental purchase price for washing machine Base Case and LLCC for average standard base case and standard base case model

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y, 220 cycles)	
	Base case (kWh/cycle)	LLCC (kWh/cycle)	Base case (litre/cycle)	LLCC (litre/cycle)	Base case C	LLCC C	difference (%)	Base case (Euro)	LLCC (Euro)	Increase (%)	Base case (€)	LLCC (€)
Average standard base case	0,998	0,900	50,7	38,7	0,186	0,168	9,8	443,5	459,7	3,7	1.952	1.829
Standard base case model	0,998	0,889	50,7	37,4	0,186	0,166	10,9	443,5	463,0	4,4	1.952	1.816

Figure 6.14: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the applied technological options for the washing machine standard base cases

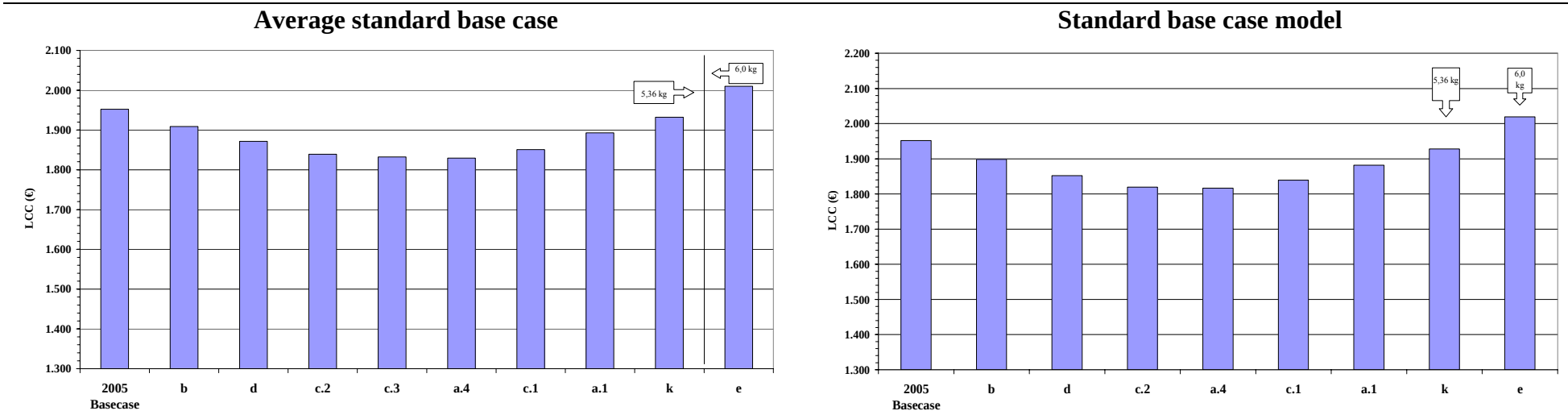


Table 6.32: Energy and water consumption and incremental purchase price for washing machine Base Case and BAT for average standard base case and standard base case model

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y, 220 cycles)	
	Base case (kWh/cycle)	BAT (kWh/cycle)	Base case (litre/cycle)	BAT (litre/cycle)	Base case C	BAT C	difference (%)	Base case (Euro)	BAT (Euro)	Increase (%)	Base case (€)	BAT (€)
Average standard base case	0,998	0,855	50,7	38,7	0,186	0,1596	14,3	443,5	540,8	21,9	1.952	1.893
		0,892		38,7		0,1663	10,7		566,3	27,7		1.932
		0,942		40,3		0,1569	15,7		566,5	27,7		2.010
Standard base case model	0,998	0,844	50,7	37,4	0,186	0,1575	15,4	443,5	545,5	23,0	1.952	1.882
		0,887		37,4		0,1654	11,2		575,5	29,8		1.928
		0,958		39,6		0,1596	14,3		575,8	29,8		2.019

Figure 6.15: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the energy consumption for washing machine analysis. Average standard base case and standard base case model are the red point on each curve. Arrows show the option application sequence.

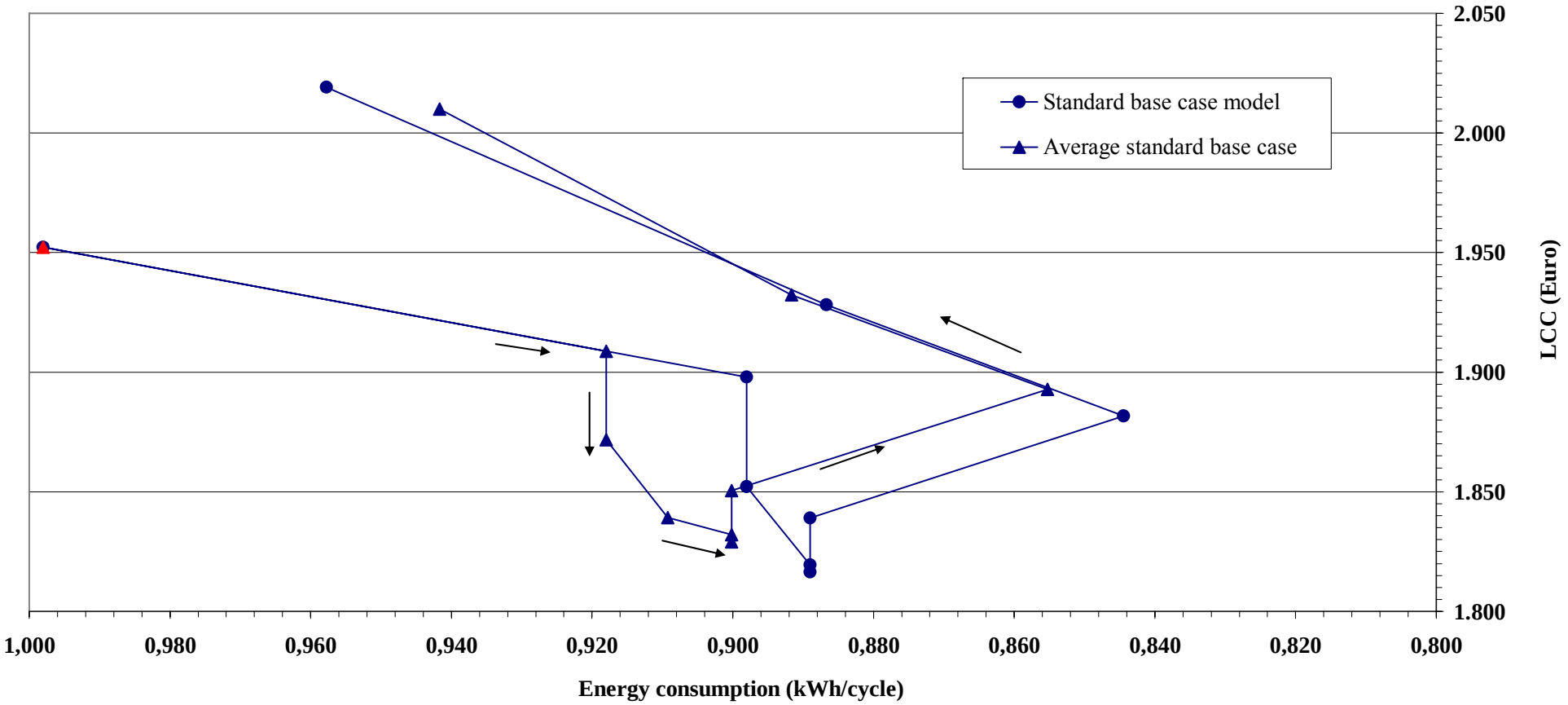


Table 6.33: Comparison of the minimum energy and water consumption for washing machine models in 2005/2006 and the results of the LCC for the standard base case models

Capacity	Min. energy consumption (kWh/cycle)		Min. water consumption (litre/cycle)	
	CECED 2005	LCC	CECED 2005	LCC
5kg	0,830	0,844*	35,0	37,4*
6kg	0,950	0,958	37,0	39,6

*for the 5,36 kg machine

6.2.3.4 The analysis results for the real-life base case

The real-life base case LCC analysis will be run by applying the technological options identified for the standard base case to the real-life base case defined in Task 5 on the basis of the consumer analysis (Task 3). The expected outcome is the evaluation of the savings achievable under real life conditions from the technological improvement of the standard washing machine.

The evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the relevant real-life base cases was run. The results are presented in Table 6.34. NPV is calculated for a lifetime of 15 years and 220 washing cycles. The same data are ordered in Table 6.35 by simple payback time. Some Options increase the energy/water consumption, and therefore the calculated payback time will be negative. The NPV is positive for the same four options already described for the standard base case analysis. It is worth noting that the washing temperature is 45,8 °C compared to the 60°C of the standard washing cycle.

The results of the aggregated option analysis are presented in Table 6.36, where the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption values for a 15 year lifetime and 220 cycles per year are given for the average real life base cases. *Option e* is not applied because there is little scope in simulating an increase in the machine capacity when a reduced load is washed.

Table 6.34: Simple payback time and net present value (at 15 years, for 220 cycles/year) for the identified technological options applied to the real-life base case for washing machine

Washing machines			
Options (n)	**Technology** (description)	SPB (years)	NPV (€)
a.1	Brushless DC motor (+ control)	44,5	-46,02
a.2	Brushless DC direct drive motor (+ control)	180,9	-183,81
a.3	Three-phase motor	66,8	-76,02
a.4	Optimised motor composition	--	3,00
b	Mechanical action optimisation	0,4	41,00
c.1	Sophisticated unbalance control (+ separate sensors)	--	-22,50
c.2	Analogue water sensor	1,6	33,63
c.3	Temperature control sensor (+ simple unbalance control)	0,4	34,28
d	Rinsing phase optimisation	2,9	39,49
e	Increased load capacity in the same machine	--	-44,47
k	Higher spinning speed (≥ 1 600 rpm)	--	-43,96

Table 6.35: Simple payback time and net present value (at 15 years, for 220 cycles/year) for the identified technological options applied to the real-life base case for washing machine

Washing machines			
Options (n)	**Technology** (description)	SPB (years)	NPV (€)
b	Mechanical action optimisation	0,4	41,00
c.3	Temperature control sensor (+ simple unbalance control)	0,4	34,28
c.2	Analogue water sensor	1,6	33,63
d	Rinsing phase optimisation	2,9	39,49
a.1	Brushless DC motor (+ control)	44,5	-46,02
a.3	Three-phase motor	66,8	-76,02
a.2	Brushless DC direct drive motor (+ control)	180,9	-183,81
a.4	Optimised motor composition	--	3,00
c.1	Sophisticated unbalance control (+ separate sensors)	--	-22,50
k	Higher spinning speed (≥ 1 600 rpm)	--	-43,96
e	Increased load capacity in the same machine	--	-44,47

Table 6.36: Technological options and marginal net present value (MNPV) at 15 years for the aggregated option analysis for average washing machine real-life base case

Washing machine		Consumption (for 3,4kg actual load)			
Options	$MNPV_{av}$	energy		water	
(n)	(€)	(kWh/cycle)	(kWh/kg cycle)	(litre/cycle)	(litre/kg cycle)
+d	32,80	0,661	0,1945	42,22	12,42
+b	30,22	0,661	0,1945	37,23	10,95
+c.2	26,62	0,655	0,1927	33,69	9,91
+c.3	5,62	0,649	0,1907	33,29	9,79
+a.4	3,00	0,649	0,1907	33,29	9,79
+c.1	-21,38	0,649	0,1907	33,29	9,79
+a.1	-47,15	0,616	0,1812	33,29	9,79
+k	-35,67	0,642	0,1889	33,29	9,79

The resulting energy consumption and incremental purchase price for Base Case and average LLCC case when the technological options are applied to real-life base case are presented in Table 6.37. The energy and water consumption of the machine is reduced by 70 Wh/cycle (or 9,7%) and 10,3 litre/cycle (or 23,6%); the purchase price increase of 3,7%. The lowest predictable energy consumption values after all options have been added, or the average Best Available Technology to the base case are presented in the same Table. For real-life washing machine, two BAT levels can be predicted, due to the fact the last added option increases the overall energy consumption of the laundry-washing cycle by increasing the spinning speed. The energy consumption for the average standard base case is reduced by 103 Wh/cycle (or 14,3%) to 0,616 kWh/cycle; the water consumption of 10,3 litre/cycle (or 23,6%), with a minimum of 33,3 litres.

When the Life Cycle Cost (lifetime=15 years, 220 cycles/year) is shown as a function of the energy consumption (in kWh/cycle) the curves in Figure 6.16 result.

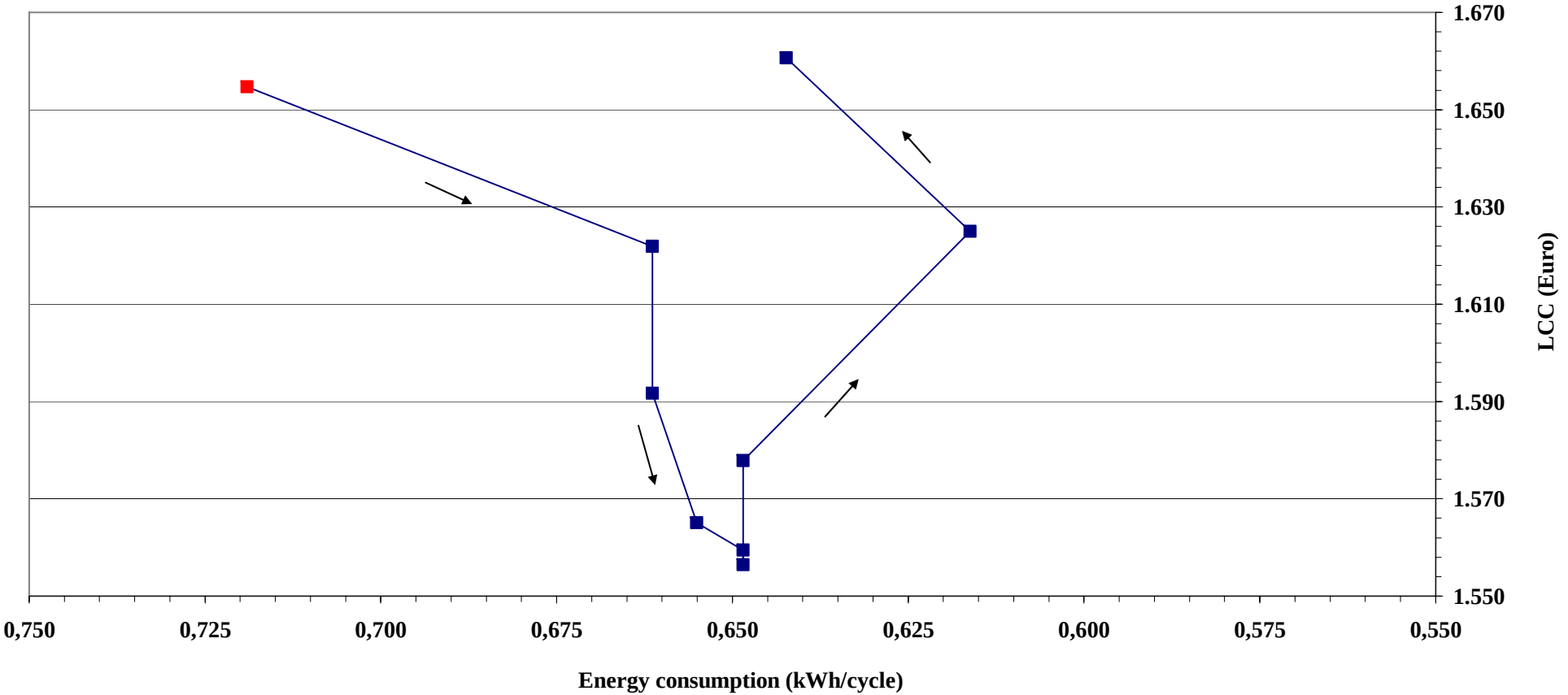
6.2.3.5 The analysis for the standard base cases with an extended option set

As in the case of dishwashers, in this analysis, the technological options identified in previous Table 6.8 as suitable for the real life will be applied to the standard base case (together with the options already identified as applicable for the standard base case itself) to evaluate the overall modification

Table 6.37: Energy and water consumption and incremental purchase price for washing machine Base Case and LLCC for real-life base case

	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC), 3,4kg			Purchase price			LCC (15y, 220 cycles)	
	Base case (kWh/cycle)	LLCC (kWh/cycle)	Base case (litre/cycle)	LLCC (litre/cycle)	Base case C	LLCC C	difference (%)	Base case (Euro)	LLCC (Euro)	Increase (%)	Base case (€)	LLCC (€)
Real-life base case	0,719	0,649	43,6	33,3	0,2115	0,1907	9,8	443,5	459,7	3,7	1.655	1.556
	Base case (kWh/year)	BAT (kWh/year)	Base case (litre/cycle)	BAT (litre/cycle)	Base case C	BAT C	difference (%)	Base case (Euro)	BAT (Euro)	Increase (%)	Base case (€)	BAT (€)
	0,719	0,616	43,6	33,3	0,2115	0,1812	14,3	443,5	540,8	21,9	1.655	1.625
		0,642		33,3		0,1889	10,7		566,3	27,7		1.661

Figure 6.16: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the energy consumption for each washing machine real-life base cases. Real-life base case is the red point on the curve. Arrows show the option application sequence.



of the energy/water consumption when the average machine is used under real-life conditions. This exercise will also potentially give indications on the energy/water consumption measurable according to a possible revised standard, more adherent to the real life conditions and usage.

Again the evaluation of the Simple Payback Time (SPB) and the Net Present Value (NPV) of the single options when applied to the standard base case was developed. The results are presented in Table 6.38. NPV is calculated for a lifetime of 15 years and 220 washing cycles. The results of the aggregated option analysis are presented in Table 6.39, where the applied options (with the order of application), the corresponding marginal net present value (MNPV) and the resulting energy/water consumption values for a 15 year lifetime and 220 cycles per year are given. It should be noted that *Options a.1* to *a.3* are alternative motor types; *Option g* and *Option j* are also considered alternatives in the simulation: *Option g* allows the reduction of the energy/water consumption for a reduced load (from 5kg to 3,4kg as stated in Task 3), while *Option j* results in the machine to be filled with a real 5kg load, making Option g useless, at least in the simplified simulation run in this paragraph. Therefore *Option j* will not be simulated. *Option e* is also an alternative to *Option g*: in fact there is little scope to increase the nominal load capacity of a machine and then wash a reduced load, at least from the simulation point of view. In this case two technological pathways will be studied, the first including *Option g* (and considering a reduced load) and the second including *Option e* (and considering an increased load). For the latter, the specific energy consumption in kWh per kg of load per cycle are given to allow the evaluation of the option impact. In addition, *Option a.4* does not decrease the machine energy consumption or the noise, but since the optimisation of the material composition of the motor decreases the motor cost for the manufacturers, the machine price for the consumers and the resources consumption for the environment this Option has been included in the technological development pathway under the overall eco-design approach.

Table 6.38: Simple payback time and net present value (at 15 years, for 220 cycles/year) for the extended technological options applied to the average standard base cases for dishwashers

Washing machines			
Options (n)	**Technology** (description)	**SPB** (years)	**NPV** (€)
a.1	Brushless DC motor (+ control)	32,09	-40,59
a.2	Brushless DC direct drive motor (+ control)	130,35	-179,47
a.3	Three-phase motor	48,13	-70,59
a.4	Optimised motor composition	--	3,00
b	Optimised mechanical action	0,28	54,22
c.1	Sophisticated unbalance control (with separate sensors)	--	-22,50
c.2	Analogue water sensor	1,33	40,72
c.3	Temperature control sensor (and simple unbalance control)	0,35	43,26
d	Rinsing phase optimisation	2,46	48,37
e	Increased load capacity in the same machine	--	-56,70
f.1	high temperature (77°C) water intake (8 litre/cycle)	--	-84,96
f.2	Boiling water/steam cycle (4 litre/cycle)	--	-145,13
k	increase spinning speed, from 1200 to ≥ 1600 rpm	--	-49,37
g	Weight sensors (load control)	3,20	50,46
h	sophisticated electronic controls (fuzzy logic)	27,27	-23,23
i	increased time control: delay start	--	-15,00
j	LCD with actual load display	32,09	-40,59

Table 6.39: Marginal net present value (MNPV, 15years, 220 cycles) for the aggregated option analysis for the extended technological options applied to the average standard base case for washing machines

5kg machine		Consumption		6kg machine		Consumption			
Options	MNPV	energy	water	Options	MNPV	energy		water	
(n)	(€)	(kWh/cy)	(litre/cy)	(n)	(€)	(kWh/cy)	(kWh/kg)	(litre/cy)	(litre/kg)
+b	43,37	0,918	49,10	**+b**	43,37	0,918	0,1713	49,10	9,16
+d	37,09	0,918	43,29	**+d**	37,09	0,918	0,1713	43,29	8,08
+c.2	32,44	0,909	39,18	**+c.2**	32,44	0,909	0,1696	39,18	7,31
+g	30,97	0,844	36,40	**+c.3**	7,15	0,900	0,1679	38,71	7,22
+c.3	6,62	0,835	35,96	**+a.4**	3,00	0,900	0,1679	38,71	7,22
+a.4	3,00	0,835	35,96	**+i**	-10,50	0,900	0,1679	38,71	7,22
+i	-10,50	0,835	35,96	**+h**	-12,90	0,893	0,1667	38,33	7,15
+h	-13,32	0,829	35,61	**+c.1**	-21,38	0,893	0,1667	38,33	7,15
+c.1	-21,38	0,829	35,61	**+e**	-33,09	0,944	0,1573*	39,92	6,65*
+a.1	-43,66	0,788	35,61	**+a.1**	-41,44	0,896	0,1494*	39,92	6,65*
+f.1	-67,03	0,956	35,61	**+f.1**	-76,09	1,089	0,1814*	39,92	6,65*
+f.2	-138,46	1,309	35,61	**+f.2**	-157,39	1,490	0,2484*	39,92	6,65*
+k	-47,10	1,365	35,61	**+k**	-50,09	1,554	0,2689*	39,92	6,65*

*for a 6kg load

The resulting energy and water consumption and incremental purchase price for Base Case and $LLCC_{av}$ for the average standard base case are presented in Table 6.40. Also the specific energy consumption "C" for kg of washed load is shown. In the calculation of the LLC also the variation of the detergent dosage due to the modification of the load has been taken into consideration. The energy and water consumption for the average 5kg machine are reduced by 163 Wh/cycle (or 16,4%) to 0,835 kWh/cycle and 14,7 litre/cycle (or 29%) to 36 litre/cycle; the specific consumption per 3,4kg of washed load for the $LLCC_{av}$ is 0,246 (due to the application of *Option g*, which implies also a decrease in the detergent dosage to 110g). When on the contrary the machine load capacity is improved to 6kg (trough the application of *Option e*, which implies also the increase of the detergent dosage to 150g) the $LLCC_{av}$ model has an energy consumption of 0,900 kWh/cycle and a water consumption of 38,7 litre/cycle, with apparently a lower absolute savings compared to the 5kg machine, but the specific energy and water consumption decrease to 0,168 kWh/kg and 7,2 litre/kg respectively for an actual load of 5,36kg. *Option e* is applied after the LLCC point due to its NPV. The forecast increase in purchase price is 9,2% for the 5kg machine and 4,5% for the 6kg machine model. For the latter, the ratio between the predicted increase in purchase price and the efficiency improvement is 0,46.

The LCC is presented in Figure 6.17 for the two machines. The sharp decrease in the life cycle cost between *Option c.2* and *Option g* for the 5kg machine is mainly due to the mentioned decrease in the detergent dosage. When *Option f.1*, *f.2* and *k* are added, due to the associated increase in the washing temperature (the first two options) and the spinning speed (for the latter) also the overall and specific energy consumption increases. In particular, to simplify the analysis, *Option f.1* and *f.2* have been added one after the other, which will hardly happen in real-life.

When the BAT_{av} values are compared (Table 6.41) the influence of the reduced (from 5,36kg to 3,4kg) or increased (from 5,36kg to 6kg) load and the consequent change in the detergent dosage is more evident. It is worth noting that the improved load machine reaches a specific energy consumption of 0,1494 kWh/kg/cycle, which is the "A++" efficiency class machine claimed by some manufacturers (see Task 5). When the Life Cycle Cost (lifetime=15 years, 220 cycles/year) is shown as a function of the energy consumption (kWh/cycle) the curves in Figure 6.18 result. In Figure 6.19 the specific energy consumption of the two machines is presented, to evaluate the affect

Table 6.40: Energy and water consumption and incremental purchase price for washing machine Base Case and LLCCav for the extended standard base case analysis

Extended standard base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y)	
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case C	$LLCC_{av}$ C	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)
5kg machine	0,998	0,835	50,7	36,0	0,186	0,2456*	-31,9	443,5	480,7	8,4	1.952	1.670
6kg machine	0,998	0,900	50,7	38,7	0,186	0,1679**	9,8	443,5	459,7	3,7	1.952	1.829

*for an actual load of 3,4kg;
**for an actual load of 5,36kg.

Table 6.41: Energy and water consumption and incremental purchase price for washing machine Base Case and BATav for the extended standard base case analysis

Extended standard base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y)	
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case C	BAT_{av} C	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)
5kg machine	0,998	0,788	50,7	35,6	0,186	0,2317*	-31,9	443,5	588,0	-32,6	1.952	1.758
		0,956				0,2813*	-24,4		589,5	-32,9		1.825
		1,309				0,3851*	-51,1		591,0	-33,3		1.964
		1,365				0,4014*	-106,8		616,5	-39,0		2.011
6kg machine	0,998	0,896	50,7	39,9	0,186	0,1494**	19,8	443,5	570,2	-28,6	1.952	1.993
		1,089				0,1814**	2,6		571,7	-28,9		2.069
		1,490				0,2484**	-33,4		573,2	-29,2		2.226
		1,554				0,2589**	-39,1		598,7	-35,0		2.276

*for an actual load of 3,4kg;
**for an actual load of 6kg.

Figure 6.17: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the applied technological options for washing machine extended standard base case analysis

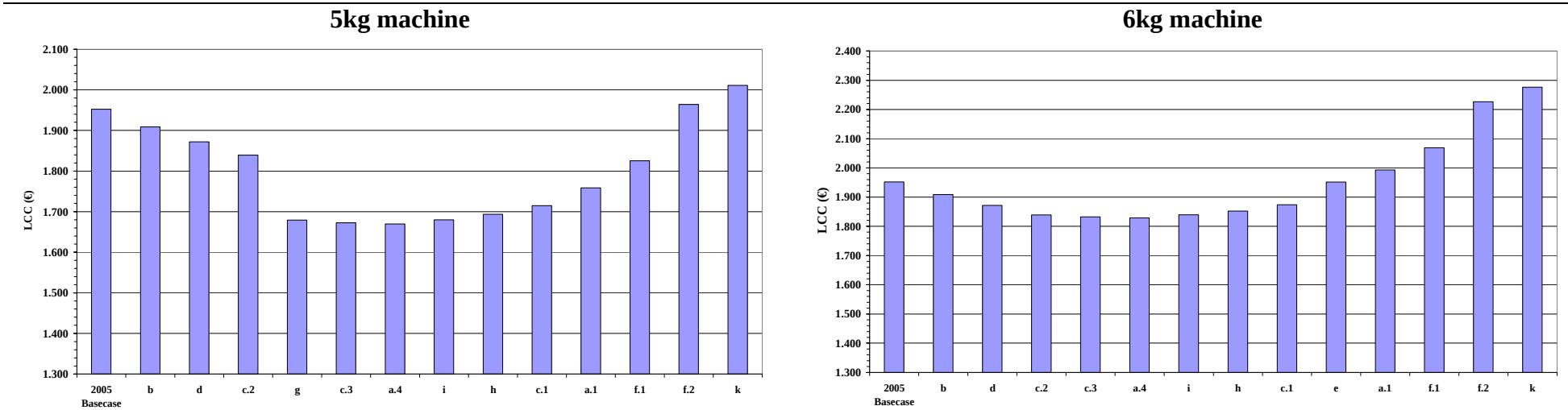


Figure 6.18: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the energy consumption for washing machine extended standard base case analysis. Average standard base cases are the first point on each curve where the arrows originate. Appliance base cases are identified by their load capacity. Arrows show the option application sequence.

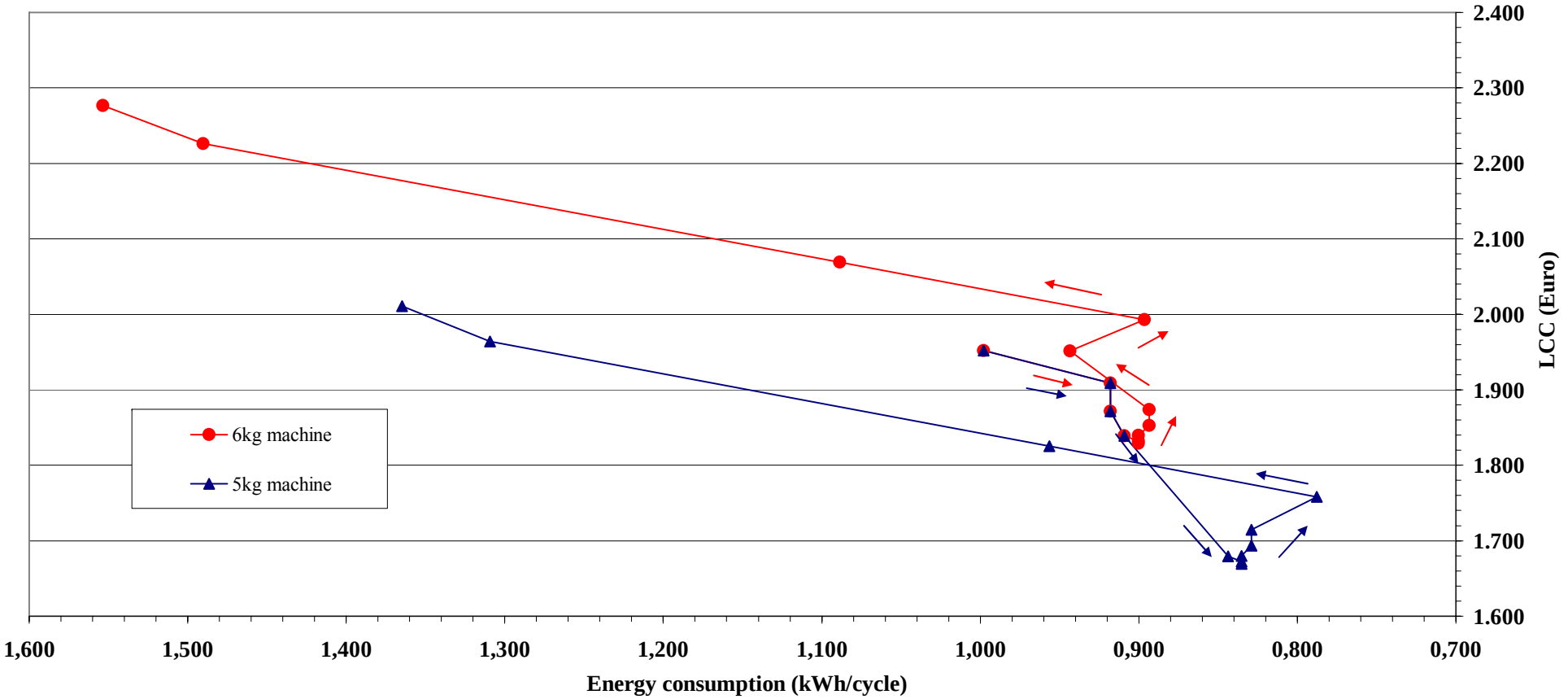
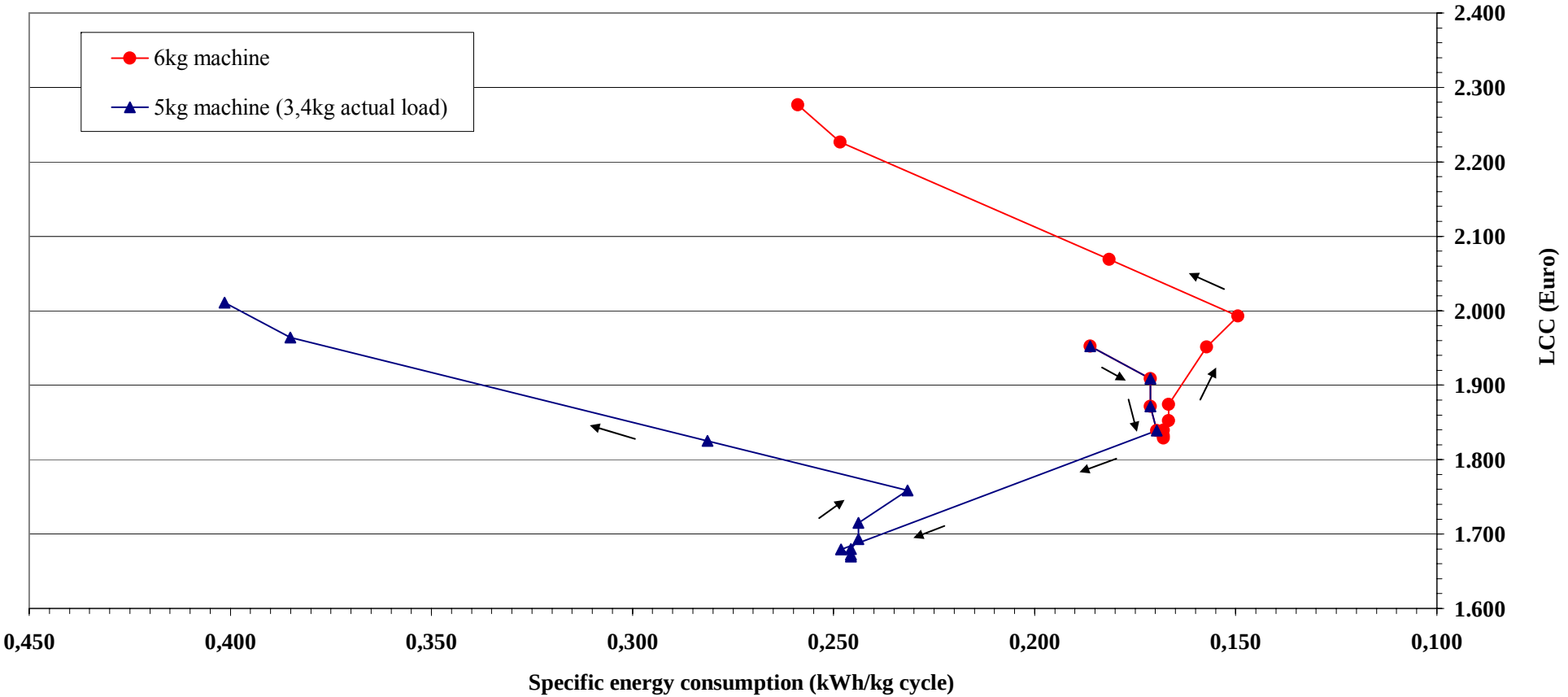


Figure 6.19: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the specific energy consumption for washing machine extended standard base case analysis. Average standard base cases are the first point on each curve. Appliance base cases are identified by their load capacity. Arrows show the option application sequence.



of the followed real life technological pathway.

6.2.3.6 Conclusions of the LCC analysis and results comparison for washing machines

The LCC is a means of expressing the overall cost of the appliance from the owner's perspective. It includes both the initial purchase price, the operating expenses for electricity, water and chemicals consumption and the other costs (maintenance, repairs, disposal) amortised to the present. In this approach, the (marginal) net present value of the operating expenses and other costs decrease from one year to the next due to discounting of their current value. Due to the time and budget constraints of the present study, and supported by the analysis of the last available technical database of the washing machine appliance models in 2005, only free-standing base cases were simulated.

A summary of the LCC analyses is presented in Table 6.42 for the $LLCC_{av}$ values and in Table 6.43 where the BAT_{av} values are compared. In the two Tables also the values for the Marginal Payback Time (MPB) have been calculated and are shown. Main results are:

a) The **LCC analysis for the standard base cases** shows that:

- for the average standard base case the LLCC occurs for appliances that are rated "A+" class (for energy efficiency) with C = 0,168 for the 5,36kg machine (the energy efficiency threshold for class A+ in CECED commercial agreement is C ≤ 0,17) and an energy consumption of 0,900 kWh/cycle; the water consumption is 38,7 litre/cycle, 12 litres below the 2005 average; the payback time is 1,2 years;
- the LCC analysis for the standard base case model predicts the energy and water consumption of the best available 6kg washing machine model on the market in 2005/2006 and the best 5kg model available in CECED 2005 technical database both in terms of energy and water consumption. The energy efficiency values for the BAT is C = 0,158 with a noise decreasing to 45d(B)A in washing (from the 53 dB(A) of the standard base case), corresponding to 0,855 kWh/cycle; the water consumption decreases to 37,4 litre/cycle. The value of C increases when the spinning speed is increased to 1 600 rpm, with a corresponding energy consumption of 0,892 kWh/cycle, with no influence on the water consumption and an increase of the spinning noise of 5dB(A);
- the payback time is 6,4 years when the spinning speed is not improved, but raises to 8,9 years when the spinning speed becomes 1 600 rpm, and to 11,6 years when the nominal load capacity of the machine is improved to 6kg;
- the increase in the nominal load capacity (from 5 to 6 kg) is not cost-effective at the overall machine (energy and water consumption) level, but becomes a positive technological development when evaluate considering the specific energy and water consumption (per unit of load weight).

b) The **LCC analysis for the real-life base cases** show that:

- for the LCC analysis of real life base case only the average base case is taken into consideration;
- the average real life machine has an actual washing temperature of 45,8°C, compared to the average standard machine with 60°C;
- for the average real-life base case the least life cycle cost occurs at an energy consumption of 0,649 kWh/cycle and with a water consumption of 33,3 litre/cycle for an actual load of 3,4kg; the payback time is 1,5 years;
- the analysis predicts also an energy and water consumption of the best available models at 0,616 kWh/cycle with a corresponding water consumption of 33,3 litre/cycle for the same 3,4kg load, and a payback time of 8,0 years that become 10,6 when the spinning speed is improved to 1 600 rpm with a contemporary increase of the energy consumption to 0,642 kWh/kg.

c) The **LCC analysis for the extended standard base cases** show that:

- in this analysis, the technological options identified as suitable for the real life will be applied to

the standard base cases (together with the options already identified as applicable for the standard base cases) to evaluate the overall modification of the energy/water consumption when the average machine is used under real-life conditions; a wash cycle with a 64% load (3,4kg) load has been simulated as result of the consumer analysis; a second simulation was run with an increase load capacity of 6kg, to evaluate also the effect of a larger capacity machine; in this case the option allowing the reduced load has not been applied;

- the increase in washing temperature due to a high temperature (77°C) water intake and a boiling water steam cycle have been applied, but not necessarily this will happen contemporarily in real life;
- for the extended standard base case encompassing a load capacity reduction, the least life cycle cost occurs at an energy consumption of 0,835 kWh/cycle with a water consumption of 36 litre/cycle, mainly due to the application of the partial load option, but the specific energy and water consumption is 0,246k Wh/kg/cycle and 10,6 litre/kg/cycle, with a payback time of 1,9y;
- the BAT occurs at an energy consumption of 0,788 kWh/cycle and a water consumption of 35,6 litre/cycle (payback time 7,2 years), which increases to 0,956 kWh/cycle when a high temperature water intake is used for hygiene purposes, with a payback time of 10,6 years. The application of the other options (steam cycle and improved spin speed) increase the energy consumption (but not the water consumption) to a level when the payback time is a nonsense;
- for the extended standard base case with a load increase to 6kg, the LLCC occurs before the improved load capacity option is applied due to its NPV; the payback time is 1,2 years;
- the BAT analysis predicts also the energy and water consumption of the best available model on the market in 2005/2006, which is claimed to reach an A++ energy efficiency class, with a specific energy consumption of 0,1494 kWh/kg/cycle (the claimed threshold of the A++ is below 0,15 kWh/kg/cycle); the payback time of this level is 10,1 years. When other options are added the energy consumption increases to values far above the base case payback time becomes meaningless.

6.2.4 Sensitivity Analysis

The life-cycle cost analysis presented in previous paragraph assumed EU average values for wash appliance prices, lifetime, electricity tariffs and discount rates. As all of these parameters will vary at the Member State level, a sensitivity analysis was performed to determine if the efficiency level associated with the least life-cycle cost might occur at a different level depending on the Member State concerned.

6.2.4.1 The key technical, economic and financial assumption

The key parameters used in the sensitivity analysis for dishwashers and washing machines are:

- Lifetime: 10y, 12y and 17y in addition to the average 15y
- Electricity price: 0,25 €/kWh and 0,10 €/kWh, in addition to the average 0,17 €/kWh
- Water prices: 3,7 Euro/m^3 ±30% or 4,8 Euro/m^3 and 2,6 Euro/m^3
- Discount rate: 4% and 6%, in addition to the average value of 5%
- Cycles per year: 200 and 220 cycle are considered in addition to the 280 used in the LCC for dishwashers
- Average 12ps dishwasher price: 552 € in West EU and 464 € in East EU (average 548,4 €). No price differentiation is possible for 9ps machines, therefore the sensitivity for price was not run
- Cycles per year: 200 and 245 cycle are considered in addition to the 220 used in the LCC for washing machines
- Washing temperature: 40°C cycle will be estimated for washing machines
- Average washing machine price: 562 Euro in West EU and 326 Euro in East EU.
- Disposal and recycling costs: 10€ in addition to the 61€.

Table 6.42: Energy efficiency, energy & water consumption and incremental purchase price for the washing machine Base Case and LLCCav Case

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15 years, 220 cycles)		
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case C	$LLCC_{av}$ C	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)	MPB (years)
5kg machine (5,36 kg load)													
Average standard	0,998	0,900	50,7	38,7	0,186	0,168	9,8	443,5	459,7	3,7	1.952	1.829	1,2
Real life	0,719	0,649	43,6	33,3	0,2115	0,1907	9,8	443,5	459,7	3,7	1.655	1.556	1,5
Extended standard	0,998	0,835	50,7	36,0	0,186	0,2456*	-31,9	443,5	480,7	8,4	1.952	1.670	1,9
6kg machine													
Extended standard	0,998	0,900	50,7	38,7	0,186	0,1679**	9,8	443,5	459,7	3,7	1.952	1.829	1,2

*for an actual load of 3,4kg;
**for an actual load of 5,36kg.

Table 6.43: Efficiency, energy & water consumption and incremental purchase price for the washing machine Base Case and BATav Case

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15 years, 220 cycles)		
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case C	BAT_{av} C	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)	MPB (years)
5kg machine													
Average standard	0,998	0,855	50,7	38,7	0,186	0,1596	14,3	443,5	540,8	21,9	1.952	1.893	6,4
		0,892		38,7		0,1663	10,7		566,3	27,7		1.932	8,9
		0,942		40,3		0,1569	15,7		566,5	27,7		2.010	11,6
Real life	0,719	0,616	43,6	33,3	0,2115	0,1812	14,3	443,5	540,8	21,9	1.655	1.625	8,0
		0,642		33,3		0,1889	10,7		566,3	27,7		1.661	10,9
Extended standard	0,998	0,788	50,7	35,6	0,1862	0,2317*	-31,9	443,5	588,0	-32,6	1.952	1.758	7,2
		0,956				0,2813*	-24,4		589,5	-32,9		1.825	10,6
		1,309				0,3851*	-51,1		591,0	-33,3		1.964	--
		1,365				0,4014*	-106,8		616,5	-39,0		2.011	--
6kg machine													
Extended standard	0,998	0,896	50,7	39,9	0,1862	0,1494**	19,8	443,5	570,2	-28,6	1.952	1.993	10,1
		1,089				0,1814**	2,6		571,7	-28,9		2.069	23,8
		1,490				0,2484**	-33,4		573,2	-29,2		2.226	--
		1,554				0,2589**	-39,1		598,7	-35,0		2.276	--

*for an actual load of 3,4kg;
**for an actual load of 6kg.

In particular:

- number of washing cycles per year: the value of 208 cycle/year has been kept for sake of comparison with previous results, 220 cycle/year is used is the labelling directive, 280 cycle/year was found in a German study made by STIWA in 2003;
- the sales weighted average price of the dishwashers sold in 2004 according GfK was 552 Euro in West EU countries and 464 Euro in East EU countries, with an average of 548,4 Euro for the 13 EU member stated where GfK collected the market data. The 9ps machine price is estimated in 520 Euro;
- the number of cycles per year in a washing machine: 200 is the number of washing cycles considered in the energy labelling directive for a four-person household and forecast for 2010 in the WASH-II study; 222 is the number of cycles used in the WASH-II study; 245 is the number of cycles used in GEA study;
- the sales weighted average price of the washing machines sold in 2004, according GfK, was 562 Euro in West EU countries and 326 Euro in East EU countries, with an average of 443,5 Euro for the 13 EU member stated where GfK collected the market data;
- additional data from literature (Table 6.44) about washing machines lifetime and number of washing cycles were collected by ÖKÖ Institute in 2004[16]. In addition, the scenario analysis (Chapter 9) of the WASH-II study, considered a number of cycles per washing machine around 240-245 per year for the EU. This is not to be confused with the number of cycles per household, which is a bit over 220 cycle/year (not every household owns a washing machine). Both the number of cycles per household and per machine are dropping very slowly. However, the number of wash cycles per capita is rising.

Table 6.44: Washing machine lifetime and number of washing cycles in literature

Study	Materials	Manufacturing	Distribution	Use phase	CED (use phase)/cycle	End of life
Current study [Rüdenauer et al. 2004]	Manufacturer data	Manufacturer data	170 km train 170 km truck	11,4 years life-span with 175 washing cycles per year; 2.000 washing cycles per lifespan	Mix of programs and loading, see section 3.7.2.6	Credits for recycling of materials
Behrendt et al. 2004	Dismantled washing machine	Not specified	750 km train 300 km big truck 30 km small truck	10 years life-span with 240 washing cycles per year; 2.400 washing cycles per life span	Cotton 60°C 5 kg loading (EPD 2001)	Redistribution 150 km train 300 km big truck 30 km small truck
Szczepanowki 2001	Dismantled washing machine	Manufacturer data	Not specified	15 years life-span with 209 washing cycles per year; 3.135 washing cycles per life span	Cotton 60°C (according to European union eco-labelling directive)	Redistribution, shredding, landfill
Ebersperger 1996	Dismantled washing machine	Not specified	Not specified	10 years life-span with 172 washing cycles per year; 1.720 washing cycles per life span	Mix of programs and loading, not specified repair, sewage treatment	Redistribution, shredding and sortation, landfill
Strubel und Gensch 1996	Manufacturer data Multiplied by factor 2 for rejections etc.	Included in materials	150 km train 300 km big truck 30 km small truck	15 years life-span with 180 washing cycles per year; 2.700 washing cycles per life span	Cotton 60°C 4 kg loading	Redistribution, assumptions equal to distribution
Durrant et al. 1991	Manufacturer data	5% of material production (estimation of manufacturers)	300 km truck	14 years life-span with 250 washing cycles per year; 3.500 washing cycles per life span	Mix of hot and economy wash	Shredding (EMPA 1984)

[16] source: ÖKÖ Insitute eV, Eco-Efficiency Analysis of Washing machines – Life Cycle Assessment and determination of optimal life span, Freiburg, November 2nd, 2004, page 51.

6.2.4.2 The sensitivity analysis for dishwashers

The Life Cycle Cost sensitivity analysis has been developed only for the two average standard base cases. The technical and financial assumptions defined in Task 5, were modified, one at time, to evaluate the impact on the LCC output values. It is worth highlighting that in the sensitivity analysis the application order of the technological options is that resulting as the most profitable for the consumers according to the MNPV analysis for the average standard base case and the basic technical and financial assumptions. The variation of parameters such as the energy and water price and the number of cycles per year might have an influence on the optimum technological option combination (corresponding to the LLCC) and more in general to the options application order, but this more sophisticated sensitivity analysis was not compatible with the time and budget constraints of the study.

In Table 6.45 the LCC analyses of the **9ps dishwashers** are presented for the three different values of the annual washing cycle number.

The most important result is that in practice the Least Life Cycle Cost point occurs at the technological option combination (b+f.1+f.2+a.1) for the variation of all the investigated parameters. In fact, only when electricity price is considered 0,10 €/kWh (or 58% of the initial value of 0,17 €/kWh) and the number of washing cycles is 208 then the LLCC occurs for the option combination (b+f.1+f.2) but with a difference of 1 Euro over 15years; the same occurs for a lifetime of 10 years and 220 cycles/year. As expected, there is no effect on the overall LCC results robustness when the disposal and recycling costs are decreased from 61 € to 10 €.

The second most important outcome of the sensitivity analysis is the large variation of the LCC at the LLCC point due to the combination of technical and economical factors: when 208 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.033 Euro; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 1.554 Euro, with a difference of 521 Euro.

The same data are presented in Figures 6.20-6.22, respectively for 208, 220 and 280 washing cycles per year, using the same scale for the LCC to allow an immediate comparison of the differences due to the consumer behaviour.

In Table 6.46 the LCC analyses of the **12ps dishwasher**s are presented for the three different values of the annual washing cycle number.

The most important result is that the Least Life Cycle Cost point occurs again at the technological option combination (b+f.1+f.2+a.1) for the variation of all the investigated parameters. As expected, there is no effect on the overall LCC when the disposal and recycling costs are varied from 61€ to 10€. The second most important outcome of the sensitivity analysis is also the large variation of the LCC at the LLCC point due to the combination of technical and economical factors: when 208 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.139 Euro; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 1.776 Euro, with a difference of 635 €.
The same data are presented in Figures 6.23-6.25, respectively for 208, 220 and 280 washing cycles per year, using the same scale for the LCC to allow an immediate comparison of the differences due to the consumer behaviour.

To allow an easier understanding of the overall LCC analysis results, the output for the different

Table 6.45: Sensitivity analysis results for the LCC of 9ps dishwashers average standard base case

Technological options			2005	+b	+f.1	+f.2	+a.1	+c	+e.1	+e.2	+g	+h.1	+h.2
cycles per year	Investigated parameters and variations		Base case	Alternating spraying of water	Avoidance/ reduction of the cold pre-rinse	partly draining and refilling of water	Lower wash temperature (45°C) & longer time	Heat exchanger (with sto-rage tank)	condenser for drying	Condenser with fan for drying	DC brushless motor	Noise reduction, level 44 dB(A)	Noise reduction, level 41 dB(A)
LCC results for basic technical and financial assumptions		kWh/cycle	0,828	0,798	0,794	0,790	0,782	0,758	0,751	0,741	0,723	0,770	0,851
		litre/cycle	13,7	12,2	11,3	10,3	10,3	10,3	10,3	10,3	9,9	9,9	9,9
		g/cycle	51	51	51	51	51	51	51	51	51	51	51
208	lifetime	10y	1.043	1.043	1.036	1.033	**1.033**	1.050	1.068	1.094	1.165	1.202	1.292
208	lifetime	12y	1.112	1.109	1.101	1.096	1.097	1.113	1.130	1.156	1.226	1.265	1.358
208	lifetime	**15y**	**1.203**	**1.196**	**1.188**	**1.181**	**1.181**	**1.196**	**1.213**	**1.238**	**1.307**	**1.348**	**1.446**
208	lifetime	17y	1.256	1.248	1.238	1.231	1.231	1.245	1.261	1.287	1.354	1.397	1.497
208	water price	€ 4,8	1.235	1.225	1.215	1.206	1.206	1.220	1.237	1.263	1.330	1.372	1.470
208	water price	€ 2,6	1.170	1.167	1.161	1.157	1.157	1.171	1.188	1.214	1.283	1.324	1.422
208	electricity price	€ 0,25	1.346	1.334	1.325	1.318	1.317	1.327	1.343	1.366	1.432	1.481	1.593
208	electricity price	€ 0,10	1.078	1.076	1.068	1.062	1.063	1.081	1.099	1.126	1.198	1.232	1.317
208	discount rate	4%	1.254	1.246	1.236	1.230	1.229	1.243	1.260	1.285	1.353	1.395	1.495
208	discount rate	6%	1.157	1.152	1.144	1.138	1.138	1.153	1.170	1.196	1.265	1.305	1.401
208	disposal&recycling	€ 10	1.178	1.172	1.163	1.157	1.157	1.171	1.188	1.214	1.282	1.324	1.421
220	lifetime	10y	1.069	1.067	1.061	1.056	1.057	1.073	1.091	1.117	1.188	1.225	1.317
220	lifetime	12y	1.141	1.137	1.129	1.124	1.124	1.139	1.157	1.182	1.252	1.291	1.386
220	lifetime	15y	**1.237**	**1.229**	**1.220**	**1.214**	**1.213**	**1.227**	**1.244**	**1.269**	**1.337**	**1.379**	**1.479**
220	lifetime	17y	1.293	1.283	1.274	1.266	1.266	1.279	1.295	1.320	1.387	1.431	1.533
220	water price	€ 4,8	1.272	1.260	1.249	1.239	1.239	1.253	1.270	1.295	1.362	1.404	1.504
220	water price	€ 2,6	1.203	1.199	1.192	1.188	1.187	1.201	1.218	1.243	1.312	1.355	1.454
220	electricity price	€ 0,25	1.388	1.375	1.365	1.358	1.356	1.366	1.381	1.405	1.469	1.520	1.635
220	electricity price	€ 0,10	1.105	1.102	1.093	1.087	1.088	1.106	1.124	1.151	1.222	1.256	1.343
220	discount rate	4%	1.291	1.281	1.271	1.264	1.264	1.277	1.293	1.318	1.386	1.429	1.531
220	discount rate	6%	1.189	1.183	1.174	1.168	1.168	1.183	1.200	1.225	1.294	1.335	1.432
220	disposal&recycling	€ 10	1.213	1.205	1.196	1.189	1.189	1.203	1.220	1.245	1.313	1.355	1.455
280	lifetime	10y	1.197	1.190	1.182	1.176	1.176	1.190	1.207	1.232	1.301	1.342	1.440
280	lifetime	12y	1.288	1.278	1.268	1.261	1.260	1.273	1.290	1.315	1.382	1.426	1.528
280	lifetime	15y	**1.409**	**1.395**	**1.383**	**1.374**	**1.373**	**1.384**	**1.400**	**1.424**	**1.489**	**1.537**	**1.645**
280	lifetime	17y	1.480	1.463	1.451	1.440	1.439	1.449	1.465	1.489	1.553	1.602	1.713
280	water price	€ 4,8	1.453	1.434	1.419	1.407	1.406	1.417	1.433	1.457	1.521	1.568	1.677
280	water price	€ 2,6	1.365	1.356	1.347	1.341	1.340	1.351	1.367	1.391	1.458	1.505	1.613
280	electricity price	€ 0,25	1.602	1.580	1.568	1.558	**1.554**	1.560	1.575	1.597	1.657	1.716	1.843
280	electricity price	€ 0,10	1.241	1.232	1.222	1.213	1.214	1.230	1.247	1.274	1.342	1.380	1.472
280	discount rate	4%	1.475	1.458	1.446	1.436	1.434	1.445	1.461	1.484	1.549	1.597	1.709
280	discount rate	6%	1.350	1.337	1.327	1.318	1.317	1.329	1.346	1.370	1.436	1.482	1.588
280	disposal&recycling	€ 10	1.385	1.370	1.359	1.349	1.348	1.359	1.376	1.400	1.465	1.512	1.620

Figure 6.20: Life Cycle Cost (lifetime = 15 years, 208 cycle/year) as a function of the technological options for 9ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve

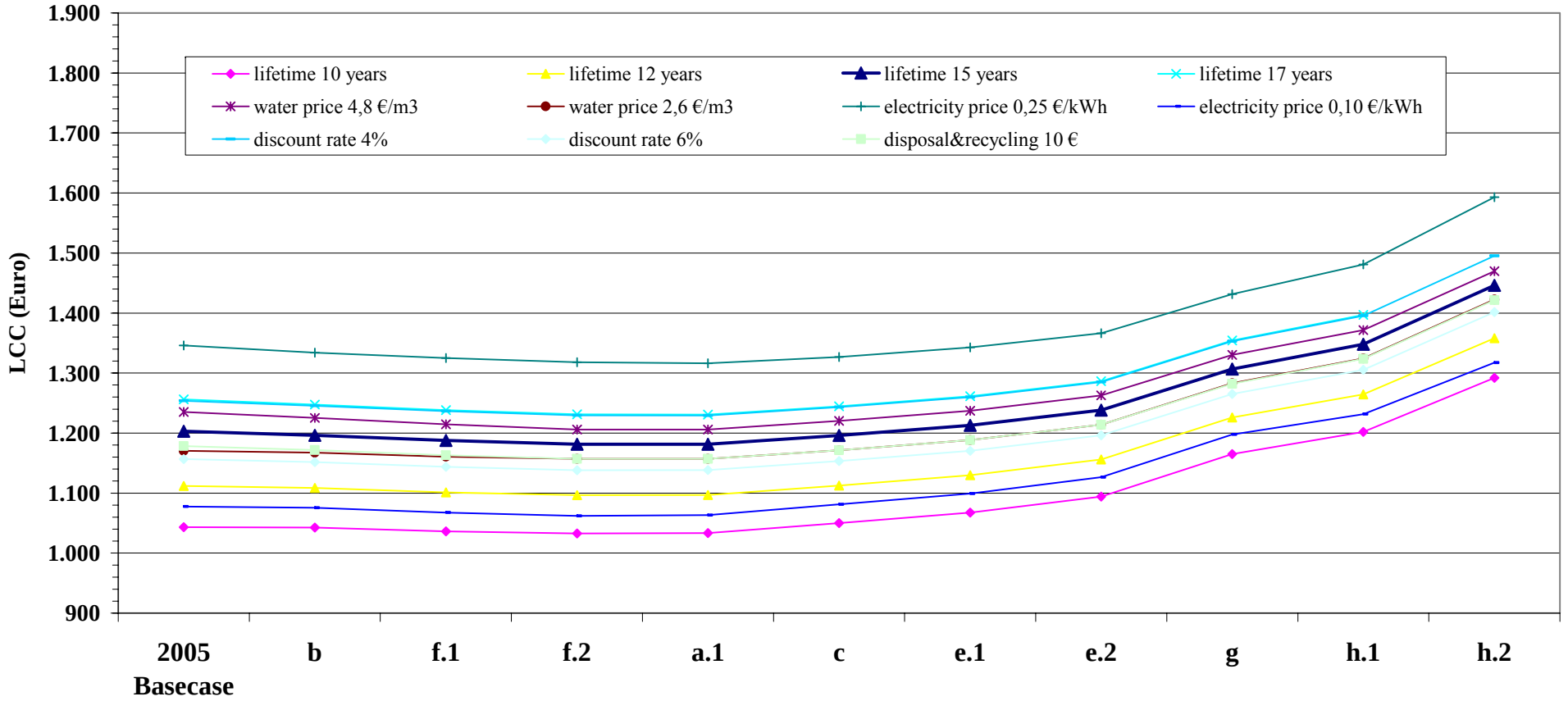


Figure 6.21: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the technological options for 9ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve

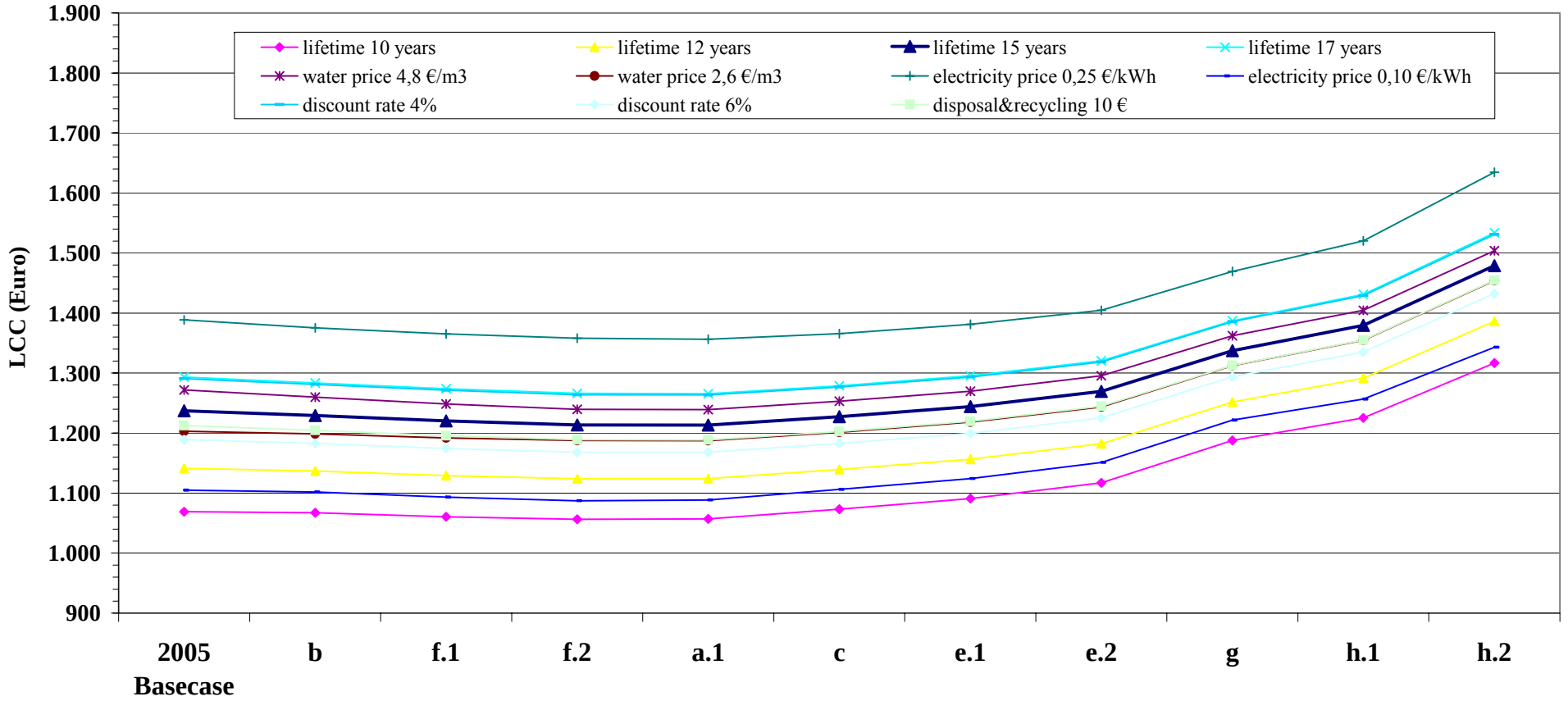


Figure 6.22: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the technological options for 9ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve

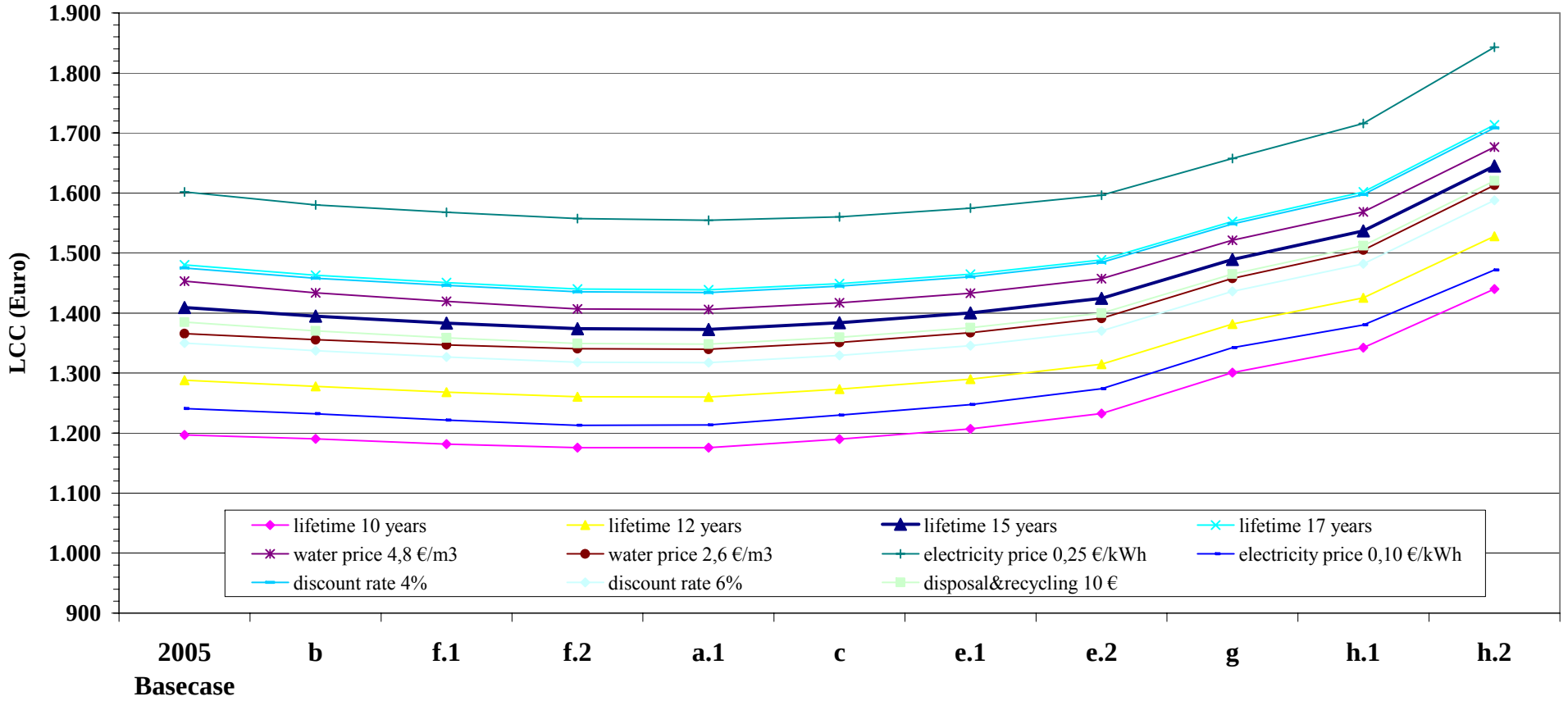


Table 6.46: Sensitivity analysis results for the LCC of 12ps dishwashers average standard base case

Technological options			2005	+b	+f.1	+f.2	+a.1	+c	+e.1	+e.2	+d	+g	+h.1	+h.2
cycles per year	Investigated parameters and variations		**Base case**	Alterna-ting spraying of water	Avoidance/ reduction of the cold pre-rinse	partly draining and refilling of water	Lower wash temperature (45°C) & longer time	Heat exchanger (with sto-rage tank)	Conden-ser for drying	Condenser with fan for drying	Cross flow heat exchanger	DC brushless motor	Noise reduction, level 44 dB(A)	Noise reduction, level 41 dB(A)
LCC results for basic technical and financial assumptions		kWh/cycle	1,070	1,028	1,024	1,020	1,009	0,985	0,978	0,968	0,931	0,914	0,975	1,079
		litre/cycle	15,2	13,4	12,3	11,0	11,0	11,0	11,0	11,0	11,0	10,6	10,6	10,6
		g/cycle	54	54	54	54	54	54	54	54	54	54	54	54
208	lifetime	10y	1.158	1.152	1.145	1.139	**1.139**	1.156	1.174	1.200	1.253	1.320	1.365	1.468
208	lifetime	12y	1.239	1.230	1.222	1.215	1.214	1.230	1.247	1.273	1.324	1.390	1.439	1.545
208	lifetime	**15y**	**1.347**	**1.334**	**1.324**	**1.315**	**1.314**	**1.329**	**1.346**	**1.371**	**1.420**	**1.485**	**1.536**	**1.649**
208	lifetime	17y	1.410	1.394	1.384	1.374	1.373	1.386	1.403	1.428	1.476	1.540	1.593	1.709
208	water price	€ 4,8	1.383	1.366	1.353	1.341	1.340	1.355	1.372	1.397	1.446	1.510	1.562	1.674
208	water price	€ 2,6	1.311	1.302	1.295	1.289	1.288	1.302	1.319	1.345	1.394	1.459	1.511	1.623
208	electricity price	€ 0,25	1.532	1.511	1.501	1.491	1.488	1.499	1.514	1.538	1.581	1.643	1.705	1.835
208	electricity price	€ 0,10	1.185	1.178	1.169	1.161	1.162	1.180	1.198	1.225	1.279	1.347	1.389	1.485
208	discount rate	4%	1.406	1.391	1.380	1.371	1.370	1.383	1.400	1.425	1.473	1.537	1.590	1.705
208	discount rate	6%	1.294	1.282	1.273	1.265	1.264	1.279	1.296	1.322	1.372	1.437	1.487	1.597
208	dw price WEU	€ 552	1.351	1.337	1.328	1.319	1.318	1.332	1.349	1.375	1.424	1.488	1.540	1.652
208	dw price EEU	€ 464	1.263	1.249	1.240	1.231	1.230	1.244	1.261	1.287	1.336	1.400	1.452	1.564
208	disposal&recycling	€ 10	1.189	1.182	1.174	1.168	1.168	1.184	1.201	1.228	1.280	1.346	1.393	1.497
220	lifetime	10y	1.189	1.182	1.174	1.168	1.168	1.184	1.201	1.228	1.280	1.346	1.393	1.497
220	lifetime	12y	1.274	1.264	1.255	1.247	1.247	1.262	1.279	1.305	1.355	1.421	1.470	1.579
220	lifetime	**15y**	**1.388**	**1.373**	**1.363**	**1.353**	**1.352**	**1.366**	**1.383**	**1.408**	**1.456**	**1.520**	**1.573**	**1.688**
220	lifetime	17y	1.455	1.437	1.426	1.415	1.414	1.427	1.443	1.468	1.516	1.579	1.634	1.751
220	water price	€ 4,8	1.426	1.407	1.394	1.381	1.380	1.394	1.411	1.436	1.484	1.547	1.600	1.714
220	water price	€ 2,6	1.350	1.339	1.332	1.326	1.324	1.338	1.355	1.380	1.429	1.494	1.547	1.661
220	electricity price	€ 0,25	1.584	1.561	1.550	1.540	1.536	1.546	1.561	1.585	1.627	1.687	1.751	1.885
220	electricity price	€ 0,10	1.217	1.209	1.199	1.190	1.191	1.209	1.226	1.253	1.307	1.374	1.417	1.515
220	discount rate	4%	1.450	1.433	1.422	1.412	1.410	1.423	1.440	1.465	1.512	1.576	1.630	1.747
220	discount rate	6%	1.332	1.319	1.309	1.301	1.300	1.314	1.331	1.357	1.406	1.471	1.522	1.634
220	dw price WEU	€ 552	1.392	1.377	1.366	1.357	1.356	1.370	1.386	1.412	1.460	1.524	1.577	1.691
220	dw price EEU	€ 464	1.304	1.289	1.278	1.269	1.268	1.282	1.298	1.324	1.372	1.436	1.489	1.603
220	disposal&recycling	€ 10	1.364	1.349	1.338	1.329	1.328	1.341	1.358	1.384	1.432	1.496	1.549	1.663
280	lifetime	10y	1.342	1.328	1.318	1.310	1.308	1.323	1.340	1.365	1.414	1.479	1.531	1.643
280	lifetime	12y	1.450	1.432	1.420	1.410	1.408	1.421	1.438	1.463	1.510	1.573	1.628	1.746
280	lifetime	**15y**	**1.594**	**1.570**	**1.557**	**1.544**	**1.542**	**1.553**	**1.569**	**1.593**	**1.638**	**1.699**	**1.758**	**1.884**
280	lifetime	17y	1.678	1.651	1.637	1.622	1.619	1.630	1.646	1.669	1.712	1.772	1.834	1.964

Technological options			2005	+b	+f.1	+f.2	+a.1	+c	+e.1	+e.2	+d	+g	+h.1	+h.2
cycles per year	Investigated parameters and variations		**Base case**	Alterna-ting spraying of water	Avoidance/ reduction of the cold pre-rinse	partly draining and refilling of water	Lower wash temperature (45°C) & longer time	Heat exchanger (with sto-rage tank)	Conden-ser for drying	Condenser with fan for drying	Cross flow heat exchanger	DC brushless motor	Noise reduction, level 44 dB(A)	Noise reduction, level 41 dB(A)
280	water price	€ 4,8	1.642	1.613	1.596	1.579	1.577	1.588	1.604	1.628	1.673	1.733	1.792	1.918
280	water price	€ 2,6	1.545	1.527	1.517	1.509	1.506	1.518	1.534	1.558	1.602	1.665	1.724	1.850
280	electricity price	€ 0,25	1.843	1.809	1.795	1.781	**1.776**	1.782	1.796	1.818	1.854	1.911	1.985	2.135
280	electricity price	€ 0,10	1.376	1.361	1.348	1.336	1.336	1.352	1.370	1.396	1.448	1.513	1.560	1.664
280	discount rate	4%	1.671	1.644	1.630	1.616	1.613	1.623	1.639	1.663	1.706	1.767	1.828	1.957
280	discount rate	6%	1.525	1.503	1.491	1.479	1.477	1.489	1.505	1.530	1.576	1.638	1.695	1.817
280	dw price WEU	€ 552	1.597	1.574	1.560	1.548	1.545	1.556	1.573	1.597	1.641	1.702	1.762	1.887
280	dw price EEU	€ 464	1.509	1.486	1.472	1.460	1.457	1.468	1.485	1.509	1.553	1.614	1.674	1.799
280	disposal&recycling	€ 10	1.569	1.546	1.532	1.519	1.517	1.528	1.544	1.569	1.613	1.674	1.734	1.859

Figure 6.23: Life Cycle Cost (lifetime = 15 years, 208 cycle/year) as a function of the technological options for 12ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve

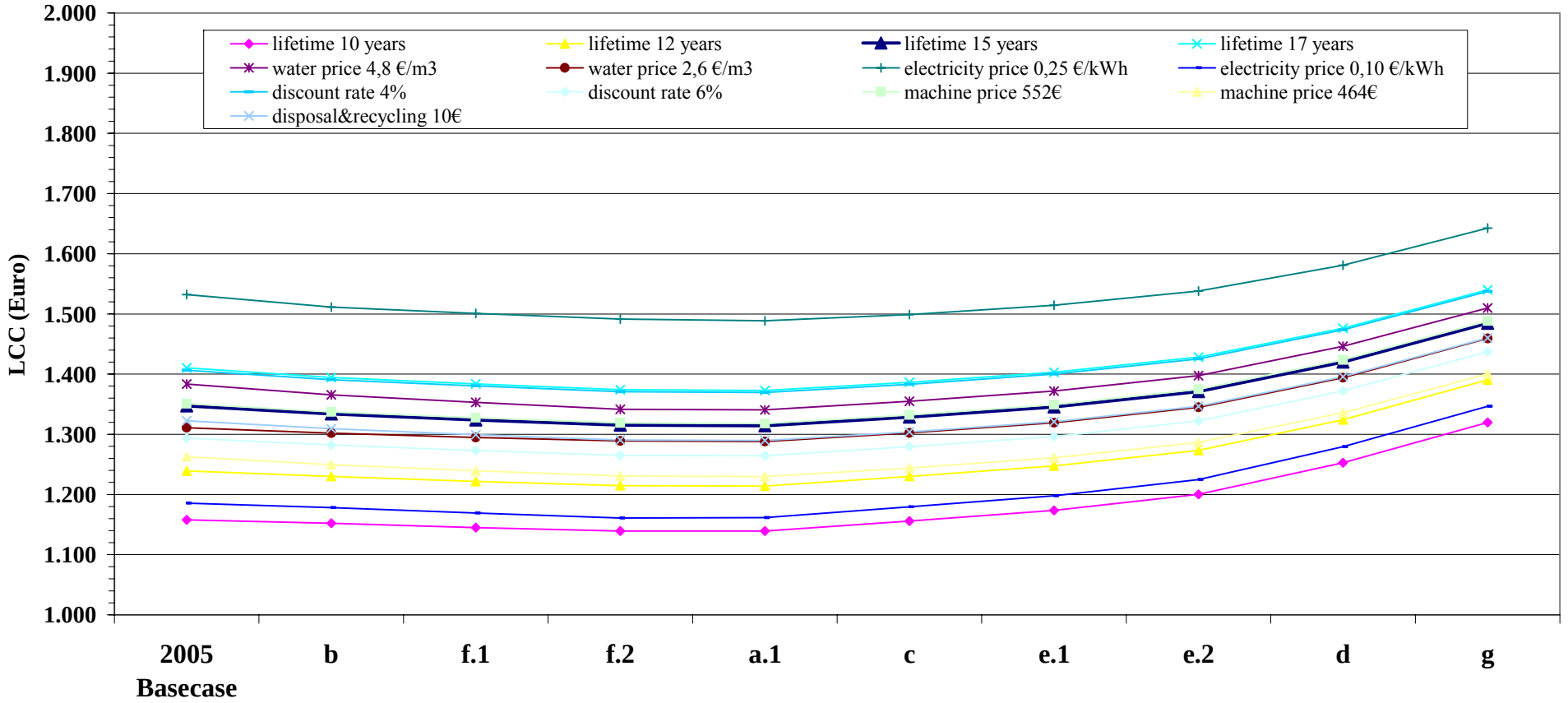


Figure 6.24: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the technological options for 12ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve

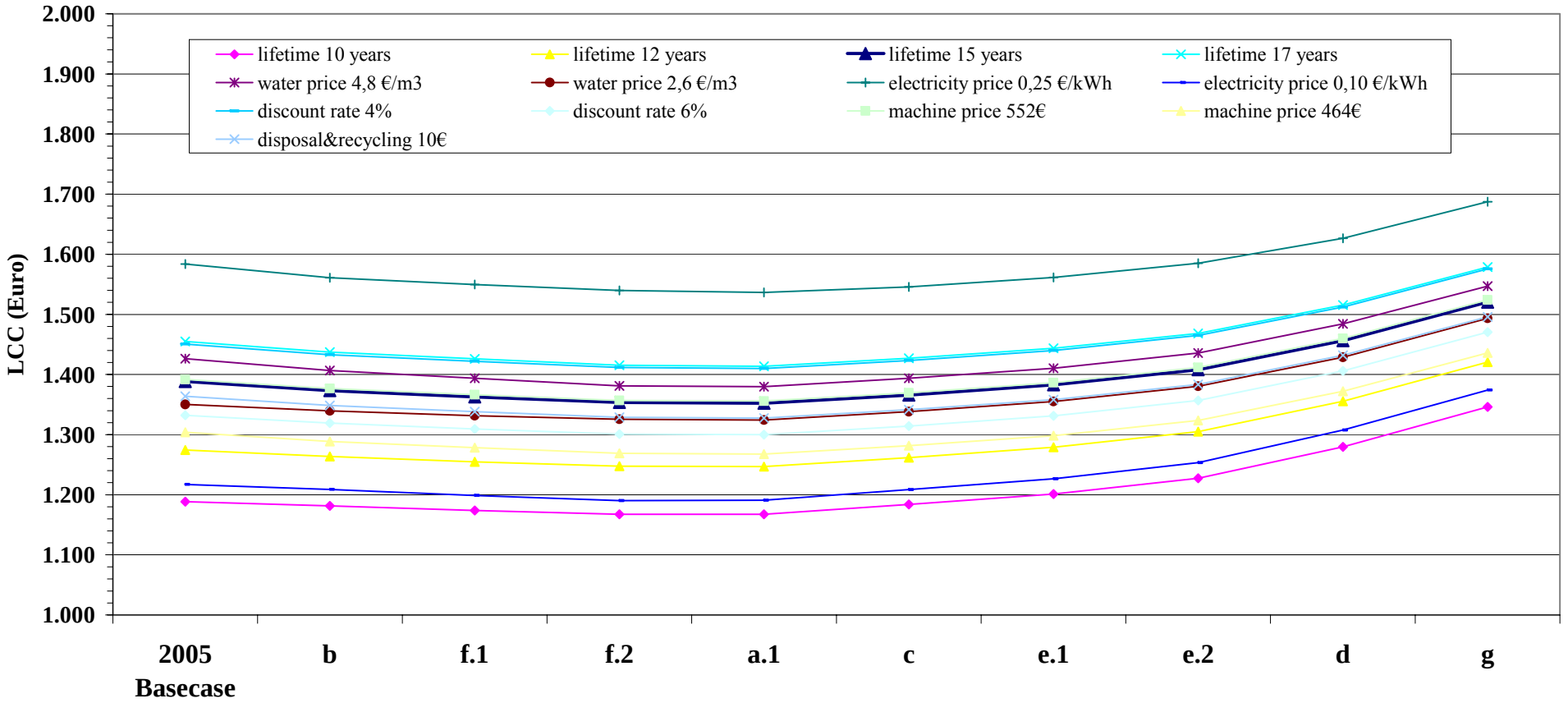
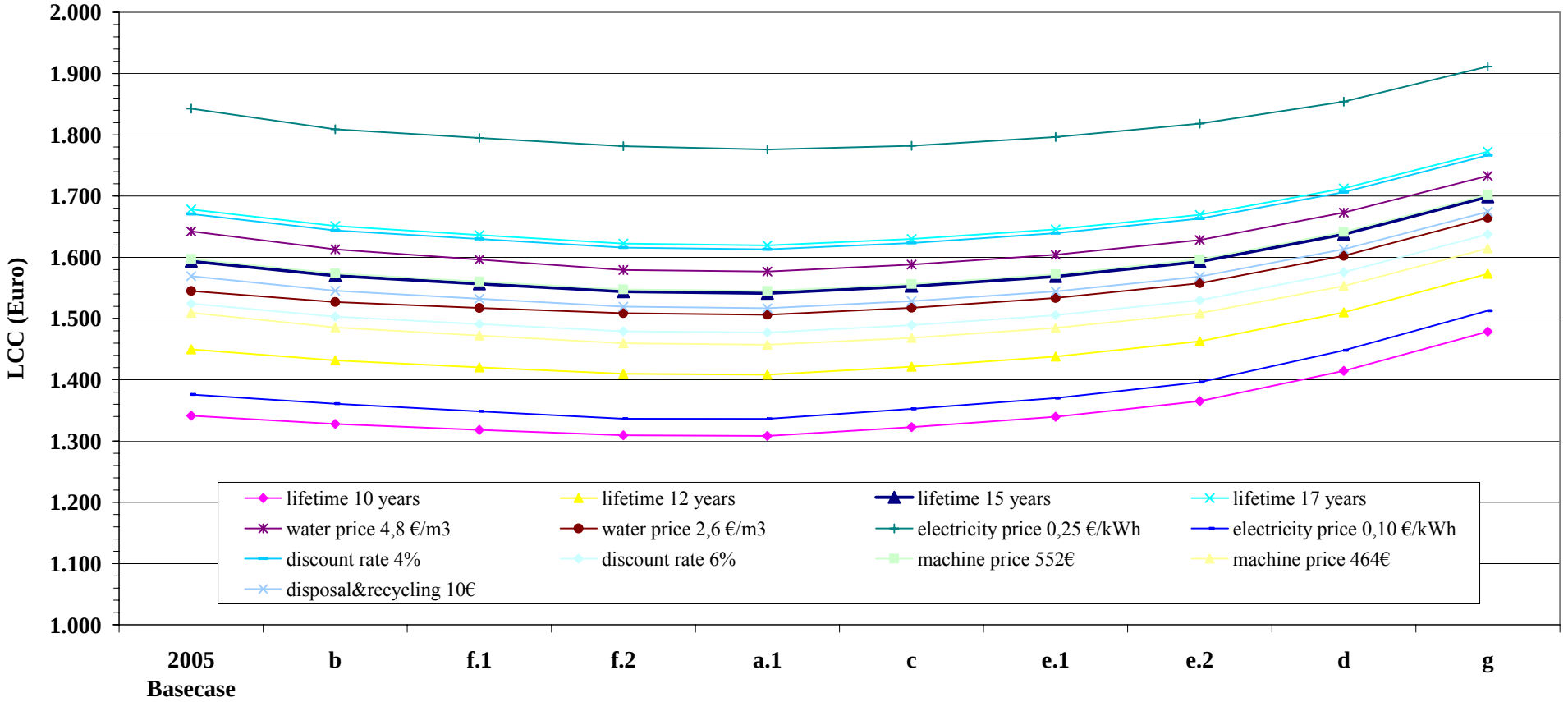


Figure 6.25: Life Cycle Cost (lifetime = 15 years, 280 cycle/year) as a function of the technological options for 12ps dishwasher sensitivity analysis. Parameters variation is indicated for each curve



number of washing cycles per year and lifetimes are compared in Table 6.47 for the 9ps machine. The standard base case, the $LLCC_{av}$, and the BAT_{av} case with noise values of 50 dB(A), 44 dB(A) and 41 dB(A) are presented. Table 6.48 shows the derived annual savings to the average standard base case for the 9ps dishwashers at a different number of washing cycles per year with an energy price of 0,17 €/kWh and a water price of 3,7 €/m^3. The energy savings going from the average standard base case to the $LLCC_{av}$ are in the range 1,6-2,2 €/year depending on the annual washing cycles, the water savings in the range 2,6-3,6 €/year, for a total of 4,2-5,7 €/year against an increase in purchase price of 23 Euro; the energy savings going from the average standard base case to the BAT_{av} at 50 dB(A) are in the range 3,7-5,0 €/year and the water savings in the range 2,8-3,8 €/year, for a total of 6,6-8,8 €/year against an increase in purchase price of 173 Euro. When the noise is decrease to 41 dB(A) there is a slight increase of the energy expenses (-0,8-1,1 €/year), while the water savings are in the range 2,8-3,8 €/year, with a price increase of 265 €.

The same analysis is given in Tables 6.49 and 6.50 for the 12ps machine. The energy savings going from the average standard base case to the $LLCC_{av}$ are in the range 2,2-2,9 €/year depending on the annual washing cycles, the water savings in the range 3,2-4,4 €/year, for a total of 5,4-7,3 €/year against an increase in purchase price of 23 €; the energy savings going from the average standard base case to the BAT_{av} at 50 dB(A) are in the range 5,5-7,4 €/year depending on the annual washing cycles and the water savings in the range 3,5-4,8 €/year, for a total of 9,1-12,2 €/year against an increase in purchase price of 231 €. When the noise is decrease to 41 dB(A) there is no energy savings, while the water savings are in the range 3,5-4,8 €/year, with a price increase of 335 €.

6.2.4.3 The sensitivity analysis for washing machines

a) The 60 °C washing temperature cycle

In Table 6.51 the LCC analyses of the 5,36 washing machine are presented for the three different values of the annual washing cycle number. The most important result is that the Least Life Cycle Cost point occurs at the technological option combination (b+d+c.2+c.3+a.4) for the variation of all the investigated parameters. As in the case of dishwashers, there is no effect on the overall LCC when the disposal and recycling costs are varied up to negative values (costs turned into profits). The second most important outcome of the sensitivity analysis is the large variation of the LCC at the LLCC point due to the combination of technical and economical factors: when 200 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.411 €; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 2.162 Euro, with a difference of 751 €. The same data are presented in Figures 6.26-6.28, respectively for 200, 220 and 245 washing cycles per year, using the same scale for the LCC to allow an immediate comparison of the differences due to the consumer behaviour.

LCC analysis output for the different amounts of washing cycles per year and lifetimes are compared in Table 6.52. The Standard base case, the $LLCC_{av}$, and the BAT_{av} for 5,36kg and 6kg load are presented as well as for the machine with a spin speed of 1 600 rpm. Table 6.53 presents the annual energy and water savings over the average standard base case. The energy savings for the $LLCC_{av}$ are in the range 3,3-4,1 €/year depending on the annual washing cycles, the water savings[17] in the range 8,9-10,9 €/year, for a total of 12,2-15,0 €/year against an increase in purchase price of 16 € the energy savings going from the average standard base case to the BAT_{av} are in the range 4,95-6,0 €/year and the water savings in the range 8,9-10,9 €/year, for a total of 13,7-16,8 €/year against an increase in purchase price of 97 €. When the spin speed is increased to 1 600 rpm or when the capacity increases to 6kg the savings decrease and the price increase of 123 €.

[17] the modification of the rinsing performance (if any) due to the decrease of the water consumption is not known.

Table 6.47: Comparison of the Life Cycle Costs for 9ps dishwashers

Washing cycles per year (n)	Consumer price (€)	Energy consumption (kWh/cycle)	Energy costs (€/year)	Water consumption (litre/cycle)	Water costs (€/year)	Chemicals costs (€/year)	LCC at 10 years (€)	LCC at 12 years (€)	LCC at 15 years (€)	LCC at 17 years (€)
9ps average standard base case										
208	520	0,828	29,28	13,70	10,54	17,63	1.044	1.112	1.203	1.256
220	520	0,828	30,97	13,70	11,15	18,65	1.069	1.141	1.237	1.294
280	520	0,828	39,41	13,70	14,19	23,74	1.197	1.288	1.409	1.481
$LLCC_{av}$										
208	542,7	0,782	27,65	10,3	7,93	17,63	1.034	1.097	1.181	1.231
220	542,7	0,782	29,25	10,3	8,38	18,65	1.057	1.124	1.213	1.266
280	542,7	0,782	37,22	10,3	10,67	23,74	1.176	1.260	1.373	1.439
BAT_{av}, 50dB(A)										
208	692,6	0,723	25,57	9,9	7,70	17,63	1.165	1.226	1.307	1.354
220	692,6	0,723	27,04	9,9	8,14	18,65	1.188	1.252	1.337	1.387
280	692,6	0,723	34,41	9,9	10,36	23,74	1.301	1.382	1.489	1.552
BAT_{av}, 44 dB(A)										
208	716,6	0,770	27,23	9,9	7,70	17,63	1.202	1.264	1.348	1.397
220	716,6	0,770	28,80	9,9	8,14	18,65	1.225	1.291	1.379	1.431
280	716,6	0,770	36,65	9,9	10,36	23,74	1.342	1.425	1.536	1.602
BAT_{av}, 41 dB(A)										
208	784,7	0,851	30,09	9,9	7,70	17,63	1.292	1.358	1.446	1.497
220	784,7	0,851	31,83	9,9	8,14	18,65	1.317	1.386	1.479	1.533
280	784,7	0,851	40,51	9,9	10,36	23,74	1.440	1.528	1.644	1.713

Table 6.48: Savings to the average standard base case for the 9ps dishwashers at different values of lifetime and washing cycles per year

Washing cycles per year (n)	Difference in consumer price (€)	Energy savings (kWh/cycle)	Energy savings (€/year)	Water savings (litre/cycle)	Water savings (€/year)	Chemicals cost savings (€/year)	Δ_{LCC} at 10 years (€)	Δ_{LCC} at 12 years (€)	Δ_{LCC} at 15 years (€)	Δ_{LCC} at 17 years (€)
$LLCC_{av}$										
208	-22,70	0,046	1,63	3,4	2,61	--	10	15	22	25
220	-22,70	0,046	1,72	3,4	2,77	--	12	17	24	28
280	-22,70	0,046	2,19	3,4	3,52	--	21	28	36	42
BAT_{av}, 50dB(A)										
208	-172,60	0,105	3,71	3,8	2,84	--	-121	-114	-104	-98
220	-172,60	0,105	3,93	3,8	3,01	--	-119	-111	-100	-93
280	-172,60	0,105	5,00	3,8	3,83	--	-104	-94	-80	-71
BAT_{av}, 44 dB(A)										
208	-196,60	0,058	2,05	3,8	2,84	--	-158	-152	-145	-141
220	-196,60	0,058	2,17	3,8	3,01	--	-156	-150	-142	-137
280	-196,60	0,058	2,76	3,8	3,83	--	-145	-137	-127	-121
BAT_{av}, 41 dB(A)										
208	-264,70	-0,023	-0,81	3,8	2,84	--	-248	-246	-243	-241
220	-264,70	-0,023	-0,86	3,8	3,01	--	-248	-245	-242	-239
280	-264,70	-0,023	-1,10	3,8	3,83	--	-243	-240	-235	-232

Table 6.49: Comparison of the Life Cycle Costs for 12ps dishwashers

Washing cycles per year (n)	Consumer price (€)	Energy consumption (kWh/cycle)	Energy costs (€/year)	Water consumption (litre/cycle)	Water costs (€/year)	Chemicals costs (€/year)	LCC at 10 years (€)	LCC at 12 years (€)	LCC at 15 years (€)	LCC at 17 years (€)
12ps average standard base case										
208	548,4	1,070	37,84	15,20	11,70	19,09	1.158	1.239	1.347	1.411
220	548,4	1,070	40,02	15,20	12,37	20,20	1.189	1.274	1.388	1.455
280	548,4	1,070	50,93	15,20	15,75	25,70	1.342	1.450	1.594	1.679
$LLCC_{av}$										
208	571,1	1,009	35,68	11,0	8,47	19,09	1.139	1.214	1.314	1.373
220	571,1	1,009	37,74	11,0	8,95	20,20	1.167	1.247	1.352	1.414
280	571,1	1,009	48,03	11,0	11,40	25,70	1.308	1.408	1.541	1.619
BAT_{av}, 50dB(A)										
208	779,5	0,914	32,32	10,6	8,16	19,09	1.319	1.390	1.484	1.540
220	779,5	0,914	34,18	10,6	8,63	20,20	1.346	1.421	1.520	1.578
280	779,5	0,914	43,51	10,6	10,98	25,70	1.479	1.573	1.698	1.772
BAT_{av}, 44 dB(A)										
208	808,8	0,975	34,48	10,6	8,16	19,09	1.365	1.439	1.536	1.593
220	808,8	0,975	36,47	10,6	8,63	20,20	1.393	1.470	1.573	1.634
280	808,8	0,975	46,41	10,6	10,98	25,70	1.530	1.628	1.758	1.834
BAT_{av}, 41 dB(A)										
208	882,9	1,079	38,15	10,6	8,16	19,09	1.468	1.545	1.648	1.709
220	882,9	1,079	40,35	10,6	8,63	20,20	1.497	1.579	1.687	1.751
280	882,9	1,079	51,36	10,6	10,98	25,70	1.643	1.746	1.883	1.964

Table 6.50: Savings to the average standard base case for the 12ps dishwashers at different values of lifetime and washing cycles per year

Washing cycles per year (n)	Difference in consumer price (€)	Energy savings (kWh/cycle)	Energy savings (€/year)	Water savings (litre/cycle)	Water savings (€/year)	Chemicals cost savings (€/year)	Δ_{LCC} at 10 years (€)	Δ_{LCC} at 12 years (€)	Δ_{LCC} at 15 years (€)	Δ_{LCC} at 17 years (€)
$LLCC_{av}$										
208	-22,70	0,061	2,16	4,2	3,23	--	19	25	33	38
220	-22,70	0,061	2,28	4,2	3,42	--	22	27	36	41
280	-22,70	0,061	2,90	4,2	4,35	--	34	42	53	60
BAT_{av}, 50dB(A)										
208	-231,10	0,156	5,52	4,6	3,54	--	-161	-151	-137	-129
220	-231,10	0,156	5,84	4,6	3,74	--	-157	-147	-132	-123
280	-231,10	0,156	7,42	4,6	4,77	--	-137	-123	-104	-93
BAT_{av}, 44 dB(A)										
208	-260,40	0,095	3,36	4,6	3,54	--	-207	-200	-189	-182
220	-260,40	0,095	3,55	4,6	3,74	--	-204	-196	-185	-179
280	-260,40	0,095	4,52	4,6	4,77	--	-188	-178	-164	-155
BAT_{av}, 41 dB(A)										
208	-334,50	-0,009	-0,31	4,6	3,54	--	-310	-306	-301	-298
220	-334,50	-0,009	-0,33	4,6	3,74	--	-308	-305	-299	-296
280	-334,50	-0,009	-0,43	4,6	4,77	--	-301	-296	-289	-285

Table 6.51: Sensitivity analysis results for the LCC of washing machine average standard base case

Technological options			2005 Base case	+b	+d	+c.2	+c.3	+a.4	+c.1	+a.1	+k	+e
cycles per year	Investigated parameters and variations			Optimised mechanical action	Rinsing phase optimisation	Analogue water sensor	Temperature control sensor (and simple unbalance control)	Optimised motor composition	Sophisticated unbalance control (with separate sensors)	Brushless DC motor (+ control)	increase spinning speed, from 1200 to 1600 rpm	Increased load capacity in the same machine
LCC results for basic technical and financial assumptions		kWh/cycle	0,998	0,918	0,918	0,909	0,900	0,900	0,900	0,855	0,898	0,948
		litre/cycle	50,7	49,1	43,3	39,2	38,7	38,7	38,7	38,7	38,7	40,3
		g/cycle	139,76	139,76	139,76	139,76	139,76	139,76	139,76	139,76	139,76	150,0
200	lifetime	10y	1.456	1.435	1.415	1.410	1.407	1.428	1.476	1.511	1.564	1.456
200	lifetime	12y	1.596	1.570	1.546	1.541	1.538	1.559	1.605	1.642	1.702	1.596
200	lifetime	**15y**	**1.784**	**1.751**	**1.722**	**1.715**	**1.712**	**1.734**	**1.778**	**1.816**	**1.887**	**1.784**
200	lifetime	17y	1.893	1.857	1.825	1.818	1.815	1.836	1.878	1.918	1.995	1.893
200	water price	€ 4,8	1.896	1.850	1.811	1.804	1.801	1.822	1.866	1.904	1.979	1.896
200	water price	€ 2,6	1.671	1.652	1.632	1.627	1.624	1.645	1.689	1.728	1.795	1.671
200	electricity price	€ 0,25	1.936	1.903	1.873	1.865	1.862	1.883	1.920	1.964	2.043	1.936
200	electricity price	€ 0,10	1.650	1.617	1.590	1.585	1.582	1.603	1.653	1.686	1.750	1.650
200	discount rate	4%	1.881	1.845	1.814	1.807	1.804	1.825	1.868	1.907	1.983	1.881
200	discount rate	6%	1.695	1.666	1.639	1.633	1.630	1.651	1.696	1.734	1.800	1.695
200	wm price WEU	€ 562	1.902	1.869	1.840	1.834	1.831	1.852	1.896	1.935	2.005	1.902
200	wm price EEU	€ 326	1.666	1.633	1.604	1.598	1.595	1.616	1.660	1.699	1.769	1.666
200	disposal&recycling	€ 10	1.798	1.759	1.726	1.697	1.691	1.688	1.709	1.753	1.791	1.862
220	lifetime	10y	1.549	1.525	1.502	1.497	1.494	1.515	1.562	1.598	1.656	1.549
220	lifetime	12y	1.703	1.673	1.647	1.640	1.637	1.659	1.704	1.741	1.808	1.703
220	lifetime	**15y**	**1.909**	**1.872**	**1.839**	**1.832**	**1.829**	**1.850**	**1.893**	**1.932**	**2.010**	**1.909**
220	lifetime	17y	2.029	1.988	1.952	1.944	1.941	1.963	2.003	2.044	2.128	2.029
220	water price	€ 4,8	2.032	1.980	1.938	1.929	1.926	1.948	1.990	2.030	2.111	2.032
220	water price	€ 2,6	1.785	1.763	1.741	1.735	1.732	1.753	1.795	1.835	1.909	1.785
220	electricity price	€ 0,25	2.076	2.039	2.005	1.997	1.994	2.015	2.049	2.095	2.182	2.076
220	electricity price	€ 0,10	1.762	1.725	1.694	1.688	1.685	1.707	1.756	1.790	1.859	1.762
220	discount rate	4%	2.015	1.975	1.940	1.932	1.929	1.950	1.991	2.032	2.115	2.015
220	discount rate	6%	1.813	1.779	1.749	1.742	1.739	1.760	1.804	1.842	1.915	1.813
220	wm price WEU	€ 562	2.027	1.990	1.958	1.951	1.948	1.969	2.011	2.051	2.128	2.027
220	wm price EEU	€ 326	1.791	1.754	1.722	1.715	1.712	1.733	1.775	1.815	1.892	1.791
220	disposal&recycling	€ 10	1.928	1.884	1.847	1.815	1.808	1.805	1.826	1.868	1.908	1.985
245	lifetime	10y	1.666	1.637	1.611	1.605	1.602	1.624	1.669	1.706	1.770	1.666
245	lifetime	12y	1.837	1.802	1.772	1.765	1.762	1.783	1.826	1.865	1.939	1.837
245	lifetime	**15y**	**2.065**	**2.023**	**1.986**	**1.978**	**1.975**	**1.996**	**2.037**	**2.078**	**2.164**	**2.065**

Technological options			2005 Base case	+b Optimised mechanical action	+d Rinsing phase optimisation	+c.2 Analogue water sensor	+c.3 Temperature control sensor (and simple unbalance control)	+a.4 Optimised motor composition	+c.1 Sophisticated unbalance control (with separate sensors)	+a.1 Brushless DC motor (+ control)	+k increase spinning speed, from 1200 to 1600 rpm	+e Increased load capacity in the same machine
cycles per year	Investigated parameters and variations											
LCC results for basic technical and financial assumptions		kWh/cycle	0,998	0,918	0,918	0,909	0,900	0,900	0,900	0,855	0,898	0,948
		litre/cycle	50,7	49,1	43,3	39,2	38,7	38,7	38,7	38,7	38,7	40,3
		g/cycle	139,76	139,76	139,76	139,76	139,76	139,76	139,76	139,76	139,76	150,0
245	lifetime	17y	2.199	2.152	2.111	2.103	2.100	2.121	2.160	2.202	2.296	2.199
245	water price	€ 4,8	2.203	2.144	2.095	2.086	2.083	2.105	2.145	2.186	2.277	2.203
245	water price	€ 2,6	1.928	1.902	1.876	1.870	1.867	1.888	1.928	1.969	2.051	1.928
245	electricity price	€ 0,25	2.252	2.209	2.171	2.161	**2.158**	2.179	2.211	2.259	2.356	2.252
245	electricity price	€ 0,10	1.902	1.859	1.824	1.818	1.815	1.836	1.884	1.919	1.997	1.902
245	discount rate	4%	2.183	2.136	2.097	2.088	2.085	2.106	2.145	2.188	2.280	2.183
245	discount rate	6%	1.959	1.920	1.886	1.878	1.875	1.897	1.938	1.979	2.059	1.959
245	wm price WEU	€ 562	2.184	2.141	2.104	2.096	2.093	2.115	2.155	2.196	2.283	2.184
245	wm price EEU	€ 326	1.948	1.905	1.868	1.860	1.857	1.879	1.919	1.960	2.047	1.948
245	disposal&recycling	€ 10	2.089	2.041	1.998	1.961	1.953	1.950	1.972	2.012	2.053	2.140

Figure 6.26: Life Cycle Cost as a function of the technological options for washing machine sensitivity analysis. Parameters variation is indicated for each curve. Base: lifetime = 15 years, 200 cycle/year.

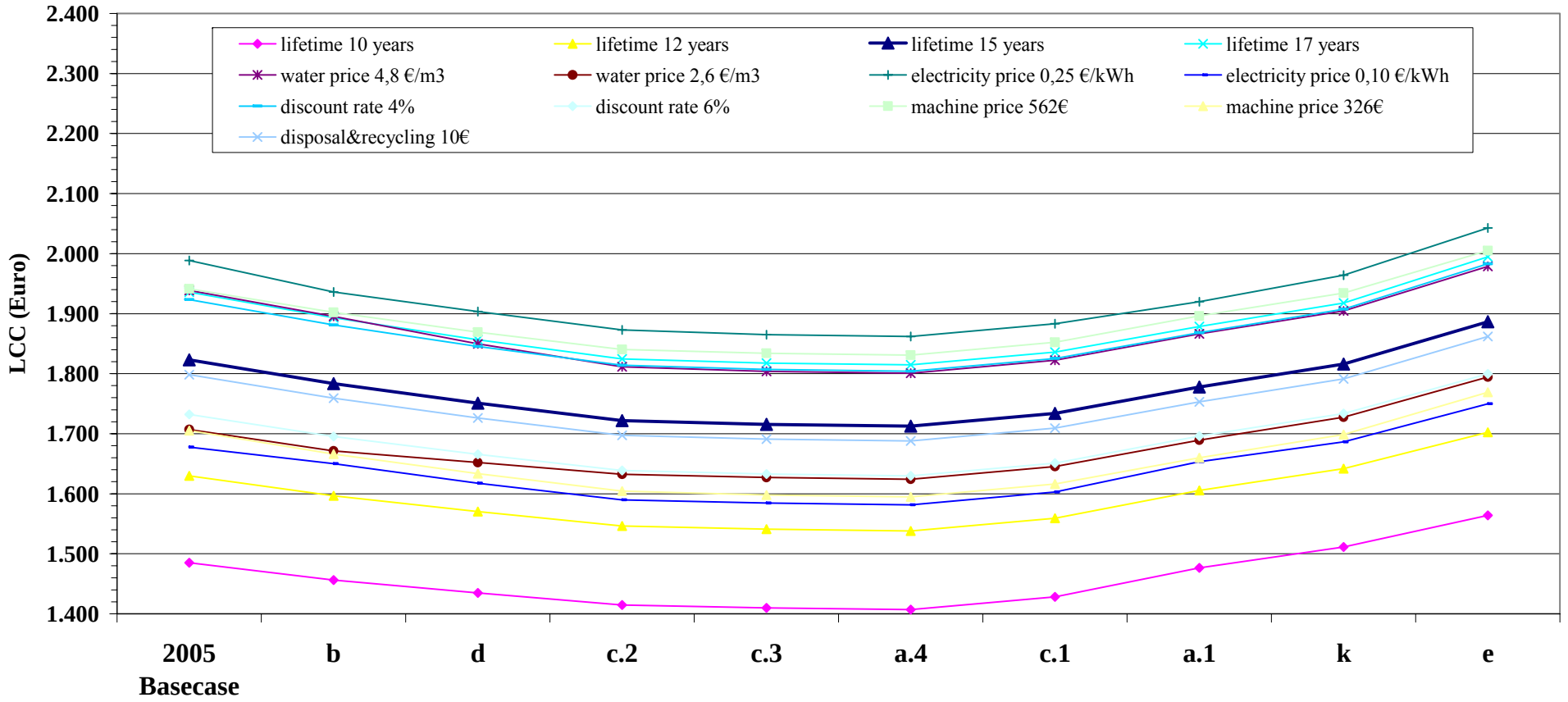


Figure 6.27: Life Cycle Cost as a function of the technological options for washing machine sensitivity analysis. Parameters variation is indicated for each curve. Base: lifetime = 15 years, 220 cycle/year.

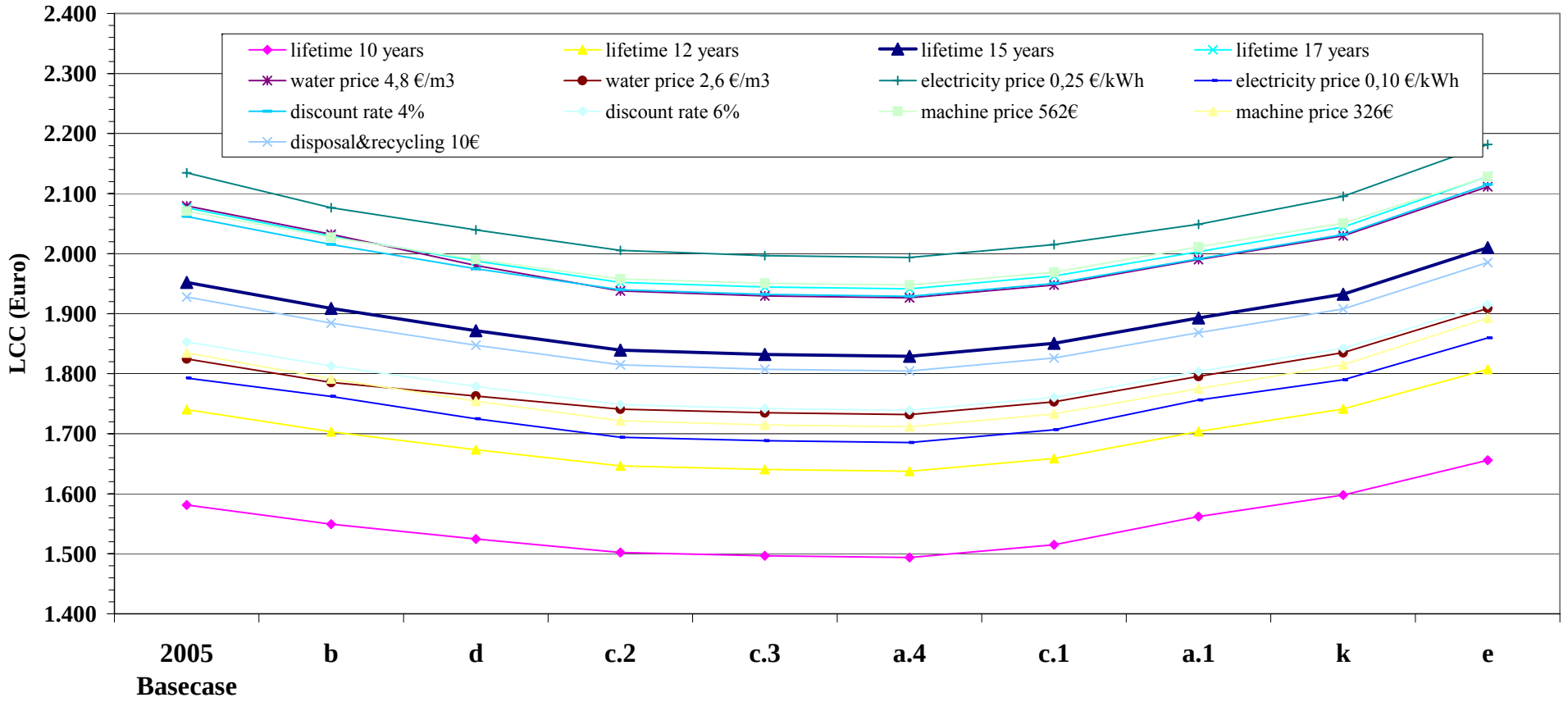


Figure 6.28: Life Cycle Cost as a function of the technological options for washing machine sensitivity analysis. Parameters variation is indicated for each curve. Base: lifetime = 15 years, 245 cycle/year.

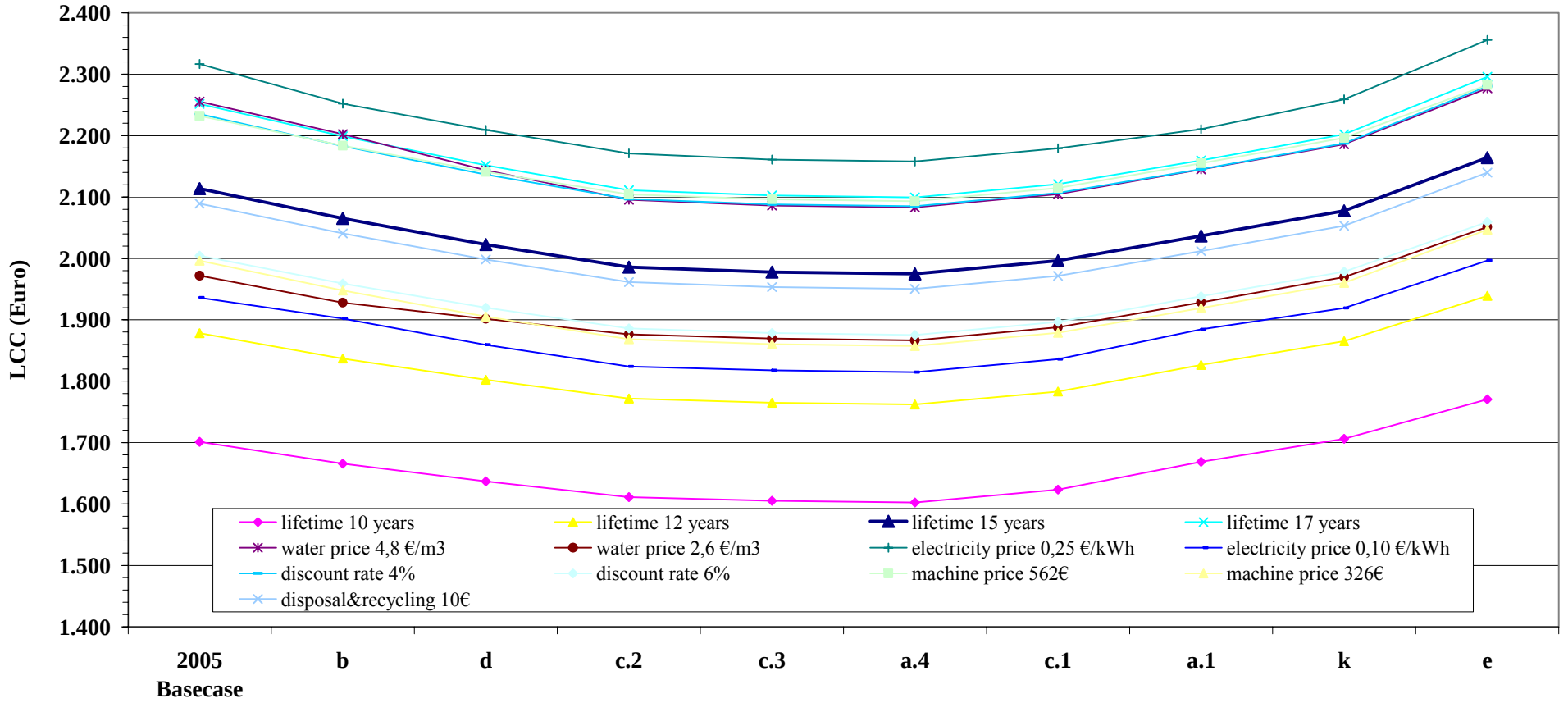


Table 6.52: Comparison of the Life Cycle Costs for the washing machines. Washing temperature 60°C

Washing cycles per year (n)	Consumer price (€)	Energy consumption (kWh/cycle)	Energy costs (€/year)	Water consumption (litre/cycle)	Water costs (€/year)	Chemicals costs (€/year)	LCC at 10 years (€)	LCC at 12 years (€)	LCC at 15 years (€)	LCC at 17 years (€)
Average standard base case (5,36 kg)										
200	443,5	0,998	33,93	50,7	37,52	53,11	1.485	1.630	1.823	1.936
220	443,5	0,998	37,33	50,7	41,27	58,42	1.581	1.741	1.952	2.077
245	443,5	0,998	41,57	50,7	45,96	65,06	1.702	1.879	2.114	2.252
$LLCC_{av}$										
200	459,7	0,900	30,60	38,7	28,64	53,11	1.407	1.538	1.712	1.815
220	459,7	0,900	33,66	38,7	31,50	58,42	1.494	1.638	1.829	1.942
245	459,7	0,900	37,49	38,7	35,08	65,06	1.602	1.762	1.975	2.100
BAT_{av}										
200	540,8	0,855	29,07	38,7	28,64	53,11	1.476	1.606	1.777	1.879
220	540,8	0,855	31,98	38,7	31,50	58,42	1.562	1.704	1.892	2.004
245	540,8	0,855	35,61	38,7	35,08	65,06	1.669	1.827	2.036	2.160
BAT_{av}, 1 600 rpm										
200	566,3	0,892	30,53	38,7	28,64	53,11	1.512	1.642	1.816	1.918
220	566,3	0,892	33,59	38,7	31,50	58,42	1.598	1.742	1.932	2.045
245	566,3	0,892	37,40	38,7	35,08	65,06	1.706	1.866	2.078	2.203
BAT_{av}, 6kg										
200	566,5	0,942	32,23	40,3	29,82	57,00	1.564	1.703	1.887	1.995
220	566,5	0,942	35,46	40,3	32,80	62,70	1.656	1.808	2.010	2.129
245	566,5	0,942	39,48	40,3	36,53	69,83	1.771	1.940	2.164	2.297

Table 6.53: Savings to the average standard base case for the washing machines at different values of lifetime and washing cycles per year. Washing temperature 60°C

Washing cycles per year (n)	Difference in consumer price (€)	Energy savings (kWh/cycle)	Energy savings (€/year)	Water savings (litre/cycle)	Water savings (€/year)	Chemicals cost savings (€/year)	Δ_{LCC} at 10 years (€)	Δ_{LCC} at 12 years (€)	Δ_{LCC} at 15 years (€)	Δ_{LCC} at 17 years (€)
$LLCC_{av}$										
200	-16,20	0,098	3,33	12,0	8,88	--	78	92	111	121
220	-16,20	0,098	3,67	12,0	9,77	--	87	103	123	135
245	-16,20	0,098	4,08	12,0	10,88	--	100	117	139	152
BAT_{av}										
200	-97,30	0,143	4,86	12,0	8,88	--	9	24	46	57
220	-97,30	0,143	5,35	12,0	9,77	--	19	37	60	73
245	-97,30	0,143	5,96	12,0	10,88	--	33	52	78	92
BAT_{av}, 1 600 rpm										
200	-122,80	0,106	3,40	12,0	8,88	--	-27	-12	7	18
220	-122,80	0,106	3,74	12,0	9,77	--	-17	-1	20	32
245	-122,80	0,106	4,17	12,0	10,88	--	-4	13	36	49
BAT_{av}, 6kg										
200	-123,00	0,056	1,70	10,4	7,70	--	-79	-73	-64	-59
220	-123,00	0,056	1,87	10,4	8,47	--	-75	-67	-58	-52
245	-123,00	0,056	2,09	10,4	9,43	--	-69	-61	-50	-45

b) The 40 °C washing temperature cycle

For the simulation of the washing cycle at 40°C an average consumption value of 0,550 kWh/cycle was considered for the average 5,36kg machine. All the other technical and financial parameters of the LCC analysis remained unchanged, as well as the energy and water percentage savings of the applicable technological options with the exclusion of *Option k – higher spin speed*, where 10% savings is considered.

To calculate the energy consumption of the standard base case machine at 40°C, the average of the energy consumption increase between 40 and 60 °C nominal wash temperature found in the German "Wash diary" study (see Task 3), the AISE stock model[18] for EU15, the Stiftung Warentest[19] and the round robin test conducted in 2004 involving 25 European laboratories in the framework of the CENELEC TC59X WG1 activity[20] were considered. Averaging all the available data a value of 0,0224 kWh/K results, leading to a predicted energy consumption of the average standard base case at 40°C of 0,590 kWh/cycle for 5,36kg load.

The simple payback time and the net present value of the applicable technological options are given in Table 6.54. Options are ordered by their SPB.

Table 6.54: Technological options ordered by simple payback time (SPB) and net present value (at 15 years, for 220 cycles/year) for technological options applied to the standard base case for a 40°C washing cycle

Options (n)	**Technology** (description)	**SPB** (years)	**NPV** (€)
b	Mechanical action optimisation	0,4	38,35
c.3	Temperature control sensor (+ simple unbalance control)	0,4	35,32
c.2	Analogue water sensor	1,4	39,13
d	Rinsing phase optimisation	2,5	48,37
a.1	Brushless DC motor (+ control)	54,3	-48,53
a.3	Three-phase motor	81,4	-78,53
a.2	Brushless DC direct drive motor (+ control)	220,5	-185,82
a.4	Optimised motor composition	--	3,00
c.1	Sophisticated unbalance control (+ separate sensors)	--	-22,50
k	Higher spin speed (up to ≥ 1 600 rpm)	--	-52,90
e	Increased load capacity in the same machine	--	-44,01

Comparing SPB and NPV in Table 6.54 with the values for the same option in Table 6.29 options encompassing an energy saving become less important than options leading to a water saving, and more in general all options are less attractive (have a higher SPB and a lower NPV), which is due to the lower potentially achievable energy savings.

To evaluate the improvement potential of the standard base case, the aggregated option analysis has been developed. This LCC analysis was run for the average standard base-case appliance only, to evaluate the potential average savings achievable through technological development in the light of a possible modification of the washing test methods including a standard 40°C washing cycle. In

[18] AISE Code of Good Environmental Practice: Final report to the European Commission 1996-2001, Annex 5 (www.aise.com)
[19] Communication to CENELEC TC59X, WG1, SG1.6
[20] The main results of the round robin test 2004 were described in the document: Gundula Czyzewski, *Updating the European performance standard for washing machines*, presented at the EEDAL06

Table 6.55 the applied options, with the order of application, the corresponding marginal net present value (MNPV) and the resulting energy/water consumption for a 15 year lifetime and 220 cycles per year are presented.

Table 6.55: Marginal net present value (MNPV, 15years, 220 cycles) for the aggregated option analysis for the average standard base case washing machine at 40°C

Options (n)	$MNPV_{av}$ (€)	Noise* (dBA)	Cycle time (min)	Consumption energy (kWh/cycle)	Consumption water (litre/cycle)
+d	38,69	53	98	0,590	44,70
+c.2	32,36	53	98	0,584	40,45
+b	27,77	53	98	0,538	39,18
+c.3	5,71	53	98	0,532	38,71
+a.4	3,00	53	98	0,532	38,71
+c.1	-21,38	53	98	0,532	38,71
+a.1	-49,40	50	88	0,506	38,71
+k	-42,18	50	92	0,549	38,71
+e	-25,71	50	103	0,579	40,32*

*during the washing cycle.

The resulting energy and water consumption and incremental purchase price for Base Case and LLCC for the average standard base case are presented in Table 6.56, compared to the same values for the 60°C. Also the energy consumption "C" for kg of washed load for the 40°C cycle is shown, calculated according to the algorithms of directive 95/12/EC. The energy and water consumption for the average machine are reduced by 58 Wh/cycle (or 9,8%) to 0,532 kWh/cycle and 12 litre/cycle (or 23,7%) to 39,7 litre/cycle; the consumption per kg of washed load for the LLCC is 0,0993, which has no correspondence in directive 95/12/EC. For the 60°C cycle the energy saving was 98 Wh/cycle.

The forecast increase in purchase price is 3,7%, while the decreasing in LCC is 108 € (it is 123 € for the 60°C cycle). The LCC is also presented in Figure 6.29. It is worth noting that *Option k* and *Option e* have been added as the last ones, due to the associated increase in the spinning speed (for the former) and in the machine load capacity (for the latter). In the LCC analysis an attempt was made to predict the lowest possible achievable energy consumption before adding this option which modifies the machine technical characteristics. In Figure 6.30 a comparison of the results for the three values of the washing cycles per year is presented, along with the variation in the cycle time.

The lowest predictable energy consumption for after all options have been added, or the average Best Available Technology (BAT_{av}) to the base case is presented in Table 6.57. For washing machines, three BAT levels can be predicted at 40°C, due again to the fact the last two added options increase the overall energy consumption of the laundry-washing cycle by increasing the spinning speed and the load capacity. The lowest predictable energy consumption for the average standard base case is 0,506 kWh/cycle, with a reduction of 84 Wh/cycle (or 14,3%) against the 143 Wh/cycle at 60°C; the water consumption of 12 litre/cycle (or 23,7%), with a minimum of 38,7 litres, unchanged compared to the $LLCC_{av}$ point and the 60°C cycle. The predicted increase in purchase price is 22% for both 40°C and 60°C.

When the Life Cycle Cost (lifetime=15 years) is shown as a function of the energy consumption (kWh/cycle) the curves in Figure 6.31 result. The technological development pathway at 60°C and at 40°C can be compared in the Figure.

Table 6.56: Energy and water consumption and incremental purchase price for washing machine Base Case and LLCC for average standard base case and standard base case model

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y, 220 cycles)	
	Base case (kWh/cycle)	$LLCC_{av}$ (kWh/cycle)	Base case (litre/cycle)	$LLCC_{av}$ (litre/cycle)	Base case C	$LLCC_{av}$ C	difference (%)	Base case (Euro)	$LLCC_{av}$ (Euro)	Increase (%)	Base case (€)	$LLCC_{av}$ (€)
Average standard base case 60°C	0,998	0,900	50,7	38,7	0,186	0,168	9,8	443,5	459,7	3,7	1.952	1.829
Average standard base case 40C	0,590	0,532	50,7	38,7	0,110	0,0993	9,8	443,5	459,7	3,7	1.794	1.686

Figure 6.29: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the applied technological options for the washing machine standard base case at 40°C

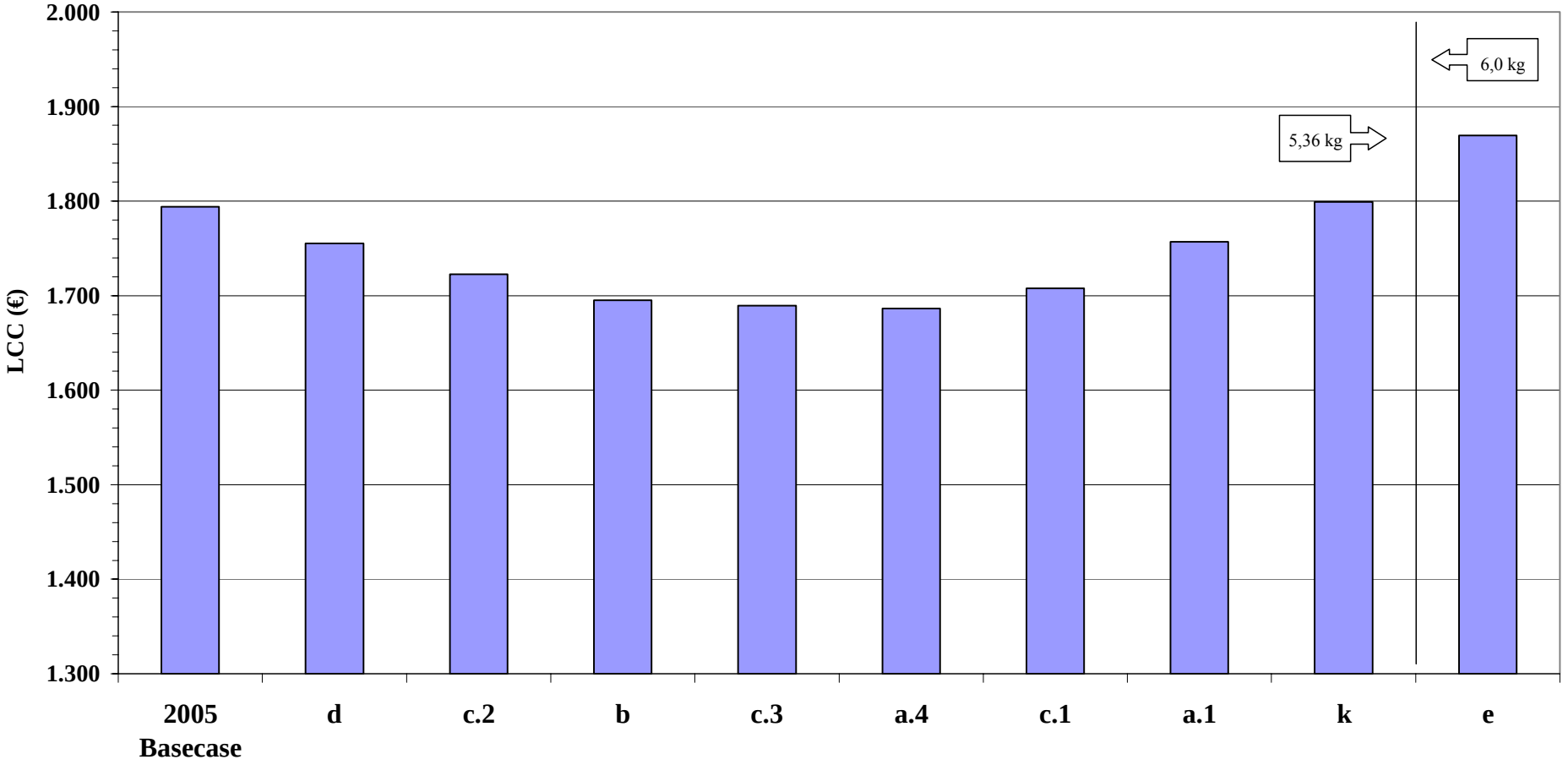


Figure 6.30: LCC (lifetime = 15 years) for 200, 220 and 245 cycle/year as a function of the applied technological options for the washing machine standard base case at 40°C

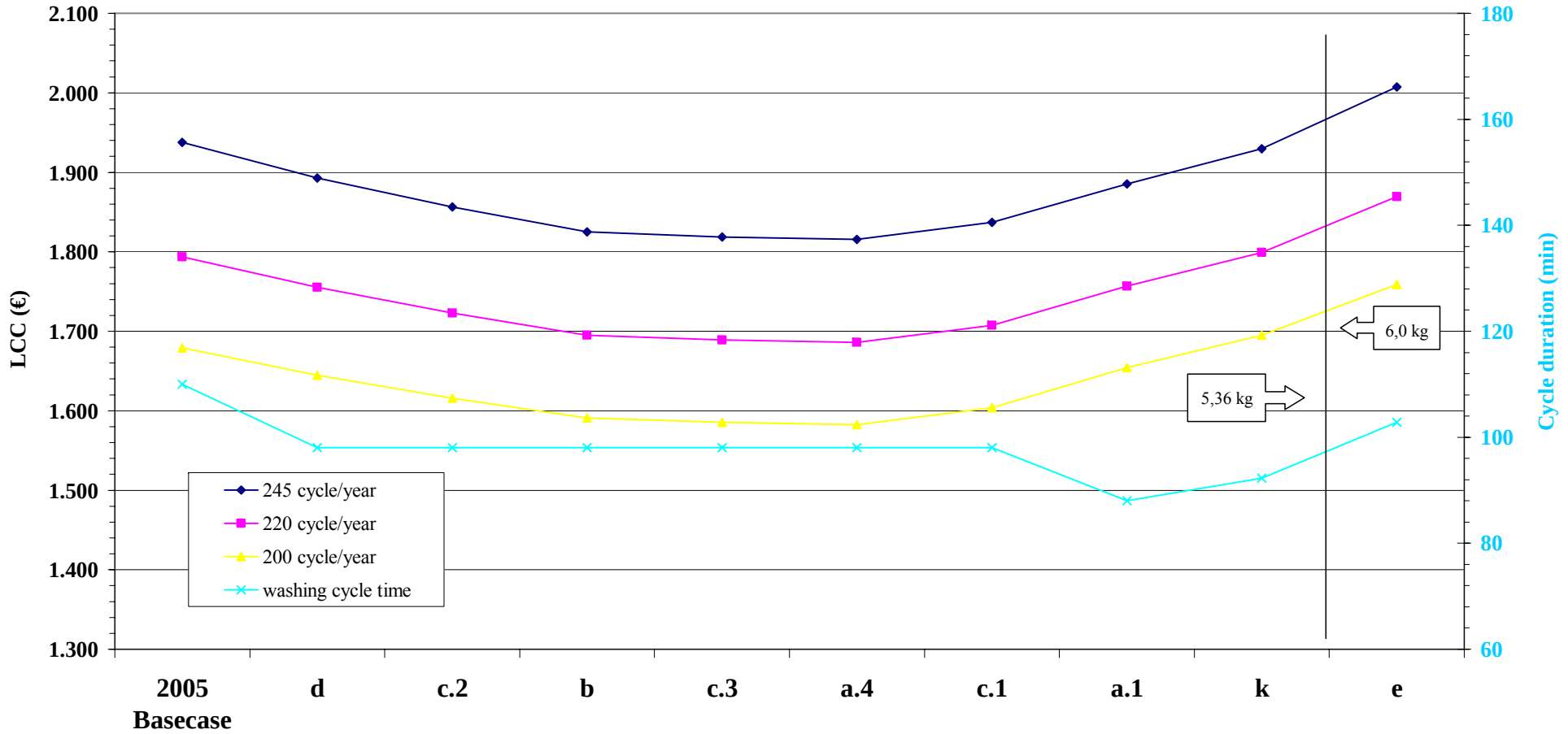
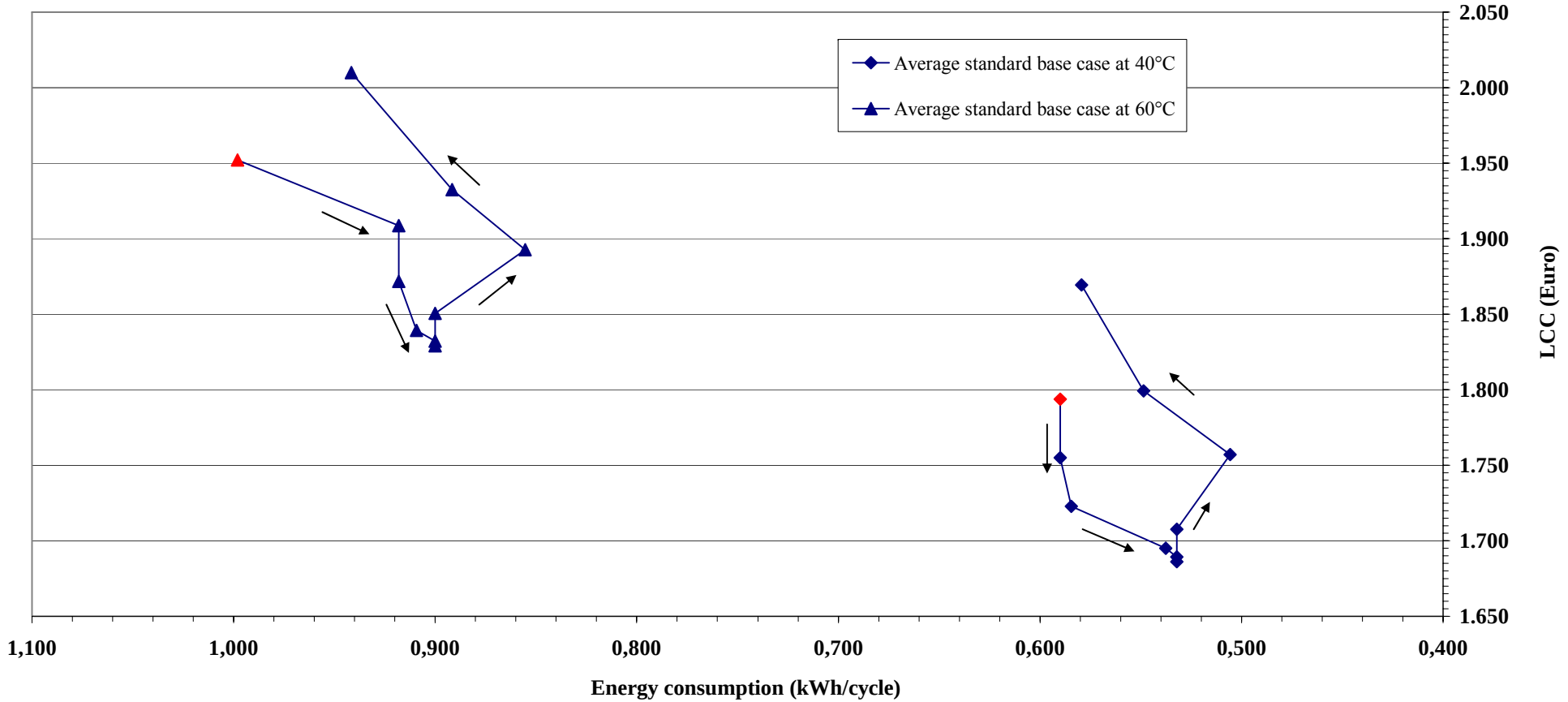


Table 6.57: Energy and water consumption and incremental purchase price for washing machine Base Case and BAT for average standard base case at 60°C and 40°C cycle

Base case	Energy consumption		Water consumption		Specific energy consumption "C" (dir. 95/12/EC)			Purchase price			LCC (15y, 220 cycles)	
	Base case (kWh/cycle)	BAT_{av} (kWh/cycle)	Base case (litre/cycle)	BAT_{av} (litre/cycle)	Base case C	BAT_{av} C	difference (%)	Base case (Euro)	BAT_{av} (Euro)	Increase (%)	Base case (€)	BAT_{av} (€)
Average standard base case 60°C	0,998	0,855	50,7	38,7	0,186	0,1596	14,3	443,5	540,8	21,9	1.952	1.893
		0,892		38,7		0,1663	10,7		566,3	27,7		1.932
		0,942		40,3		0,1569	15,7		566,5	27,7		2.010
Average standard base case 40°C	0,590	0,506	50,7	38,7	0,110	0,0943	14,3	443,5	540,8	21,9	1.794	1.757
		0,549		38,7		0,1024	7,02		566,3	27,7		1.799
		0,579		40,3		0,0966	12,3		566,5	27,7		1.869

Figure 6.31: Life Cycle Cost (lifetime = 15 years, 220 cycle/year) as a function of the energy consumption for washing machine analysis. Average standard base cases are the red point on each curve. Arrows show the option application sequence.



To allow an easier understanding of the overall LCC analysis results, the output for the different number of washing cycles per year and lifetimes are compared in Table 6.58. The Standard base case, the $LLCC_{av}$, and the BAT_{av} for 5,36kg and 6kg load are presented as well as for the machine with a spin speed of 1 600 rpm.

Table 6.59 presents the derived annual energy and water savings over the average standard base case at a different number of washing cycles per year with an energy price of 0,17 €/kWh and a water price of 3,7 €/m^3. The energy savings for the $LLCC_{av}$ are in the range 2,0-2,4 €/year depending on the annual washing cycles, the water savings in the range 8,9-10,9 €/year, for a total of 10,9-13,3 €/year against an increase in purchase price of 16 €; the energy savings going from the average standard base case to the BAT_{av} are in the range 2,9-3,5 €/year and the water savings in the range 8,9-10,9 €/year, for a total of 11,7-14,4 €/year against an increase in purchase price of 97 €. When the spin speed in increased to 1.600 rpm there is a slight decrease in the energy savings (1,4-1,7 €/year), while the water savings are in the same range 8,9-10,9 €/year, with a total of 10,3-12,6 €/years against a price increase of 123 €. Finally, when the load capacity is increased to 6kg, the energy savings (compared to the 5,36kg load machine and keeping the number of cycles constant) are on the range of 37-47 €cent/year and the water savings in the same range 7,7-9,4 €/year with a total of 8,1-9,9 €/year against a price increase of 123 €.

6.3 SUBTASK 6.3: LONG TERM TARGETS (BNAT) AND SYSTEM ANALYSIS

6.3.1 Long Term Targets in Previous Studies for Wash Appliances

Long term targets were described in the GEA study in 1995 as forecast after 2000-2005. These options are here reported more for sake of completeness of the background historical information than on an actual applicability of the highlighted technological development:

- insulated water storage tank: beside the reduction of water consumption it might also be possible t reduce the energy consumption for heating if the hot rinsing water is store in a thermally insulated vessel. It is possible (at low cost) to insulate the water storage tank in such a way that the heat loss does not exceed the 15W (currently available as electric boiler with storage capacity of 5 litres with gross volume of 15 litres). The average time between two cycles is 40 hours, that means that the water has cooled down to 25°C at the beginning of the next cycle, the savings are therefore about 35 Wh/cycle (0,95 Ecu/year);
- storage tank with phase change material: as a substitute for the insulated water storage tank described in the previous option the dishwasher can be equipped with a storage tank containing a phase change material. Phase change materials are materials that feature a high melting heat at a temperature that is within the range of temperatures of the ingoing and drain water. Both fluids are led thorough a tank containing phase change material. The drain water is used to melt the phase change material, the fresh ingoing water again makes it be solid again. With phase change materials a lot of energy can be stored in a very compact container.
- differentiation of the water level for each phase of the washing cycle: one of the determining factors for the total amount of water needed is the water that is moving through the air or flowing down from the load. The amount of water in this process is depending on the recirculation flow: an increased flow means more water, a decreased flow means less. The total amount of water travelling was estimated in 0,75 litre. If it is possible to reduce water flow in certain phases of the wash cycle, the total amount of water needed in this phase will be less too, leading to lower water consumption and if applicable in the wash or hot rinse phase, to a lower heating consumption. If, for instance during the hot rinse phase, the water flow is reduced to half the amount, the water level could be reduced with 0,75 litres. The related energy saving

Table 6.58: Comparison of the Life Cycle Costs for the washing machines. Washing temperature 40°C

Washing cycles per year (n)	Consumer price (€)	Energy consumption (kWh/cycle)	Energy costs (€/year)	Water consumption (litre/cycle)	Water costs (€/year)	Chemicals costs (€/year)	LCC at 10 years (€)	LCC at 12 years (€)	LCC at 15 years (€)	LCC at 17 years (€)
Average standard base case (5,36 kg)										
200	443,5	0,590	20,06	50,7	37,52	53,11	1.378	1.507	1.679	1.780
220	443,5	0,590	22,07	50,7	41,27	58,42	1.464	1.605	1.794	1.905
245	443,5	0,590	24,57	50,7	45,96	65,06	1.570	1.728	1.937	2.061
$LLCC_{av}$										
200	459,7	0,532	18,09	38,7	28,64	53,11	1.311	1.427	1.582	1.674
220	459,7	0,532	19,90	38,7	31,50	58,42	1.388	1.516	1.686	1.786
245	459,7	0,532	22,16	38,7	35,08	65,06	1.484	1.626	1.816	1.927
BAT_{av}										
200	540,8	0,506	17,20	38,7	28,64	53,11	1.385	1.501	1.654	1.745
220	540,8	0,506	18,92	38,7	31,50	58,42	1.461	1.588	1.757	1.857
245	540,8	0,506	21,07	38,7	35,08	65,06	1.557	1.698	1.885	1.996
BAT_{av}, 1 600 rpm										
200	566,3	0,549	18,67	38,7	28,64	53,11	1.422	1.539	1.695	1.787
220	566,3	0,549	20,53	38,7	31,50	58,42	1.499	1.628	1.799	1.900
245	566,3	0,549	22,87	38,7	35,08	65,06	1.596	1.739	1.929	2.042
BAT_{av}, 6kg										
200	566,5	0,579	19,69	40,30	29,82	57,00	1.469	1.593	1.758	1.856
220	566,5	0,579	21,65	40,30	32,80	62,70	1.551	1.688	1.869	1.976
245	566,5	0,579	24,12	40,30	36,53	69,83	1.654	1.806	2.007	2.126

Table 6.59: Savings to the average standard base case for the washing machines at different values of lifetime and washing cycles per year. Washing temperature 40°C

Washing cycles per year (n)	Difference in consumer price (€)	Energy savings (kWh/cycle)	Energy savings (€/year)	Water savings (litre/cycle)	Water savings (€/year)	Chemicals cost savings (€/year)	Δ_{LCC} at 10 years (€)	Δ_{LCC} at 12 years (€)	Δ_{LCC} at 15 years (€)	Δ_{LCC} at 17 years (€)
$LLCC_{av}$										
200	-16,20	0,058	1,97	12,0	8,88	--	67	80	96	106
220	-16,20	0,058	2,17	12,0	9,77	--	76	90	108	118
245	-16,20	0,058	2,41	12,0	10,88	--	86	102	122	134
BAT_{av}										
200	-97,30	0,084	2,86	12,0	8,88	--	-7	7	25	35
220	-97,30	0,084	3,15	12,0	9,77	--	3	17	37	48
245	-97,30	0,084	3,50	12,0	10,88	--	13	30	52	65
BAT_{av}, 1 600 rpm										
200	-122,80	0,041	1,39	12,0	8,88	--	-44	-32	-16	-7
220	-122,80	0,041	1,54	12,0	9,77	--	-35	-23	-5	5
245	-122,80	0,041	1,70	12,0	10,88	--	-26	-11	8	19
BAT_{av}, 6kg										
200	-123,00	0,011	0,37	10,4	7,70	--	-91	-86	-80	-76
220	-123,00	0,011	0,42	10,4	8,47	--	-87	-82	-75	-71
245	-123,00	0,011	0,45	10,4	9,43	--	-84	-78	-70	-65

amounts to 45 Wh/cycle. A reduced water level will certainly have impact on rinsing performance because of reduced mechanical action and a reduced flow. Therefore it might be necessary to prolong the rinse phase. This again results in additional motor energy, but whereas this only amounts to 2Wh/min it might be a trade-off worth investigating.

- cold last rinse: when the last rinse is performed without additional heating, the temperature of the load is till not down to 20°C at the beginning of the drying phase. The temperature will be around 30°C. That means that, if more time is available for the drying process, no heat at all has to be fed to the load for a good drying result. To speed up the drying process it is possible to use a small silent fan, at the cost of some motor energy. Even if the drying process would take the rest of the night after a regular wash cycle, say 7 hours, the energy consumption of a 5W fan would only be 35 Wh. Yet another possibility is to omit the heating of the last rinse phase and instead heat up the load (and inevitably the machine) up to 65°C after the last rinsing water has been drained. If we assume that in a normal cycle the last rinse phase is used only to increase the temperature of the load, the alternative of heating load only definitely makes sense: in this way the last rinse water is drained at a much lower temperature. The energy need for the following drying phase would be 350 Wh.

No long term targets were hypothesised for washing machines in the WASH-2 study.

6.3.2 BNAT and Long Term Targets for Wash Appliances in 2005

6.3.2.1 Long Term and BNAT for dishwashers and washing machines

In addition to long term and BNA Technologies for dishwashers and for washing machines, the following new technologies apply for long term targets:

- ***Washing dishes without water***[21]: this concept unit is a bit out of the design box. The dishwasher, developed by students from the University of New South Wales, Australia, won the top prize at the Electrolux Design Laboratory 2004 competition in New York, U.S. The winning concept combines a sophisticated waterless cleaning technology with a simple user interface. Carbon dioxide is used in a closed-loop operation to clean the dishes.



- ***Electronic control for washing machine motors***: to agitate and brake the motor in washing machines. A very fast CPU with DSP capability, and a fast and accurate ADC, is needed for these software and agitation method changes[22].
- ***Washing laundry without water***[23]: "Airwash" (Figure 6.32) is a waterless washing machine for the home of 2020 from Electrolux. Eliminating the use of detergent and water resources,

[21] Source: "Washing dishes without water", Appliance, February 2005.
[22] Source: Moving Forward - Motor Technology, Appliance, January 2007

it cleans clothes with pressurized air and negative ions. The form is inspired by the waterfall and has a touch-light interface.

Figure 6.32: Airwash waterless washing machines from Electorlux



- ***Washing laundry with ozone and recycled (bath) water***: in March 2007 SANYO Electric Co., Ltd.[24] announced starting April 2007 the marketing of an improved version of the 'AQUA' washer-dryer (model AWD-AQ2000) with a rated capacity of 9kg in washing and 6kg in drying.
  This improved machine includes the "*Air Wash Wide*" function (an expanded application of the previous *Air Wash* function) able to disinfect (tests conducted by Japan Food Research Laboratories/testing methods agar plate cultural method, bacteria elimination using ozone), deodorize and remove light stains from items previously un-washable or temperature-sensitive such as shoes, gloves, leather jackets, blouses, ties, silk) through the power of ozone. This function can treat contents under 2 kg, and some metal/fur items can not be used; in addition not all dirt and stains will be removed as ozone is not a substitute for bleach.
  Through the power of ozone, the 'Aqualoop' water recycle function has evolved to become the 'Aqualoop Wide' which is able to purify and disinfect bath water. The 'Aqualoop Wide' cleans the bathwater using ozone inside of the storage tank: water absorbed by the water hose from the bath is first filtered through an antimicrobial filter to remove larger items such as hair and other items, and is then sent to the storage tank; ozone enters the pipe and is injected into the storage tank before water is filled in; the water that then enters the tank is circulated through the ozone and disinfected. When using the 'water recycle/bathwater' setting, the recycled bathwater is used in the fabric softener cycle. The result is that for one single load of laundry, from wash to dry, the machine only uses 8 litres of fresh tap water, the rest of the water being recycled from the bath.
  The machine allows the traditional use of fresh tap water for all cycles, consuming 78 litres of water for a 9kg load, or for only the final rinse cycle and users can select the setting of 'Aqualoop' that meets their individual need. The machines uses 76 litres of pure tap water (of which 70 litres can be substituted by purified bath water) for the 6kg load cycle.

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[23] Source: ELECTROLUX Airwash system, see: http://www.electrolux.com/node49.aspx?Assid=10865&FolderID=20806&Page=1
[24] Source: SANIO news release, see : http://www.sanyo.co.jp/koho/hypertext4-eng/0703/0327-2e.html#02

According to the manufacturer press release, the product is sold in Japan. An overseas launch of this product is as yet undecided.

- ***Washing laundry with steam***: due to the very high temperature steam (100°C water vapour) is used by for (laundry and machine) specific hygiene at the end of a washing cycle, as already discussed in paragraph 6.3.3.3. But some manufacturers have also started to include steam in specific garment refreshing short (about 20 minutes) programmes or in washing cycles together with water. For the latter, the energy and water savings claimed in a 60°C cotton washing cycle are explained by the fact steam heats the whole machine drum (and laundry), consuming only a small amount of water and more effectively than hot water, allowing the load to reach the optimal temperature faster and reducing the energy and water consumption. At present this system is applied only to one large 8kg capacity machines sold on the UK market (see Table 5.22 for the technical data). It is not clear if the same savings will be achieved in smaller 5-6 kg machines (which use a lower amount of hot water in the washing cycle) or in washing cycles at temperature lower than 60°C (where the overall heat amount and heat transfer are lower).

6.3.2.2 BNAT potential analysis for dishwashers

Hypothesised costs and savings for BNAT and long term technologies (known technologies but whose application to the market is considered to happen in the long term) for **dishwashers** are presented in Tables 6.60 and 6.61 for the 9ps and the 12ps standard base cases.

Since Option BNAT1 is alternative to Option f.1, and this latter have been already applied to the standard base cases, BNAT1 will not be further considered in the long term analysis; Option BNAT3 is not applicable to 9ps machines. To evaluate the effect of Options BNAT5 and BNAT6, where an increase of 5W in the standby power is foreseen, the increased power consumption has been converted into energy consumption under the hypotheses that the 5W power is consumed for 8 760 hours/year with the machine being always plugged in and there is no increase in power consumption when the specific function is working (interned connected or the machine responding to vocal commands). This means that 43,8 kWh are added per year for each option, or - for dishwashers - 156,4 Wh/cycle considering 280 washing cycles; for a 12ps machine this equals to 13,8% of the standard base case consumption (1,070 kWh/cycle), for a 9ps dishwasher to 18,9% of the standard base case consumption (0,828 kWh/cycle).

The simple payback time and the net present value of the BNAT options for 9ps and 12ps dishwashers when applied to the BAT_{av} machines with a noise of 50 dB(A), or $BAT_{av,50}$, are given in Table 6.62; the washing cycle time is 97 min and 107 min respectively for the two cases and is assumed to remain unchanged (no hypothesis on the impact of the BNATs on washing time was done). Option BNAT2, reducing the hot rinse temperature to 55°C is the most effective on the machine energy consumption, followed by Option BNAT4, where energy and water are saved.

The aggregated option analysis allows to estimate the improvement potential when the BNATs are applied to the $BAT_{av,50}$ case, the aggregated option analysis has been developed. This LCC analysis was run for the average standard base case appliance only, to evaluate the potential average savings achievable through not yet available technological development. Due to the fact that *Option BNAT2 - Hot rinse at 55°C* and *Option BNAT4 - Direct heating of the load (avoid last hot rinse)* are mutually exclusive, two technological pathways were identified:

- pathway 1: including the application of Options BNAT2, 5 and 6 for the 9ps dishwasher case and BNAT2, 3, 5 and 6 for the 12ps dishwasher case
- pathway 2: including the application of Options BNAT4, 5 and 6 for the 9ps dishwasher case Options BNAT4, 3, 5 and 6 for the 12ps dishwasher case.

Table 6.60: Technological Option List, improvement in cost/price and energy/water savings for BNAT for 9ps dishwasher standard base case

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
BNAT1	(Partly) reuse of last rinsing water	0	8	10,4	-7	-0,0085	-2,5	-0,1825	0	31,2	alternative to Option f.1
BNAT2	Hot rinse at 55°C	0	0	0	-230	-0,2778	0	0	0	0	never used in dishwashers, need redesign of drying phase, critical application. Present rinse aid will not work at 55°C.
BNAT3	Insulated water tank										Not feasible for 9ps
BNAT4	Direct heating of the load (avoid last hot rinse)	0	25	32,5	-124,2	-0,15	-1,03	-0,075	0	97,5	lack of suitable technology today
BNAT5	Internet connectivity	0	30	39	+5W* (+156,4)	+0,189	0	0	0	117	increase consumption in low-power modes, long term technology
BNAT6	Voice controlled appliances	0	30	39	+5W* (+156,4)	+0,189	0	0	0	117	increase consumption in low power modes; long term development, even if known technology

*standby power

Table 6.61: Technological Option List, improvement in cost/price and energy/water savings for the BNAT for 12ps dishwasher standard base case

Options		Application to the market	Unit production		Savings				Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water				
No	Description	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(± min)	(€)	
BNAT1	(partly) reuse of last rinsing water	0	10	13	-10	-0,0935	-3,5	-0,2303	0	39	alternative to Option f.1
BNAT2	Hot rinse at 55°C	0	0	0	-250	-0,2336	0	0	0	0	never used in dish-washers, need re-design of drying phase, critical application. Present rinse aid will not work at 55° C
BNAT3	Insulated water tank	0	7	9,1	-26,75	-0,025	0	0	0	27,3	considered not feasible due to hygiene of the long stored water
BNAT4	Direct heating of the load (avoid last hot rinse)	0	25	32,5	-160,5	-0,15	1,14	-0,075	0	97,5	lack of suitable technology today
BNAT5	Internet connectivity	0	30	39	+5W* (+156,4)	+0,146	0	0	0	117	increase consumption in low-power modes, long term technology
BNAT6	Voice controlled appliances	0	30	39	+5W* (+156,4)	+0,146	0	0	0	117	increase consumption in low power modes; long term develop-ment, even if known technology

*standby power

Table 6.62: BNA Technological options ordered by simple payback time (SPB) and net present value (at 15 years, for 280 cycles/year) for 9ps and 12ps BATav,50 dishwashers with 50dB(A) noise

Options (n)	Technology (description)	9ps dishwasher		12ps dishwasher	
		SPB (years)	**NPV** (€)	**SPB** (years)	**NPV** (€)
BNAT1	(Partly) reuse of last rinsing water	14,43	-8,75	13,29	-8,53
BNAT2	Hot rinse at 55°C	0	99,23	0	105,51
BNAT3	Insulated water tank	--	--	25,10	-16,01
BNAT4	Direct heating of the load (avoid last hot rinse)	16,44	-35,93	13,27	-21,21
BNAT5	Internet connectivity	n.a.	-184,49	n.a.	-183,02
BNAT6	Voice controlled appliances	n.a.	-184,49	n.a.	-183,02

In Table 6.63 the applied options, with the order of application, the corresponding MNPV and LCC for a 15 year lifetime and 280 cycles per year, the resulting energy/water consumption and the new purchase price are presented for the 9ps and the 12ps $BAT_{av,50}$ machine are given. The energy and water consumption for the $BAT_{av,50}$ 9ps machine are reduced by 201 Wh/cycle (or 27,8%) to 0,522 kWh/cycle (E_I = 0,41) for the first technological pathway and by 108 Wh/cycle (or 15%) to 0,615 kWh/cycle E_I = 0,49) for the second technological pathway where also the water is reduced from 9,9 to 9,2 litre/cycle. The LCC has a minimum when Option BNAT2 is applied in technological pathway 1, while for the second technological pathway the LCC always increases. For the 12ps $BAT_{av,50}$ dishwasher, the energy and water consumption are reduced by 231 Wh/cycle (or 25,3%) to 0,683 kWh/cycle (E_I = 0,41) for the first technological pathway and by 157 Wh/cycle (or 17,1%) to 0,757 kWh/cycle (E_I = 0,46) for the second technological pathway where also the water consumption is reduced from 10,6 to 9,8 litre/cycle.

Table 6.63: Marginal net present value (MNPV, 15years, 280 cycles) for the aggregated option analysis for the BATav,50 base case 9ps and 12ps dishwasher (noise 50dB(A))

Options (n)	Economic values			Consumption		
	$MNPV_{av}$ (€)	Price (€)	LCC (€)	energy (kWh/cycle)	E_I	water (litre/cycle)
9ps $BAT_{av,50}$	--	692,6	1.489	0,723	0,574	9,9
Technological pathway 1						
+BNAT2	99,23	692,6	1.390	0,522	0,414	9,9
+BNAT5	-165,74	809,6	1.556	0,621	0,493	9,9
+BNAT6	-174,95	926,6	1.731	0,738	0,586	9,9
Technological pathway 2						
+BNAT4	-35,93	790,1	1.525	0,615	0,488	9,2
+BNAT5	-174,36	907,1	1.699	0,731	0,580	9,2
+BNAT6	-185,20	1.024,1	1.885	0,869	0,689	9,2
12ps $BAT_{av,50}$	--	779,5	1.699	0,914	0,554	10,6
Technological pathway 1						
+BNAT2	105,51	779,5	1.593	0,700	0,425	10,6
+BNAT3	-18,65	806,8	1.611	0,683	0,414	10,6
+BNAT5	-166,33	923,8	1.778	0,783	0,474	10,6
+BNAT6	-173,54	1.040,8	1.951	0,897	0,544	10,6
Technological pathway 2						
+BNAT4	-21,21	877,0	1.720	0,777	0,471	9,8
+BNAT3	-17,70	904,3	1.737	0,757	0,459	9,8
+BNAT5	-171,71	1.021,3	1.909	0,868	0,526	9,8
+BNAT6	-179,71	1.138,3	2.089	0,995	0,603	9,8

When a BAT_{av} machine with a lower noise at 41 dB(A) is considered, the base case energy consumption and purchase price increase to 0,851 kWh/cycle (E_I = 0,675) for the 9ps machine and to 1,079 kWh/cycle (E_I=0,65) for the 12ps machine. Therefore also the energy consumption and the life cycle cost of the models with the BNATs increase correspondingly.

Simulation results are presented in Table 6.64. The energy and water consumption for the $BAT_{av,41}$ 9ps machine are reduced to 0,615 kWh/cycle (E_I = 0,48) for the first technological pathway and to 0,723 kWh/cycle E_I = 0,57) for the second technological pathway where also the water is reduced from 9,9 to 9,2 litre/cycle. The LCC has a minimum when Option BNAT2 is applied in technological pathway 1, while for the other technological pathway the LCC always increases. For the 12ps dishwasher, the energy consumption is reduced to 0,806 kWh/cycle (E_I = 0,49) for the first technological pathway and to 0,894 kWh/cycle (E_I=0,54) for the second technological pathway where also the water consumption is reduced from 10,6 to 9,8 litre/cycle.

Table 6.64: Marginal net present value (MNPV, 15years, 280 cycles) for the aggregated option analysis for the BATav base case 9ps and 12ps dishwasher (noise 41dB(A))

Options	Economic values			Consumption		
	$MNPV_{av}$	Price	LCC	energy		water
(n)	(€)	(€)	(€)	(kWh/cycle)	E_I	(litre/cycle)
9ps $BAT_{av,41}$	--	784,7	1.645	0,851	0,675	9,9
Technological pathway 1						
+BNAT2	116,79	784,7	1.528	0,615	0,488	9,9
+BNAT5	-174,37	901,7	1.702	0,731	0,580	9,9
+BNAT6	-185,21	1.018,7	1.887	0,869	0,690	9,9
Technological pathway 2						
+BNAT4	-26,45	882,2	1.671	0,723	0,574	9,2
+BNAT5	-184,52	999,2	1.855	0,860	0,683	9,2
+BNAT6	-197,27	1.116,2	2.053	1,022	0,811	9,2
12ps $BAT_{av,41}$	--	882,9	1.884	1,079	0,654	10,6
Technological pathway 1						
+BNAT2	124,56	882,9	1.759	0,827	0,501	10,6
+BNAT3	-17,09	910,2	1.776	0,806	0,489	10,6
+BNAT5	-175,23	1.027,2	1.951	0,924	0,560	10,6
+BNAT6	-183,75	1.144,2	2.135	1,059	0,642	10,6
Technological pathway 2						
+BNAT4	-8,99	980,4	1.892	0,917	0,556	9,8
+BNAT3	-15,97	1.007,7	1.908	0,894	0,542	9,8
+BNAT5	-181,59	1.124,7	2.090	1,025	0,621	9,8
+BNAT6	-191,03	1.241,7	2.281	1,175	0,712	9,8

6.3.2.3 BNAT potential analysis for washing machines

Hypothesised costs and savings for BNAT and long term technologies for **washing machine**s are presented in Tables 6.65 for the standard base case. For this appliance only the application of *Option BNAT1 - Internet connectivity* and *Option BNAT2 - Voice controlled appliances* be evaluated. Mixed appliances or alternative washing systems encompass in fact a different product archetype compared with the washing machine standard base case or BAT_{av}.

Table 6.65: Technological Option List, improvement in cost/price and energy/water savings for BNAT for washing machine standard base case

Options		Application to the market	Unit production		Savings				Noise	Cycle time variation	Increase in consumer price	Notes
			cost	price	Electricity		Water					
(No)	(description)	(%)	(€)	(€)	(Wh/cycle)	(%)	(litre/cycle)	(%)	(dBA)	(± min)	(€)	
BNAT 1	Internet connectivity	0,1	57,7	75	+5W* (+199)	+0,1994	0	0	0	0	225	increase consumption in low power modes, long term technology
BNAT 2	Voice controlled appliances	0	30	39	+5W* (+199)	+0,1994	0	0	0	0	117	increase consumption in low power modes; long term develop-ment, even if known technology
BNAT 3	Mixed appliances	--	--	--	--	--	--	--	--	--	--	comparison with the traditional washing machine to be studied
BNAT 4	Alternative washing systems	--	--	--	--	--	--	--	--	--	--	comparison with the traditional washing machine to be studied

*standby power

When Options BNAT1 and BNAT2 are applied to the BAT_{av} washing machine, an increase of 5W in the standby power is foreseen for each option; the increased power consumption is again converted into energy consumption under the hypotheses that the 5W power is consumed for 8 760 hours/year with the machine always plugged in and there is no increase in power consumption when the specific function is working (interned connected or the machine responding to vocal commands). This means that 43,8 kWh are added per year for each option, considering 220 washing cycles per year, which is 199 Wh/cycle or 19,9% of the standard base case consumption (0,998 kWh/cycle).

When the two options are applied to the BAT_{av} machine with a load capacity of 5,36 kg or $BAT_{av,5,36kg}$ (the washing cycle time is 88 min and the noise during washing 53dB(A) and are assumed to remain unchanged), the LCC analysis results show (Table 6.66) always a negative MNPV and the energy consumption increases; the water consumption (38,7 litre/cycle) is not affected by the applied BNATs. The same occurs when BNAT1 and BNAT2 are applied to the BAT_{av} machine with a higher spin speed at 1 600rpm or $BAT_{av,1600rpm}$ (the washing cycle time is 92 min and the noise during washing 53dB(A)) and to the larger capacity machine or $BAT_{av,6kg}$ (the washing cycle time is 103 min and the noise during washing 53dB(A).

Table 6.66: Marginal net present value (MNPV, 15years, 220 cycles) for the aggregated option analysis for the BATav cases for washing machines

Options (n)	Economic values			Consumption		
	$MNPV_{av}$ (€)	Price (€)	LCC (€)	energy (kWh/cycle)	(kWh/kg)	water (litre/cycle)
$BAT_{av,5,36kg}$	--	540,8	1.893	0,855	0,1596	38,7
+BNAT1	-183,18	657,8	2.076	1,025	0,1913	38,7
+BNAT2	-304,38	882,8	2.380	1,230	0,2295	38,7
$BAT_{av,1600rpm}$	--	566,3	1.932	0,892	0,1663	38,7
+BNAT1	-186,05	683,3	2.118	1,070	0,1996	38,7
+BNAT2	-307,81	908,3	2.426	1,283	0,2394	38,7
$BAT_{av,6kg}$	--	566,5	2.010	0,942	0,1569	40,3
+BNAT2	-189,92	683,5	2.200	1,130	0,1883	40,3
+BNAT1	-312,46	908,5	2.512	1,355	0,2259	40,3

6.3.2.4 Conclusions of the BNAT analysis

The analysis of the potential impact of the BNAT for wash appliances showed that, in the long run, a further decrease of the energy consumption could be possible for **dishwashers**, mainly provided the temperature of the final hot rinse is decreased, or this phase avoided and wet tableware are dried through a different system (although not yet known). In the latter case also few more water can be saved.

The Marginal Net Present Value is positive (and the LCC lower than the starting case) only for the hot rinse temperature decrease at 55°C. The energy efficiency index E_I can reach 0,41 for both 9ps and 12ps machines (corresponding to 0,522 kWh/cycle for the 9ps dishwasher and to 0,683 kWh/cycle for the 12ps dishwasher) for the former when the last hot rinse temperature is set at 55°C, for the latter when also an insulated water tank is added. When an alternative drying system is used the energy consumption decreases less, but some water is saved.

When "communication" technology is added to the machines through the possibility of internet connection or to respond to vocal commands the energy consumption increases, but positive

features for consumers - particularly for elder and disable people - are also added (see paragraph 1.3.2.1).

For **washing machines** no further technological improvement is likely possible without the modification of the product archetype through the use of mixed appliances or alternative washing systems. However, those new systems need to be studied more in detail before any conclusions could be drawn about their actual effectiveness and impact.

Also for this product type, when more "communication" technology is added to the machines through the possibility of internet connection or to respond to vocal commands the energy consumption increases, with indeed positive effects for consumers - particularly for elder and disable people.

Although feasible in principle, and practically applied in some countries (Japan), the re-use of purified bath water into the washing machine should be considered in the light of a potentially different "hygiene sensibility" of western consumers towards this practice and, more practically, the spreading use of the shower as a recommended water saving alternative to the bath in western countries. The energy consumption for the ozone purification of bath water should also be considered.

6.3.3 System Analysis

In addition to the product system analysis developed in Task 4, some specific aspects will be dealt in this paragraph, mainly for washing machines:
1. the standby definition for washing machines and dishwashers
2. the trade-off between washed load amount and nominal washing machine capacity
3. the impact of the energy used in detergent production
4. the trade-off between washing machine spin speed and the use of a (tumble) dryer (methodological analysis).

6.3.3.1 The "standby" for wash appliances

a) The standby definition issue

Standby power is a term used widely and loosely in policy circles, and although intuitively understandable and generally referring to the power consumption in one or several low power consumption modes, the lack of an univocal definition (or a set of definitions) is the major barrier to a successful implementation of relevant policy measures for wash (and other) appliances. This ambiguity is still partially persisting, despite the efforts of international stakeholders such as the international standardisation bodies and the European Commission.

After a series of initiatives enforced by single countries (Australia, Denmark, Switzerland, etc.) and the International Energy Agency, the IEC started to address the "standby" definition issue at worldwide level (see Task 1). At present, the standard IEC 60301, Ed.1: 2005 "*Household Electrical Appliances – measurement of the standby power* and the corresponding EN 60301 defines standby mode as:

- *standby mode*: the lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions. The standby mode is usually a non-operational mode when compared to the intended use of the

appliance's primary function.

A number of changes to the definitions and test conditions of IEC 62301 are under preparation by TC 59/WG 9 - "Measurement of standby power", **to better reflect the normal range of low power modes found in many products**, which were only partially known when this Task Report was prepared.

The European standard EN 60301:2005 includes the same definition(s) and will follow the modifications of the corresponding IEC standard in due course.

As far as the specific wash appliances are concerned, the June 2007 draft of IEC 60456 "*Clothes washing machines for household use - Methods for measuring the performance*" 5th Edition[25] defines:

- *off mode*: is where the product is switched off using appliance controls or switches that are accessible and intended for operation by the user during normal use to attain the lowest power consumption that may persist for an indefinite time while connected to a mains power source and used in accordance with the manufacturer's instructions. Where there are no controls, the washing machine is left to revert to a steady state power consumption of its own accord;
- *left on mode*: is the lowest power consumption mode that may persist for an indefinite time after the completion of the programme and unloading of the machine without any further intervention of the user. In some products this mode may be an equivalent power to off mode.

For dishwashers the standby issues is not addressed in the current IEC 60346:2004 "*Electric dishwashers for household use - Methods for measuring the performance*" or the corresponding EN 50242 Ed. 2/EN 60346, but will be considered for inclusion in a new standards Edition, very likely following the outcome of washing machines.

The European Commission recently addressed the standby issue within the preparatory studies for eco-design requirements for EuPs, with the study "Lot 6-Standby and Off-mode losses of EuPs"[26]. The declared approach followed by this study[27] is to achieve a broad coverage of standby issues by structuring the energy uses by functions offered during standby. Standby energy consumption is understood not as an energy loss, but as a service offered to the user, which should be supplied as efficiently as possible. Off-mode losses are a separate issue, in that energy is consumed without delivering a function. In cases, where valid reasons for off-mode energy consumption exists, the energy level in the off-mode should be as low as possible. The definition of Lot 6 standby and off-mode losses follows a stringent differentiation of functions and their allocation to defined modes. This distinction is based on a hierarchy of energy demand and reflects also predefined or user defined time durations, in which a function is provided.

In Task 1 of Lot 6 study seven modes (operating conditions or states in which a product provides a certain spectrum of functions, a single functions or no function at all) are identified:

1. Disconnected mode
2. 0 Watt off-mode
3. Off-mode with losses
4. Lot 6 passive standby mode
5. Lot 6 networked standby mode

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[25] See document: 59D/336/INF, at http://www.iec.ch .
[26] See: http://www.ecostandby.org .
[27] Source: Standby and Off-mode Losses (Lot 6), Public Report for Task 1 (draft final status before stakeholder meeting), Berlin, 20 April 2007.

6. Transition to standby and off-mode
7. Active mode.

These modes are defined as:

Mode	Description
Disconnected	This mode defines the status in which all connections to power source of the EuP are removed or interrupted. The common terms “unplugged” or “cut off form the mains” may apply to this definition as well.
0 Watt off-mode	This mode defines the status in which the EuP is connected to a power source but not drawing energy. The common terms “hard-off” or “galvanically switched off” may apply to this definition as well.
Off-mode with losses	This mode defines the status in which the EuP is connected to a power source but is drawing energy although not providing any function (for completeness a switch on the main part of the EuP has to be allowed). All energy drawn from the energy supply during that time shall be considered as off-mode losses. The common term “lowest power consumption” could apply to this definition as well, although it should preferably be differentiated between “*lowest mode offering no function*” and “*lowest mode offering a function*”. Another common term is “soft off”.
Lot 6 passive standby mode	This mode defines the status in which the EuP is connected to a power source, drawn energy and offers a selection of the following reactivation and continuity functions: reactivation function provided by soft or hard switch, remote control, internal sensor, timer or network command; continuity function (information storage, sensor-based safety functions); network functions limited to network integrity communication. When at least one network function is available (reactivation via network command or network integrity communication) the mode is called “*Lot 6 networked standby*”, otherwise “*Lot 6 passive standby*”. This set of functions is defining the spectrum of Lot 6 standby and the associated energy consumption. The common term “passive standby” and “active standby low” may apply to this definition as well.
Lot 6 networked standby mode	
Transition to standby and off-mode	This mode defines the status in which the EuP is connected to a power source, has been activated previously by any means (switch, remote control, timer, etc.) and has been manually or automatically switched to a reduced set of functions, in order to either be reactivated soon after or to traverse into lower power modes after some time. Transitional modes are handled according to the above definition: when only “Lot 6 standby functions” are active, the product is considered in standby mode, otherwise the transitional model is still part of the active operation. The EuP should however switch as fast as possible to standby or off-mode. The common terms “energy save mode”, “ready”, “idle”, “sleep” may apply to this mode as well.
Active mode	This mode defines the status in which the EuP is connected to a power source and provides one or more main functions. The common terms “on”, “in-use”, “normal operation” may apply to this definition as well.

The strict separation between ‘disconnected’ and ‘0 off mode’ (both consume no energy) and between ‘0 W off mode’ and ‘off mode with losses’ (both supply no function) is not always necessary, but adds clarity when describing the mode durations.

In addition Lot 6 defines "sensor-based safety functions" as a continuously running sensor circuitry necessary to monitor safety related status of the product or the environment (unless the sensing is the main function of the EuP). Examples are: heat sensor to warn against hot cooking plates or water leak sensor in washing machines.
Finally Lot 6 concludes that the status is that globally harmonised understanding of standby and off-modes is necessary but not yet reachable. It is outside the scope of this study to achieve this harmonisation. The goal of this study is to investigate the significance of standby use and off-mode losses within the European Union and to develop the framework for promoting or regulating ecodesign in this area.

b) Comparison of standby definitions in Lot 6 and draft IEC 60456 5th Ed.

Comparing the latest IEC 60456 5th Ed. 'left-on-mode' and 'off-mode' definitions with the definitions of the Lot 6 study, there is a certain correspondence with the 'Lot 6 standby' or 'Lot 6 off-mode', but the specific washing machine modes cannot be allocated more precisely, as the knowledge of the function(s) provided in these modes needs to be analysed per model and per mode.

The result of the application of Lot 6 definitions to wash appliances is illustrated in Figure 6.33, while in Figure 6.34 the IEC 60456 definitions are shown.

Figure 6.33: Wash appliance modes distinction and relevant functions according to Lot 6 definition

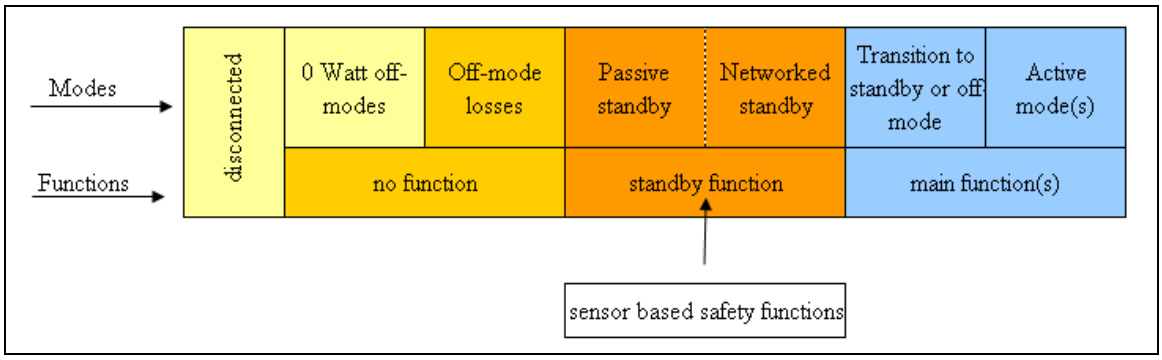
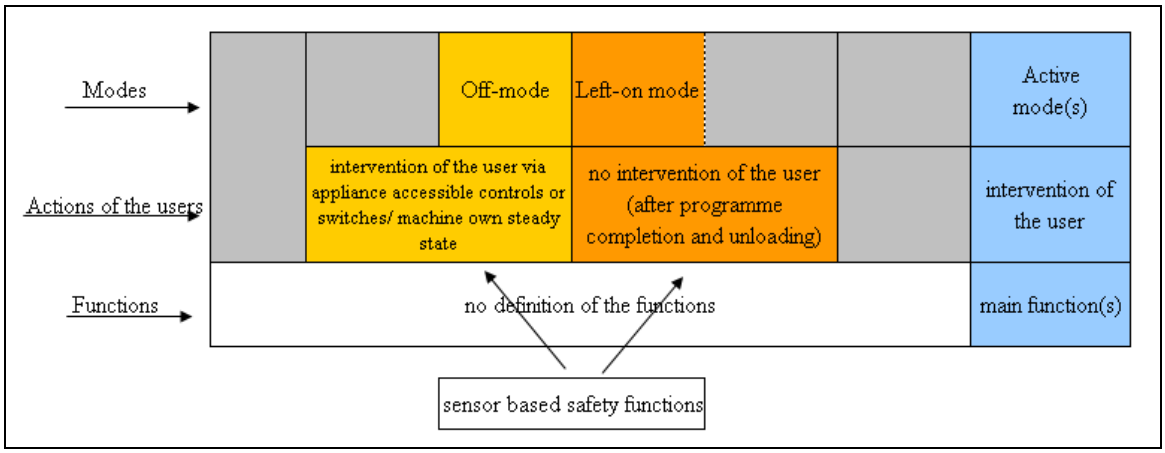


Figure 6.34: Wash appliance modes distinction and relevant functions according to draft IEC 60456 5th Ed. definition



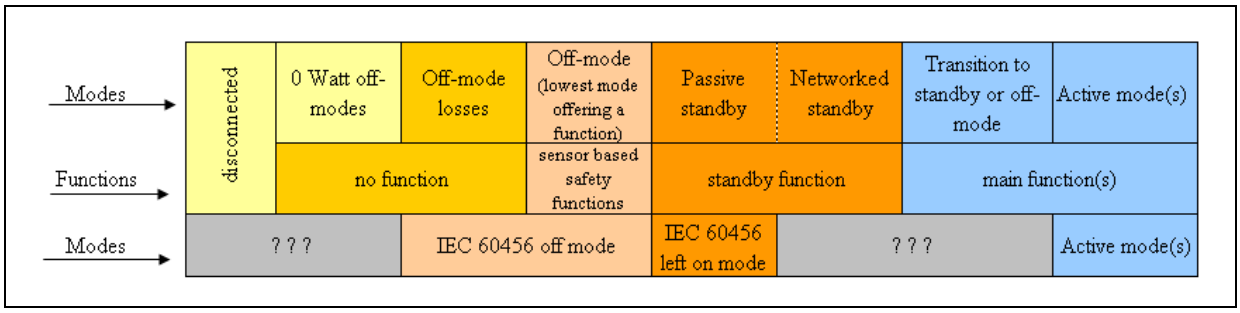
The major problem with the application of the Lot 6 study definitions to wash appliances is that 'off-mode' losses per definition (no function) can not be correlated with a functional unit, and safety functions are considered among reactivation and continuity functions of a functional unit activated when the EuP is in 'Lot 6 standby mode'. However, non primary (from the point of view of a wash appliance, whose primary function is to wash textiles or tableware) safety functions (sensor-based safety functions against water leakage and backsiphonage[28]) are intuitively useful for the consumer but also generally transparent to him/her (not intended to be voluntarily activated when the machine is plugged in) being considered granted features of a wash appliance.

If the sensor based safety functions are included in 'Lot 6 passive standby', then they will be deactivated when a machine reverts (of its own) or is switched (using appliance controls or switches) to 'Lot 6 off-mode' because no functions are associated to this mode, and the appliance will be – at least potentially – "unsafe". Under this hypothesis, to have sensor based safety functions working the machine should – through a reactivation function provided by soft or hard switch, remote control, internal sensor, timer or network command – be entered into 'Lot 6 passive standby' mode.

One might argue that consumers, once informed about the energy consumption of the sensor based safety functions, should decide about having a "less safe" machine with the lowest possible or no energy losses or a "more safe" machine with a Lot 6 standby consumption, and willingly activate the energy consuming safety functions, provided this is possible in their machine model. However, the danger is that consumers will then leave their own machine always in Lot 6 standby mode just to be on the safer side, or will complain with the machine manufacturer after having suffered a water leakage just because they forgot to activate the safety functions. Another negative element of this hypothesis is that since 'Lot 6 passive standby' mode is not defined in any current or under preparation IEC/EN standards for wash appliances, it could not be rapidly included in an implementing measure, unless defined by the legislator under its own responsibility.

For wash appliances, the definition of an additional "off-mode" as the "*lowest mode offering a function*" (Figure 6.35) is probably the most appropriate solution, but if a (useful) function is offered (and safety is intuitively useful), than the associated energy consumption is not a loss, and this contradicts the definition of 'Lot 6 off-mode'. Although not perfect, this compromise solution allows to harmonise Lot 6 and IEC standard definitions for washing machines.

Figure 6.35: Possible harmonisation of Lot 6 and draft IEC 60456 5th Ed. definitions for wash appliance modes



[28] For the protection against flooding from any machine component or water pipe and the prevention of the backflow of non-potable water into the water mains and working not only during normal functioning (as addressed in the International Standard IEC 61770:1999 "*Electric appliances connected to the water mains – avoidance of backsiphonage and failure of the hose-set*"), but also when the machine is switched off.

c) The standby for washing machines and dishwashers

As conclusion, **the definitions of "off-mode" and "left-on-mode" as given in IEC 60456, 5th edition draft are seen here as being more appropriate for washing machines**, considering that they will in a short time the be included also in the new edition of the EN 60456 standard. These definitions will be therefore used in Task 7 for the proposal of standby policy measures specific for washing machines and dishwashers.

A compromise solution for an acceptable harmonisation of Lot 6 and the draft IEC 60456 5th Ed. definitions had also been developed.

6.3.3.2 The trade-off between load amount and nominal washing machine capacity

a) The methodological approach

In the past, washing machines had few operating options, or washing programs, rarely combined with the possibility to select among saving programs. The energy and water consumptions per washing cycle were approximately fixed and users didn't care too much about such a kind of problems. This behaviour, along with the common unawareness on environmental resource consumption went so deeply in the imagination of people that for a long time nobody cared about savings. Though in the last 10-20 years experts put a precious effort to develop new technologies for saving resources, the market was main concerned with the nominal working conditions in order to assess the efficiency and efficacy of a single machine. The same things happened with the standards as if the test washing cycle was really adopted by all users in normal life. This has never been true, but this problem has been always demanded to the responsibility of the user.

In case of a different use of the appliance, or different testing conditions, one must expect a change in energy/water consumption, energy efficiency and performance compared to the results under nominal conditions.

By switching from the point of view of the single machine to that of an holistic system that includes the users of wash appliances – with their habits and needs for textile washing – a new scenario arises in which washing machine efficiency/performance should also be assessed *inter alia* against a partial loading and/or reduced temperature washing programmes.

In the last years, a better knowledge and consideration of the actual consumers behaviour and the overall environmental issue pushed the technological progress toward the design of new and more flexible machines, able to reduce the energy and water consumption according to the real washing conditions. Modern machines allow selecting a full range of washing temperatures and adapt the energy/water consumption to different loads, thus performing a large set of different working cycles. At the same time, even larger machines are manufactured, to target families with a large number of persons of specific washing needs..

The actual consumption of the whole set of washing appliances doesn't just depend on the efficiency or performance in the standard washing programme, but only this specific cycle is addressed in European standards and EU policy measures.

On the other side, a complex scenario should be hypothesised and analysed in order to appreciate the overall behaviour of the 'machine and user system' under different behaviour conditions. .

The objective of the present analysis is to understand the interaction between the two system components, in order to establish an evaluation framework that can be finally adopted to assess the "trade-off" between washing machine technical characteristics on one side and the actual consumer needs on the other side.

Analysing the saving potential of technical options from an almost theoretical point of view and accounting for differences in maximum load size, washing programmes, and other functionalities could be an amazing combinatorial problem, but the interpretation of the results could even be questionable. To evaluate the 'machine and user system' a simple but effective model should be created. Thus, from a practical point of view, a small set of theoretical machine types are herewith hypothesised, mainly differing in their maximum load sizes and energy consumption. Users' habits are also simplified, in order to develop an easily understandable model, whose statistical variables represent a clear cut of the real life, as assessed in the consumers analysis in Task 3.

The presented evaluation methodology could also be seen as a framework for more refined analyses, keeping into account data coming from extended machine tests and more detailed investigations of consumer habits, along with their interaction with technical and logistic constraints.

b) Saving characteristics of the washing machines

The main scope of this analysis is to estimate the impact of larger sized machines on the resources consumption, taking into account the user habits.

One can easily expect that - for a fixed load amount - larger washing machines working at partial load will not have the same efficiency than smaller machines working at nominal load, because the latter have been optimised through the years for that load.

Larger load capacity machines present a lower specific consumption levels: to wash, for example, 10 kg of laundry, a 10kg washing machine will very likely need less energy and water than washing the same amount of laundry in a 5 kg machine for two times. But on the contrary, if only 5kg of laundry have to be washed a larger energy/water consumption is expected when a 10kg machine is used at half load, compared again with a 5kg machine working at nominal load capacity. This expected outcome derives from the fact that all the components in both machines are optimized for the nominal load and the same technological levels for energy management are implemented.

Unfortunately, no comprehensive data on energy and water consumption by load and washing temperature are available, mainly because tests at different load and temperature conditions are not fully covered by the worldwide standards. Therefore, in this analysis theoretical characteristics are assumed for a virtual machine.

When a machine is partially loaded, the resources consumption is not linearly reduced: its (energy and water) efficiency decreases, the appliance being featured for the full-load. So far, if the consumption is fixed and independent from the load, the specific consumption (consumption per load unit) would increase with an hyperbolic trend by reducing the load.

Although the general efficiency of washing appliances has been largely improved in the last decade, due to the introduction of more sophisticated components (motors, pumps, electro valves, etc.) with a higher intrinsic efficiency, as well as better control (electronic) devices, such components can't avoid to waste energy at null-load, neither afford to preserve their efficiency when required to handle less energy or less water, than the nominal ones. Some experimental tests can confirm these

assumptions, as reported in Table 6.67-6.68. Data on specific energy (energy per load unit), and specific amount of water (water per load unit) consumptions are respectively shown in Figures 6.36-6.37. Correspondingly, energy and water consumptions per cycle are presented Figures 6-38-6.39.

Specific energy consumption by load			
Load [(kg)	Load (%)	Specific consumption (kWh/kg)	Consumption. per cycle (kWh)
6,00	100%	0,18	1,08
4,50	75%	0,23	1,04
3,00	50%	0,32	0,96
1,50	25%	0,57	0,86

Table 6.67: Specific energy and energy per cycle consumed by some tested washing machines.

Specific water consumption by load			
Load [(kg)	Load (%)	Specific consumption (kWh/kg)	Consumption. per cycle (kWh)
6,00	100%	9,86	59,2
4,50	75%	12,00	54,0
3,00	50%	15,23	45,7
1,50	25%	23,24	34,9

Table 6.68: Specific water and water per cycle consumed by some tested washing machines.

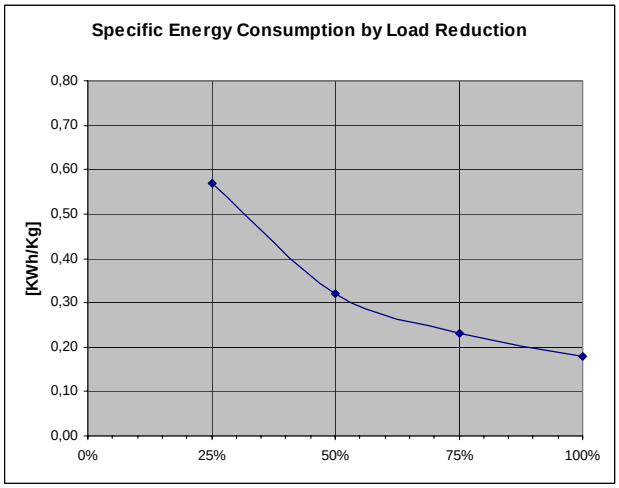


Figure 6.36: Experimental data on specific energy consumption against load reduction

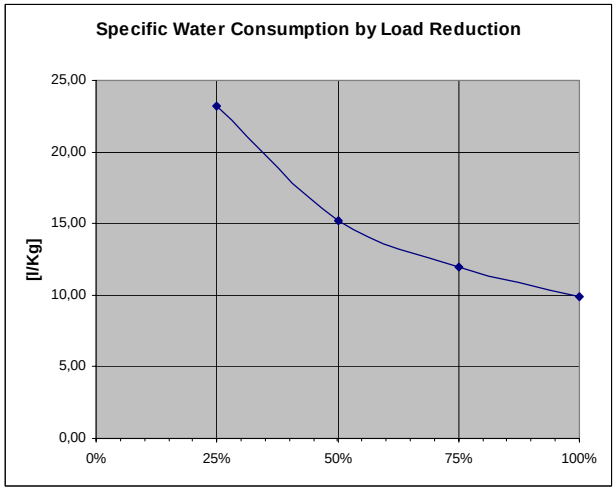


Figure 6.37: Experimental data on specific water consumption against load reduction

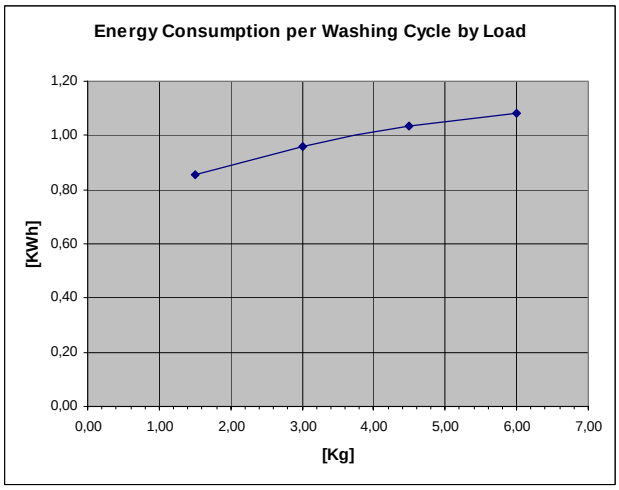


Figure 6.38: Experimental data on energy consumption per washing cycle against load reduction

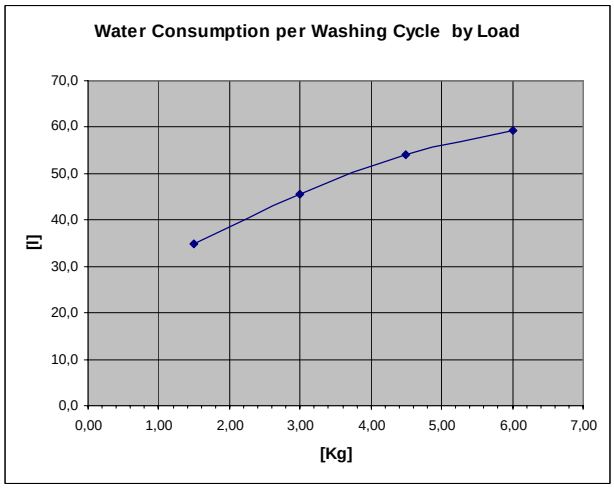


Figure 6.39: Experimental data on water consumption per washing cycle against load reduction

Although these data reflect the performance of real machines, the following analysis will be focussed on the trend more than on absolute value. Direct comparison between two machines belonging to different load capacity categories would have no meaning, since - for different reasons - higher load capacity machines are able to manage the resources (energy, water, detergent) better than smaller load capacity machines, due to a well known scale effect, already happening for other household appliances. It would be also worthless to compare average machines, representing the average features of the real machines in each load capacity category. The present analysis is in fact aimed at enhancing the efficiency and performance of washing machines in each load category, given that the best components and control systems are installed.

In addition, due to the lack of standard data (limited to tests driven at full-load and standard temperatures) and the different consumer habits (in terms of used washing temperatures and loads) suitable interpolations and extrapolations for the available data are needed, so that a theoretical model is necessary.

A mathematical model has been defined, to approximate the saving characteristics over a feasible range of values for the independent variables. Given a set of boundary data (no matter if experimental, or estimated), which represent the consumption levels for both idle (i.e. null load), and full-loaded cycles at different washing temperatures, a set of theoretical curves, representing the resources (energy and water) consumption, have been set - through an interpolation - as function of he load, and in case of the energy consumption as function of the washing temperature, according to the following definitions:

$$W_{l,t} = W_{t,i} + \left(W_{t,f} - W_{t,i}\right) \times \left(\frac{l}{l_f}\right)^n$$

where:

- $W_{l,t}$ is the variable resource consumption level at load l and temperature t;
- $W_{t,i}$ is the resource consumption level for the null load washing cycle (idle);
- $W_{t,f}$ is the resource consumption level for the full-load washing cycle (nominal size);
- l is the variable load;
- l_f is the machine nominal load capacity;
- n = 0,7

The mathematical model exactly fits the boundary data $W_{t,i}$ and $W_{t,f}$.
Two appliance categories that differ by just 1 kg are defined to be “adjacent”.

This mathematical model represents the energy consumption of an ideal, best performing, theoretical machine – herewith named “archetype” – supposed to be available for each load category and representing its category. Each archetype is also defined as having the possibility to select among six differ washing temperatures and having been optimized for the nominal load capacity (i.e. the same maximum technological level is considered for all categories).

Resulting numerical values of the energy consumption are reported in Tables 6.69-6.72 related to four different archetypes: 5 kg, 6 kg, 7 kg, and 8 kg nominal load. Trend curves are plotted for each characteristic in Figures 6.40-6.43. The characteristics of the different archetypes are extrapolated from each other by means of a multiplying coefficient: an estimated but optimistic 5% increase in the energy consumption between two adjacent categories is assumed, consistently with the mathematical models of each archetype.

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kg T	Energy per cycle (kWh) 20°C	30°C	40°C	50°C	60°C	90°C
0	0,092	0,235	0,36	0,49	0,59	0,85
1	0,19	0,35	0,50	0,66	0,79	1,06
2	0,25	0,43	0,59	0,76	0,91	1,19
3	0,31	0,49	0,67	0,85	1,02	1,30
4	0,36	0,55	0,74	0,93	1,11	1,41
5	0,40	0,60	0,80	**1,00**	1,20	1,50

Table 6.69: Energy consumption per cycle for the 5 kg archetype

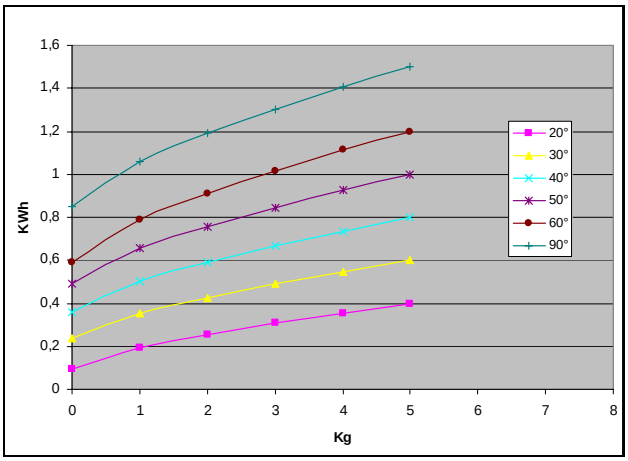


Figure 6.40: Energy consumption per cycle for the 5 kg archetype

kg T	Energy per cycle (kWh) 20°C	30°C	40°C	50°C	60°C	90°C
0	0,10	0,25	0,38	0,51	0,62	0,89
1	0,20	0,37	0,53	0,69	0,83	1,11
2	0,27	0,45	0,62	0,80	0,96	1,25
3	0,32	0,51	0,70	0,89	1,07	1,37
4	0,37	0,57	0,77	0,97	1,17	1,48
5	0,42	0,63	0,84	1,05	1,26	1,58
6	0,46	0,68	0,90	**1,12**	1,35	1,67

Table 6.70: Energy consumption per cycle for the 6 kg archetype

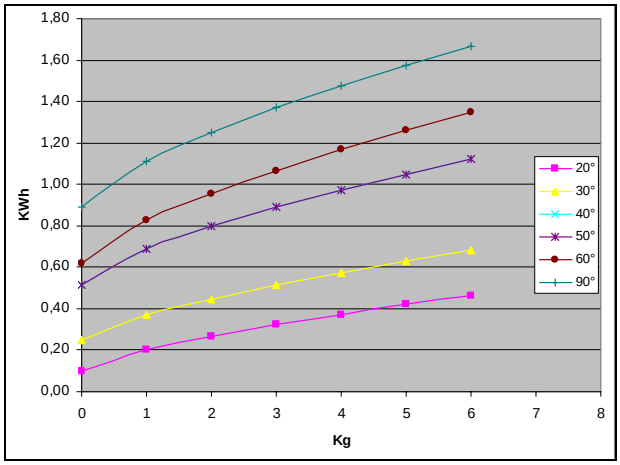


Figure 6.41: Energy consumption per cycle for the 6 kg archetype

kg T	Energy per cycle (kWh) 20°C	30°C	40°C	50°C	60°C	90°C
0	0,10	0,26	0,40	0,54	0,65	0,94
1	0,21	0,39	0,55	0,72	0,87	1,17
2	0,28	0,47	0,65	0,84	1,00	1,31
3	0,34	0,54	0,74	0,93	1,12	1,44
4	0,39	0,60	0,81	1,02	1,23	1,55
5	0,44	0,66	0,88	1,10	1,32	1,65
6	0,49	0,72	0,95	1,18	1,41	1,75
7	0,53	0,77	1,01	**1,25**	1,50	1,84

Table 6.71: Energy consumption per cycle for the 7kg archetype

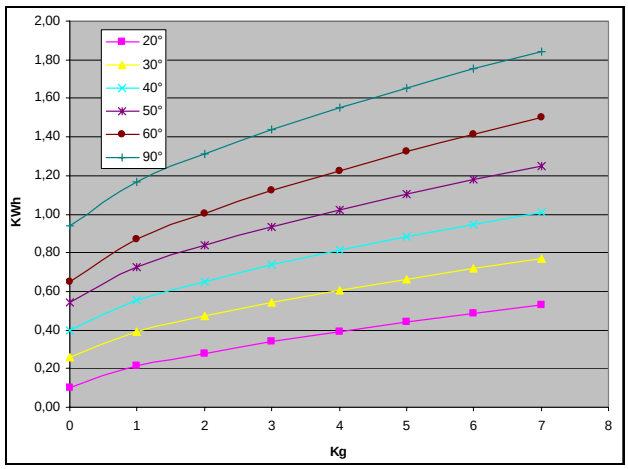


Figure 6.42: Energy consumption per cycle for the 7kg archetype

kg T	Energy per cycle (kWh) 20°C	30°C	40°C	50°C	60°C	90°C
0	0,11	0,27	0,42	0,57	0,68	0,98
1	0,22	0,41	0,58	0,76	0,91	1,23
2	0,29	0,49	0,68	0,88	1,05	1,38
3	0,36	0,57	0,77	0,98	1,18	1,51
4	0,41	0,63	0,85	1,07	1,29	1,63
5	0,46	0,69	0,93	1,16	1,39	1,74
6	0,51	0,75	1,00	1,24	1,49	1,84
7	0,56	0,81	1,06	1,31	1,58	1,94
8	0,60	0,86	1,12	**1,39**	1,66	2,03

Table 6.72: Energy consumption per cycle for the 8kg archetype

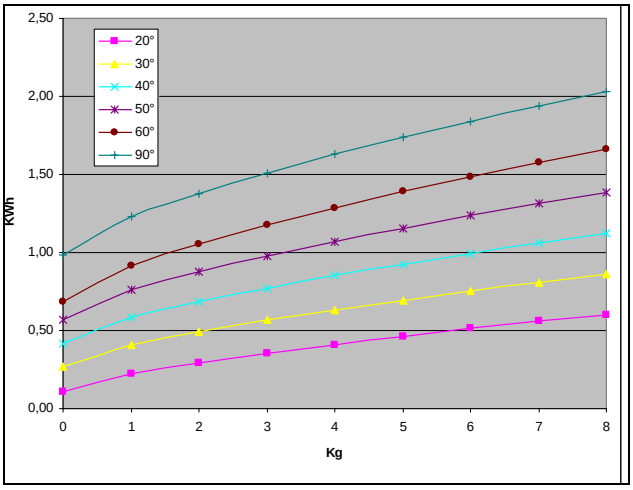


Figure 6.43: Energy consumption per cycle for the 8kg archetype

c) Present consumer habits and future scenarios

As stated in Task 3, differences between the "real life" behaviour in machine use and the standard test conditions could bring to significant differences in resources consumption. The two main factors affecting these differences are:

1. the actual amount of textile washed;
2. the water temperature (directly set by the user or indirectly selected with the chosen washing programme).

The real life frequency distributions for actual loads and washing temperatures, shown in Tables 6.73-6.74 and Figures 6.44-6-45 are derived from Task 3 results and are here considered "standard habits". From the frequency distribution of the washing loads per week is also possible to estimate the average number of washing cycles per week for each machine, which is approximately equal to 4.9 cycles/week, with an average load about 4,02 kg/cycle. These give an average load per week of about 19,71 kg/week for the average installed washing machine.

These figures are a very important point of reference, as they are related to the sizes of existing washing machines. The machine size is not the only issue that affects the consumer habits, the washing needs being another one and is related to both the availability at home of a stock of different clothes and laundry items and the inopportunity to store a large amount of dirty laundry for long periods.

Therefore, in spite of the possibility to wash larger loads, some inertia to change the own habits could be expected in the population. For this reason, some possible scenarios are investigated. The first scenario is based on the continuation of the "standard habits". This scenario is a reference scenario when applied to the 5kg archetype machine, which is very close to the standard base case" machine, defined in this Task 5.

Supposing two variables (load & temperature) to be statistically independent, a joint probability '$P_{l,t}$' to have a washing cycle with load 'l' at temperature 't', can be defined as the product of the corresponding probability of each variable, which is here inferred as the product of the two single

Load (kg)	Frequency (%)
2	1,2
3	12,6
4	69,0
5	17,2

Average load = 4,023 kg

Table 6.73: Washing cycles frequency distribution by load

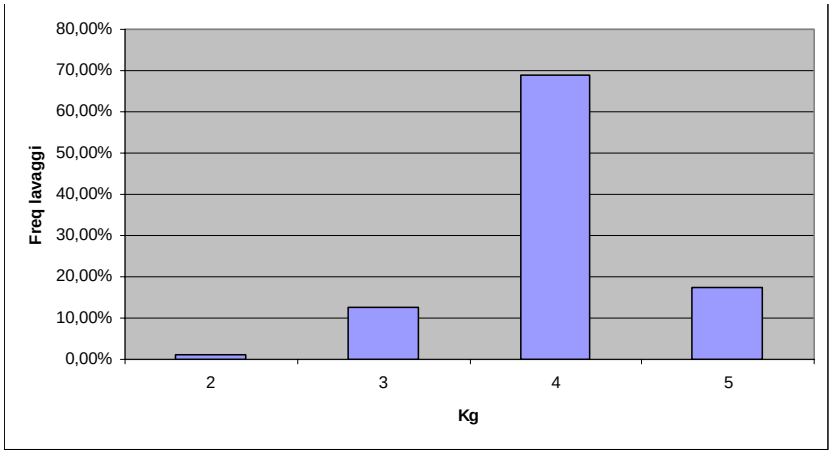


Figure 6.44: Washing cycles frequency distribution by load

Temperature (°C)	Frequency (%)
20°	6
30°	18
40°	37
50°	10
60°	22
90°	7

Table 6.74: Washing cycles frequency distribution by temperature

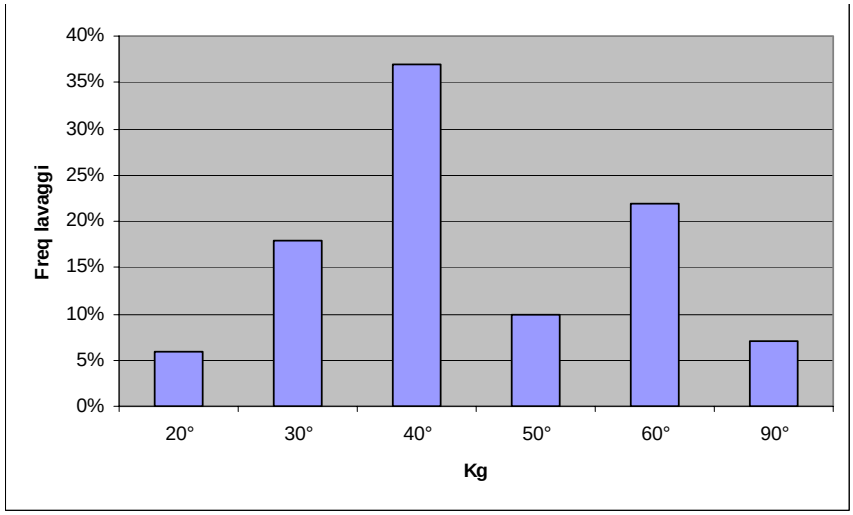


Figure 6.45: Washing cycles frequency distribution by temperature

frequencies, as shown in Table 6.75 and Figure 6.46. This is one of the major – and questionable - simplifications within this analysis. Nevertheless, if the actual joint distribution is available, it can easily used in Table 6.75 and the spreadsheet simulation can run as well.

The weekly washing cycles by loads and temperatures in standard habits, presented in Table 6.76 are obtained by the product of the joint frequencies and the average number of washing cycles per week.

Because of figures on standard habits – which show an average of about 4 kg and no loads (or almost no loads, according to available information from Task 3) over 5kg there is little chance for larger capacity machines to work at full load if consumer habits would not change. Therefore, there is no need to simulate the standard scenario for the other archetypes but the 5 kg one. By assuming that standard habits are used with other archetypes it is possible to analyse the impact of the different archetypes energy consumption characteristics. In fact, in case of invariant habit scenario the analysis results will just reflect the differences among the technical characteristics of archetypes.

Standard Scenario - Standard habits

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	0,07%	0,21%	0,43%	0,11%	0,25%	0,08%	1,15%
3	0,76%	2,28%	4,68%	1,26%	2,78%	0,89%	12,64%
4	4,14%	12,41%	25,52%	6,90%	15,17%	4,83%	68,97%
5	1,03%	3,10%	6,38%	1,72%	3,79%	1,21%	17,24%
Tot.	6,00%	18,00%	37,00%	10,00%	22,00%	7,00%	**100,0 %**

Table 6.75: Joint frequency distribution of washing cycles by loads and temperatures in standard habits

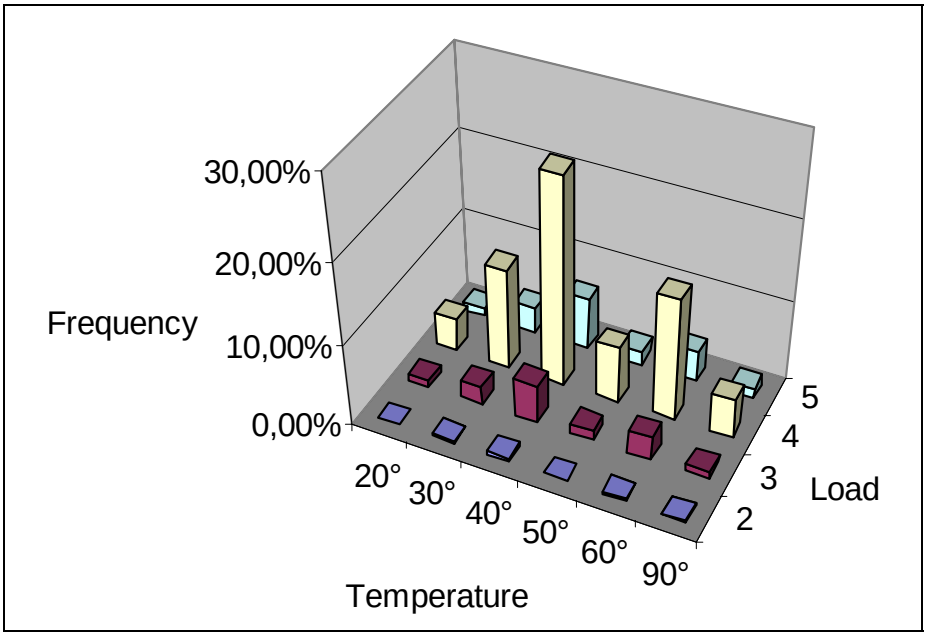


Figure 6.46: Joint frequency distribution of washing cycles by loads and temperatures in standard habits

Standard Scenario (standard habits)

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	0,003	0,010	0,021	0,006	0,012	0,004	0,056
3	0,037	0,112	0,229	0,062	0,136	0,043	0,620
4	0,203	0,608	1,250	0,338	0,743	0,237	3,379
5	0,051	0,152	0,313	0,084	0,186	0,059	0,845
Tot.	0,29	0,88	1,81	0,49	1,08	0,34	4,90

Table 6.76: Number of weekly washing cycles by loads and temperatures in standard habits.

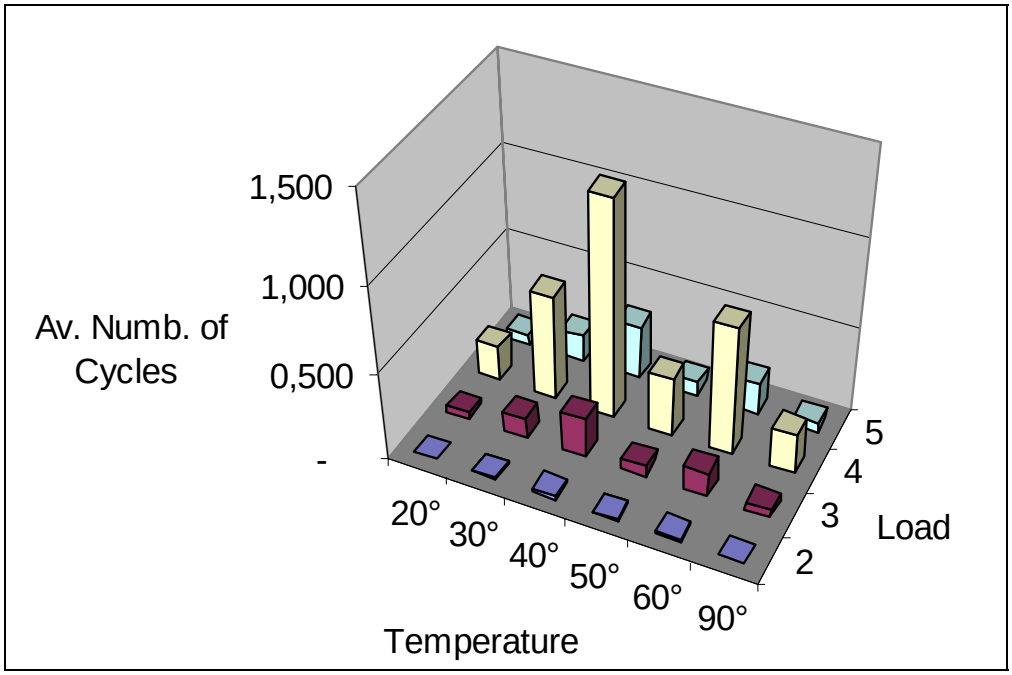


Figure 6.47: Washing cycles per week by load and temperature in Standard Scenario

In order to evaluate the variation in the load capacity category, two scenarios were defined for the 7kg archetype where no change is supposed on the distribution of washing temperatures:

- the first scenario, named "**Scenario I**", includes the changing of the frequency distribution of loads, without any variation of the average figures in the consumer habits (i.e. the average load remains 4,023 kg). Results are given in Tables 6.77-6.78. For sake of consistency in data distribution when an increase occurs in the frequency of higher loads also the frequency of smaller loads has be increased, so that a bimodal distribution of loads is implicit in this scenario. From a practical point of view, this scenario can be considered as a boundary situation: the consumer behaviour is pushed towards larger washing loads by the availability of larger capacity machines, but the "washing needs" are limiting any reduction in the number of washing cycles, and consequently any increase in the average washing load, since the total amount of laundry per week (19,71 kg/week) is assumed to be constant. An increase in smaller loads is therefore forecast for this scenario;

- in the second scenario – named "**Scenario II**" – the load distribution is quite similar to the standard scenario, but shifted to higher loads. The number of washing cycles per week is reduced accordingly in order to preserve the total amount of laundry to be washed per week (the average "washing need" estimated to be about 19,71 kg/week). Figures are given in Tables 6.79 and 6.80.

Scenario I: standard cycles per week with a different distribution of loads

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	1,94%	5,81%	11,94%	3,23%	7,10%	2,26%	1,15%
3	1,26%	3,77%	7,75%	2,09%	4,61%	1,47%	12,64%
4	0,60%	1,80%	3,70%	1,00%	2,20%	0,70%	68,97%
5	0,68%	2,04%	4,18%	1,13%	2,49%	0,79%	17,24%
6	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	
7	1,53%	4,59%	9,43%	2,55%	5,61%	1,78%	
Tot.	6,00%	18,00%	37,00%	10,00%	22,00%	7,00%	100,0 %

Table 6.77: Joint frequency distribution (%) of washing cycles by loads and temperatures in Scenario I

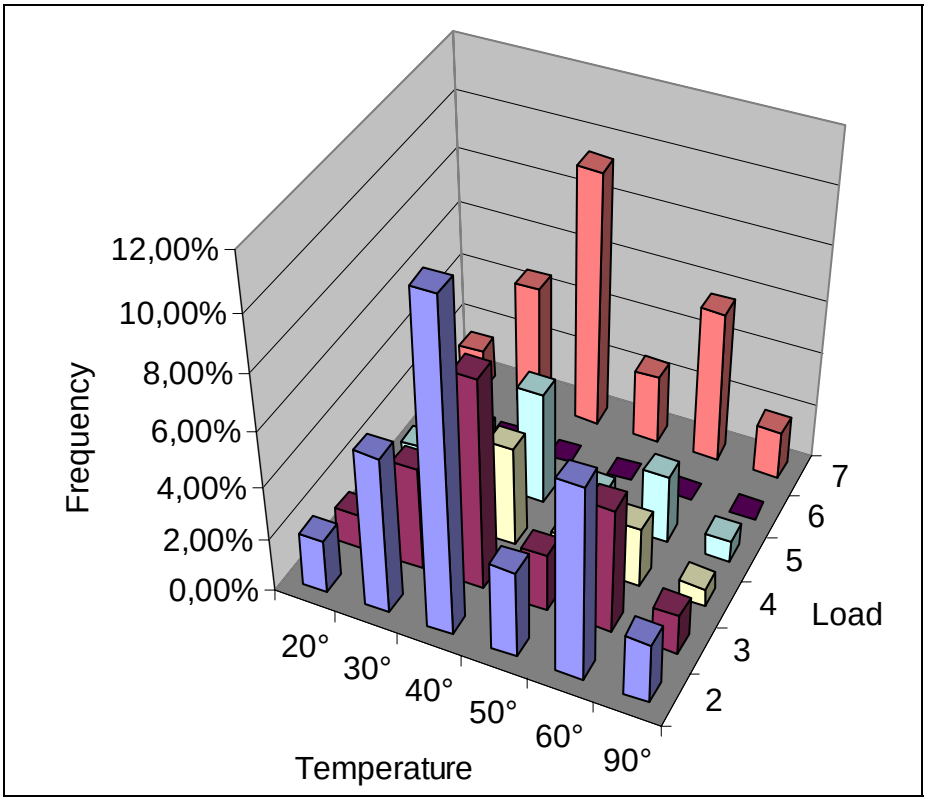


Figure 6.48: Washing cycles joint frequency (%) by load and temperature in Scenario I

Scenario I: Standard cycles per week with a different distribution of loads

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	0,095	0,285	0,585	0,158	0,348	0,111	0,056
3	0,062	0,185	0,380	0,103	0,226	0,072	0,620
4	0,029	0,088	0,181	0,049	0,108	0,034	3,379
5	0,033	0,100	0,205	0,055	0,122	0,039	0,845
6	-	-	-	-	-	-	
7	0,075	0,225	0,462	0,125	0,275	0,087	
Tot.	0,29	0,88	1,81	0,49	1,08	0,34	4,90

Table 6.78: Number of weekly washing cycles by loads and temperatures in Scenario I

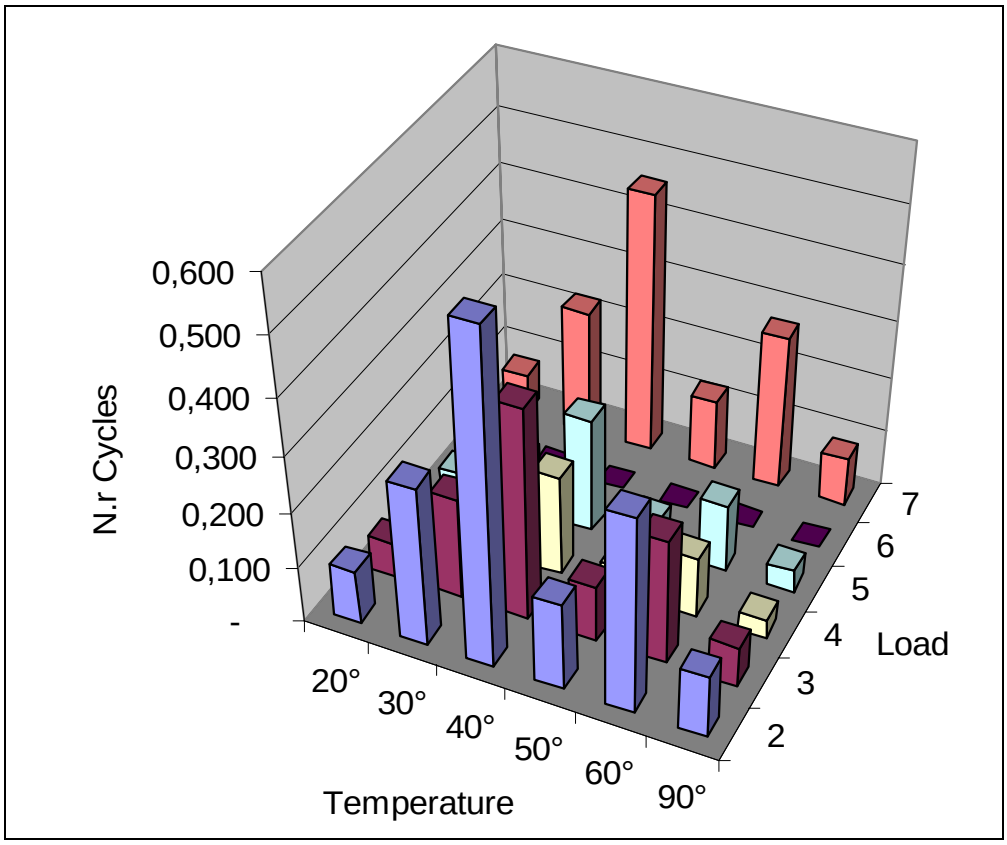


Figure 6.49: Number of washing cycles per week by load and temperature in Scenario I

Scenario II – Reduced cycles per week

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
3	0,07%	0,21%	0,43%	0,11%	0,25%	0,08%	1,15%
4	0,64%	1,92%	3,94%	1,06%	2,34%	0,75%	10,64%
5	3,90%	11,69%	24,04%	6,50%	14,29%	4,55%	64,97%
6	0,91%	2,74%	5,64%	1,52%	3,35%	1,07%	15,24%
7	0,48%	1,44%	2,96%	0,80%	1,76%	0,56%	8,00%
Tot.	6,00%	18,00%	37,00%	10,00%	22,00%	7,00%	**100,0 %**

Table 6.79: Joint frequency distribution (%) of washing cycles by loads and temperatures in Scenario II

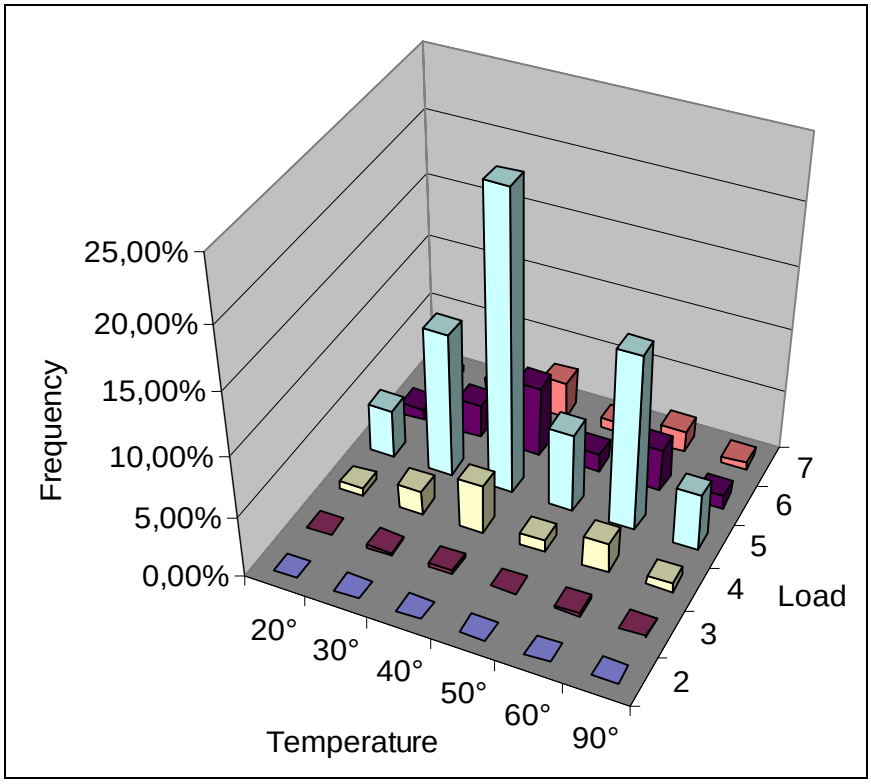


Figure 6.50: Washing cycles joint frequency (%) by load and temperature in Scenario II

Scenario II – Reduced cycles per week

kg T	20°C	30°C	40°C	50°C	60°C	90°C	Tot.
2	-	-	-	-	-	-	0,000
3	0,003	0,008	0,016	0,004	0,010	0,003	0,044
4	0,024	0,073	0,150	0,040	0,089	0,028	0,405
5	0,148	0,445	0,914	0,247	0,544	0,173	2,471
6	0,035	0,104	0,214	0,058	0,128	0,041	0,580
7	0,018	0,055	0,113	0,030	0,067	0,021	0,304
Tot.	0,23	0,68	1,41	0,38	0,84	0,27	**3,80**

Table 6.80: Number of weekly washing cycles by loads and temperatures in Scenario II

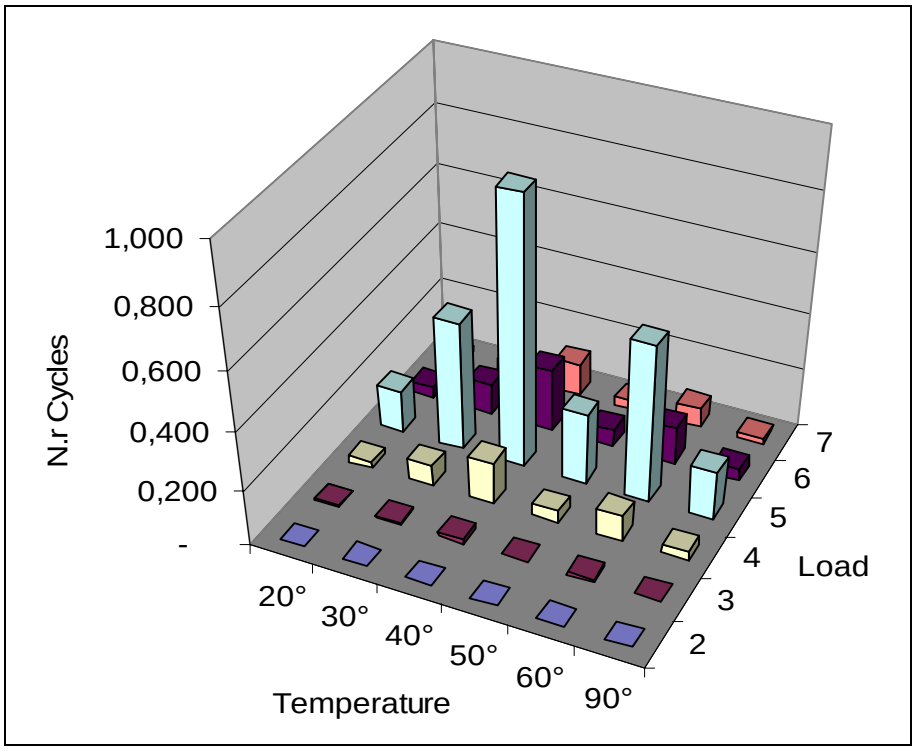


Figure 6.51: Number of washing cycles per week by load and temperature in Scenario II

d) Analysis results

Given the distribution of the "weekly washing cycles" and the resource consumption of each archetype, the weekly amount of resources required for washing according to each Scenario can be obtained by the sum of products between the corresponding elements of the two data matrix, namely the resource consumption curves and the weekly cycles by load and temperature joint frequencies, as follows:

$$W_{tot} = \sum_{L,T} \left(W_{l,t} \times P_{l,t} \right)$$

where:

L, T are the discrete sets of loads and temperatures, respectively.

With reference to the archetypes and scenarios, the energy consumed by the system per week, as well as its variation with respect to the reference case, are summarized in Table 6.81.

Table 6.81: Machine energy weekly used by each archetype, in front of different scenarios

Archetype (load)	Scenario	Energy consumption (kWh/week)	Variation (%)
5 kg	Standard	4,06	--
6 kg	Standard	4,26	+ 5,0%
7 kg	Standard	4,48	+ 10,3 %
7 kg	Scenario I	4,43	+ 9,0 %
7 kg	Scenario II	3,24	- 20,2 %
8 kg	Scenario II	3,65	- 10,1 %

As expected, the larger load capacity category archetypes result in an increase in the weekly energy consumption, if no change in the consumer behaviour takes place. From a theoretical point of view, it is worth noting that the Scenario I differs from the standard one only for the shape in the two frequency distributions, but the first order moments in the respective data sets are equivalent. Scenario II results in a significant savings in energy per week with the 7kg archetype, but this savings are reduced considerably (up to50%) with the 8 kg archetype.

The main conclusions is that with the larger capacity machines, represented by the 7kg archetype, a very large variation in energy savings, from -10% (negative savings) if consumers do not change their behaviour, and up to +20% savings if they do, along the lines of Scenario II. This is a 30% variation in energy consumption due to consumers behaviour, which is strongly related to the promotion of the proper information to them.

As any theoretical investigation, although based on actual information collected in Task 3, also this analysis has some limits, which are essentially the realism of the Scenarios due the possible necessity of small capacity washes for special fabrics or special needs.

Given the distribution of the washing loads from consumer habits, with an average load of about 4,02 kg/week, the load capacity of the average washing machine (the so called standard Base Case) is not fully used. This could be a symptom of the robustness of actual constraints (i.e. the user the washing needs) in spite of the possibility to wash larger loads.

The hypothesised Scenarios cannot be taken as absolute models. Different analytical models can be assumed for the archetype, within the same framework methodology. Similarly, users' habits have been inferred over the whole European population, but different behaviours do co-exist in different countries or geographical areas. The three hypothesised Scenarios are therefore to be considered as boundary situations a the extremes of the washing machine use. Any other behaviour scenario lies among such extreme cases.

Nevertheless, the achieved results are in quite good agreement with a previous analysis developed in 2004 by the German Öko-Institut[29], concluding than when comparison a standard 5kg washing machines with a larger 7kg washing machine, the latter is slightly better on the basis of the same

[29] Source: I. Rüdenauer, C. Gensch, D.Quack, Eco-Efficiency Analysis of Washing machines – Life Cycle Assessment and determination of optimal life span, Öko-Institut e.V. Geschäftsstelle FreiburgFreiburg, November 2nd, 2004, downloadable from http://www.oeko.de .

amount of wash laundry. But depending on the consumer behaviour the acquisition and use of a large washing machine can become much worse than the acquisition and use of a standard washing machine when the two are compared on the basis of the same amount of washing cycles.

Finally the investigated Scenarios are occurring against the backdrop of decreasing family size in Europe, and this element has not been considered in the simulation.

6.3.3.3 The impact of the energy used in detergent production

a) The methodological approach

In this paragraph the theoretical framework presented in the previous paragraph is extended to the evaluation of the detergent impact on energy resources consumption. The methodology is the same, but the energy consumption is given by the sum of two components: the energy consumed for the washing cycle by the washing machine plus the energy needed to manufacture the used detergent.

The potential impact of larger load capacity machines under different consumer habits is analysed through a mix of actual and theoretical hypothesis. The same four archetypes and three scenarios are instantiated herewith, which are consistent with the results of Task 3. The same weekly average laundry load is assumed in each scenario. In this analysis however, the total "energy consumption" is based on two system components that are separately analysed versus different loads and temperatures: the machine energy consumption and the specific energy needed to produce the detergent. The former has been evaluated in the previous paragraph, the latter is based on the amount of detergent dissolved in washing liquor at the selected loads and temperatures. It is known that the "washing performance" of this liquor depends on several factors: the type of detergent, the water amount and temperature, the water hardness, the type of fabric, the stains, etc.. To simplify the analysis, the amount of detergent defined in 4th Edition of IEC 60456 for the standard "cotton wash programme at 60°C" and used for the LCC analysis of the standard base case machine, is assumed, which is calculated according to the formula:

Detergent Amount = $d_0 + d_1$ * ("load")

where: $d_0 = 54$ g
$d_1 = 16$ g/kg

Notice that an "optimal" use of the detergent is here assumed, neglecting the overdosing generally occurring in practice. In fact, although the appliance and detergents instructions describe the amount of detergent to be used according to the selected programme and load conditions, usually consumers tend to overdose it. In addition, when different loads and temperatures are considered the amount of detergent should be adapted to preserve the same final wash performance. This analysis assumes that the "ideal" detergent dosage is used for the different washing cycles, according to the actual load and temperature. Therefore, the above formula is modified to estimate the correct amount of detergent for each washing cycle:

(1) the constant term (detergent amount at null load) in the formula itself is incremented versus different archetypes;
(2) the standard dose obtained for the 60° programme is normalized by means of a suitable coefficient, in order to account for washing programmes at different temperatures.

The first variation is justified by the increased amount of water that a larger archetype loads independently from the laundry load. A 10% increase in the constant term of the formula is

hypothesised between two "adjacent" machine categories (archetypes). In practice, values reported in Table 6.82 are assumed for the archetypes.

The second variation is introduced to account for the detergent performance at different temperatures. According to Task 3 results, it is assumed that the cotton 60°C programme performance level can be achieved by using just 50% of the nominal detergent dose in a cotton 90°C programme, or by 150% of the nominal dose in a cotton 40°C programme. The amount of detergent for the standard cotton 60° programme is multiplied by a corrective coefficient, according to the figures reported in Table 6.83 (ratio to standard case), to get the amount of detergent giving the same performance at the selected programme temperature.

Table 6.82: Used detergent amount for the standard "cotton 60°C programme", for different archetypes

Machine capacity (kg)	Constant term d_0 (g)	coefficient d_1 (g/kg)
5	54,0	16,0
6	59,4	16,0
7	65,3	16,0
8	71,9	16,0

Table 6.83: Relative amount of detergent for washing cycles at different temperatures (ratio to standard case). Values at T=20, 30, and 50 °C are extra/interpolated according to the experimental results in Task 3

Temperature (°C)	**20**	**30**	**40**	**50**	**60**	**90**
Ratio	2	1,72	1,5	1,3	1	0,5

Finally, the calculated amount of detergent for each washing cycle is converted into "energy resources" to account for the manufacturing impact on the energy consumption and added to the energy used by the archetype machine to get the total amount of energy resources consumed by the overall washing system. To this purpose, **a conversion factor of 41,16 MJ per kg of detergent** is adopted.

b) Total energy consumption per washing cycle in different machine archetypes

The values of the overall energy consumption per washing cycle are reported in Tables 6.84-6.91 for the 5kg, 6kg, 7kg and 8kg archetypes. Trend curves are shown in Figures 6.52-6.55.

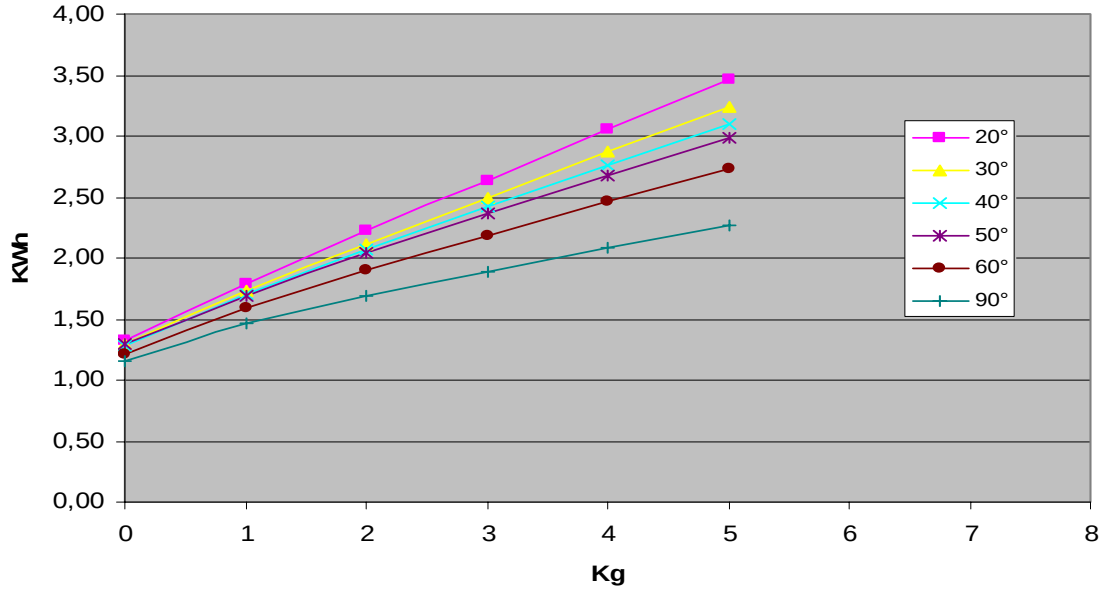
kg / T	**Equiv. energy for detergent** (kWh/cycle) 20°C	30°C	40°C	50°C	60°C	90°C
0	1,23	1,06	0,93	0,80	0,62	0,31
1	1,60	1,38	1,20	1,04	0,80	0,40
2	1,97	1,69	1,48	1,28	0,98	0,49
3	2,33	2,01	1,75	1,52	1,17	0,58
4	2,70	2,32	2,02	1,75	1,35	0,67
5	3,06	2,64	2,30	1,99	1,53	0,77

Table 6.84: Equivalent energy consumption per washing cycle required to manufacture the detergent in the 5kg archetype machine

kg / T	**Total energy consumption** (kWh/cycle) 20°C	30°C	40°C	50°C	60°C	90°C
0	1,33	1,30	1,29	1,29	1,21	1,16
1	1,79	1,73	1,70	1,70	1,59	1,46
2	2,22	2,12	2,07	2,04	1,89	1,68
3	2,64	2,50	2,42	2,36	2,18	1,89
4	3,05	2,87	2,76	2,68	2,46	2,08
5	3,46	3,24	3,10	2,99	2,73	2,27

Table 6.85: Total energy consumption per cycle with the 5kg archetype machine

Figure 6.52: Total energy consumption per cycle with the 5kg archetype machine



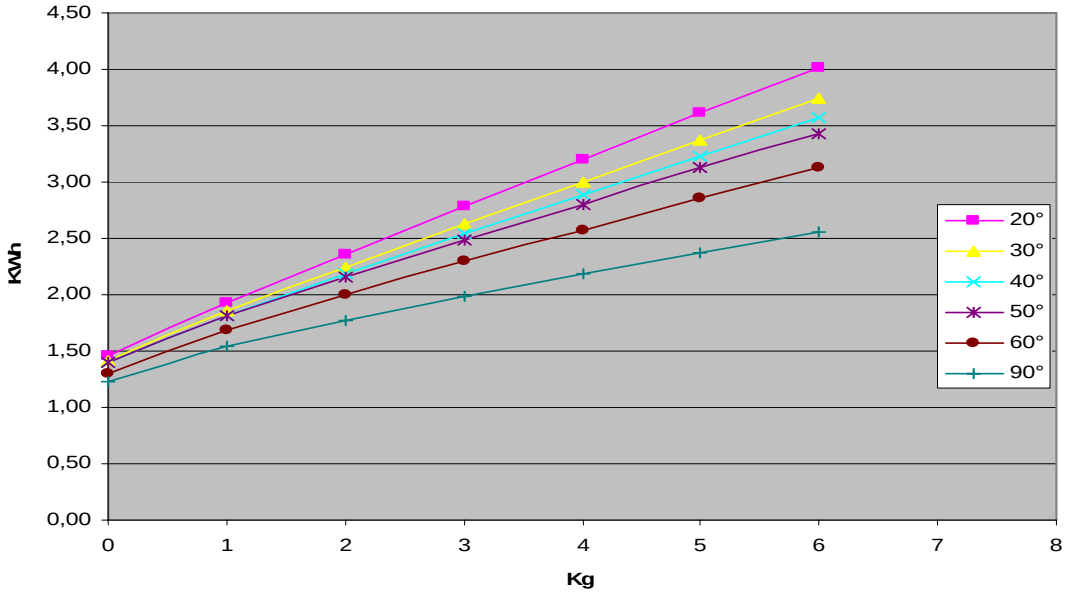
kg T	Equiv. energy for detergent (kWh/cycle) 20°C	30°C	40°C	50°C	60°C	90°C
0	1,36	1,17	1,02	0,88	0,68	0,34
1	1,72	1,48	1,29	1,12	0,86	0,43
2	2,09	1,80	1,57	1,36	1,05	0,52
3	2,46	2,11	1,84	1,60	1,23	0,61
4	2,82	2,43	2,12	1,83	1,41	0,71
5	3,19	2,74	2,39	2,07	1,59	0,80
6	3,55	3,06	2,67	2,31	1,78	0,89

Table 6.86: Equivalent energy consumption per washing cycle required to manufacture the detergent in the 6kg archetype machine

kg T	Total energy consumption (kWh/cycle) 20°C	30°C	40°C	50°C	60°C	90°C
0	1,46	1,42	1,40	1,40	1,30	1,23
1	1,93	1,85	1,82	1,81	1,69	1,54
2	2,36	2,25	2,19	2,16	2,00	1,77
3	2,78	2,63	2,54	2,49	2,30	1,98
4	3,20	3,00	2,89	2,81	2,58	2,18
5	3,61	3,37	3,23	3,12	2,85	2,37
6	4,02	3,74	3,57	3,43	3,12	2,56

Table 6.87: Total energy consumption per cycle with the 6kg archetype machine

Figure 6.53: Total energy consumption per cycle with the 6kg archetype machine



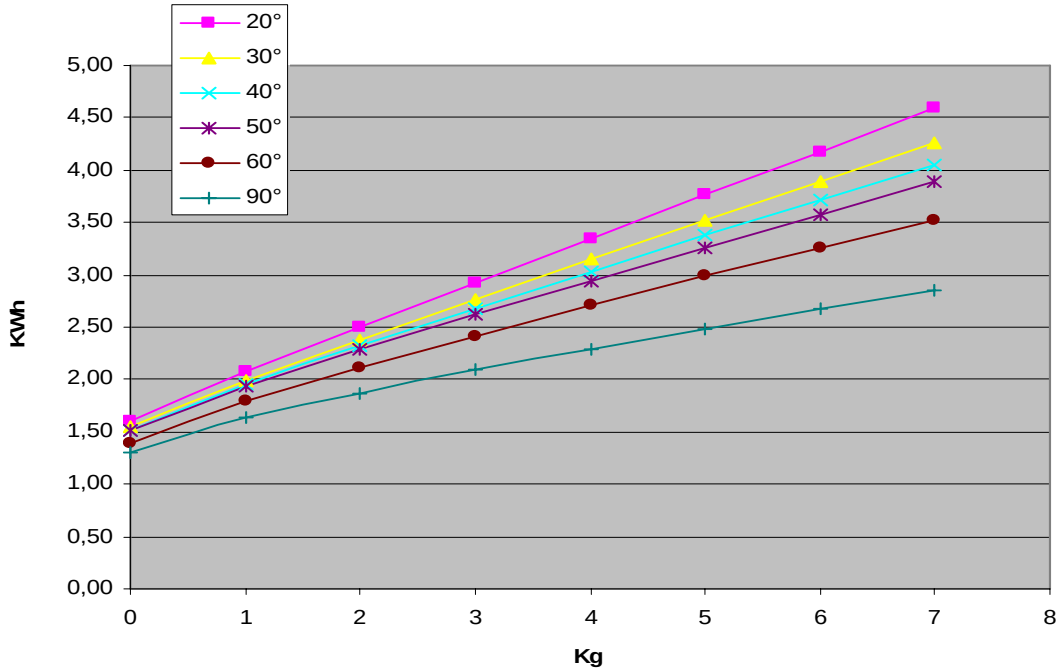
kg	Equiv. energy of detergent (kWh/cycle)					
T	20°C	30°C	40°C	50°C	60°C	90°C
0	1,49	1,29	1,12	0,97	0,75	0,37
1	1,86	1,60	1,40	1,21	0,93	0,47
2	2,23	1,91	1,67	1,45	1,11	0,56
3	2,59	2,23	1,94	1,68	1,30	0,65
4	2,96	2,54	2,22	1,92	1,48	0,74
5	3,32	2,86	2,49	2,16	1,66	0,83
6	3,69	3,17	2,77	2,40	1,84	0,92
7	4,06	3,49	3,04	2,64	2,03	1,01

Table 6.88: Equivalent energy resources per washing cycle required to manufacture the needed detergent in the 7kg load category archetype

kg	Total energy consumption (kWh/cycle)					
T	20°C	30°C	40°C	50°C	60°C	90°C
0	1,60	1,54	1,52	1,51	1,40	1,31
1	2,07	1,99	1,95	1,93	1,80	1,63
2	2,51	2,39	2,32	2,28	2,12	1,87
3	2,93	2,77	2,68	2,62	2,42	2,09
4	3,35	3,15	3,03	2,94	2,70	2,29
5	3,76	3,52	3,37	3,26	2,98	2,48
6	4,18	3,89	3,72	3,58	3,26	2,67
7	4,59	4,26	4,05	3,89	3,53	2,86

Table 6.89: Total energy consumption per cycle with the 7kg archetype machine

Figure 6.54: Total energy per cycle consumption curves by washing with the 7kg load category archetype



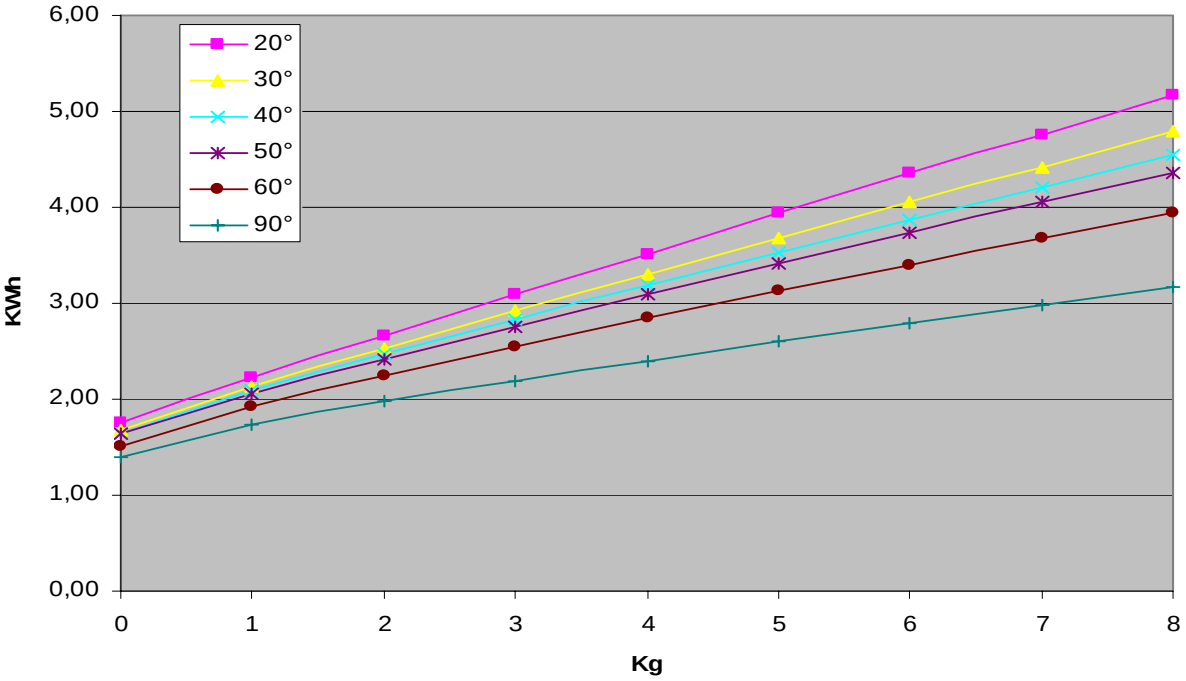
kg	Equiv. energy for detergent (kWh/cycle)					
T	20°C	30°C	40°C	50°C	60°C	90°C
0	1,64	1,41	1,23	1,07	0,82	0,41
1	2,01	1,73	1,51	1,31	1,00	0,50
2	2,38	2,04	1,78	1,54	1,19	0,59
3	2,74	2,36	2,06	1,78	1,37	0,69
4	3,11	2,67	2,33	2,02	1,55	0,78
5	3,47	2,99	2,60	2,26	1,74	0,87
6	3,84	3,30	2,88	2,50	1,92	0,96
7	4,21	3,62	3,15	2,73	2,10	1,05
8	4,57	3,93	3,43	2,97	2,29	1,14

Table 6.90: Total energy consumption per cycle with the 7kg archetype machine

kg	Total energy consumption (kWh/cycle)					
T	20°C	30°C	40°C	50°C	60°C	90°C
0	1,75	1,69	1,65	1,64	1,50	1,39
1	2,23	2,14	2,09	2,06	1,92	1,73
2	2,67	2,54	2,47	2,42	2,24	1,97
3	3,10	2,93	2,83	2,76	2,55	2,20
4	3,52	3,31	3,18	3,09	2,84	2,40
5	3,94	3,68	3,53	3,42	3,13	2,60
6	4,35	4,05	3,87	3,73	3,40	2,80
7	4,76	4,42	4,22	4,05	3,68	2,99
8	5,17	4,79	4,55	4,36	3,95	3,17

Table 6.91: Equivalent energy resources per washing cycle required to manufacture the needed detergent in the 8kg load category archetype machine

Figure 6.55: Total energy per cycle consumption curves by washing with the 8kg load category archetype



c) Analysis results

To compare the analysis results with the results of the previous analysis dealing only with the machine energy consumption, the same three Scenarios have been hypothesised.

Given the distribution of the "weekly washing cycles" and the "total energy per cycle" consumption of each archetype, the weekly overall amount of energy required to wash according to each Scenario can be obtained by the sum of products between the corresponding elements of the two data matrix, namely the resource consumption curves and the weekly cycles by load and temperature joint frequencies, as follows:

$$W_{tot} = \sum_{L,T} \left(W_{l,t} \times P_{l,t} \right)$$

where L, T are the discrete sets of loads and temperatures, respectively.

With reference to the archetypes and Scenarios, the overall energy consumed by the system per week, as well as its variation with respect to the reference case, are summarized in Table 6.92.

Table 6.92: Total energy (machine and detergent) weekly archetype, in front of different scenarios

Archetype (kg)	Scenario	Energy/Week (kWh)	Variation (%)
5 kg	Standard	13,14	--
6 kg	Standard	13,76	+ 4,7
7 kg	Standard	14,43	+ 9,8
7 kg	Scenario I	14,38	+ 9,4
7 kg	Scenario II	10,71	- 18,5
8 kg	Scenario II	12,27	- 6,6

As expected, the larger load capacity archetypes show an increase in the total energy consumption per week, if no change in the consumer behaviour takes place.

From a theoretical point of view, it is worthy noting that Scenario I differs from the standard one only for the shape in the two frequency distributions, but the first order moments in the respective data sets are equivalent. Scenario II presents significant savings in the total energy consumption for the 7kg archetype, but this savings is considerably reduced (to 1/3 of the initial value) with the 8kg archetype.

Besides the concerns discussed for the analysis developed in the previous paragraph, it is worth noting that the energy required to produce the detergent has a significant impact over the overall washing system energy consumption.

6.3.3.4 The trade-off between washing machine spin speed and the use of a (tumble) dryer (methodological analysis and preliminary results)

a) Basic information and analysis boundaries

To dry wet clothes energy is needed in any case. If a 5 kg laundry load is 60% wet, no matter which method is used including drying around the house on radiators, it must cost at least 2,4 kWh to dry it; if this load is dried in a tumble dryer, additional energy is taken up in turning the drum and heating the load and tumble dryer itself[30].

The more water is removed by mechanical treatment (usually through spinning in the washing machine) the less thermal energy is required for subsequently drying. This causes on one side an additional energy demand through higher spin speeds at the washing machine level and a contemporary reduction in thermal energy demand in the drying action, again whatever drying system and energy source is considered.

According to the German Energy Agency Dena[31], a high-speed spinning, above 1 200 rpm, requires between 5% (at 60°C) and 10% (at 40°C) more energy than lower spin speeds. The increase in energy consumption for an increase in spinning speed from 1 200rpm to 1 600 rpm has been evaluated in 50 Wh/cycle (Table 6.8) with an increase of the purchase price of 30 € for the consumer. Considering that the same 400 rpm increase occurs from 800 rpm to 1200 rpm, a similar increase in energy consumption can be assumed.

When the laundry is dried:
- on a clothes line outside besides direct sun or wind energy
- in a non heated room or in a direct solar heated greenhouse
- in a heated room where wasted heat is provided (for example an open boiler room, where heat is provided by the thermal loss of the boiler and will be in any case wasted),

no other energy source is needed. In all other cases additional energy is used that is usually supplied by the residential heating system or, in case a (tumble) drier is used, by electricity or natural gas.

[30] Source: BNW19: Domestic clothes dryers –current and future technologies, market status and priority action plan, version 1.1, 08 october 2006, downlodable from http://www.mtprog.com .
[31] source: Revision of the Energy Labelling System, Final Report, 2006, Deutsche Energie-Agentur GmbH (Dena)

To calculate the influence of different spin speeds on the energy demand for the drying process the specific energy demand of a conventional condenser (energy efficiency class C) drier is taken. The energy demand against percentage of water remaining after spin (Residual Moisture Content, RMC) is assumed to be according to the data of a 2004 German Öko-Institut study presented in Table 6.93[32].

Table 6.93: Spin speed and energy demand with respect to remaining water after spin

Water remaining after spin (cotton)	Unit	62 %	56 %	52 %	49 %
Corresponding approximately spin speed	rpm	1 000	1 200	1 400	1 600
Relative energy demand ('cotton dry' programme)	%	100	90	86	82
Specific energy demand ('cotton dry' programme)	kWh/kg	0,70	0,64	0,60	0,57

A linear correlation is assumed between the water remaining after spin and the specific energy demand (in kWh/kg of dried load), according to the following formula:

Specific energy demand = 0,0100 x RMC + 0,0800

which allows to estimate the energy demand also at higher residual moisture contents (or lower spin drying efficiency classes) as shown in Table 6.94

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Table 6.94: Washing machine spin speed and dryer energy demand with respect to remaining water after spin

Spin drying efficiency classes (WM)		A	B	C	D	E	F	G
Residual moisture content	(%)	45	54	63	72	81	90	94
Energy consumption condenser dryer, C class[33], 5kg	(kWh/kg)	0,530	0,620	0,710	0,800	0,890	0,980	1,020
Washing machine spin speed	(rpm)	1600	1300	1000	800	600	480	400

Analysing in detail the 2005 CECED technical database, and associating a residual moisture content to each model (assuming that for each spin drying class the residual moisture content is the highest compatible with the declared class, for G class a value of 94% has been used) the resulting models disaggregation is presented in Table 6.95.

It is worth noting that the models in the database, which are assumed to reflect the market share of the relevant sales, are almost perfectly divided intro two groups: machines with spinning speed in the range 400-1100 rpm and machines with spinning speed in the range 1150-2000 rpm. Very few models (34 in total), highlighted in blue in the Table, deviate from this disggregation. Excluding the

[32] Source: I. Rüdenauer, C. Gensch, D.Quack, Eco-Efficiency Analysis of Washing machines – Life Cycle Assessment and determination of optimal life span, Öko-Institut e.V. Geschäftsstelle FreiburgFreiburg, November 2nd, 2004, downloadable from http://www.oeko.de .

[33] According to Commission Directive 95/13/CE of 23 May 1995, implementing Council Directive 92/75/EEC with regard to energy labelling of household electric tumble driers OJ. L. 136, 21.6.1995, the energy efficiency classes of condenser dryers depend from the energy consumption (in kWh/kg) of the iron-dry cotton: class A, C ≤0,55; class B: 0,55 < C ≤ 64; class C: 0,64 < C ≤ 73; class D: 0,73 < C ≤ 82; class E: 0,82 < C ≤ 91; class F: 0,91 < C ≤ 1,00; class G > 1,00.

'deviating models' from the analysis (leaving a database of 5 158 models), the weighted average spin speed and residual moisture content can be calculated, as shown in Table 6.96.

Table 6.95: Number of models per spin speed and (estimated) residual moisture content in 2005 CECED technical database

Spin drying class	A	B	C	D	E	F	G	Models number	
RMC (%) Spin speed	**45**	**54**	**63**	**72**	**81**	**90**	**94**		
400						54	33	87	
450						4	2	6	
500					65	50		115	
550					1			1	
600				20	245			265	
650				28	5			33	
700			1	32	17			50	
750			2	10	1			13	2 425
800			74	383	1			458	
850			22	50				72	
900			59	77				136	
950			4					4	
1000		**4**	978	4				986	
1050			8					8	
1100		**14**	177					191	
1150		4						4	
1200		1 016	**9**	**4**				1 029	
1250		6	**2**					8	
1300		230	**1**					231	
1350		4						4	
1400	67	740						807	
1450		6						6	2 767
1500	33	63						96	
1550		6						6	
1600	497	23						520	
1700	3							3	
1800	47							47	
2000	6							6	
Models number	2 769		2.423						5 162
	653	2 116	1337	608	335	108	35	5 192	Tot.

Table 6.96: Average spinning speed and RMC for the two groups of washing machines in 2005 CECED technical database

Machine types	Models number	rpm (number)			RMC (%)		
		min	max	weighted aver.	min	max	weighted aver.
lower spin speed	2.407	400	1 100	**856**	63	94	**69,4**
higher spin speed	2.751	1 150	2 000	**1 367**	45	54	**52,2**

A quite good agreement can be seen with the outcome of Task 3. Looking at the final spin speed (Figure 6.56) the distribution showed large differences among countries: while in Italy, Spain,

Poland, Hungary and Czech about 70% of the spin cycles are at or below 900 rpm, in UK, Germany and Sweden 70% are above 900 rpm. Taking the average of the individual range of spin speeds given from ≤400rpm up to ≥1 300rpm, the average spin speed per country can be calculated which confirms the same differentiation between the low-spin and high-spin countries. The average of all investigated country is 914 rpm (Figure 6.57).

Figure 6.56: Distribution of spin speeds

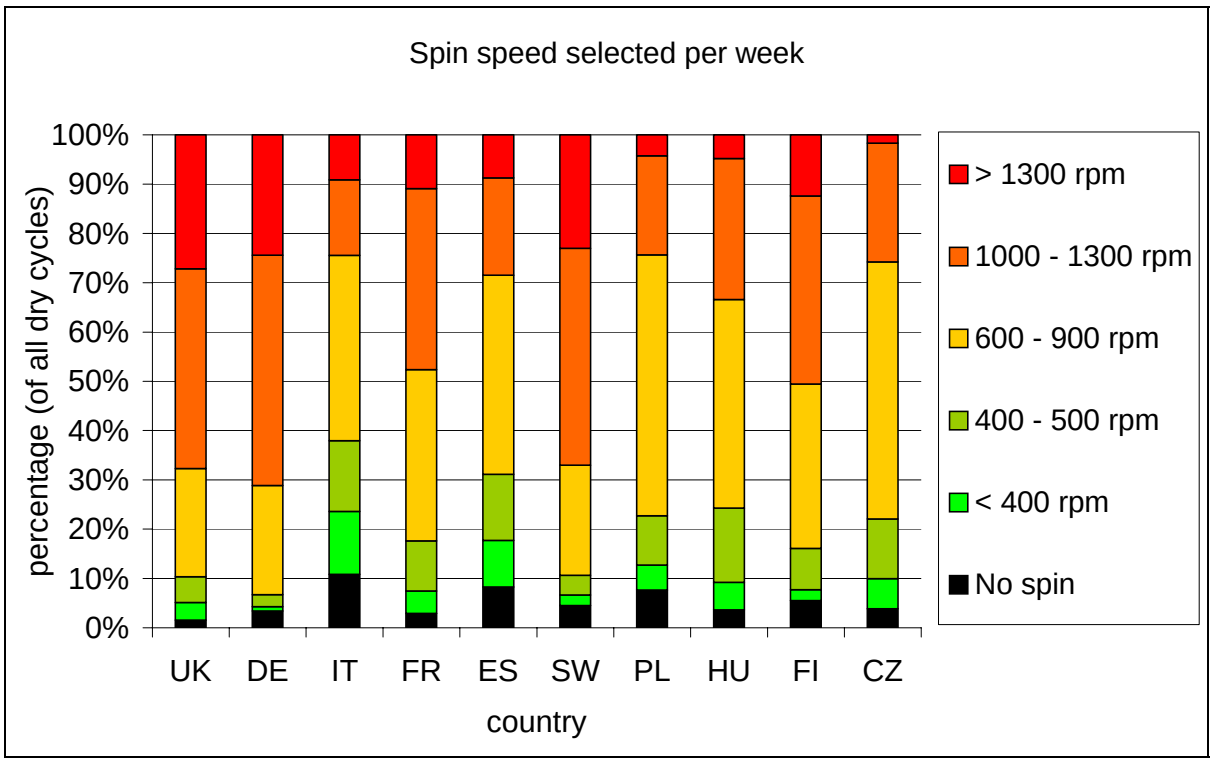
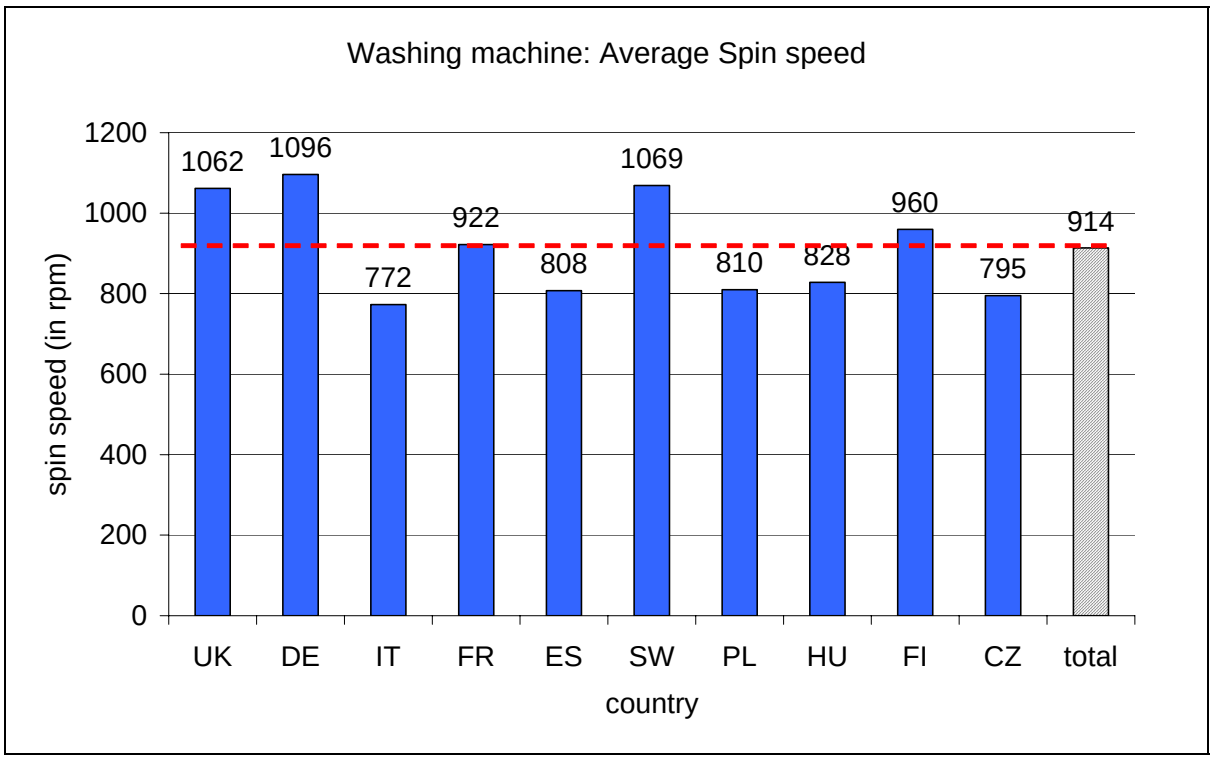


Figure 6.57: Calculated average spin speed per country and in total



Regarding drying of the clothes, large differences can be found between summer and winter time: while in summer time (Figure 6.58), about 40% of the consumer always dry the clothes outside on a cloth line and another 28% do it often (total 68%) these figures reduce in winter time (Figure 6.59) to just 7% and 10 %, respectively. The preferred way of drying clothes in winter is to dry them in the house in a heated room: this is always done by 28% and often by 33% of the consumers (total 61%). However, no better disaggregation of the dryer use is reported as being outside of the study scope.

Figure 6.58: Ways of drying in summer time

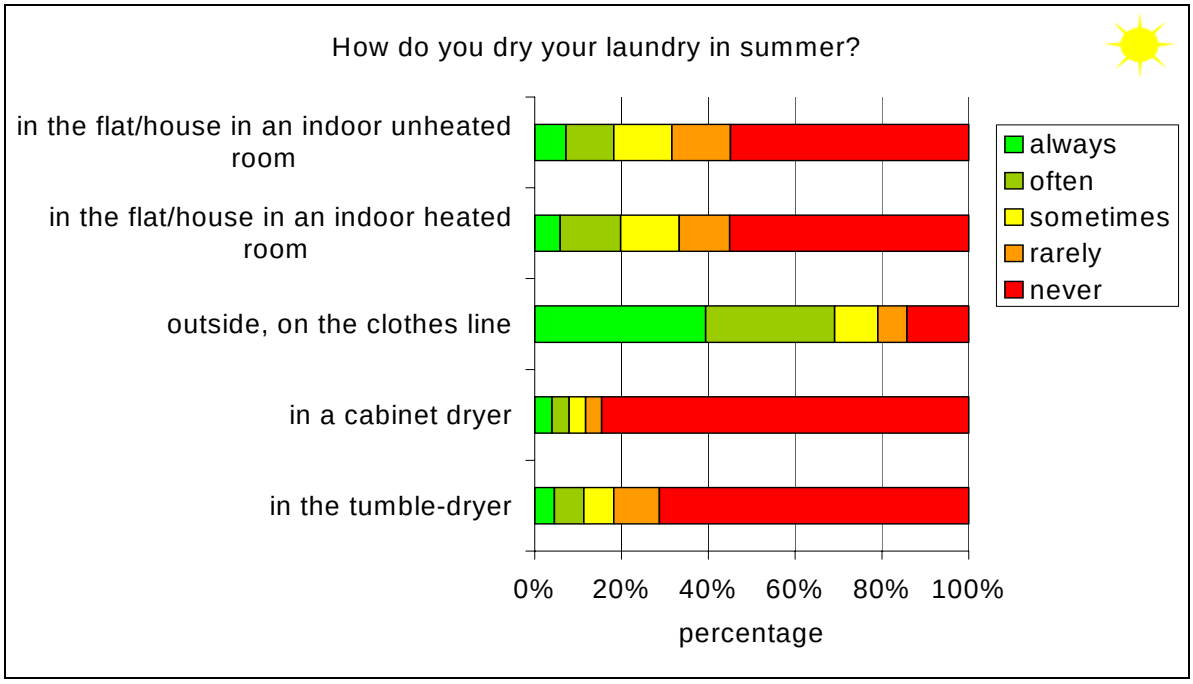
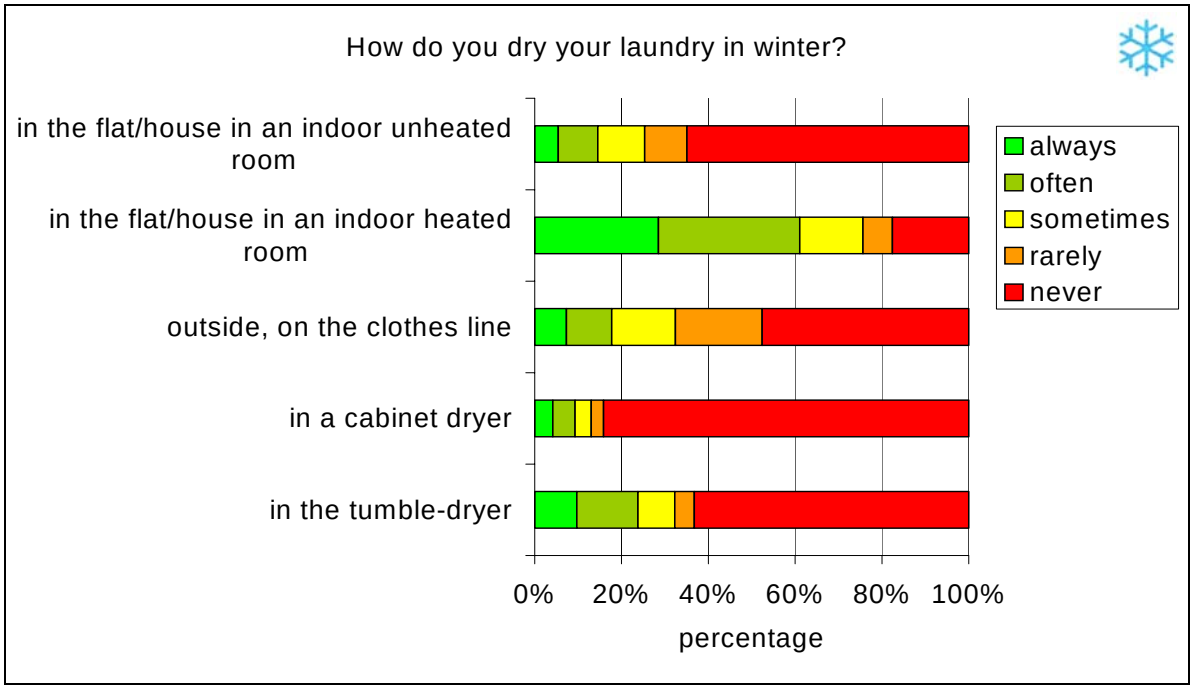


Figure 6.59: Ways of drying in winter time

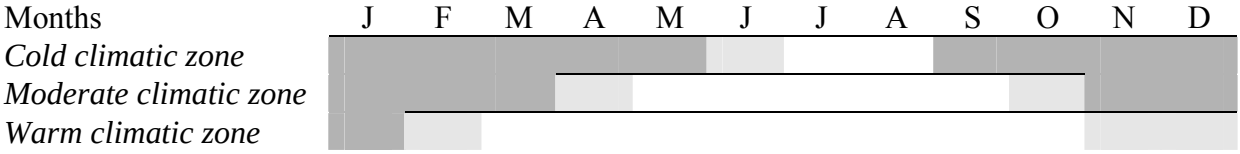


According to another study of the German Öko-Institut[34], the different climatic conditions in Europe can roughly be summed up in three climatic zones. The '*cold climatic zone*' (comprising Finland, Norway and Sweden), the '*moderate climatic zone*' (comprising countries as Belgium, Denmark, Germany, France, UK, Ireland, Luxembourg, The Netherlands, Austria and Switzerland) and the '*warm climatic zone*' (comprising Greece, Italy, Portugal, Spain and Turkey). With a multi-criteria approach the countries Norway, Germany, France and Spain were chosen as representative of their respective climatic zone.

Unfortunately there is no statistical data about the dryer annual use pattern available. To cover different situations both the use of the drier during the whole year and the use of the drier only during the heating season have to be regarded. The length of the heating period varies between the different countries. Of course it is not possible to draw a sharp line between 'heating season/use of the drier' and 'non-heating season/no use of the drier' (as also confirmed by the previously presented data from Task 3) as not only temperature but also other weather conditions make people use their drier in the summer (e.g. when it is raining). But this is assumed to be compensated by the contrary effect during the heating season, when the laundry is hanged on a clothesline on a sunny and dry day.

Considering the average mean temperatures per month in the different countries the heating/non heating months could roughly be estimated as "heating season = months when the drier is used" by the owners of this appliance. The dark grey highlighted months in Table 6.96 are considered as months where the drier is used the whole month, the lighter grey highlighted months are considered as months where the drier is used only half of the month and the not highlighted months are considered as months where the drier is not used at all.

Table 6.97: Heating and non-heating periods according to the climatic zones (dryer use- and non-use months)



The capacity of the regarded driers is 5 kg, whereas average loading is generally assumed to be 3,2 kg. Due to reduced loading the specific energy demand of driers (electricity demand per kilogramme fabric) is higher than with full load conditions. The total and the specific energy demand against loading is shown in Table 6.97. Under standard conditions the loading for 'cotton dry' programme is set 5 kg (for driers with a capacity of 5 kg).

Table 6.98: Total and specific energy demand (%) with respect to loading of the dryer (m=measured; i=interpolated)

Loading	5,0 kg	4,5 kg	4,0 kg	3,5 kg	3,2 kg	3,0 kg
Total energy demand (per cycle)	100	93	85	78	73	70
Specific energy demand (per kg)	100	103	106	111	114	117
data quality	m	m	m	m	i	m

Taking into consideration that not all laundry washed is suitable to be dried in a tumble-dryer, an

[34] Source: I. Rüdenauer, C. Gensch, Energy demand of tumble dryers with respect to differences in technology and ambient conditions, Öko-Institut e.V. Geschäftsstelle FreiburgFreiburg, 13 January 2004, downloadable from http://www.oeko.de .

estimate was done of 80% of the total washed amount that can be dried in a tumble drier in the 'dry cotton' programme. Since the real life base case washing machine (Task 5) has a capacity of 5,36kg, and a load on 3,4kg, the calculated 80% is 3,2 kg, which is surprisingly in line with previous seen average loading from the Öko-Institut study.

Therefore the actual energy consumption of dryer with a 3,2 kg load is 73% of the consumption at full load standard (5kg) conditions.

b) Energy consumption evaluation for countries in the Warm Climatic Zone

The trade-off is evaluated in terms of the minimum dryer ownership that saves enough energy when using a lower RMC laundry from a washing machine with increased spinning speed (of 400 rpm, from 800rpm to 1200 rpm) needed to compensate the increase in the washing machine energy consumption due to the higher spin speed.

Basic assumption:
- washing machine ownership: 100%
- washing machine average load: 3,4 kg
- number of washing cycles per year: 200 equally divided during the year
- increase in washing machine energy consumption for a 400rpm increase in spin speed, from 800 rpm to 1200 rpm): 50 Wh/cycle
- RMC = 72% (Class D) at 800rpm; RMR = 54% (Class B) at 1200 rpm
- increase in washing machine purchase price: 30€
- dryer type: condenser, 5kg
- dryer average load 3,2 kg with a 73% of the full load energy consumption
- dryer energy consumption 0,800 kWh/kg (energy efficiency class C) at RMC = 72%
- dryer use profile: according to the climatic zone.

Since the washing machine cycles are equally divided during the year, an average of 16,7 wash cycles/month are considered. The same maximum number of drying cycles is also considered.

When the spinning speed of the standard base case washing machine (5,36 kg) is increased from 800 rpm to 1200 rpm (with an increase of 400 rpm) the same 50Wh increase in the energy consumption is assumed as for the improvement from 1200 rpm to 1600 rpm. But since the washing machine load is only 3,4 kg, the 50Wh are reduced to 31,7 Wh/cycle (or 50/5,35*3,4). For 200 washing cycles per year, this amounts to 6,34 kWh/year or 95,1 kWh over the 15 year washing machine lifetime.

The number of months for the 'heating season' and the 'use of the drier' for the warm climatic zone is 1 month where the drier is used the whole month and 3 months where the drier is used only half of the month, or in other terms, the dryer is fully used (16,7 cycles/month) for 2,5 months or 41,7 drying cycle/year.

To dry 3,2kg of 72% RMC laundry, a 5kg dryers uses 73% (or 2,92 kWh/cycle) of the full load energy consumption (or 0,800 kWh/kg x 5 kg = 4kWh). To dry 3,2kg of 54% RMC laundry the same dryers consumes 73% (or 2,26 kWh/cycle) of the full load energy consumption (or 0,620kWh/kg x 5 kg = 3,1 kWh). The savings is therefore 657 Wh/cycle, or 27,4 kWk/year, giving a total saving of 410,6 kWh/15y when 41,7 cycles per year are considered.

On a machine basis, the use of the dryer with a lower RMC (from 72% to 54%) allows to save 315 kWh over 15 years or about 3 times the amount of extra energy consumed by the washing machine with the improved spinning speed.

But the dryer is not owned in 100% of the families (while the washing machine is, or better is assumed to be). This means that when 100 washing machines are considered, the extra energy consumption reaches 9.515 kWh/15y. Only when 23,2 dryers are run for the same 15 years the saved energy reaches 9.527 kWh and starts to overcome the energy waste.

The difference in price for the consumer of the higher spin speed machine is 30 €, unused for the moment because the difference in energy cost has been considered the trade-off until now. Instead, from an economic point of view the trade-off is when the discounted savings minus the difference in price becomes positive (or positive NPV, like in all the previous analysis).

The NPV could be easily calculated with the existing data. For a tumble dryer machine, assuming 100% recovery that is 100% ownership of the dryers it is:

NPV = [(27,4 kWh/year × 0,17 €/kWh) × 10,4 × do] - 30 € = 18,4 €

where:

- 10,4 is the PWF at 5% discount rate for 15 years
- do = dryer ownership (1 = 100%)
- 0,17 € is the average price of the electric energy per kWh.

Thus if ownership of dryers (the 'do' factor) drops below 62% the higher spin speed and higher price washing machines are not convenient in the warmer climatic zone, as a whole.

This means that if the dryer ownership is lower than 20-25% the energy wasted through the increase of the washing machine spinning speed is not recovered via the energy savings of the drying process. But with the 30€ subtracted and the annual energy savings discounted, the breakeven point is even higher in terms of dryers ownership and reaches 62%. For a specific individual user in the warm climatic zone, if she/he will use the dryer more than 62% of the time, it is convenient; otherwise no.

c) Energy consumption evaluation for countries in the Moderate Climatic Zone

The same analysis is repeated for the countries belonging to the *moderate climatic zone*. The number of months for the 'heating season' and the 'use of the drier' for this climatic zone is 5 months where the drier is used the whole month and 2 months where the drier is used only half of the month, or in other terms, the dryer is fully used (16,7 cycles/month) for 6 months or 100 drying cycle/year.

To dry 3,2kg of 72% RMC laundry, a 5kg dryers uses 73% (or 2,92 kWh/cycle) of the full load energy consumption (or 0,800 kWh/kg x 5 kg = 4kWh). To dry 3,2kg of 54% RMC laundry the same dryers consumes 73% (or 2,26 kWh/cycle) of the full load energy consumption (or 0,620kWh/kg x 5 kg = 3,1 kWh). The savings is therefore 657 Wh/cycle, or 65,7 kWk/year, giving a total saving of 985,5 kWh/15y when 100 cycles per year are considered.

On a machine basis, the use of the dryer with a lower RMC (from 72% to 54%) allows to save 894,4 kWh over 15 years or about 9 times the amount of extra energy consumed by the washing machine with the improved spinning speed.

But again the dryer is not owned in 100% of the families (while the washing machine is, or better is assumed to be). This means that when 100 washing machines are considered, the extra energy consumption reaches 9.515 kWh/15y. Only when 9,7 dryers are run for the same 15 years the saved energy reaches 9.559 kWh and starts to overcome the energy waste.

For a tumble dryer machine, assuming 100% recovery that is 100% ownership of the dryers the NPV is:

NPV = [(65,7 kWh/year × 0,17 €/kWh) × 10,4 × do] - 30 € = 116,2 €

Thus if ownership of dryers drops below 26% the higher spin speed and higher price washing machines are not convenient in the moderate climatic zone, as a whole.

This means that if the dryer ownership is lower than 9-10% the energy wasted through the increase of the washing machine spinning speed is not recovered via the energy savings of the drying process. But with the 30€ subtracted and the annual energy savings discounted, the breakeven point is even higher in terms of dryers ownership and reaches 26%. For a specific individual user in the moderate climatic zone, if she/he will use the dryer more than 26% of the time, it is convenient; otherwise no.

d) Energy consumption evaluation for countries in the Cold Climatic Zone

The same analysis is finally repeated for the countries belonging to the *cold climatic zone*. The number of months for the 'heating season' and the 'use of the drier' for this climatic zone is 9 months where the drier is used the whole month and 1 month where the drier is used only half of the month, or in other terms, the dryer is fully used (16,7 cycles/month) for 9,5 months or 158,3 drying cycle/year.

To dry 3,2kg of 72% RMC laundry, a 5kg dryers uses 73% (or 2,92 kWh/cycle) of the full load energy consumption (or 0,800 kWh/kg x 5 kg = 4kWh). To dry 3,2kg of 54% RMC laundry the same dryers consumes 73% (or 2,26 kWh/cycle) of the full load energy consumption (or 0,620kWh/kg x 5 kg = 3,1 kWh). The savings is therefore 657 Wh/cycle, or 104 kWk/year, giving a total saving of 1 560,4 kWh/15y when 158,3 cycles per year are considered.

On a machine basis, the use of the dryer with a lower RMC (from 72% to 54%) allows to save 1.465,2 kWh over 15 years or about 15 times the amount of extra energy consumed by the washing machine with the improved spinning speed.

But again the dryer is not owned in 100% of the families (while the washing machine is, or better is assumed to be). This means that when 100 washing machines are considered, the extra energy consumption reaches 9.515 kWh/15y. Only when 6,1 dryers are run for the same 15 years the saved energy reaches 9.518 kWh and starts to overcome the energy waste.

For a tumble dryer machine, assuming 100% recovery that is 100% ownership of the dryers the NPV is:

NPV = [(104 kWh/year × 0,17 €/kWh) × 10,4 × do] - 30 € = 183,9 €

Thus if ownership of dryers drops below 16% the higher spin speed and higher price washing machines are not convenient in the moderate climatic zone, as a whole.

This means that if the dryer ownership is lower than 6% the energy wasted through the increase of the washing machine spinning speed is not recovered via the energy savings of the drying process. But with the 30€ subtracted and the annual energy savings discounted, the breakeven point is even higher in terms of dryers ownership and reaches 16%. For a specific individual user in the cold climatic zone, if she/he will use the dryer more than 16% of the time, it is convenient; otherwise no.

e) Conclusions

A simple calculation of the additional energy consumption for a 400 rpm improvement of the washing machine spinning speed, with the spin drying efficiency going from class D to class B, and the energy savings of the drying phase in a condenser, class C, tumble dryer due to the lower laundry moisture content was developed. Depending from the climatic zone of a country, the dryer ownership and the dryer use there is an overall energy consumption increase or a savings.

Data about the dryer ownership in Member States have been collected during the study[35] from different sources and are reported in Table 6.99 together with the estimated economic ownership threshold.

Table 6.99: Dryer ownership and threshold level for some Member States in different climatic zones

Country	Dryer ownership (%)	Year	Threshold dryer ownership level (%)
	Warm climatic zone		
MT	12,2	2001	
PO	13	2006	
SL	18	2003	62
ES	n.a.	--	
IT	n.a.	--	
GR	n.a.	--	
	Moderate climatic zone		
FR	29	2005	
DE	39	2005	
PL	41	2003	
DK	44	2004	26
IR	46	2005	
UK	54	2003	
NL	68	2005	
	Cold climatic zone		
FIN	59	2004	16
SW	52	2004	

Although no complete and updated data are available about the ownership of the dryers in countries belonging to the different climatic zones and moreover about the pattern of use (with the exception of UK[36] where the dryer is estimated to be used for 60% of the washing machine use), it is clear that for counties in the warm climatic zone the use of the dryer is far below the economic threshold. In other words, is these countries a 400 rpm higher spin speed machine is not convenient from both the energy consumption and the economic points of view: the higher energy consumption for the

[35] Source: A Portrait of the Household Appliance Industry and Market in Europe, Task 1 common deliverable.
[36] Source: BNW06: Assumptions underlying the energy projections for domestic tumble dryers, version 2.0, 19 September 2006, downloadable from http://www.mtprog.org .

washing cycle will never be recovered through the use of a dryer. Even for UK, with a nominal ownership of 54% for the dryer, if the use of this appliance is only 60% of the washing cycles, then the actual use is 32,4%, which is higher than the economic ownership threshold but less higher that probably expected. Should the ownership level be confirmed, France is in a border line situation.

The same approach can be also used to estimate the transition between the average machine with 856 rpm and RMC=69,4% to a machine with 1 367 rpm and RMC=52,2%, as described in Table 6.96, although the difference is 511 rpm, higher than the previously hypothesised 400 rpm and therefore the increase in the energy consumption for the washing machine is expected to be higher.

To achieve robust results, the previous analysis was developed considering an additional energy consumption for the improved spin speed washing machine of 31,7 Wh/cycle only, instead of 50Wh, considering that a reduced 3,4kg load could lead to a lower spinning time and therefore overall energy consumption. However, if this reduction does not occur (i.e. the spinning consumption is independent from the machine load) and the initial 50Wh/cycle are considered the minimum dryer ownership percentage necessary to compensate the higher washing machine energy consumption increases:

- warm climatic zone: 36,6% on a pure energy consumption balance basis
- moderate climatic zone: 15,3%
- cold climatic zone 9,7.

The general impression deriving from the preliminary analysis results is that the existing market division of different spin speed machines (see Table 6.95) is rational and a one minimum high spin speed machine for all of Europe is a suboptimum

In this paragraph the environmental impact assessment of the LCC and BAT cases analysed in paragraph 1.4 is carried out and the results have been compared to those calculated for the base cases in task 5. The technological improvements analysed in paragraph 1.4 do not change in sensible way the bill of material - at least for what concerns the environments impact of the production and waste phases - so the environmental analysis has been focused to the use phase only. The analysis developed in this paragraph concerns in particular the 5 kg Washing Machines and the 12 settings Dishwasher and the tool used has been the EuP Ecoreport

6.4 ENVIRONMENTAL ASSESSMENT OF THE TECHNOLOGICAL IMPROVEMENTS

In the following two paragraphs the environmental impact assessment of the LCC and BAT cases analysed in paragraphs 6.4.2 and 6.4.3 are carried out and the results have been compared to those calculated for the base case in task 5. The technological improvements analysed in these paragraphs do not change in sensible way the bill of material - at least for what concerns the environments impact of the production and waste phases - so the environmental analysis has been focused to the use phase only. The tool used for this analysis has been the EuP Ecoreport

6.4.1 Washing machine 5 kg

The following table shows the main base case, LCC and BAT data that have been taken into consideration in this analysis.

Table 6.100: WM 5 kg – Main data for comparison of BASE CASE, LLCC and BAT cases

WM 5 KG		BASE CASE	LLCC	BAT
Use	cycles/year	245	245	245
Energy consumption	kWh/cycle	0,998	0,9	0,855
Water consumption	litre/cycle	50,7	38,7	38,7
	m3/year	12,42	9,48	9,48

According to this inputs the main environmental outputs as energy consumption and air and water emissions has been calculated for all the WM life (all other parameters, as materials used, transport and end of life have been considered to be the same in the three cases).

Table 6.101:WM 5 kg – Output of LCA made by EuP-Ecoreport for BASE CASE, LLCC and BAT cases

CASE	Resources Use and Emissions	Unit	Production	Distribution	Use	END-OF-LIFE	TOTAL
01 - BASE CASE	Total Energy (GER)	MJ	3830	547	39855	-507	43725
02 - LLCC	Total Energy (GER)	MJ	3830	547	36073	-507	39943
03 - BAT	Total Energy (GER)	MJ	3830	547	34337	-507	38206
01 - BASE CASE	of which, electricity (in primary MJ)	MJ	923	1	39439	-47	40316
02 - LLCC	of which, electricity (in primary MJ)	MJ	923	1	35658	-47	36535
03 - BAT	of which, electricity (in primary MJ)	MJ	923	1	33921	-47	34798
01 - BASE CASE	Water (process)	ltr	1358	0	188942	-31	190269
02 - LLCC	Water (process)	ltr	1358	0	144590	-31	145917
03 - BAT	Water (process)	ltr	1358	0	144474	-31	145801
01 - BASE CASE	Water (cooling)	ltr	1105	0	105158	-260	106003
02 - LLCC	Water (cooling)	ltr	1105	0	95074	-260	95919
03 - BAT	Water (cooling)	ltr	1105	0	90443	-260	91288
01 - BASE CASE	Waste, non-haz./ landfill	g	69120	290	46410	-146	115674
02 - LLCC	Waste, non-haz./ landfill	g	69120	290	42025	-146	111289
03 - BAT	Waste, non-haz./ landfill	g	69120	290	40012	-146	109276
01 - BASE CASE	Waste, hazardous/ incinerated	g	176	6	910	362	1454
02 - LLCC	Waste, hazardous/ incinerated	g	176	6	823	362	1367
03 - BAT	Waste, hazardous/ incinerated	g	176	6	783	362	1327
01 - BASE CASE	Greenhouse Gases in GWP100	kg CO2 eq.	245	34	1753	-8	2024
02 - LLCC	Greenhouse Gases in GWP100	kg CO2 eq.	245	34	1588	-8	1859
03 - BAT	Greenhouse Gases in GWP100	kg CO2 eq.	245	34	1512	-8	1783
01 - BASE CASE	Ozone Depletion, emissions	mg R-11 eq.					
02 - LLCC	Ozone Depletion, emissions	mg R-11 eq.					
03 - BAT	Ozone Depletion, emissions	mg R-11 eq.					
01 - BASE CASE	Acidification, emissions	g SO2 eq.	1870	102	10202	-12	12162
02 - LLCC	Acidification, emissions	g SO2 eq.	1870	102	9228	-12	11188
03 - BAT	Acidification, emissions	g SO2 eq.	1870	102	8781	-12	10741
01 - BASE CASE	Volatile Organic Compounds (VOC)	g	7	8	21	1	37

CASE	Resources Use and Emissions	Unit	Production	Distribution	Use	END-OF-LIFE	TOTAL
02 - LLCC	Volatile Organic Compounds (VOC)	g	7	8	20	1	36
03 - BAT	Volatile Organic Compounds (VOC)	g	7	8	19	1	35
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq	427	2	263	0	691
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq	427	2	238	0	666
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq	427	2	227	0	655
01 - BASE CASE	Heavy Metals	mg Ni eq.	2429	15	784	24	3251
02 - LLCC	Heavy Metals	mg Ni eq.	2429	15	719	24	3186
03 - BAT	Heavy Metals	mg Ni eq.	2429	15	689	24	3156
01 - BASE CASE	PAHs	mg Ni eq.	190	19	164	-2	371
02 - LLCC	PAHs	mg Ni eq.	190	19	157	-2	363
03 - BAT	PAHs	mg Ni eq.	190	19	153	-2	360
01 - BASE CASE	Particulate Matter (PM, dust)	g	388	1248	1632	375	3643
02 - LLCC	Particulate Matter (PM, dust)	g	388	1248	1611	375	3622
03 - BAT	Particulate Matter (PM, dust)	g	388	1248	1602	375	3612
01 - BASE CASE	Heavy Metals	mg Hg/20	1597	0	270	2	1870
02 - LLCC	Heavy Metals	mg Hg/20	1597	0	246	2	1845
03 - BAT	Heavy Metals	mg Hg/20	1597	0	235	2	1834
01 - BASE CASE	Eutrophication	g PO4	40,71	0,01	1,62	-0,94	41,39
02 - LLCC	Eutrophication	g PO4	40,71	0,01	1,50	-0,94	41,27
03 - BAT	Eutrophication	g PO4	40,71	0,01	1,45	-0,94	41,22
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq					
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq					
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq					

Table 6.102 shows the decrease in percentage of the LLCC and BAT main environmental indicators with respect the base case.

For some environmental impact indicators (as ozone depletion and POP) no value have been reported because, according to EuP Ecoreport, these impacts are negligible.

Table 6.102: WM 5 kg – Percentage decrease of LCA's outputs from Base case vs LLCC and BAT cases

CASE	Resources Use and Emissions	UNIT	USE	TOTAL
01 - BASE CASE	Total Energy (GER)	MJ		
02 - LLCC	Total Energy (GER)	MJ	-9%	-9%
03 - BAT	Total Energy (GER)	MJ	-14%	-13%
01 - BASE CASE	of which, electricity (in primary MJ)	MJ		
02 - LLCC	of which, electricity (in primary MJ)	MJ	-10%	-9%
03 - BAT	of which, electricity (in primary MJ)	MJ	-14%	-14%
01 - BASE CASE	Water (process)	ltr		
02 - LLCC	Water (process)	ltr	-23%	-23%
03 - BAT	Water (process)	ltr	-24%	-23%
01 - BASE CASE	Water (cooling)	ltr		
02 - LLCC	Water (cooling)	ltr	-10%	-10%
03 - BAT	Water (cooling)	ltr	-14%	-14%

CASE	Resources Use and Emissions	UNIT	USE	TOTAL
01 - BASE CASE	Waste, non-haz./ landfill	g		
02 - LLCC	Waste, non-haz./ landfill	g	-9%	-4%
03 - BAT	Waste, non-haz./ landfill	g	-14%	-6%
01 - BASE CASE	Waste, hazardous/ incinerated	g		
02 - LLCC	Waste, hazardous/ incinerated	g	-10%	-6%
03 - BAT	Waste, hazardous/ incinerated	g	-14%	-9%
01 - BASE CASE	Greenhouse Gases in GWP100	kg CO2 eq.		
02 - LLCC	Greenhouse Gases in GWP100	kg CO2 eq.	-9%	-8%
03 - BAT	Greenhouse Gases in GWP100	kg CO2 eq.	-14%	-12%
01 - BASE CASE	Ozone Depletion, emissions	mg R-11 eq.		
02 - LLCC	Ozone Depletion, emissions	mg R-11 eq.		
03 - BAT	Ozone Depletion, emissions	mg R-11 eq.		
01 - BASE CASE	Acidification, emissions	g SO2 eq.		
02 - LLCC	Acidification, emissions	g SO2 eq.	-10%	-8%
03 - BAT	Acidification, emissions	g SO2 eq.	-14%	-12%
01 - BASE CASE	Volatile Organic Compounds (VOC)	g		
02 - LLCC	Volatile Organic Compounds (VOC)	g	-7%	-4%
03 - BAT	Volatile Organic Compounds (VOC)	g	-10%	-6%
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq		
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq	-9%	-4%
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq	-14%	-5%
01 - BASE CASE	Heavy Metals	mg Ni eq.		
02 - LLCC	Heavy Metals	mg Ni eq.	-8%	-2%
03 - BAT	Heavy Metals	mg Ni eq.	-12%	-3%
01 - BASE CASE	PAHs	mg Ni eq.		
02 - LLCC	PAHs	mg Ni eq.	-5%	-2%
03 - BAT	PAHs	mg Ni eq.	-7%	-3%
01 - BASE CASE	Particulate Matter (PM, dust)	g		
02 - LLCC	Particulate Matter (PM, dust)	g	-1%	-1%
03 - BAT	Particulate Matter (PM, dust)	g	-2%	-1%
01 - BASE CASE	Heavy Metals	mg Hg/20		
02 - LLCC	Heavy Metals	mg Hg/20	-9%	-1%
03 - BAT	Heavy Metals	mg Hg/20	-13%	-2%
01 - BASE CASE	Eutrophication	g PO4		
02 - LLCC	Eutrophication	g PO4	-7,18%	-0,28%
03 - BAT	Eutrophication	g PO4	-10,48%	-0,41%
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq		
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq		
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq		

6.4.2 Dish Washer 12 ps

In the following table main data for base case, LCC and BAT has been reported.

Table 6.103: DW 12 ps – Main data for comparison of BASE CASE, LLCC and BAT cases

DW12ps		BASE CASE	LLCC	BAT
Use	cycles/year	280	280	280
Energy consumption	kWh/cycle	1,07	1,009	0,914
Water consumption	litre/cycle	15,2	11	10,6
	m3/year	4,256	3,08	2,968

According to this input the following output, as energy consumption and air and water emissions has been calculated for all the life of the DW (all other parameters, as materials used, transport and end of life have been considered to be the same in the three cases).

Table 6.104: DW 12 ps – Output of LCA made by EuP-Ecoreport for BASE CASE, LLCC and BAT cases

CASE	Resources Use and Emissions	UNIT	PRODUCTION	DISTRIBUTION	USE	END-OF-LIFE	TOTAL
01 - BASE CASE	Total Energy (GER)	MJ	**3945**	**595**	**43250**	**-291**	**47499**
02 - LLCC	Total Energy (GER)	MJ	**3945**	**595**	**41008**	**-291**	**45257**
03 - BAT	Total Energy (GER)	MJ	**3945**	**595**	**37517**	**-291**	**41766**
01 - BASE CASE	of which, electricity (in primary MJ)	MJ	**1142**	**1**	**39535**	**-29**	**40649**
02 - LLCC	of which, electricity (in primary MJ)	MJ	**1142**	**1**	**37293**	**-29**	**38407**
03 - BAT	of which, electricity (in primary MJ)	MJ	**1142**	**1**	**33802**	**-29**	**34916**
01 - BASE CASE	Water (process)	ltr	**1955**	**0**	**55933**	**-19**	**57869**
02 - LLCC	Water (process)	ltr	**1955**	**0**	**41084**	**-19**	**43019**
03 - BAT	Water (process)	ltr	**1955**	**0**	**39451**	**-19**	**41386**
01 - BASE CASE	Water (cooling)	ltr	**1213**	**0**	**105407**	**-160**	**106461**
02 - LLCC	Water (cooling)	ltr	**1213**	**0**	**99429**	**-160**	**100483**
03 - BAT	Water (cooling)	ltr	**1213**	**0**	**90119**	**-160**	**91173**
01 - BASE CASE	Waste, non-haz./ landfill	g	**66470**	**313**	**50318**	**781**	**117884**
02 - LLCC	Waste, non-haz./ landfill	g	**66470**	**313**	**47719**	**781**	**115284**
03 - BAT	Waste, non-haz./ landfill	g	**66470**	**313**	**43671**	**781**	**111236**
01 - BASE CASE	Waste, hazardous/ incinerated	g	**409**	**6**	**991**	**1514**	**2920**
02 - LLCC	Waste, hazardous/ incinerated	g	**409**	**6**	**939**	**1514**	**2869**
03 - BAT	Waste, hazardous/ incinerated	g	**409**	**6**	**859**	**1514**	**2788**
01 - BASE CASE	Greenhouse Gases in GWP100	kg CO2 eq.	**270**	**37**	**1901**	**0**	**2208**
02 - LLCC	Greenhouse Gases in GWP100	kg CO2 eq.	**270**	**37**	**1804**	**0**	**2110**
03 - BAT	Greenhouse Gases in GWP100	kg CO2 eq.	**270**	**37**	**1651**	**0**	**1958**
01 - BASE CASE	Ozone Depletion, emissions	mg R-11 eq.					
02 - LLCC	Ozone Depletion, emissions	mg R-11 eq.					
03 - BAT	Ozone Depletion, emissions	mg R-11 eq.					

CASE	Resources Use and Emissions	UNIT	PRODUCTION	DISTRIBUTION	USE	END-OF-LIFE	TOTAL
01 - BASE CASE	Acidification, emissions	g SO2 eq.	**2155**	**111**	**11084**	**7**	**13357**
02 - LLCC	Acidification, emissions	g SO2 eq.	**2155**	**111**	**10507**	**7**	**12780**
03 - BAT	Acidification, emissions	g SO2 eq.	**2155**	**111**	**9608**	**7**	**11881**
01 - BASE CASE	Volatile Organic Compounds (VOC)	g	**9**	**8**	**22**	**1**	**41**
02 - LLCC	Volatile Organic Compounds (VOC)	g	**9**	**8**	**22**	**1**	**40**
03 - BAT	Volatile Organic Compounds (VOC)	g	**9**	**8**	**20**	**1**	**39**
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq	**433**	**2**	**285**	**6**	**726**
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq	**433**	**2**	**270**	**6**	**711**
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq	**433**	**2**	**247**	**6**	**688**
01 - BASE CASE	Heavy Metals	mg Ni eq.	**3249**	**16**	**850**	**53**	**4169**
02 - LLCC	Heavy Metals	mg Ni eq.	**3249**	**16**	**812**	**53**	**4130**
03 - BAT	Heavy Metals	mg Ni eq.	**3249**	**16**	**752**	**53**	**4070**
01 - BASE CASE	PAHs	mg Ni eq.	**152**	**20**	**169**	**-2**	**340**
02 - LLCC	PAHs	mg Ni eq.	**152**	**20**	**165**	**-2**	**335**
03 - BAT	PAHs	mg Ni eq.	**152**	**20**	**158**	**-2**	**328**
01 - BASE CASE	Particulate Matter (PM, dust)	g	**295**	**1370**	**1650**	**431**	**3746**
02 - LLCC	Particulate Matter (PM, dust)	g	**295**	**1370**	**1637**	**431**	**3733**
03 - BAT	Particulate Matter (PM, dust)	g	**295**	**1370**	**1618**	**431**	**3714**
01 - BASE CASE	Heavy Metals	mg Hg/20	**2150**	**0**	**279**	**13**	**2442**
02 - LLCC	Heavy Metals	mg Hg/20	**2150**	**0**	**264**	**13**	**2427**
03 - BAT	Heavy Metals	mg Hg/20	**2150**	**0**	**242**	**13**	**2405**
01 - BASE CASE	Eutrophication	g PO4	**57**	**0**	**4859**	**0**	**4917**
02 - LLCC	Eutrophication	g PO4	**57**	**0**	**4859**	**0**	**4917**
03 - BAT	Eutrophication	g PO4	**57**	**0**	**4859**	**0**	**4917**
01 - BASE CASE	Persistent Organic Pollutants (POP)	ng i-Teq					
02 - LLCC	Persistent Organic Pollutants (POP)	ng i-Teq					
03 - BAT	Persistent Organic Pollutants (POP)	ng i-Teq					

Table 6.105 shows the decrease in percentage of the LLCC and BAT main environmental indicators with respect the base case.

Also in this case, the ozone depletion and POP environmental impact indicators have not been reported because, according to EuP Ecoreport, these impacts are negligible.

Table 6.105: DW 12 ps – Percentage decrease of LCA's outputs from Base case vs LLCC and BAT cases

CASE	OUTPUT	Resources Use and Emissions	UNIT	USE	TOTAL
01 - BASE CASE	**Other Resources & Waste**	Total Energy (GER)	MJ		
02 - LLCC	**Other Resources & Waste**	Total Energy (GER)	MJ	-5,18%	-4,72%
03 - BAT	**Other Resources & Waste**	Total Energy (GER)	MJ	-13,26%	-12,07%
01 - BASE CASE	**Other Resources & Waste**	of which, electricity (in primary MJ)	MJ		
02 - LLCC	**Other Resources & Waste**	of which, electricity (in primary MJ)	MJ	-5,67%	-5,51%
03 - BAT	**Other Resources & Waste**	of which, electricity (in primary MJ)	MJ	-14,50%	-14,10%
01 - BASE CASE	**Other Resources & Waste**	Water (process)	ltr		

CASE	OUTPUT	Resources Use and Emissions	UNIT	USE	TOTAL
02 - LLCC	**Other Resources & Waste**	Water (process)	ltr	-26,55%	-25,66%
03 - BAT	**Other Resources & Waste**	Water (process)	ltr	-29,47%	-28,48%
01 - BASE CASE	**Other Resources & Waste**	Water (cooling)	ltr		
02 - LLCC	**Other Resources & Waste**	Water (cooling)	ltr	-5,67%	-5,62%
03 - BAT	**Other Resources & Waste**	Water (cooling)	ltr	-14,50%	-14,36%
01 - BASE CASE	**Other Resources & Waste**	Waste, non-haz./ landfill	g		
02 - LLCC	**Other Resources & Waste**	Waste, non-haz./ landfill	g	-5,17%	-2,20%
03 - BAT	**Other Resources & Waste**	Waste, non-haz./ landfill	g	-13,21%	-5,64%
01 - BASE CASE	**Other Resources & Waste**	Waste, hazardous/ incinerated	g		
02 - LLCC	**Other Resources & Waste**	Waste, hazardous/ incinerated	g	-5,21%	-1,77%
03 - BAT	**Other Resources & Waste**	Waste, hazardous/ incinerated	g	-13,33%	-4,52%
01 - BASE CASE	**Emissions (Air)**	Greenhouse Gases in GWP100	kg CO2 eq.		
02 - LLCC	**Emissions (Air)**	Greenhouse Gases in GWP100	kg CO2 eq.	-5,15%	-4,43%
03 - BAT	**Emissions (Air)**	Greenhouse Gases in GWP100	kg CO2 eq.	-13,16%	-11,33%
01 - BASE CASE	**Emissions (Air)**	Ozone Depletion, emissions	mg R-11 eq.		
02 - LLCC	**Emissions (Air)**	Ozone Depletion, emissions	mg R-11 eq.		
03 - BAT	**Emissions (Air)**	Ozone Depletion, emissions	mg R-11 eq.		
01 - BASE CASE	**Emissions (Air)**	Acidification, emissions	g SO2 eq.		
02 - LLCC	**Emissions (Air)**	Acidification, emissions	g SO2 eq.	-5,21%	-4,32%
03 - BAT	**Emissions (Air)**	Acidification, emissions	g SO2 eq.	-13,32%	-11,05%
01 - BASE CASE	**Emissions (Air)**	Volatile Organic Compounds (VOC)	g		
02 - LLCC	**Emissions (Air)**	Volatile Organic Compounds (VOC)	g	-3,76%	-2,07%
03 - BAT	**Emissions (Air)**	Volatile Organic Compounds (VOC)	g	-9,62%	-5,30%
01 - BASE CASE	**Emissions (Air)**	Persistent Organic Pollutants (POP)	ng i-Teq		
02 - LLCC	**Emissions (Air)**	Persistent Organic Pollutants (POP)	ng i-Teq	-5,16%	-2,02%
03 - BAT	**Emissions (Air)**	Persistent Organic Pollutants (POP)	ng i-Teq	-13,18%	-5,18%
01 - BASE CASE	**Emissions (Air)**	Heavy Metals	mg Ni eq.		
02 - LLCC	**Emissions (Air)**	Heavy Metals	mg Ni eq.	-4,52%	-0,92%
03 - BAT	**Emissions (Air)**	Heavy Metals	mg Ni eq.	-11,57%	-2,36%
01 - BASE CASE	**Emissions (Air)**	PAHs	mg Ni eq.		
02 - LLCC	**Emissions (Air)**	PAHs	mg Ni eq.	-2,61%	-1,30%
03 - BAT	**Emissions (Air)**	PAHs	mg Ni eq.	-6,68%	-3,33%
01 - BASE CASE	**Emissions (Air)**	Particulate Matter (PM, dust)	g		
02 - LLCC	**Emissions (Air)**	Particulate Matter (PM, dust)	g	-0,75%	-0,33%
03 - BAT	**Emissions (Air)**	Particulate Matter (PM, dust)	g	-1,91%	-0,84%
01 - BASE CASE	**Emissions (Water)**	Heavy Metals	mg Hg/20		
02 - LLCC	**Emissions (Water)**	Heavy Metals	mg Hg/20	-5,18%	-0,59%
03 - BAT	**Emissions (Water)**	Heavy Metals	mg Hg/20	-13,25%	-1,51%
01 - BASE CASE	**Emissions (Water)**	Eutrophication	g PO4		
02 - LLCC	**Emissions (Water)**	Eutrophication	g PO4	-0,0014%	-0,0014%
03 - BAT	**Emissions (Water)**	Eutrophication	g PO4	-0,0036%	-0,0036%
01 - BASE CASE	**Emissions (Water)**	Persistent Organic Pollutants (POP)	ng i-Teq		

CASE	OUTPUT	Resources Use and Emissions	UNIT	USE	TOTAL
02 - LLCC	**Emissions (Water)**	Persistent Organic Pollutants (POP)	ng i-Teq		
03 - BAT	**Emissions (Water)**	Persistent Organic Pollutants (POP)	ng i-Teq		

7 Task 7: Scenario, Policy, Impact and Sensitivity Analysis

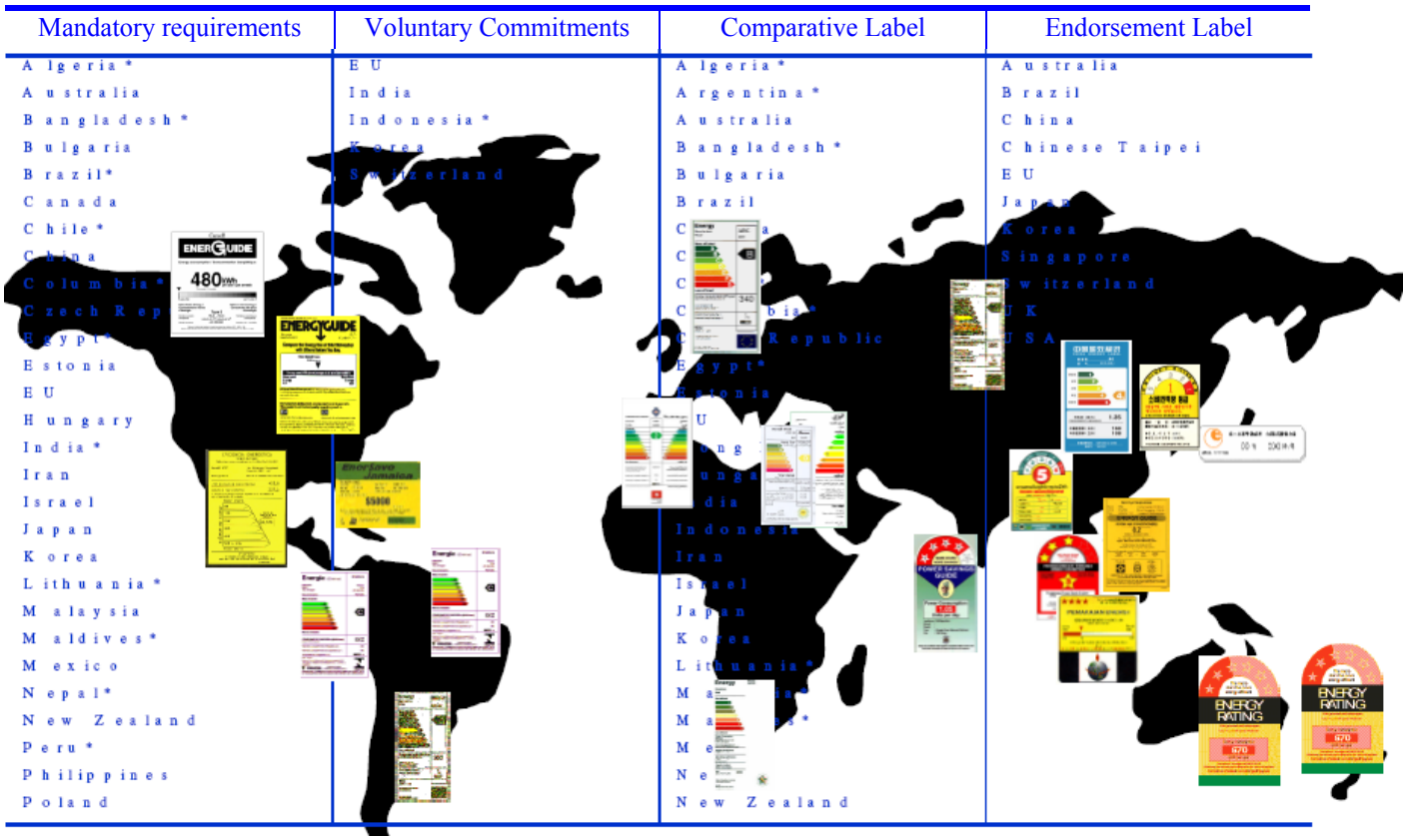
7.1 SUBTASK 7.1: WORLDWIDE SCENARIOS FOR WASH APPLIANCES

In this Subtask the main policy measures existing and planned worldwide for cold appliances will be summarised and tentatively compared with those of the EU to evaluate the European position in the international context.

7.1.1 A summary of the worldwide policy measures for wash appliances

As described in Task 1, household appliance policy measures (labelling schemes and efficiency requirements) are in force in most industrialised economies and many industrialising economies worldwide. The number of nations adopting energy efficiency requirements and labels for EuPs is growing rapidly, from 9 in 1984 to 36 in 1994 to over 54 in 2006 (Figure 7.1). The number of regulations worldwide on individual appliances and equipment is growing even more rapidly, increasing from 543 to 878 between 2000 and 2004[37].

Figure 7.1: ***International use of mandatory and voluntary policy measures in 2006***[38]



[37] Source: APEC," A Strategic Vision for International Cooperation on Energy Standards and Labelling", June 2006.

[38] Source: P. Waide, EEDAL End of Term Report, EEDAL 06, London, June 2006.

The most common policies and measure for wash appliances are labelling (efficiency or other type) and efficiency requirements, implemented in many countries, as described in Table 7.1. The main outcome of the Table is that policy measures for dishwashers are less spread than for washing machines and that the harmonisation is either with the US scheme or with the EU one, depending mostly on the geographical position of the single Countries and the political influence area of the two main schemes.

Table 7.1: Labelling schemes and energy requirements for dishwashers and washing machines around the world[39]

Country	**Dishwashers**			**Washing machines**		
	Min. eff. requirements	labelling		Min. eff. requirements	labelling	
		comparative	endorsement		comparative	endorsement
Algeria	--	--	--	UC	--	--
Argentina	--	UC	--	--	UC	--
Australia	**M**[3,5]	**M**[3,5]	V	**M**[3,5]	**M**[3,5]	V
Brazil	--	UC	--	V	**M**[2]	V
Canada	**M**[4]	**M**[4]	V[4]	**M**[4]	**M**[4]	V[4]
Chile	--	UC	--	--	UC	--
China	--	--	--	**M**	--	V
Chinese Taipei	--	--	--	--	--	V[4]
Colombia	--	--	--	--	UC	--
Egypt	--	--	--	**M**	**M**[3]	--
EU27	**V**	**M**	V	**V**	**M**	V
Hong Kong (CN)	--	--	--	--	V	--
Indonesia	--	--	--	UC	--	--
Iran	--	--	--	--	**M**[3]	--
Israel	**M**	**M**	--	**M**	**M**	--
Jordan	--	--	--	--	**M**[3]	--
Korea	**M**	**M**	--	**M**	**M**	--
Malaysia	--	--	--	UC	--	--
Mexico	--	--	--	**M**[4]	**M**[4]	V
New Zealand	**M**[5]	**M**[5]	V	**M**[5]	**M**[5]	V
Peru	--	--	--	UC	UC	--
Russia	**M**	--	--	UC	--	--
Singapore	--	--	--	--	V[2]	--
Switzerland	**V**[2]	**M**[2]	V	**V**[2]	**M**[2]	V
South Africa	--	--	--	**V**[2]	--	--
Thailand	--	--	--	--	--	V
Turkey	**V**[2]	**M**[2]	--	**V**[2]	**M**[2]	--
United States	**M**	**M**	V	**M**	**M**	V
Vietnam	--	UC	--	--	UC	--

M = Mandatory, V = voluntary, UC = under consideration

[1] Framework legislation is passed but the implementing legislation is believed to still be under consideration.

[2] Harmonised with EU;

[3]Partially harmonised with EU;

[4] Partially or fully harmonised with USA

[5] Harmonised between Australia and New Zealand.

The comparison of the different efficiency requirements for wash appliances around the world with those applied in the EU could be an interesting exercise in order to see if there are any major differences in performance. However, the standard used to measure the energy consumption and the other parameters are based on different measurement methods as is applied in Europe, which makes comparison almost impossible. Wash appliance standards have been described in detail in Task 1 and are here summarised.

[39] Source: www.clasponline.org .

In particular for **dishwashers**:

- in Australia and New Zealand, AS/NZS 2007.1 standard includes a number of requirements

derived from the 3rd Edition of IEC 60436: 2004, which will bring it closer to the IEC standard, but differences still occur;
- in USA dishwashers are measured under the US Department of Energy Code of Federal Regulations (CFR 10, Part 430, Subpart B, Appendix C - U*niform Test Method for Measuring the Energy Consumption of Dishwashers*), which incorporates and refers to the American National Standard, Household Electric Dishwashers, ANSI/AHAM DW-1-1992;
- in the EU, EN 50242 Ed.2/EN 60436, was published in October 2005. The standard contains the text of IEC60436, Edition 3 with the changes and added text as common modifications. The standard in Europe gets both numbers, EN60436 and EN50242 due to the labelling mandate of the European Commission.

For **washing machines**:
- in Australia and New Zealand AS/NZS 2040.1 is based on IEC 60456:1994, *Electric clothes washing machines for household use-Methods for measuring the performance*. But it differs from IEC standard in a number of ways:
- the standard for washing machine in Japan is JIS C 9811:1999 "*Electric clothes washing machines for household use - Methods for measuring the performance*", IEC 60456:1994 (MOD). JIS standard reflects the structure of the IEC standard for washing machines, but changes in structure are permitted provided that the altered structure permits easy comparison of the content of the two standards;
- in the EU, EN 60456:2004 includes the text of IEC 60456:2003 together with the common modifications prepared by CENELEC.

7.1.1.1 Australia and New Zealand

a) The energy efficiency requirements

Although no minimum energy efficiency requirements have been set for **dishwashers**, a number of requirements must be met by this product during a test for energy consumption. These include:
- *washing index*: the washing index of the test machine must exceed the specified value measured on the reference machine, which is tested in parallel. The reference machine is a dishwasher which specially constructed and calibrated for this purpose;
- *drying index*: the drying index of the test machine must exceed 50%;
- *rated capacity*: all specified load items shall be supported;
- *water consumption*: shall not exceed 110% of the value stated by the manufacturer.
- *water pressure*: machine shall be capable of operating at the maximum and minimum water pressure stated by the manufacturer;
- *energy consumption* is determined on the program recommended by the manufacturer for energy labelling that is capable of meeting the above mentioned requirements; from April 2004, all dishwashers are to be re-labelled using the "normal" program.

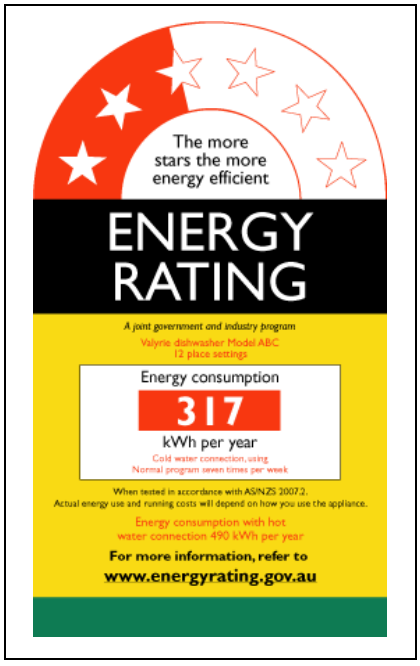
The same occurs for **washing machines**, to be eligible for an energy label. Products are classified into either drum type (generally front loading) or non drum type (all other types such as top loaders with impellers or agitators, twin tub machines). A number of performance requirements must be met by machines during a test for energy consumption. These include:
- *wash performance*: soil removal from soiled swatches which are attached to a clothes load of rated capacity, must exceed 80% (there are also limits on the variability of the wash)
- *spinning performance*: the water extraction index (defined as ratio of the remaining water in the load after the final spin to the bone dry mass) must not exceed 1,1;
- *severity of washing*: the severity of washing index must not exceed 0,3 after a single run;

- *water consumption*: shall not exceed 110% of the value stated by the manufacturer;
- *water pressure*: machine shall be capable of operating at the maximum and minimum water pressure stated by the manufacturer;
- *rinse performance*: from July 2006 a rinse performance requirement was set;
- *energy consumption* is determined on the program recommended by the manufacturer for a normally soiled cotton load at the rated capacity; the minimum wash temperature for energy labelling tests is 35°C.

b) The energy rating labelling scheme

AS/NZS 2007: *Performance of household electrical appliances - Dishwashers Part 2: Energy labelling requirements* – includes algorithms for the calculation of the energy efficiency star rating and projected energy usage, performance requirements, details of the energy label and requirements for the valid application thereof. Over a year, it is assumed that the dishwasher is used 7 times per week (365 times per year). This gives the Comparative Energy Consumption (CEC) shown in the Energy Rating label (Figure 7.2). The program used for the energy labelling program is the "normal" program. The Base Energy Consumption (BEC) defines the "1 star" line for the specific product. An additional star is awarded when the CEC of the model is reduced by a defined percentage from the BEC. The energy reduction per star is 30% for dishwashers. For example, a model that had a CEC that was 0,70 of the BEC or less would achieve 2 stars. Similar, a CEC of 0,49 (0,70 x 0,70) of the BEC or less would achieve 3 stars and so on

Figure 7.2: Energy rating for a 12 place settings dishwasher in Australia



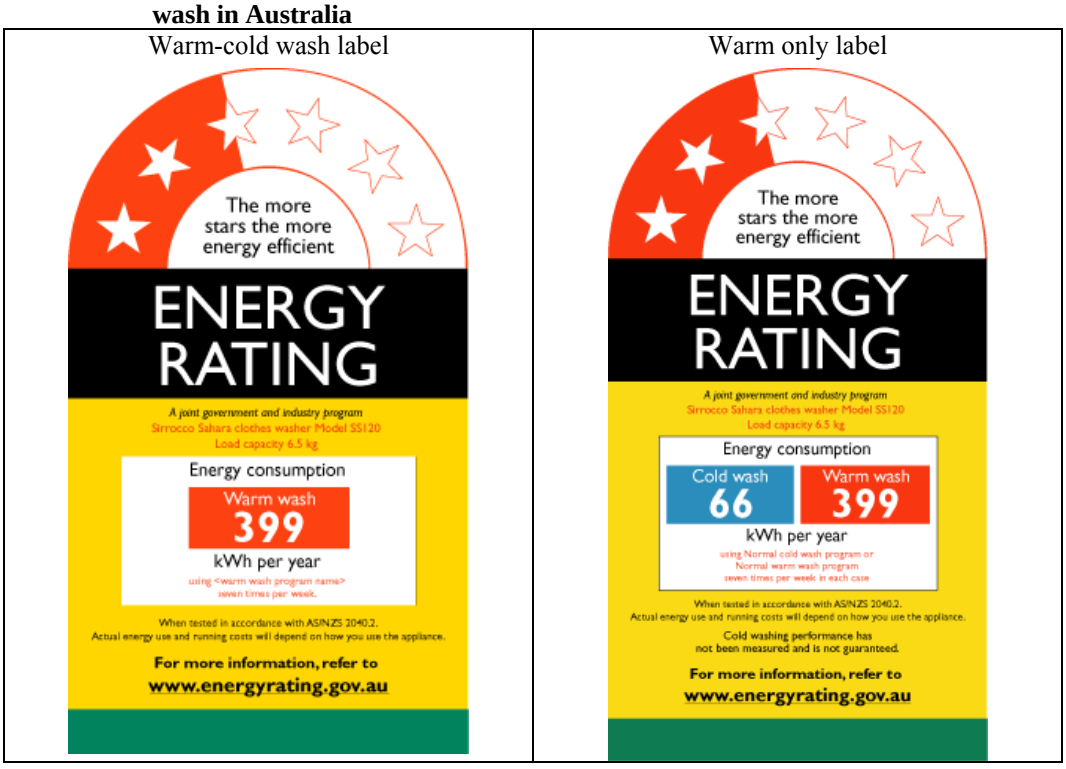
The warm wash energy consumption (warm CEC) and a component of residual moisture (spin performance) are used to define the star rating for **washing machines** in comparison with the BEC. Therefore a model that has a good spin performance may get a marginally higher star rating than a model of the same capacity and CEC with a poor spin performance. The Base Energy Consumption (BEC) defines the "1 star" line for the particular product. An additional star is awarded when the CEC of the model is reduced by a defined percentage from the BEC. The energy reduction per star is 27% for clothes washers. For example, a model that had a CEC that was 0,73 of the BEC or less

would achieve 2 stars (Figure 7.3). Similar, a CEC of 0,533 (0,73 x 0,73) of the BEC or less would achieve 3 stars and so on. Front and top loading models are rated on the same basis.

The warm wash energy consumption (warm CEC) and a component of residual moisture (spin performance) are used to define the star rating in comparison with the BEC. Therefore a model that has a good spin performance may get a marginally higher star rating than a model of the same capacity and CEC with a poor spin performance.

Over a year, it is assumed that the machine is used 7 times per week at rated capacity on a warm wash (warm Comparative Energy Consumption, in red in the label shown in Figure 7.3); a value for a cold wash energy of 7 times per week is also shown on the label (cold CEC in blue). The washing machine is labelled on the "normal" or "regular" program (program specified for a normally soiled cotton load).

Figure 7.3: Energy rating for washing machines for machines with warm wash only and with warm and cold wash in Australia



c) The TESAW and the future Energy Star scheme

The Tower Energy Saver Award or TESAW[40] is an award system to help consumers quickly identify the most efficient products on the market. TESAW complements the mandatory labelling with an endorsement label. Each year, the energy efficiency of all products on the market is reviewed. the product must meet or exceed the performance requirements as set out in the performance criteria schedules. TESAW criteria for 2006 for wash appliances are[41]:

- dishwashers: appliances registered for energy labelling and have achieve 3,5 stars or more
- washing machines: appliances registered for energy labelling and achieve 4,5 stars or more.

[40] http://www.energyrating.gov.au/tesaw-main.html.
[41] Source: Top Energy Saver Award Winner: Final Award Criteria for 2006 – January 2006.

In 2005 detailed discussions and negotiations were held with the US Environmental Protection Agency and the US Department of Energy, resulted in an in-principle agreement that Australia and New Zealand could set local Energy Star criteria for products that were sold in the Australasian market (such as white goods, where the USA had their own domestic criteria), subject to detailed review by EPA and DOE on a product by product basis. This has been agreed on the basis that the energy star label would be available on products that are specifically for sale in Australia and New Zealand and would not appear on the US market. To allow a smooth transition from TESAW to Energy Star, EEEC has decided to continue the TESAW scheme for each product until suitable Energy Star criteria are finalised. At present it is not known when this will happen.

d) The water efficiency labelling scheme

The Commonwealth Department of the Environment and Heritage introduced in 2003 a mandatory Water Efficient Labelling and Standards (WELS) Scheme that applies national mandatory water efficiency labelling and minimum performance requirements to household water-using products and replaces the voluntary scheme in force since 1998. The specified products are: washing machines, dishwashers, lavatory equipment, showers, tap equipment and urinal equipment; flow controllers may be voluntarily rated and labelled.

The requirements and timetable for the implementation of the WELS scheme apply in Australia only. For New Zealand, the exact details of the WELS process implementation date have yet to be finalised, but the date is intended to be 1st December 2007[42].

The requirements of the WELS scheme generally only apply to new products and not to second-hand products. However, products that are imported second-hand to be supplied in Australia will be subject to the requirements.

The dishwashers and washing machines SRI (Star Rating Index) is calculated as:

$$\text{Star Rating Index} = 1 + \frac{\log_e\left(\frac{WC}{BWC}\right)}{\log_e(1 - WRF)}$$

where:

- Star Rating Index = fractional star rating used to determine the number of stars to appear on the label, rounded down to the nearest half star rating
- WC = water consumption of the model in litres
- BWC = base water consumption = 2,5 + P × 1,6 and P = number of place settings of the *dishwasher*
- BWC = base water consumption = 30 × C and C = rated load capacity of the *washing machine* (kg) as determined under AS 2040.1, rounded to the nearest 0,1 litre
- WRF = water reduction factor per additional star (17,5%) = 0,175.

The water consumption of a washing machine is the higher of (a) the claimed total water consumption of the warm-wash or (b) the claimed total water consumption of the cold-wash. In Figure 7.4 the water rating label for dishwashers is shown.

[42] Source: Water Efficiency Labelling Standards (WELS), at: www.mfte.govt.nz.

Figure 7.4: Water rating label for a 12 place setting dishwasher under WELS scheme



e) The rinse performance requirements

Assessment of the rinse performance of a washing machine is based upon the measurement of the apparent mass of retained marker (PBIS) in the load at the completion of the program. The pass mark for rinse performance has been set at 2,25 mg PBIS/kg load. The introduction of a rinse performance requirement facilitated the introduction of mandatory water efficiency rating and labelling: without a rinse performance requirement higher water efficiency rating could be achieved by reducing rinse performance levels that may not meet the needs of washing machine users.

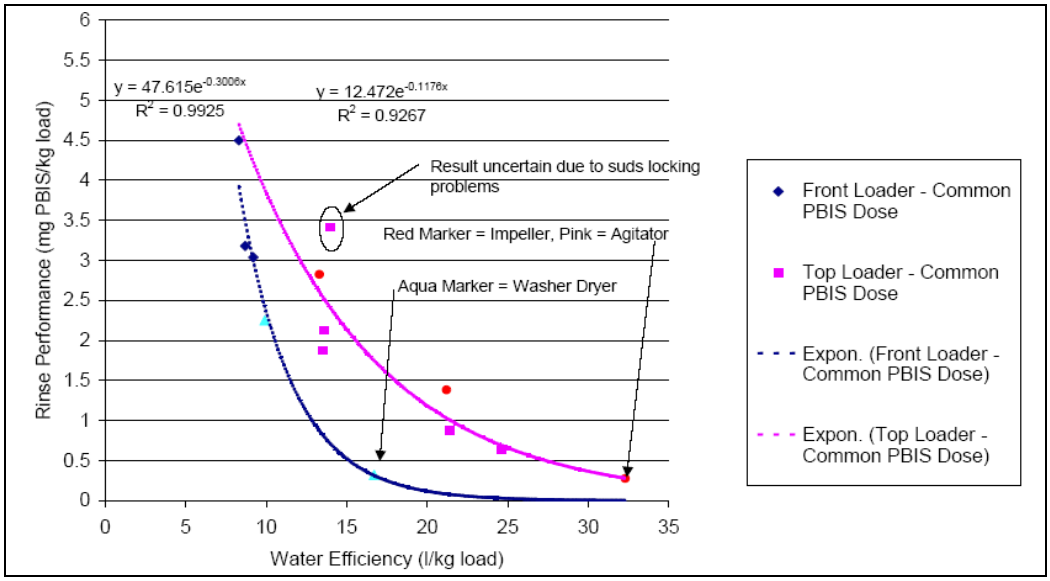
The results of a test developed on 8 top loader machines and 5 front loader machines (a representative cross section of the product available in 2004 in the Australian market) including a wide range of water efficiencies are presented in Figure 7.5[43], where the mass of retained PBIS is plotted against the water efficiency (l/kg load). The trend lines show a clear relationship between water efficiency and rinse performance whereby an increase in water efficiency will result in a decrease in rinse performance. However, for a given water efficiency some significant variation in rinse performance between different models was found.

f) The standby requirements

The Australian Standby Power Strategy 2002-2012 contains a wide range of possible policy measures to address excessive standby power. The document sets out the long-term strategy to address excessive standby energy used by consumer appliances and equipment. The strategy

[43] Source: Energy Efficient Strategies, Method for the Determination of Rinse Performance in Clothes Washers, Summary Report, Report for The Department of Environment and Heritage – Australian Federal Government, June 2005

Figure 7.5: Rinse performance (PBIS) vs. water efficiency for a representative sample of washing machines in the Australian market in 2004



foresees:

1. outlines the measures that governments will use to address excessive standby;
2. identifies the products to be targeted in the first of three-year rolling plans under the strategy;
3. establishes the procedure whereby standby targets will be set for each of the targeted products (Stage 1 targets);
4. identifies the sanctions that will apply should suppliers not meet the targets for these products (Stage 2 targets).

Stage 1 and 2 targets for dishwashers and washing machines are:

- Stage 1 (2007): off mode power < 1W, end of cycle mode power < 4W
- Stage 2 (2012): off mode power < 0,3W, end of cycle mode power < 1W

where:

- off mode power = lowest power when connected to the mains. Limit is applicable to models which have an off mode;
- end of programme power = power consumed when the machine has ended the program or cycle, where the unit does not revert to off mode after a fixed period.

The strategy sets out a number of possible policy tools that were to be considered on a product by product basis as follows:

- Promotion of Energy Star
- Industry Codes of Conduct
- Publication of targets in Australian Standards
- Collection of data for new products
- Publication of standby data for products
- Inclusion of standby into the energy label for selected products
- Introduction of MEPS on standby for selected products
- Warning label for products with high standby.

The purpose is to provide that Australian products will meet the ultimate target, of one watt in 2012.

Contemporarily, investigations regarding low power modes and **the inclusion of standby power into the energy label** have been developed for wash appliances and these were implemented in late 2005 with a transition period to April 2007. After this date all dishwashers and washing machines will have standby energy consumption included in the energy label value, which will also affect the product star rating.

The initially proposed algorithms for the calculation of the CEC (Comparative Energy Consumption) including standby for wash appliances was:

$$CEC = E_t \times C + [P_d \times 2 \times C + P_e \times 15 \times C + (8760 - T_c \times C - 2 \times C - 15 \times C) \times P_o]$$

where:

- E_t = the cycle energy consumption measured according to the AU/NZS Part 1 standard
- C = is the defined number of cycles per year, 365 for washing machines and dishwashers
- P_d = the measured power (in W) in the "delay start" mode, it is 0 where the appliance does not have a delay start function; the delay start mode is assumed 2 hours where present
- P_e = the measured power (in W) in the "end of programme" mode, it is 0 where the appliance does not have end of programme mode; end of programme mode is assumed for 15 hours when present
- P_o = measured power in off mode (W), for the remaining standby time after delay start and end of programme modes
- T_c = cycle time (in hours).

The value of CEC is in Wh and should be divided by 1000 for use on the energy label.

The proposal was subsequently modified, considering only an average of "off mode" and "end of cycle mode" for inclusion into the energy label CEC and deleting the "delay start mode" from the overall standby calculation, to avoid any penalisation of this mode, which was recognised to have a positive impact on the machine use by allowing the delay of the washing cycle to off-peak hours. In addition, the overall standby power is considered 100% the time in "off mode" where the "end of cycle" mode is not present (when products automatically revert to "off" after the end of cycle) [44]:

$$CEC = E_t \times C + [P_s \times (8760 - T_c \times C)]$$

where P_s = the average measured standby power, in Watts which is the average of end of cycle mode and off mode, (where this mode is present). Again, the value of CEC is in Wh and should be divided by 1000 for use on the energy label.

7.1.1.2 USA

The US has both mandatory and voluntary policy measures for household appliances including dishwashers and washing machines.

a) US Energy efficiency labelling programmes

The US has two primary federally funded labelling programmes for consumer products and appliances: "Energy Guide" and "ENERGY STAR".

[44] For sake of coherence, the shown algorithm is not the one eventually published in the standard, but is presented in the same form as the previous formula.

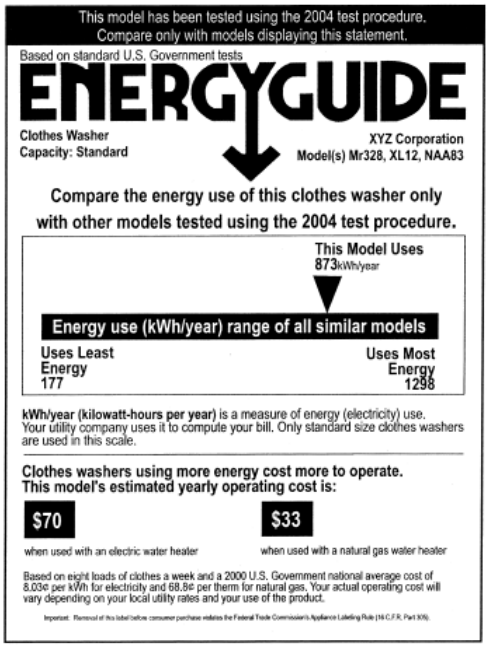
The **Energy Guide** label on **dishwashers** indicates how much electricity (in kWh) a particular model uses in one year. The program covers two dishwasher categories: 'compact capacity' and 'standard capacity'. The standby power consumption is included when calculating estimated annual energy use for all dishwashers.

The 2006 ranges of comparability for 'standard dishwashers' are: *low energy consumption 176 kWh/year* and *high energy consumption 247 kWh/year*. Dishwasher manufacturers must base the disclosures of estimated annual operating cost required at the bottom of Energy Guide labels for dishwashers on 8,60 USD cents per kWh and natural gas 91,0 cents per therm.

The new ranges of comparability for 'compact dishwashers' effective from 23 January 2006 are: l*ow energy consumption 143 kWh/year* and *high energy consumption 320 kWh/year*. Compact dishwasher manufacturers must base the disclosures of estimated annual operating cost required at the bottom of Energy Guide labels for compact dishwashers on 9,06 USD cents per kWh and natural gas 1,09 USD per therm.

The Energy Guide label on **washing machines** (Figure 7.6) indicates how much electricity (in kWh) a particular model uses in one year. The program covers two machine categories: 'compact capacity' and 'standard capacity', where ''compact'' includes all domestic washing machines washers with a tub capacity of less than 1,6 cu. ft. (45 litre).

Figure 7.6: Example (black and white) of Energy Guide for standard washing machines



On January 2006 required range of comparability for *compact washing machines* were amended[45] as: *low energy consumption 125 kWh/year* and *high energy consumption 462 kWh/year*. When the above range of comparability is used on Energy Guide labels for compact washing machines, the estimated annual operating cost disclosure must be derived using a cost for electricity of 8,60 USD cent per kWh and for natural gas at 91,0 USD cent per therm.

[45] See: Federal Register / Vol. 71, No. 20 / Tuesday, January 31, 2006 / Rules and Regulations.

The ranges of comparability for 'standard washing machines', have not been modified and the value in force since April 2005: *low energy consumption 113 kWh/year* and *high energy consumption 680 kWh/year* are currently valid.

ENERGY STAR (Figure 7.7), introduced in 1992, is a voluntary labelling program operated jointly by the Environmental Protection Agency (EPA) and Department of Energy (DOE). It is designed to reduce greenhouse gas emissions by identifying and promoting energy-efficient products. The program functions as a voluntary partnership between government and various businesses, including manufacturers and various trade allies like retailers, installers, utilities, and energy service companies.

Figure 7.7: US Energy Star logo

Qualified **dishwashers** must have a minimum Energy Factor from 1st January 2007, expressed in cycles per kWh, as the reciprocal of the sum of the machine electrical energy per cycle plus the water heater energy consumption per cycle as described in the federal energy efficiency legislation. Qualified dishwashers use at least 41% less energy than the federal minimum requirement for energy consumption. In detail criteria for dishwasher types are:

Product Type	**Federal EF**	**Energy Star EF**
Standard (≥ 8 place settings + six serving pieces)	≥ 0,46	≥ 0,65
Compact (< 8 place settings + six serving pieces)	≥ 0,62	≥ 0,88

Only standard sized (with a tub capacity larger than 1,6 ft^3 or 45 litre), front- or top-loading **washing machines** are eligible for the Energy Star. Qualified d machines must have a minimum Modified Energy Factor (MEF) of increasing from the current level of 1,42 to 1,72 plus a maximum water consumption factor (WF) of 8,0 where:

- MEF is the quotient of the cubic foot capacity of the clothes container divided by the total washing machine energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load. The units are (ft^3/kWh/cycle). The higher the value, the more efficient the clothes washer.
- WF is the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer.

New qualifying levels for washing machines will be established not later than 1st January 2008, for clothes washers, effective beginning 1st January 2010.

b) The energy efficiency requirements

Efficiency requirements for **dishwashers** are based on the Energy Factor EF (in cycles/kWh), which must be not less than 0,62 for compact dishwashers and 0,46 for standard dishwashers, starting from 1st January 2004. It has to be noted that the annual energy and cost calculation include standby energy consumption, but it has not be included into the energy factor calculation. The average cycles per year is 215.

The Energy Factor EF (in cycles/kWh) of consumer dishwashers must be not less than 0,62 for compact dishwashers and 0,46 for standard dishwashers, starting from 1st January 2004.

Energy efficiency requirements for residential **washing machines** include the following appliance types:

- 'Compact clothes washer': a clothes washer which has a clothes container capacity of less than 45 litre (1,6 ft^3)
- 'Standard clothes washer': a clothes washer which has a clothes container capacity of 45 litre (1,6 ft^3) or greater
- 'Front-loading clothes washer': a clothes washer with the clothes container compartment access located on the front of the machine
- 'Top-loading clothes washer': clothes washer with the clothes container compartment access located on the top of the machine
- 'Suds-saving': a feature or option on a clothes washer, which allows the user to store, used wash water in an external laundry tub for use with subsequent wash loads.

The energy efficiency requirements for residential washing machines are described in Table 7.2. For top loading standard and compact washing machines and front loading washing machines the MEF Modified Energy Factor (in ft^3/kWh/cycle) must be higher than the indicated value.

Table 7.2: **Energy efficiency requirements for residential washing machines in USA in 2003-2007**

Appliance	*Minimum Energy Factor [ft^3/(kWh/cycle)] Effective May 14, 1994 Through December 31, 2003*	*Minimum Modified Energy Factor [ft^3/(kWh/cycle)]**	
		Effective January 1, 2004	*Effective January 1, 2007*
Top-loading compact clothes washers	0.90	0.65	0.65
Top-loading standard clothes washers	1.18	1.04	1.26
Top-loading, semi-automatic	N/A[1]	N/A[1]	N/A[1]
Front-loading clothes washers	N/A[1]	1.04	1.26
Suds-saving	N/A[1]	N/A[1]	N/A[1]

[1]Must have an unheated rinse water option.

*The sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load.

Top-loading semi-automatic and suds-saving washing machines do not need to meet the Modified Energy Factor standard but must have an unheated rinse water option. The MEF of a washing machine is the quotient of the ft^3 capacity of the clothes container divided by the total washing machine energy consumption per cycle, with such energy consumption expressed as the sum of the

machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load.

c) The 2006 Appliance Efficiency Regulations for California

The 2006 Appliance Efficiency Regulations includes requirements for both federally regulated appliances and non-federally-regulated appliances, among those wash appliances: for dishwashers the federal requirements apply, for domestic washing machines the federal requirements about energy efficiency apply, while for the water efficiency specific requirements have been set.

The Water Factor (in gallons per cubic foot) of washing machines must not be greater than the values shown in Table 7.3. The Water Factor is the quotient of the total weighted per-cycle water consumption divided by the capacity of the washing machine.

Table 7.3: **Water efficiency requirements for washing machines in California in 2007 and 2010**

Appliance	Maximum Water Factor (gallons/cubic foot)	
	effective 1st January 2007	effective 1st January 2010
Top loading	8,5	6,0
Front loading	8,5	6,0

d) The standby issue

Annual standby energy consumption for **dishwashers** is calculated in kWh per year as:

$S = S_m \times (H_s/1000)$ and
$H_s = H - (N \times L)$

where:

- S_m = measured average standby power (in Watt) and
- H = the total number of hours per year, or 8.766
- N = the representative average dishwasher use of 215 cycle/year
- L = the average of the duration (in hours) of the normal washing cycle, measured for the different types of dishwashers addressed in the test procedure

In order to determine standby power usage, the energy use of each dishwasher in the Energy Star products database was calculated. Since 60% of current qualified products use standby power and the trend for new products is to offer more features that will draw power in the standby mode, comments were required to stakeholders on the value of incorporating a standby power requirement into the new criteria for dishwashers. In addition, DoE is trying to determine whether it is preferable the (a) setting a maximum amount of standby power in terms of Watts or kWh/year or (b) setting the maximum total allowable Energy Star qualified product usage in terms of kWh/year instead of EF.

e) The tax incentives for manufacturers

The Energy Policy Act of 2005 offers incentives that promote the use of more efficient appliances. This legislation is expected to increase the market penetration of products meeting and exceeding the act's Energy Star criteria. The new legislation provides credits to the manufacturer for very efficient refrigerators, washing machines and dishwashers. The incentives are for products sold in 2006 and 2007, relative to *additional* sales by each manufacturer above the average of the previous

three years. This type of policy has the distinct advantage of minimizing the problem of free riders that would have purchased the new model in any case; and thus is more effective than such policies as rebate or reduction in value added taxes, which allow and pay for free riders.

For washing machines there is only one efficiency tier, a 100 USD credit for units meeting the 2007 Energy Star criteria. The same applies for dishwashers where the amount of credit is 3 USD for every percent beyond the Energy Star criteria in force in 2005.

All the appliance credits only apply to products produced in the USA, which could affect the foreign production plans of US manufacturers and also means that imported products are not eligible. There is also a total cap per manufacturer of 75 million USD, a figure some larger manufacturers may reach but the smaller manufacturers will not.

7.1.1.3 Brazil

In Brazil the energy efficiency and the spinning performance of washing machines are respectively expressed in kWh per kg of load and as percentage of residual moisture and classified in an scale with 5 classes only, from A to E. The energy efficiency for the warm wash and for the cold wash for automatic and semi-automatic machines and the spinning performance are expressed in kWh/cycle/kg load in Table 7.4.

Table 7.4: **Warm and cold wash energy consumption thresholds for washing machines labelling in Brazil**

Classes	Warm wash	Cold wash		Spinning performance
		automatic	semi-automatic	
	(kWh/cycle/kg)			(%)
A	0,190	0,031	0,019	60
B	0,230	0,035	0,022	68
C	0,270	0,039	0,025	76
D	0,310	0,043	0,028	84
E	0,350	0,047	0,031	94

The washing performance is expressed as a continuous scale (Figure 7.8) between a minimum and a maximum values (Table 7.5) and where the position of the specific machine is indicated by an arrow. The scale is defined for the three types of machines: with heating, automatic without heating and semi-automatic with specific values for the more performing and less performing models.

Figure 7.8: Washing performance scale for automatic washing machines in Brazil

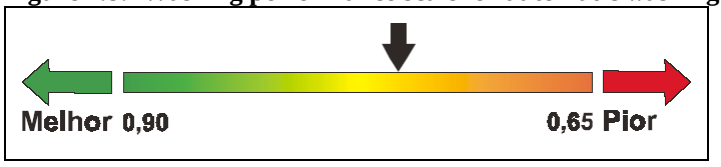


Table 7.5: **Warm and cold wash for the washing machine labelling in Brazil**

Washing machine types	Better	Worse
automatic with heating	1,00	0,65
automatic without heating	0,90	0,65
semi-automatic	0,80	0,55

7.1.1.4 China

Maximum allowable values of the energy consumption and energy efficiency grade for household electric washing machines have been established in China for all household electric washing machines (pulsator type and drum type) and spin dryer and are based on the values shown in Table 7.6. The requirements are effective since 1st May 2005. Dishwashers are not addressed at present.

No efficiency requirements are set for dishwashers.

***Table 7.6*: Maximum energy consumption for washing machines and spin dryers in China**

Washing machine (type)	Machine technology	Maximum energy consumption (Wh/kg)
Pulsator type	Single-tub	24,0
	Twin-tub	28,0
	Half-automatic single-tub	29,0
	Half-automatic twin-tub	32,0
	Automatic	38,0
Drum type	Automatic without water heating	Not set
	Automatic with water heating	Not set
Spin dryer		4,0

In 2005[46], a new appliance noise regulation "*Noise Limit Value for Household and Similar Electrical Appliances* went into effect in China on 1st August. Appliance manufacturers are required to mark the noise value on the product label or instruction booklet. Products that exceed the noise limits will not be allowed on the market. For washing machines the noise limits are: wash 62 dBA, spin cycle 72dBA; microwave oven noise limits: 68 dBA. Dishwashers are not addressed for the moment by this regulation.

7.1.2 A worldwide approach to energy efficiency of wash appliances ?

A recently published APEC (ASIA-Pacific Economic Cooperation) monograph sponsored by Australian and co-sponsored by New Zealand and United States[47] presents a vision for international cooperation on energy efficiency requirements and labelling achieved through a series of invited workshops on four continents sponsored by the Australian Greenhouse Office to prompt discussion about a common strategic vision on energy-efficiency requirements and labelling, with the aim to develop a consensus on implementing the best possible scheme in each economy within APEC.

The issue was initiated by the recognition of the management within the Australian Greenhouse Office that the Australian program could benefit from a change to its then-insular approach. Rather than negotiating with resident industry representatives about possible improvements in the energy efficiency of products manufactured in, or imported into Australia, an opportunity existed to shift the focus to examining and matching the product-efficiency targets proposed in the major trading economies in North America, Asia and Europe. The Ministerial Council on Energy accepted

[46] V. Han, China Implements Appliance Noise Standard, Appliance, October 2005, p.18

[47] A Strategic Vision for International Cooperation on Energy Standards and Labelling, A monograph with commentary by international experts, June 2006. Prepared as part of the self-funded APEC project, A Vision for Cooperation on Energy Standards and Labelling Programs. Published by Australian Greenhouse Office.

recommendations for sweeping changes to the Australian standards and labelling program, allowing any product consuming energy to be considered for inclusion in mandatory or voluntary measures based on equivalent efficiency standards in a major trading partner economy.

The number of nations adopting energy efficiency standards and labels is growing rapidly, from 9 in 1984 to 36 in 1994 to 56 in 2004. The number of regulations worldwide on individual appliances and equipment is growing even more rapidly, increasing from 543 to 878 between 2000 and 2004. There is a need among these countries for harmonized test facilities and protocols, mutual recognition of test results, common comparative energy label content, harmonized endorsement energy labels, harmonized minimum energy requirements for some markets, shared learning of the labelling process, and shared learning of the standard-setting process. Such an approach allows countries, companies, and consumers to avoid the costs of duplicative testing and non-comparable performance information, while benefiting from a reduction in non-tariff trade barriers and access to a wider market of goods. Such an approach reduces the aggregate cost among the world's governments of designing and implementing the energy-efficiency regulations and labels.

Some critical elements and priority list of actions emerged from the mentioned APEC document :

- The primary focus is on standards alignment, as the most useful basis for comparability and a pre-requisite for the benchmarking of product performance and policies. Harmonised (aligned) standards and test facilities is the first step towards mutual recognition of test results. However, when harmonising standards some of the local/regional specificity could be lost.
- Worldwide standardisation bodies IEC/ISO are working towards globally applicable standards, but there also needs to be recognition that there are bilateral treaties, multilateral organizations, such as APEC and several regional trading blocks, and global organizations, such as WTO, who are critical institutions when policy measures are set. This is also the institutional context within which the multi-nationals who deliver energy efficient products also operate to influence policies.
- Shared learning of the labelling and requirements setting process is part of the capacity building in markets and regions only recently starting to address the eco-energy efficiency of end-uses. It is the basis for the setting of comparative energy label content, harmonized endorsement energy labels, and harmonized energy efficiency requirements (at least for some markets).
- The importance of regional collaborations should not be understated towards international ones. They are crucial to the evolution of the practice of efficiency requirements setting and labelling, and in the long run the interregional activities will likely dominate.
- In the road towards harmonization and alignment, there is a need to recognize that the short- and long-term benefits for different local and global stakeholders may be different. More often than not, even countries in favour of alignment need to provide a time period or temporary incentives to enable the local industry to adjust. The experts working in the field of efficiency requirements and labelling must respect the pace of progress toward harmonization and alignment.
- The critical issue facing efficiency requirements and labelling programs is the need for establishing consistent and cost-effective mechanisms for collection and analysis of end-use data, which can, in turn, provide a baseline and monitored information on savings for the investor. Otherwise, the belief that efficient appliances leads to energy conservation or savings can be challenged.

Finally, it should be reminded that the adoption of the WTO (World Trade Organization) Technical Barriers to Trade Agreement (TBT) places an obligation on IEC to ensure that the International Standards it develops, adopts and publishes are globally relevant. International Standards and other type of Publications are globally relevant when they can be used or implemented as broadly as

possible by all stakeholders in markets around the world. According to WTO[48], in order to serve the interests of the WTO membership in facilitating international trade and preventing unnecessary trade barriers, international standards need to be relevant and to effectively respond to regulatory and market needs, as well as scientific and technological developments in various countries. They should not distort the global market, have adverse effects on fair competition, or stifle innovation and technological development. In addition, they should not give preference to the characteristics or requirements of specific countries or regions when different needs or interests exist in other countries or regions. Whenever possible, international standards should be performance based rather than based on design or descriptive characteristics.

7.2 SUBTASK 7.2: WORLDWIDE COMPLIANCE ASSESSMENT

Two elements should be taken into consideration in the discussion about the assessment of the compliance of major household appliances to policy measures:

- the measurement certification: the number of units to be tested by suppliers before any declaration or compliance to a criteria claimed is done (and relevant technical documentation reported to regulators) and the way the measured quantities are treated before declaration/compliance
- the enforcement verification of the declared values: either labelling declarations or minimum requirements (threshold values).

7.2.1 The Measurement Declaration

7.2.1.1 Australia

In Australia the registration for energy labelling and minimum energy efficiency requirements is mandatory. To obtain registration of a product, manufacturers are generally required to submit test reports to demonstrate compliance with the requirements of the relevant Australian standard. The veracity of the energy consumption, efficiency and performance values claimed in these reports are usually accepted on initial application without requirement for verification through independent testing.

For household appliances the number of units to be tested are reported in the relevant standard. In particular:

- **washing machines**: for the purpose of determining the CEC (Comparative Energy Consumption) of a model for labelling, three separate units of the model shall be tested for energy consumption and standby power. At the supplier's discretion, more than three units may be tested. Each unit shall be subjected to at least one valid test run to obtain values of E_t standby power and Water Extraction Index (WEI) for that unit. Where more than one test run is performed on a unit, the value of E_t and WEI shall be recorded for each run and then averaged and treated as the results for that unit. The measured values for the three units are averaged and declared rounded to the nearest whole kWh/year.
  The minimum performance criteria shall be met by each individual unit tested on the program for energy efficiency labelling;
- **dishwashers**: for the purpose of determining the CEC of a model for labelling, three separate units of the model shall be tested for energy consumption and standby power. At the supplier's discretion, more than three units may be tested. Each unit shall be subjected to at least one valid

[48] Source: WTO second triennial review of the operation and implementation of the agreement on Technical Barriers to Trade, Annex 4.

test run to obtain values of E_t and standby power for that unit. Where more than one test run is performed on a unit, the value of E_t shall be recorded for each run and then averaged and treated as the result for that unit. The measured values for the three units are averaged and declared rounded to the nearest whole kWh/year.
The minimum performance criteria shall be met by each individual unit tested on the program for energy efficiency labelling,

- **cold appliances**: for the purpose of determining the CEC (Comparative Energy Consumption) of a model for labelling, three separate units of the model shall be tested for energy consumption. At the supplier's discretion, more than three units may be tested. Each unit shall be tested with sufficient test runs to enable a valid value of E_t to be determined for that unit. This determination shall be documented in a test report containing the test results for all test runs used to derive E_t (E_t is expressed in Wh per 24 hours and is rounded to the nearest whole number). After testing three or more separate units, the separate values of PAEC (in kWh/year to be calculated from E_t) shall be averaged and referred to as $PAEC_{av}$ The average PAEC is rounded to the nearest unit to obtain the minimum allowable value for CEC.
The minimum performance criteria shall be met by each individual unit tested on the program for energy efficiency labelling.

7.2.1.2 USA

a) Energy and water conservation requirements

The CFR, Title 10: Energy, Part 430 - Energy Conservation Program for Consumer Products, Subpart F - *Certification and Enforcement*, sets forth the procedures to be followed for certification and enforcement testing to determine whether a basic model of a covered product complies with the applicable energy conservation requirements or water conservation requirements (in the case of faucets, showerheads, water closets, and urinals) set forth in Subpart C - *Energy and Water Conservation Standards* of Part 430. Energy conservation requirements and water conservation requirements include minimum levels of efficiency and maximum levels of consumption, and prescriptive energy design requirements.

For certification purposes, each manufacturer or private labeller before distributing in commerce any basic model of a covered product shall certify by means of a compliance statement and a certification report that each basic model(s) meets the applicable energy conservation requirements or water conservation requirements as prescribed in section 325 of the Act. The compliance statement, signed by the company official submitting the statement, and the certification report(s) shall be sent to DOE, Office of Energy Efficiency and Renewable Energy, Office of Codes and Standards.

The above mentioned Subpart F - *Certification and Enforcement* includes two Appendixes:
- Appendix A: Compliance Statement and Certification Report
- Appendix B: Sampling Plan for Enforcement Testing.

In Appendix A an example of the compliance statement and certification report is given. The compliance statement is signed by a responsible official of the above named company. The basic model(s) listed in certification reports comply with the applicable energy conservation standard or water (in the case of faucets, showerheads, water closets, and urinals) conservation standard. All testing on which the certification reports are based was conducted in conformance with applicable test requirements prescribed in 10 CFR part 430 subpart B. All information reported in the certification report(s) is true, accurate, and complete. The company is aware of the penalties

associated with violations of the Act, the regulations there-under, and is also aware of the provisions that prohibits knowingly making false statements to the Federal Government.

For purposes of a certification of compliance, the determination that a basic model complies with the applicable energy/water requirements is based upon a defined sampling procedure[49]. The sample to be selected and tested comprises units which are production units, or are representative of production units of the basic model being tested, and shall meet the following applicable criteria:

a) for each basic model of **refrigerators, refrigerator-freezers and freezer**, a sample of sufficient size shall be tested to insure that:
- any represented value of estimated annual operating cost, energy consumption or other measure of energy consumption of a basic model for which consumers would favour lower values shall be no less than the higher of (A) the mean of the sample or (B) the upper 95% confidence limit of the true mean divided by 1,10, and
- any represented value of the energy factor or other measure of energy consumption of a basic model for which consumer would favour higher values shall be no greater than the lower of (A) the mean of the sample or (B) the lower 95% confidence limit of the true mean divided by 0,90;

b) for each basic model of **dishwashers**, a sample of sufficient size shall be tested to insure that:
- any represented value of estimated annual operating cost, energy consumption or other measure of energy consumption of a basic model for which consumers would favour lower values shall be no less than the higher of (A) the mean of the sample or (B) the upper 97,5% confidence limit of the true mean divided by 1,05, and
- any represented value of the energy factor or other measure of energy consumption of a basic model for which consumers would favour higher values shall be no greater than the lower of (A) the mean of the sample or (B) the lower 97,5% confidence limit of the true mean divided by 0,95;

c) for each basic model of **washing machine**, a sample of sufficient size shall be tested to insure that:
- any represented value of estimated annual operating cost, energy consumption or other measure of energy consumption of a basic model for which consumers would favour lower values shall be no less than the higher of (A) the mean of the sample or (B) the upper 97,5% confidence limit of the true mean divided by 1,05, and
- any represented value of the energy factor or other measure of energy consumption of a basic model for which consumers would favour higher values shall be no greater than the lower of (A) the mean of the sample or (B) the lower 97,5% confidence limit of the true mean divided by 0,95.

b) Appliance labelling

The CFR, Title 16, Part 305 - *Rule concerning disclosures regarding energy consumption and water use of certain home appliances and other products required under the energy policy and conservation act ("appliance labelling rule")*, establishes requirements for consumer appliance products with respect to energy/water labelling and/or marking the products with information indicating their operating cost (or different useful measure of energy consumption) and related information. It states that the determinations of the estimated annual energy consumption, the estimated annual operating costs, the energy efficiency ratings, and the efficacy factors of refrigerators and refrigerator-freezers, freezers, dishwashers, water heaters, room air conditioners, washing machines, central air conditioners and heat pumps, furnaces, pool heater and fluorescent

[49] CFR, Title 10: Energy, PART 430 - Energy Conservation Program for Consumer Products, Subpart B - Test Procedures, paragraph 430.24 – Units to be tested.

lamp ballasts, are those located in 10 CFR part 430, subpart B, where the Department of Energy has adopted and published test procedures for measuring energy usage or efficiency, according to the sampling procedures set forth in the same subpart B (except general service fluorescent lamps, medium base compact florescent lamps, and general service incandescent lamps, including incandescent reflector lamps).

Test data shall be kept on file by the manufacturer of a covered product for a period of two years after production of that model has been terminated. Upon notification by the Commission or its designated representative, a manufacturer or private labeller shall provide, within 30 days of the date of such request, the underlying test data from which the water use or energy consumption rate, the energy efficiency rating, the estimated annual cost of using each basic model, or the light output, energy usage and life ratings and, for fluorescent lamps, the colour rendering index, for each basic model or lamp type were derived.

7.2.1.3 The European Union

a) Energy labelling and efficiency requirements

In the EU the veracity of the energy consumption, efficiency and performance values and other information contained in the label and the fiche are accepted without requirement for verification through independent testing. But Member States shall take all necessary measures to ensure that all suppliers and dealers established in their territory fulfil their obligations under the different Directives.

Suppliers (manufacturers and importers) are required to establish technical documentation, sufficient to enable the accuracy of the information contained in the label and the fiche to be assessed. It shall include (i) a general description of the product, (ii) the results of design calculations carried out, where these are relevant, (iii) test reports, where available, including those carried out by relevant notified organizations as defined under other Community legislation, (iv) where values are derived from those obtained for similar models, the same information for these models. The supplier shall make this documentation available for inspection purposes for a period ending five years after the last product has been manufactured.

The information required by the relevant Directives shall be measured according to the harmonised standards, the reference numbers of which have been published in the Official Journal of the European Communities and for which Member States have published the reference numbers of the national standards transposing those harmonized standards.

Both in the energy labelling and efficiency requirement schemes and in the relevant standards there is no specific request to test more than one unit of the model.

b) The eco-label scheme

According to the Annex of Commission Decision (2004/669/EC) of 6 April 2004 establishing the ecological criteria for the award of the Community eco-label to **refrigerators**, and amending Decision 2000/40/EC, for the measurement declaration, the applicant has to provide a copy of the technical documentation referred to under article 2 paragraph 1 of Commission Directive 94/2/EC as amended by Commission Directive 2003/66/EC, including the reports of at least three measurements of energy consumption made according to EN 153 and the test guidelines as detailed in CECED's Operational Code. The arithmetic mean of these measurements shall be less or equal to the energy efficiency ecolabel requirement (energy efficiency class A+ or A++). In addition, the

value declared on the energy label shall not be lower than this mean value, and the energy efficiency class indicated on the energy label shall correspond to this mean value.

According to the Annex of Commission Decision 2000/45/EC of 17 December 1999 establishing the ecological criteria for the award of the Community eco-label to **washing machines** (as amended by Decisions 2003/240/EC of 24.03.2003 and 2005/783/EC of 14 October 2005), the applicant has to provide a copy of the technical documentation referred to under Article 2(1) of Directive 95/12/EC. This documentation shall include the reports of at least 3 measurements of energy consumption, the water consumption, the spin extraction and the noise made according to EN 60456:1999, using the same standard 60°C cotton cycle as chosen for Directive 95/12/EC. The arithmetic mean of these measurements shall be less or equal to the above requirement. The value declared on the energy label shall not be lower than this mean value, and the energy efficiency class and the spin drying efficiency class indicated on the energy label shall correspond to this mean value. The noise value shall appear on the energy label. In case of verification, which is not required on application, competent bodies shall apply the tolerances and control procedures laid down in EN 60456:1999.

For **dishwashers**, according to the Annex of Commission Decision (2001/689/EC) of 28 August 1999 establishing the ecological criteria for the award of the Community eco-label to dishwashers (as amended by Decision 2005/783/EC, of 14 October 2005), the applicant has to provide a copy of the technical documentation referred to under Article 2(1) of Directive 97/17/EC. This documentation shall include the reports of at least three measurements of energy consumption, the water consumption and the noise made according to EN 50242, using the same programme cycle as chosen for Directive 95/12/EC. The arithmetic mean of these measurements shall be less or equal to the above requirement. The value declared on the energy label shall not be lower than this mean value, and the energy efficiency class indicated on the energy label shall correspond to this mean value. The noise value shall appear on the energy label. In case of verification, which is not required on application, competent bodies shall apply the tolerances and control procedures laid down in EN 50242.

7.2.1.4 Comparison of the declaration procedures

In Table 7.7 the described test procedures are compared to highlight the differences and similarities in the procedures.

Table 7.7: **Comparison of the declaration procedures (minimum units to be tested) for household appliances in selected Countries worldwide**

Country	**Product**	**RF** (n)	**FZ** (n)	**WM** (n)	**DW** (n)	Product registration (y/n)
AU/NZ	EE requirements	3	3	3	3	Y
AU/NZ	Labelling	3	3	3	3	Y
USA	EE requirements	sufficient size for 95% confidence limit		sufficient size for 97,5% confidence limit		N
USA	Labelling	sufficient size for 95% confidence limit		sufficient size for 97,5% confidence limit		N
EU	EE requirements	1	1	1	1	N
EU	Labelling	1	1	1	1	N
EU	Ecolabel	3	3	3	3	Y

7.2.2 The verification procedures

7.2.2.1 Australia

National Appliance and Equipment Energy Efficiency Program Administrative Guidelines"[50] have been developed and agreed by all Australian regulators. Although not legally binding, the purpose of the Guidelines is to explain how the national legislative scheme for energy labelling and minimum energy efficiency requirements are intended to be administered, to act as a guide to relevant State and Territory regulatory agencies to facilitate uniform and consistent practice among State and Territory regulatory agencies and to explain to stakeholders the responsibilities of relevant State and Territory regulatory agencies and the responsibilities of industry.

An essential element of the E_3 Program is ensuring that manufacturers' energy efficiency and performance claims accurately reflect the information contained within their original application for registration. This verification process is known as check testing and is effectively the major quality assurance procedure for the energy labelling and minimum energy efficiency requirements schemes in Australia., that ensures that the scheme maintains high levels of credibility both with consumers and manufacturers.

The Guidelines include, *inter alia*, a detailed description of the programme compliance monitoring through laboratory check testing. The E_3 Committee is charged with the ongoing management of these guidelines and conducts since 1991 a national "check testing" program to provide the community and stakeholders with data on accuracy of the labelling scheme and compliance by suppliers.

a) Check testing programme and principles

Appliances are purchased from retail outlets or obtained anonymously and tested in NATA accredited independent laboratories to verify the claims associated with the energy label and minimum requirements where applicable for six appliance types (air conditioners, ballasts, dryers, washing machines, dishwashers, electric motor, refrigerated display cabinets, refrigerators & freezers and water heaters).

As part of the National Greenhouse Strategy, the E_3 Committee allocates around a quarter of its budget (in excess of AU$ 300.000 in 2002) to conduct check testing in laboratories and related testing used for standards development and round robins, measures compliance on a regular basis and benchmarks against overseas results. From modest beginnings, the national program now tests as many as 100 products per year. Models **are not randomly selected** for check testing, rather **sophisticated selection criteria and market intelligence** are used to target testing towards **models more likely to fail**.

b) Selection criteria

Recommendations for appliance and equipment groups and models to be check tested are to be

[50] "Administrative Guidelines for the Appliance and Equipment Energy Efficiency Program of Mandatory Labelling and Minimum Energy Performance Standards", Edition 5, June 2005, downloadable from: www.energyrating.gov.au/pubs/admin-guidelines.pdf

based on the following criteria, with reference to the listed information sources:

1 Group Selection:
2
1.1 Plan to cover all product groups: over a two to three year period, there is a strategic plan to ensure that most major categories and types of appliances and equipment are included to ensure a broad and consistent coverage of the entire market. Source of information: check test annual reports.
1.2 Number and turnover of models: regard should be given to the numbers of models and the annual turnover of new models of each appliance group. Appliance groups will be given attention in proportion to such numbers and or turnover; source of information: Energy Labelling Register and Energy Labelling Brochures.
1.3 History of non compliance in each appliance group: groups with a demonstrated history of high levels of non-compliance should be selected because of the likelihood of a continuation of such historical trends; source of information: check test data base.
2 Model Selection (a system of weighting and prioritisation for each the following factors is in use):
2.1 History of testing of specific models: models tested in previous years of the check test program should normally be excluded from any further testing unless specific evidence becomes available to suggest that a re-test is warranted; source of information: check test data base.
2.2 Age of models: newer models should normally be given preference when considering models for check testing because of their potential to remain on the market for a longer period as compared to older models. The exception to this rule is models that have been on the market for a considerable period of time (3 years or more) without being subjected to testing; source of information: Energy Labelling Register and Energy Labelling Brochures.
2.3 Volume of sales of models: models with high volumes of sales should normally be given preference when considering models for check testing because of their greater potential to impact on energy usage as compared to models with low sales volumes; source of information: market survey data (e.g. GFK white goods survey).
2.4 Star rating of models: models with the highest claims for energy efficiency (e.g. high star ratings) should normally be given preference when considering models for check testing because of the market's higher expectations with respect to the performance of these models as compared to models with low ratings. This is an important selection criteria; source of information: Energy Labelling Register and Energy Labelling Brochures, Galaxy award nominations.
2.5 Record of non compliance by supplier: suppliers with a demonstrated record of check testing non-compliance should be subject to greater scrutiny in the check testing program because of the likelihood of a continuation of such historical trends; source of information: check test data base.
2.6 Third party referrals: complaints as to the accuracy of express (labelling etc) or implied (minimum efficiency and performance requirements) energy use/efficiency claims from third parties such as competitors, consumers, consumer groups or regulatory agencies, will be considered by the Manager of the Check Testing Program, who will be responsible for establishing a complaints handling mechanism that reflects best practice, and will include a 'complaints' report in the Annual Check Testing Report; source of information: manufacturing competitors either directly or via regulators, ACA (Australian Consumer’s Association), or other sources.
2.7 New market entrants: a preference will be given to the selection of products that appear as new brands on the market or from suppliers that do not have any check testing track record; source of information: Energy Labelling Register and Energy Labelling Brochures.

c) The check testing process

In general, the check testing includes a two stage process:

- **Stage I** (also known as the *screen test*)
  Initially, a Stage I check test, which is a full or part test to the relevant Australian and New Zealand standard, is performed on **one sample of the model**. This sample will generally be independently purchased (usually through a retail outlet) and tested by a laboratory accredited for check testing on behalf of the regulatory authorities. In cases of Stage I check test non-compliance, the supplier may choose to request cancellation of the registration for the model in question on the basis of the Stage I check test result or, alternatively, may choose the option of proceeding to Stage II check testing.
  In accordance with the requirements of the relevant standards, prior to test measurements being collected, a laboratory is required to check each sample to ensure that it has no obvious operating defects. A manufacturer/importer who believes that the tested unit is in fact defective will be able to inspect the unit in situ (under supervision of the test laboratory) and report on their findings to the regulator. The onus is on the manufacturer/importer to provide evidence that a defect capable of affecting the test results does exist. Furthermore, it must be demonstrated that the "defect" is peculiar to the test unit alone and not common to other samples of the stock of the appliance. If such evidence is provided and accepted, the original check test will be voided and a new check test will be required to be undertaken at the same laboratory either on the original unit with repairs or on a randomly selected second sample of the stock. The costs associated with inspection and re-testing of defective samples shall be borne by the manufacturer/importer.
- **Stage II**
  Stage II check test procedures require that satisfactory test reports from an accredited check testing laboratory be supplied to the regulator. If the submissions provided by the registration holder are not, in the regulatory agency's opinion, satisfactory, or if the submissions set out details and a timetable for testing which is subsequently not complied with, the regulatory agency may decide to cancel the registration. The actual units to be tested in Stage II will be randomly selected from stock by a representative of the regulatory authority.
  For failures which fall into the "supplier declaration" category, three samples are required to be tested in Stage II check testing to establish whether the registration of a model will be maintained (however, the manufacturer or importer can choose to accept the results of check tests undertaken on fewer than three samples if the results of each sample subsequently tested also do not confirm the original claims made by the registration holder in the application for registration); for results which fall into the "energy efficiency/performance requirements" category, regulatory authorities require at least two samples have to be tested in Stage II check testing.

Additional conditions for check testing are:

- **Costs:** Stage I check test costs will generally be met by the regulatory agency. Where the registration holder elects to undertake Stage II check testing, the registration holder will be liable for all Stage II check testing related costs irrespective of the outcome. Where a unit selected for check testing is demonstrated to be defective in manufacture, then the registration holder will be liable for all resulting additional costs incurred for check testing.
- **Screening tests conducted by competitors**: where a product fails a screening test conducted at a NATA accredited laboratory (or one affiliated with an organisation with a mutual recognition agreement with NATA) and the test report is provided by the party that commissioned the test to a regulator or the E_3 Committee, the E_3 Committee will reimburse the (reasonable) costs of conducting the screening tests.

- **Laboratories accredited for Check Testing**: only NATA or other laboratories (not associated with the registration holder) accredited by bodies with a mutual recognition agreement with NATA, and with a registration that permits the laboratory to issue test reports for the test in question, will be accredited to undertake check testing. In circumstances where Stage II check testing can be undertaken at a supplier's own Australian located NATA registered laboratory, regulatory agencies will accept the results provided a NATA appointed witness is present throughout the testing. Costs associated with the provision of a NATA appointed witness will be borne by the supplier.
- **Test requirements**: all testing will be undertaken in accordance with the requirements of the relevant standard.
- **Public reporting on check testing program outcomes**: all State and Territory regulatory agencies, as well as the other members of E_3 will be informed of the identity of product suppliers and retailers whose products fail the check testing program. These agencies and/or the relevant Ministers may publicly report on check testing program outcomes.

The check testing flow chart is presented in Figure 7.8. The validity criteria are described in paragraph e).

d) The NATA accredited laboratories

The National Association of Testing Authorities (NATA) is Australia's national laboratory accreditation authority[51]. NATA accreditation provides a means of determining, recognising and promoting the competence of facilities to perform specific types of testing, measurement, inspection and calibration.

The latest list of NATA (National Association of Testing Authorities) accredited laboratories has been published on 27 July 2007[52]: 13 laboratories are included, of which 5 are accredited for household refrigerators and freezers (and an additional one is considered capable of doing the test but is yet to be accredited by NATA), 4 laboratories are accredited for both washing machines and dishwashers and only 1 laboratory is accredited for air conditioners (Figure 7.9). The Australian Consumers' Association Test Research is among accredited laboratories. NATA accreditation does not imply that the laboratory in NATA is accredited to do the full range of possible tests covered by the standard.

e) The statistical approach for check testing: validity criteria

The aim of a verification procedure is to ensure that manufacturers' energy efficiency and other performance claims accurately reflect the information contained within their original application for registration. A failed check test is generally subject to regulatory action so there needs to be a reasonable degree of certainty regarding the results of the test procedure.

The validity criteria should ideally be developed to account for inherent product variability, inter-laboratory variability (reproducibility) and intra-laboratory variability (repeatability) some of which will be attributable to testing apparatus, so that there is a low probability of:

- passing models where the label claims do not reflect the actual values for the entire population of the model in question and which should, therefore, fail check testing; or
- failing models that should pass.

[51] See: http://www.nata.asn.au .
[52] Downloadable from: http://www.energyrating.gov.au/pubs/nata-laboratorylist.pdf .

Figure 7.8: Australian check testing flow chart

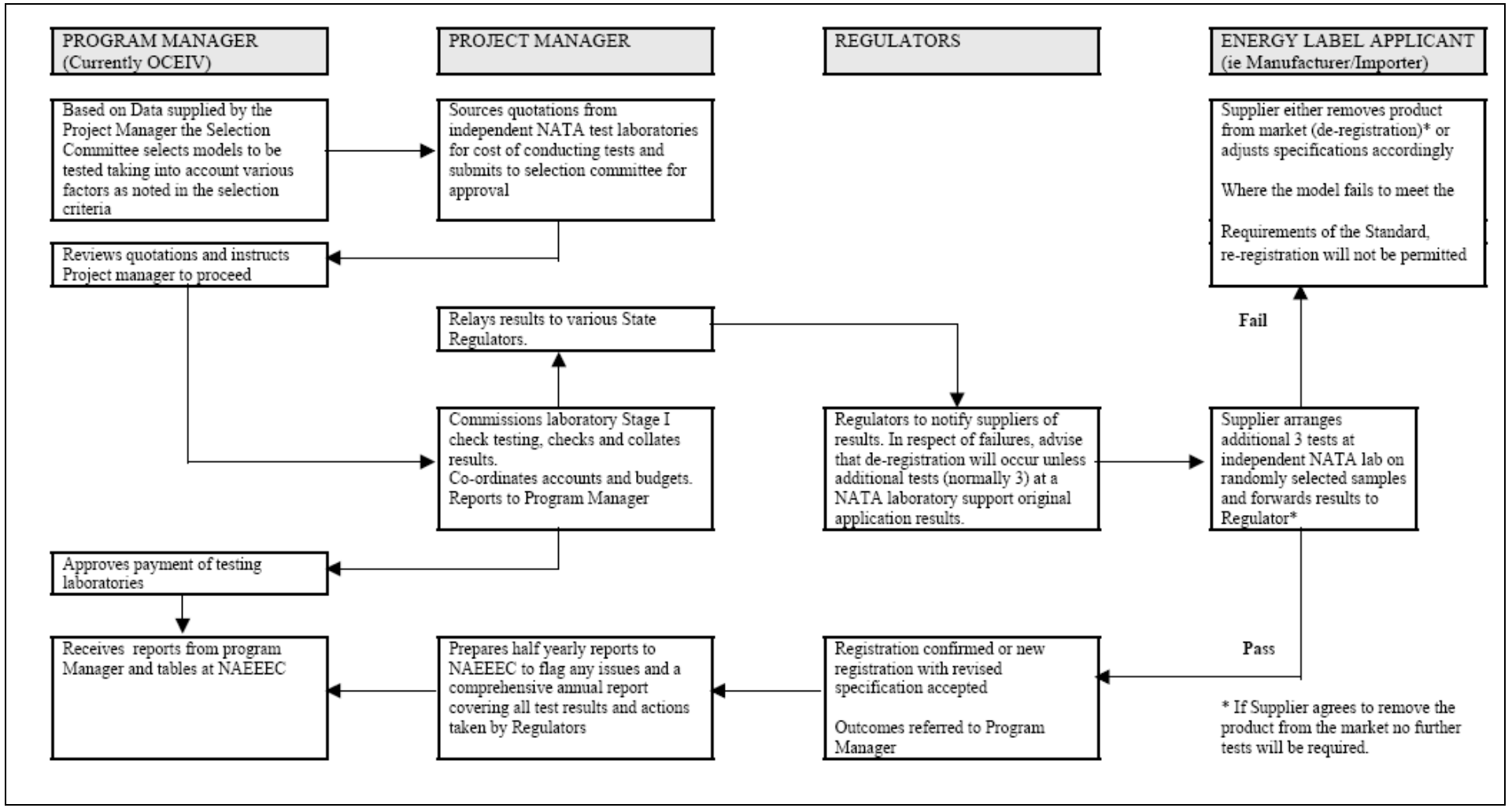


Figure 7.9: NATA accredited laboratories list description

NATA Accredited Laboratories** – last updated 27 July 2007

**NATA accreditation does not imply that the laboratory is NATA accredited to do the full range of possible tests covered by the Standard. For the most up to date accreditation details of each laboratory, reference should be made to the NATA website at www.nata.asn.au

Notes: ✓ indicates NATA accreditation, * indicates accreditation is imminent, # indicates laboratory may be capable of doing the test but is yet to be accredited by NATA, ® indicates related NATA accreditation. Only laboratories that can test electric products are listed. Some of these labs can also test gas products (marked with §).

Laboratory (in order of NATA accreditation number)	Air-conditioners	Ballasts	Clothes Dryers	Clothes Washers	Dishwashers	Distribution Transformers	Electric Motors	Fluorescent Lamps	Refrigerators/ Freezers - household	Refrigerated Display Cabinets	Storage Water Heaters	Standby	External Power Supplies

There are two types of verification that occur during a check test: (i) verification of a supplier's declaration (e.g. energy, volume, capacity etc.) and (ii) verification that an energy efficiency/ performance requirement specified in the standard (i.e. minimum energy efficiency requirements in the case of energy) is achieved by the relevant model.

- **The verification of a supplier declaration**: a supplier declaration is a declaration of energy or performance made either within an energy labelling application or through manufacture information supplied with the product (accompanying literature, user manuals, information affixed to the product such as a rating plate) or at the point of sale (advertising).
  During the verification of a supplier declaration, the focus is on verifying that the average performance level of the model is as claimed by the manufacturer. While some units may have a worse performance level than claimed, these can be balanced by units with a better performance level provided the average performance level of the model is as claimed. The main purpose of a manufacturer declaration is to provide information to the consumer. The general rule for verification of a supplier's declaration is:
  – a single Stage I check test must not be more than 10% worse than the declaration (Stage I);
  – if this is found to be the case, a further three units are to be check tested at the supplier's expense (Stage II);
  – if the mean of the three additional units check tested for Stage II are found to be more than 10% worse than the declaration, the product fails.

  The Australian experts[53] found that for typical measurement errors and variability, the current rule of allowing a 10% variation as the trigger for additional check tests and as the basis of verification of a further 3 units is sound. The probability of deregistration of a model under this rule is extremely small if the supplier's original declaration is in fact accurate (Table 7.8).

  It is important to note that **verification tolerances are not applied** to checks of supplier declarations – the assumed limit of 10% (or the relevant limit for other variables) includes allowances for elements such as **production variability, measurement accuracy and uncertainties**.
  A special case is the **volume declaration for refrigerators and freezers**, where the standard specifies an allowable tolerance of 3% on the measurement (note that the precise rule depends on the compartment volume). Given that the measurement of gross volume by third parties is

[53] During 1999, a statistical consultancy was commissioned to prepare a methodology to determine an approach for verification or rejection of a supplier's claim, based on the testing of up to three units via check tests.

difficult in some cases (and therefore subject to some uncertainties), the check testing tolerance for refrigerator volume is set at 5% less than the declared value before regulatory action is to be taken (i.e. an allowance of 2% above the tolerance value specified in the standard).

Table 7.8: **Summary of verification limits for supplier declarations in Australia**

Supplier Declarations	Verification Limit Stage I	Stage II Check testing Number of units tested	Criteria for Passing Stage II Check testing
Energy declarations (input: all applicable products *)	1.1 × claim	3	Average < 1.1 × claim
Air conditioner cooling capacity	0.9 × claim	3	Average > 0.9 × claim
Air conditioner heating capacity	0.9 × claim	3	Average > 0.9 × claim
Air conditioner efficiency (EER & COP)	0.9 × claim	3	Average > 0.9 × claim
Clothes washer water extraction index	1.1 × claim	3	Average < 1.1 × claim
Refrigerator compartment volume	0.95 × claim	3	Average > 0.95 × claim
Rated hot water delivery capacity	0.97 × claim	3	Average > 0.97 × claim
Water consumption	1.1 × claim	3	Average < 1.1 × claim

Note *: For some products this limit is not applicable, eg ballasts, where the declaration is the Energy Efficiency Index (EEI) which is based on a total circuit power.

The following supplier declarations are not verified directly (declared value defines test conditions): dryer capacity (0,5 kg steps), washing machine capacity (0,5 kg steps), dishwasher capacity (whole number of place settings), and electric motor output (kW).

- **The verification that a product meets energy efficiency/performance requirements**: verification of minimum requirements (threshold values) has a different objective. In principle, all units of the model should satisfy the performance limit. In practice, product variability might lead to some units of a model, which operates close to the set limit failing to meet it. This suggests that the verification of the limit(s) should allow for some percentage of failures, say 5% or 10%. The main purpose of a minimum requirement is to provide a degree of consumer protection (consumers are not normally explicitly informed of efficiency/performance minimum requirements).

  For the verification of minimum energy efficiency/performance limits, it is assumed that the actual energy efficiency/performance across individual units of the same model is **normally distributed**. But, under a normal distribution, it is not possible to be assured that all units will be able to pass the set requirements (see also Annex A of this Task).
  For the verification of energy efficiency/performance requirements, a practical requirement would be to allow the worst 10% of units of a particular model to fail the limit(s) (meaning that 90% are required to pass). If it is assumed that the measurement error is equal to the variability of the test measurement, during a check test it would be reasonable to allow about 18% of units to fail the requirement. The practical general application of this rule is:

  – a single initial Stage I check test is conducted and the unit must not fail the specified energy efficiency/performance requirements (**Stage I**);

- if it does fail, a further two units are to be tested - at the supplier's expense - (**Stage IIa**);
- if both of the additional units tested for Stage IIa are found to fail the specified energy efficiency/performance requirements, the product fails;
- if both of the additional units tested for Stage IIa are found to pass the specified energy efficiency/performance requirements, the product shall be deemed to pass;
- if one of the additional units tested for Stage IIa is found to fail the specified energy efficiency/performance requirements while one passes, one additional unit is tested (**Stage IIb**);
- if two of the additional three units tested in Stages IIa and IIb are found to fail the specified energy efficiency/performance requirements, the product shall fail;
- if two of the additional three units tested for Stages IIa and IIb are found to pass the specified energy efficiency/performance requirements, the product shall be deemed to pass.

If 3 units are initially tested in Stage II, then Stages IIa and IIb above are not required. However, 2 of the 3 units tested in Stage II must pass the requirements. For some products, a larger sample may be requested to verify the Stage II check test (e.g. for fluorescent lamps where product variability may be a factor). For some larger products, such as certain models of distribution transformers, a sample of 3 units may not be possible.

Table 7.9 summarises the verification procedures and criteria for the energy efficiency/performance requirements.

- **Verification tolerances**: where there is a known margin of error or uncertainty in the measurement procedure for a particular test, then this value will be used as a verification tolerance by the regulatory agencies on the specified energy efficiency/performance level. Generally, this measurement error is set **at a maximum of 2% of the specified level**, except in cases (see Table 7.10) that are documented to have different measurement errors on the basis of a series of round robin tests conducted for regulatory agencies or on error analysis. Regulatory agencies will also take into account other factors where these are known to impact on the energy efficiency/performance measure, such as the calibration of swatches used to assess washing performance of washing machines. These tolerances relate only to the verification of the claim associated with energy labelling or minimum requirements.

For cold appliances a different approach is followed. Unlike other products in Australia, domestic refrigerators and freezers follow an approach where the minimum efficiency requirement level (maximum energy consumption) applies to the average of production rather than defining an absolute maximum allowable for every individual product. To verify compliance for this product regulators have to establish the likely average energy for the product and whether this exceeds the set level or not so this product is subject to a different verification procedure.

For a model to fail minimum efficiency requirements, it's necessary to be confident that the average energy consumption of the model exceeds the minimum efficiency requirements level (is lower than the maximum permitted annual energy consumption). Based on the data collected in the Stage II test, the ***single sided t statistic*** is calculated to determine whether this is true to a specified level of confidence. A maximum allowable mean energy consumption limit (unadjusted) of 5% over the minimum efficiency requirements is also set as a secondary compliance criteria to take into account those cases that may have a larger than normal variability within a particular model and so pass the *t statistic* criteria. In some cases, further units beyond Stage II may have to be tested to provide certainty of the result.

Table 7.9: **Summary of verification limits - Minimum requirements in Australia**

Product (name)	**Parameter** (description)	**Requirement in policy measure** (description)	**Stage I verification limit** (description)	**Stage II tested units** (number)	**Stage II passing criteria** (description)
Cold appliances	pull down test	< 6 hours	< 6 hours	2 + 1	2 of the 3 units passes the verification limit*
Cold appliances	maximum annual energy consumption (minimum efficiency requirements)	defined by group in AS/NZS 4474.2	defined by group in AS/NZS 4474.2	3 (additional units may need to be tested to establish the criteria in some circumstances. The procedure to determine efficiency requirements validity for refrigerators and freezers is complex and was released for discussion in June 2005	90% confidence that the mean does not exceed the requirements level and mean energy with verification tolerance <1,03 limits
Washing machines	soil removal	>0,80	>0,80*	2+1	2 of the 3 units passes the verification limit*
	soil removal < 2 x SD	>0,72	>0,72*	2+1	2 of the 3 units passes the verification limit*
	water extraction index	< 1,1	< 1,1*	2+1	2 of the 3 units passes the verification limit*
Dryer	energy efficiency	< 1,36	< 1,36*	2+1	2 of the 3 units passes the verification limit*
Dishwasher	washing performance	>0,90	>0,90*	2+1	2 of the 3 units passes the verification limit*
	drying performance	>0,50	>0,50*	2+1	2 of the 3 units passes the verification limit*

*with a verification tolerance.

Table 7.10: **Verification tolerances for specified products exceeding the 2% level**

Product	Parameter	Verification tolerance
Washing machine	washing performance (if < 2 x SD)	0,03
Dishwasher	wash performance	0,03
	drying performance	0,03
Electric water heater	max. daily heat loss	3% of the limit
Air conditioner	EER minimum requirements	3% of the limit

g) Compliance Newsletter and check results

E_3 Newsletters are periodically prepared by the Australian Greenhouse Office (on behalf of the E_3 Committee) and they provide the latest news and information on energy efficient appliances and electrical equipment.

Since October 2006 *Compliance Newsletter* (formerly known as "*Switched-On*") is quarterly published, which shared with stakeholders the latest information about compliance and enforcement activities in Australia and New Zealand. Details of de-registered products and infringement notices (2005-2006) were published in Issue 1[54] (October 2006) of the Newsletter. In fact, the major sanction employed against manufacturers and importers of non-complying equipment is to withdraw the legal right to sell that equipment. Some models have been subsequently reregistered with revised performance claims in line with the results obtained in the verification test.

A total of 46 "check" tests were finalised during the 2005-2006 financial year (Table 7.11), of which 27 (58%) failed at least one of the screen test validity criteria (of particular note is the 87% failure rate of air-conditioners[55] which continues to be a major focus for the check programme). Of the 27 referred failures, 4 suppliers were able to establish to regulators' satisfaction that the equipment range met requirements: 3 of the screen test fail results were subsequently overturned when Stage II check testing failed to confirm the initial finding, and a further screen test fail result was overturned following evidence that the original tested unit (a refrigerated display cabinet) was in fact faulty and the screen test was invalid. At the end of the two-stage process, 23 models or 50% of the 46 initially selected models failed. The nature of failures was also reported:

- electric motors and refrigerated display cabinets typically failed to meet the required minimum efficiency requirements level. One refrigerated display cabinet model failed to meet its claim of "High Efficiency";
- a majority of air-conditioners failed due to either over statement of cooling capacity, EER or both. Many of these also failed the validity criteria in heating mode;
- the main reason that refrigerators failed was due to understating energy consumption; 2 units failed to meet the required minimum efficiency requirements level

one washing machine failed the soil removal validity test and one washing machine and one dishwasher failed due to understating the energy consumption.

In addition a further Dishwasher sold in New Zealand that failed its check test was found not to be registered and was therefore banned from further sale.

[54] Compliance Newsletter, Issue 1, October 2006, downloadable from: http://www.energyrating.gov.au/newsletters.html

[55] After several instances over some years, energy efficiency regulators complained to the Australian Competition and Consumer Commission about LG and problems with air conditioner efficiency claims. The ACCC and LG subsequently agreed to a $3,1 million package recompensing purchasers for their likely additional energy costs plus a set of additional requirements to be fulfilled by the company.

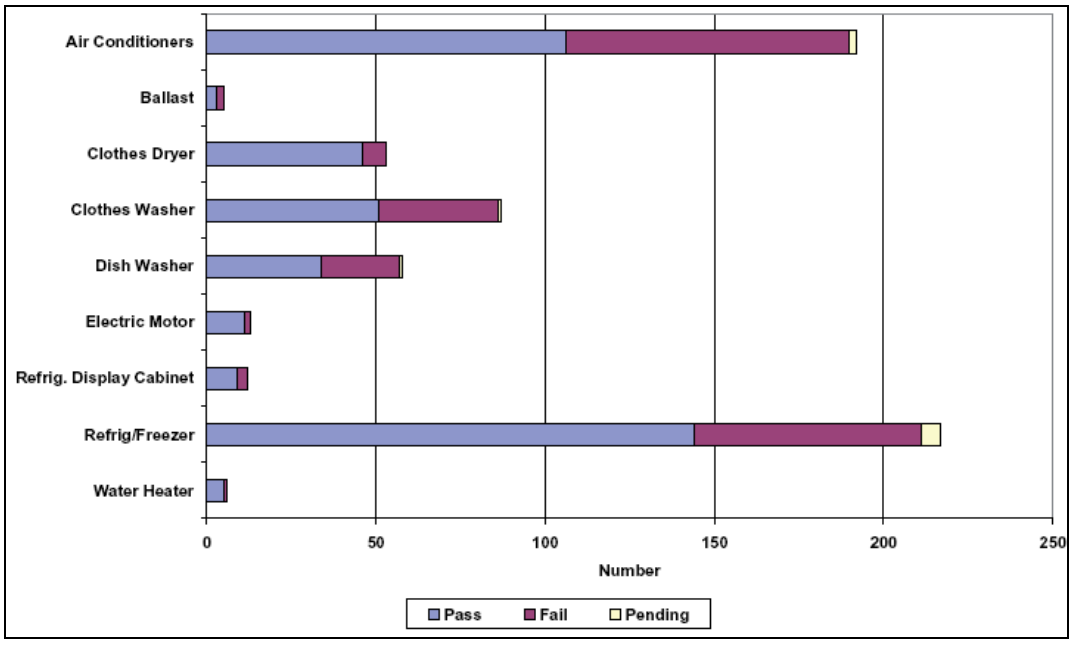
Table 7.11: **Final outcome of the validating manufacturers' energy rating and or energy efficiency claim in fiscal year 2005/2006**

Appliance type	Screen test (n)	Passed the screen test (n)	Failed the screen test (n)	Negative results overturned (n)	Confirmed (n)
Air conditioner	15	2	13	1	12
Washing machine	2	0	2	0	2
Dishwasher	8	6	2	0	2
Electric Motor	6	5	1	0	1
Refrigerated display cabinet	10	6	4	1	3
Refrigerator & freezer	5	0	5	2	3
Total	**46**	**19**	**27**	**4**	**23**

In 2007, two Issues of the Compliance Newsletter were published, the February issues dealing with white goods and the May issue dealing with air-conditioners. The planned check tests to be undertaken during the first half of 2007 for white goods include 2 dryers, 2 washing machines, 2 dishwashers and 6 refrigerators & freezers.

The E_3 Committee and its predecessors have undertaken verification testing for some years. Since its inception the program has tested a total of 643 products (in over 10 product categories). The tests target product suspected of being at risk of failing. Detailed in the chart over is a summary of all the check test results conducted since 1991 by product type (Figure 7.10)[56]. Over that time, one third (35%) of these verification tests failed. It should be noted that this high rate of failure reflects a policy of selecting product with a higher risk of failing the test. Risk assessment is based on a number of factors as detailed in the administrative guidelines

Figure 7.10: Summary of all the check test results since 1991 by product type in Australia/New Zealand



[56] Source: E_3 Compliance Newsletter, AIR CONDITIONER EDITION May 2007.

7.2.2.2 USA

a) Energy and water conservation requirements

In the case of performance requirements, upon receiving information in writing concerning the energy/water performance of a particular covered product of a particular manufacturer or private labeller which indicates that the covered product may not be in compliance with the applicable energy/water requirements, the Secretary may conduct testing of that covered product under 10 CFR, 430 Subpart F - *Certification and Enforcement* by means of a test notice addressed to the manufacturer in accordance with the following requirements.

The test notice will specify the model to be selected for testing, the method of selecting the test sample, the timetable for testing and the facility at which testing will be conducted. The Secretary may require that the manufacturer ships at his expense a reasonable number of units of the specified basic model to a designated testing laboratory. The number of units of a basic model specified in a test notice shall not exceed 20. A DOE inspector will select a batch, a batch sample of up to 20 units randomly selected within the batch, and test units randomly selected from the batch sample

Such a procedure will only be followed after the Secretary or his designated representative has examined the underlying test data provided by the manufacturer and after the manufacturer has been offered the opportunity to meet with DOE to verify compliance with the applicable requirements. A representative designated by the Secretary shall be permitted to observe any re-verification procedures, and to inspect the results of such re-verification.

The Appendix B - *Sampling Plan for Enforcement Testing* of Subpart F includes the sampling plan for enforcement testing. A **Double Sampling** procedure is used, including the following Steps:

Step 1. The first sample size (n_1) must be four or more units.

Step 2. Compute the mean (x_1) of the measured energy/water performance of the n_1 units in the first sample as follows:

$$\bar{x}_1 = \frac{1}{n_1}\left(\sum_{i=1}^{n_1} x_i\right) \qquad (1)$$

where (x_i) is the measured energy efficiency, energy or water consumption of unit *i*.

Step 3. Compute the standard deviation (s_1) of the measured energy or water performance of the (n_1) units in the first sample as follows:

$$s_1 = \sqrt{\frac{\sum_{i=1}^{n_1} \left(x_i - \bar{x}_1\right)^2}{n_1 - 1}} \qquad (2)$$

Step 4. Compute the standard error (S_{X1}) of the units in the first sample as follows:

$$s_{\bar{x}_1} = \frac{s_1}{\sqrt{n_1}} \qquad (3)$$

Step 5. Compute the upper control limit (UCL_1) and lower control limit (LCL_1) for the mean of the first sample using the applicable DOE energy or water performance requirements (*EPS*) as the desired mean and a probability level of 95% (two-tailed test) as follows:

$$LCL_1 = EPS - ts_{\bar{x}_1} \qquad (4)$$

$$UCL_1 = EPS + ts_{\bar{x}_1} \qquad (5)$$

where t is a statistic based on a 95% two-tailed probability level and a sample size of n_1.

Step 6(a). For an energy efficiency requirement, compare the mean of the first sample (x_1) with the upper and lower control limits (UCL_1 and LCL_1) to determine one of the following:

1) if the mean of the first sample is below the lower control limit, then the basic model is in non-compliance and testing is at an end;
2) if the mean of the first sample is equal to or greater than the upper control limit, then the basic model is in compliance and testing is at an end;
3) if the sample mean is equal to or greater than the lower control limit, but less than the upper control limit, then no determination of compliance or non compliance can be made and a second sample size is determined by Step 7(a).

Step 6(b). For an energy or water consumption requirement, compare the mean of the first sample (x_1) with the upper and lower control limits(UCL_1 and LCL_1) to determine one of the following:

1) if the mean of the first sample is above the upper control limit, then the basic model is in non-compliance and testing is at an end;
2) if the mean of the first sample is equal to or less than the lower control limit, then the basic model is in compliance and testing is at an end;
3) if the sample mean is equal to or less than the upper control limit but greater than the lower control limit, then no determination of compliance or non-compliance can be made and a second sample size is determined by Step 7(b).

Step 7(a). For an energy efficiency requirement, determine the second sample size (n_2) as follows:

$$n_2 = \left(\frac{ts_1}{0.05\ EPS} \right)^2 - n_1 \qquad (6a)$$

where s_1 and t have the values used in Steps 4 and 5, respectively. The term '0,05 EPS' is the difference between the applicable energy efficiency requirement and 95% of the requirement, where 95% of the requirement is taken as the lower control limit.

This procedure yields a sufficient combined sample size ($n_1 + n_2$) to give an estimated 97,5% probability of obtaining a determination of compliance when the true mean efficiency is equal to the applicable requirement. Given the solution value of n_2, determine one of the following:

1) if the value of n_2 is ≤0 and if the mean energy efficiency of the first sample (x_1) is either equal to or greater than the lower control limit (LCL_1) or ≥ 95% of the applicable energy efficiency requirement (EES), whichever is greater, i.e., if $n_2 \leq 0$ and $x_1 \geq$ max (LCL_1, 0,95 *EES*), the basic model is in compliance and testing is at an end;
2) if the value of n_2 is ≤0 l and the mean energy efficiency of the first sample (x_1) is less than the lower control limit (LCL_1) or less than 95% of the applicable energy efficiency requirement (*EES*), whichever is greater, i.e., if $n_2 \leq 0$ and $x_1 \geq$ max (LCL_1, 0,95 *EES*), the basic model is in non-compliance and testing is at an end;

3) if the value of n_2>0, then value of the second sample size is determined to be the smallest integer equal to or greater than the solution value of n_2 for equation (6a). If the value of n_2 so calculated is greater than (20−n_1), set n_2 equal to (20−n_1)

Step 7(b). For an energy or water consumption requirement, determine the second sample size (n_2) as follows:

$$n_2 = \left(\frac{ts_1}{0.05\ EPS} \right)^2 - n_1 \qquad (6b)$$

where s_1 and t have the values used in Steps 4 and 5, respectively. The term '0,05 *EPS*' is the difference between the applicable energy or water consumption requirement and 105% of the requirement, where 105% of the requirement is taken as the upper control limit. This procedure yields a sufficient combined sample size (n_1 + n_2) to give an estimated 97,5% probability of obtaining a determination of compliance when the true mean consumption is equal to the applicable requirement. Given the solution value of n_2, determine one of the following:

1) if the value of $n_2 \leq 0$ and if the mean energy or water consumption of the first sample (x_1) is either equal to or less than the upper control limit (UCL_1) or equal to or less than 105% of the applicable energy or water performance requirement (*EPS*), whichever is less, i.e., if $n_2 \leq 0$ and $x_1 \leq$ min (UCL_1, 1,05 EPS), the basic model is in compliance and testing is at an end;
2) if the value of $n_2 \leq 0$ and the mean energy or water consumption of the first sample (x_1) is greater than the upper control limit (UCL_1) or more than 105% of the applicable energy or water performance requirement (*EPS*), whichever is less, i.e., if $n_2 \leq 0$ and $x_1 >$ min (UCL_1, 1,05 *EPS*), the basic model is in non-compliance and testing is at an end;
3) if the value of n_2>0, then the value of the second sample size is determined to be the smallest integer equal to or greater than the solution value of n_2 for equation (6b). If the value of n_2 so calculated is greater than (20−n_1), set n_2 equal to (20−n_1).

Step 8. Compute the combined mean (x_2) of the measured energy or water performance of the n_1 and n_2 units of the combined first and second samples as follows :

$$\bar{x}_2 = \frac{1}{n_1 + n_2} \left(\sum_{i=1}^{n_1+n_2} x_i \right) \qquad (7)$$

Step 9. Compute the standard error (S_{x1}) of the measured energy or water performance of the n_1 and n_2 units in the combined first and second samples as follows (s_1 is the value obtained in Step 3):

$$s_{\bar{x}_2} = \frac{s_1}{\sqrt{n_1 + n_2}} \qquad (8)$$

Step 10(a). For an energy efficiency requirement, compute the lower control limit (LCL_2) for the mean of the combined first and second samples using the DOE energy efficiency requirement (*EES*) as the desired mean and a one-tailed probability level of 97,5% (equivalent to the two-tailed probability level of 95% used in Step 5) as follows:

$$LCL_2 = EES - ts_{\bar{x}_2} \qquad (9a)$$

where the t-statistic has the value obtained in Step 5.

Step 10(b). For an energy or water consumption requirement, compute the upper control limit (UCL_2) for the mean of the combined first and second samples using the DOE energy or water

performance requirement (*EPS*) as the desired mean and a one-tailed probability level of 102,5% (equivalent to the two-tailed probability level of 95% used in Step 5) as follows:

$$UCL_2 = EPS + ts_{\bar{x}_2} \qquad (9b)$$

where the t-statistic has the value obtained in Step 5.

Step 11(a). For an energy efficiency requirement, compare the combined sample mean (x_2) to the lower control limit (LCL_2) to find one of the following:

1) if the mean of the combined sample (x_2) is less than the lower control limit (LCL_2) or 95% of the applicable energy efficiency requirement (*EES*), whichever is greater, i.e., if $x_2 <$ max (LCL_2, 0,95 *EES*), the basic model is in non-compliance and testing is at an end;
2) if the mean of the combined sample (x_2) is equal to or greater than the lower control limit (LCL_2) or 95% of the applicable energy efficiency requirement (*EES*), whichever is greater, i.e., if $x_2 \geq$ max (LCL_2, 0,95 *EES*), the basic model is in compliance and testing is at an end;

Step 11(b). For an energy or water consumption requirement, compare the combined sample mean ($_{x2}$) to the upper control limit (UCL_2) to find one of the following:

1) if the mean of the combined sample (x_2) is greater than the upper control limit (UCL_2) or 105% of the applicable energy or water performance requirement (*EPS*), whichever is less, i.e., if $x_2 >$ min (UCL_2, 1,05 *EPS*), the basic model is in non-compliance and testing is at an end;
2) if the mean of the combined sample (x_2) is equal to or less than the upper control limit (UCL_2) or 105% of the applicable energy or water performance requirement (*EPS*), whichever is less, i.e., if $x_2 \leq$ min (UCL_2, 1,05 *EPS*), the basic model is in compliance and testing is at an end.

Manufacturer-Option Testing: if a determination of non-compliance is made in Steps 6, 7 or 11, the manufacturer may request that additional testing be conducted, in accordance with the following procedures:

Step A. The manufacturer requests that an additional number, n_3, of units be tested, with n_3 chosen such that (n_1+n_2+n_3) does not exceed 20;

Step B. Compute the mean energy or water performance, standard error, and lower or upper control limit of the new combined sample in accordance with the procedures prescribed in Steps 8, 9, and 10, above;

Step C. Compare the mean performance of the new combined sample to the revised lower or upper control limit to determine one of the following:

- a.1) for an Energy Efficiency Standard, if the new combined sample mean is equal to or greater than the lower control limit or 95% of the applicable energy efficiency standard, whichever is greater, the basic model is in compliance and testing is at an end;
- a.2) for an Energy or Water Consumption Standard, if the new combined sample mean is equal to or less than the upper control limit or 105% of the applicable energy or water consumption standard, whichever is less, the basic model is in compliance and testing is at an end;
- b.1) for an Energy Efficiency Standard, if the new combined sample mean is less than the lower control limit or 95% of the applicable energy efficiency standard, whichever, is greater, and the value of (n_1+n_2+n_3) is less than 20, the manufacturer may request that additional units be tested. The total of all units tested may not exceed 20. Steps A, B, and C are then repeated;
- b.2) for an Energy or Water Consumption Standard, if the new combined sample mean is greater than the upper control limit or 105% of the applicable energy or water consumption standard, whichever is less, and the value of (n_1+n_2+n_3) is less than 20, the manufacturer may request that additional units be tested. The total of all units tested may not exceed 20. Steps A, B, and C are then repeated;
- c) otherwise, the basic model is determined to be in non-compliance.

The manufacturer bears the cost of all testing conducted under this Option.

b) Appliance labelling

The CFR, Title 16, Part 305 - *Rule concerning disclosures regarding energy consumption and water use of certain home appliances and other products required under the energy policy and conservation act ("appliance labelling rule")*, establishes requirements for consumer appliance products with respect to energy/water labelling and/or marking the products with information indicating their operating cost (or different useful measure of energy consumption) and related information.

It states that upon notification by the Federal Trade Commission or its designated representative, a manufacturer of a covered product shall supply, at the manufacturer's expense, no more than two of each model of each product to a laboratory, which will be identified by the Commission or its designated representative in the notice, for the purpose of ascertaining whether the estimated annual energy consumption, the estimated annual operating cost, or the energy efficiency rating, or the light output, energy usage and life ratings or, for general service fluorescent lamps, the colour rendering index, disclosed on the label or fact sheet or in an industry directory, or, as required in a catalogue, or the representation made by the label that the product is in compliance with applicable requirements is accurate.

Such a procedure will only be followed after the Commission or its staff has examined the underlying test data provided by the manufacturer and after the manufacturer has been afforded the opportunity to re-verify test results from which the estimated annual energy consumption, the estimated annual operating cost, or the energy efficiency rating for each basic model was derived, or the light output, energy usage and life ratings or, for general service fluorescent lamps, the colour rendering index, for each basic model or lamp type was derived. A representative designated by the Commission shall be permitted to observe any re-verification procedures required by this part, and to inspect the results of such re-verification.

The Commission will pay the charges for testing by designated laboratories

c) Laboratory accreditation

No accredited laboratories are requested for household appliances, while the testing for general service fluorescent lamps, general service incandescent lamps, incandescent reflector lamps, and medium base compact fluorescent lamps, shall be conducted by test laboratories accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) or by an accrediting organization recognized by NVLAP. NVLAP is a program of the National Institute of Standards and Technology, U.S. Department of Commerce. NVLAP standards for accreditation of laboratories that test for compliance with standards for lamp efficacy and CRI are given in 15 CFR part 285 as supplemented by NVLAP Handbook 150–01, "Energy Efficient Lighting Products, Lamps and Luminaires." A manufacturer's or importer's own laboratory, if accredited, may conduct the applicable testing.

7.2.2.3 The European Union

a) Energy efficiency requirements

The energy efficiency requirement directive 96/57/EC for cold appliances bases the verification on a two stage procedure: in **Stage 1** the check is performed on one sample of the model. In case of

non-compliance, the **Stage 2** check is developed on three additional samples of the model. The test procedures are described in Annex 1 of the directive "*Method for calculating the maximum allowable electricity consumption of a refrigeration appliance and procedure for checking conformity*" as:

> **Test procedures for checking whether an appliance complies with the electricity consumption requirements of this Directive**
>
> If the electricity consumption of a refrigeration appliance submitted for verification is less than or equal to E_{max} (the maximum allowable electricity consumption value for its category, as defined above), plus 15 %, the appliance is certified as conforming to the electricity consumption requirements of this Directive. If the electricity consumption of the appliance is greater than E_{max} plus 15 %, the electricity consumption of a further three appliances must be measured. If the arithmetic mean of the electricity consumptions of these three appliances is less than or equal to E_{max} plus 10 %, the appliance is certified as conforming to the electricity consumption requirements of this Directive. If the arithmetic mean exceeds E_{max} plus 10 %, the appliance must be judged not to conform to the electricity consumption requirements of this Directive.

b) Energy labelling

The energy labelling schemes for household appliances base the verification on the provisions included in a specific Clause or normative Annex of the relevant standards, which are mentioned in the specific directives. In general, the verification is based on a two stage procedure: in Stage 1 the check is performed on one sample of the model. In case of non-compliance, the Stage 2 check is developed on three additional samples of the model. Depending on the parameter to be verified, a verification tolerance is applied to both Stages.

For cold appliances, Annex C - Rated characteristics and control procedure of EN 153, states the control procedure for :

1) Volumes and areas
- **Rated gross volume**: the measured value shall not be less than the rated value by more than 3% or 1 litre, whichever is the greater value;
- **Rated storage volume**: the measured value shall not be less than the rated value by more than 3% or 1 litre, whichever is the greater value. Where the volumes of the cellar compartment and fresh-food storage compartment are adjustable relative to one another by the user, this requirement applies when the cellar compartment is adjusted to its minimum volume;
- **Rated storage shelf area**: the measured storage shelf area, including that of any cellar and chill compartment, shall not be less than the rated storage shelf area by more than 3%;
- **Control procedure**: if the previous requirements are not met on a single refrigerating appliance, the measurements shall be made on a further 3, randomly selected, refrigerating appliances. The arithmetical mean of the measured values of these 3 refrigerating appliances shall be in accordance with the requirements.

2) Performance characteristics
- **Storage temperatures**: the values on the first refrigerating appliance tested shall comply with the requirements of the standard. If any result of the test carried out on the first refrigerating appliance is outside the specified values, the test shall be carried out on a further 3, randomly selected, refrigerating appliances. All the values on these 3 refrigerating appliances tested shall comply with requirements given in the standard;
- **Freezing capacity**: the value measured on the first refrigerating appliance tested shall not be less than the rated value by more than 15%. If the result of the test carried out on the first refrigerating appliance is less than the rated value minus 15% , the test shall be carried out on a

further 3 randomly selected refrigerating appliances. The arithmetical mean of the values of these 3 refrigerating appliances shall be equal to or greater than the rated value minus 10%.
The value obtained either on the first refrigerating appliance tested or the arithmetical mean value obtained on a further 3 refrigerating appliances shall be in accordance with the minimum stated values;

- **Energy consumption, Ice making, Temperature rise time**: the value measured shall not be greater than the rated value by more than 15%. If the result of the test carried out on the first refrigerating appliance is greater than the rated value plus 15%, the test shall be carried out on a further 3 randomly selected refrigerating appliances. The arithmetical mean of the values of these 3 refrigerating appliances shall be equal to or less than the rated value plus 10%.

For wash appliances:

1) **Dishwashers**: Clause Z2 of - Tolerances and control procedures of EN 50242 Ed.2 and EN 60436, states the control procedure for:

- **Cleaning performance**: the cleaning performance shall not be less than the value declared by the manufacturer minus 6%. If the result of the test carried out on the first appliance is less than the value declared by the manufacturer minus 6% the test shall be carried out on a further 3 appliances. The arithmetic mean of the values of these 3 appliances shall not be less than the declared value minus 4%;
- **Drying performance**: the drying performance shall not be less than the value declared by the manufacturer minus 15%. If the result of the test carried out on the first appliance is less than the value declared by the manufacturer minus 15% the test shall be carried out on a further 3 randomly selected appliances. The arithmetic mean of the values of these 3 appliances shall not be less than the declared value minus 10%;
- **Energy consumption**, **Water consumption**, **Cycle time**: the measured value shall not be greater than the value declared by the manufacturer plus 15%. If the result of the test carried out on the first appliance is greater than the declared value plus 15%, the test shall be carried out on a further 3 randomly selected appliances. The arithmetical mean of the values of these 3 appliances shall not be greater than the declared value plus 10%;

By retesting the further 3 appliances with limited tolerances all values shall be specified (cleaning, drying, energy, water and time).

2) **Washing machines**: Clause Z3 - Tolerances and control procedures of EN 60456, states the control procedure for :

- **Energy consumption**, **Water consumption, Spin extraction**: the measured value shall not be greater than the value declared by the manufacturer plus 15%. If the result of the test carried out on the first appliances is greater than the declared value plus 15% , the test shall be carried out on a further 3 appliances, which shall be randomly selected from the market. The arithmetic mean of the values of these 3 appliances shall not be greater than the declared value plus 10%;
- **Spin speed**: the spin speed shall not be less than the value declared by the manufacturer minus 10% or minus 100 rpm, whichever is the smaller value. If the result of the test carried out on the first appliances is less than the declared value minus 10% or minus 100 rpm (whichever is the smaller value), the test shall be carried out on a further 3 appliances, which shall be randomly selected from the market. The value of each of these 3 appliances shall not be less than the declared value minus 10% or minus 100 rpm, whichever is the smaller value;
- **Washing performance**: the washing performance, shall not be less than the value declared by the manufacturer minus 0,03. If the result of the test carried out on the first appliance is less than the declared value minus 0,03, the test shall be carried out on a further 3 appliances, which shall

be randomly selected from the market. The arithmetic mean of the values of these 3 appliances shall not be less than the declared value minus 0,02;

- **Programme duration**: the programme duration shall not be longer than the value declared by the manufacturer plus 15 %. If the result of the test carried out on the first appliances is longer than the declared value plus 15%, the test shall be carried out on a further 3 appliances, which shall be randomly selected from the market. The arithmetic mean of the values of these 3 appliances shall not be longer than the declared value plus 10%.

A summary of the EU verification system for the energy consumption declarations in the energy labelling and energy efficiency requirement schemes is presented in Table 7.12.

Table 7.12: **Summary of the EU verification system for energy consumption in labelling and efficiency requirements**

Appliance	Implementing Directives	Standard	Verification procedure			
			Stage 1		Stage 2	
			Units (number)	Tolerance (%)	Units (number)	Tolerance (%)
Energy labelling scheme						
Refrigerators & freezers	94/2/EC, 2003/66/EC	EN 153	1	15%	3	10%
Washing machines	95/12/EC, 96/89/EC	EN 60456	1	15%	3	10%
Tumble dryers	95/13/EC	EN 61121	1	15%	3	10%
Washer-dryers	96/60/EC	EN 50229	1	15%	3	10%
Dishwashers	97/17/EC, 99/9/EC	EN 50242	1	15%	3	10%
Air conditioning	2002/31/EC	EN 14511	1	15%	3	10%
Ovens	2002/40/EC	EN 50304	1	40Wh+10%	3	10%
Efficiency requirements						
Refrigerators & freezers	96/57/EC	EN 153	1	15%	3	10%

c) The eco-label scheme

In the Annex of Commission Decision (2004/669/EC) of 6 April 2004 establishing the ecological criteria for the award of the Community eco-label to refrigerators, and amending Decision 2000/40/EC, only the procedure for the measurement declaration are described. A brief mention of the verification procedure and criteria was included in previous Decision 2000/40/EC, which reported: “in case of verification, which is not required on application, competent bodies shall apply the tolerances and control procedures laid down in EN 153”.

No verification procedure is described for washing machines and dishwashers in the respective Commission Decisions.

d) Laboratory accreditation:

No accreditation is requested in the European Union to laboratories for the verification activity.

7.2.2.4 Conclusions for the verification procedures

A comparison of the test procedures described in the previous paragraphs shows that that there are some common elements:

- the most important outcome is that under the different form of a measurement error considered equal to the variability of the test measurement, or a verification limit taking care of measurement uncertainty, systematic and random errors and production variability, a 'tolerance' is always used in testing, both for the labelling declarations and for the compliance with minimum requirements;
- countries foreseeing accredited laboratories for verification generally use a lower value of 'tolerance', usually set equal to the error of the laboratory (reproducibility of the measurement method); but only accredited laboratories can then run official verification tests;
- a complete and correct verification procedure includes at least 2 Stages (sometimes three), and 4 or more units of the tested models (from 4 up to 20 units in US);
- the verification of the energy consumption for cold appliances is more complex than for other household appliances in Australia and US, while in the EU the same procedure is followed for all household appliance.

7.2.3 The Enforcement and market surveillance

7.2.3.1 The Australian market compliance control

As reported in the Issue 2 of Compliance Newsletter, a registration compliance audit was undertaken in the second half of 2006 into air conditioners on the Australian marketplace. The in store compliance audit consisted of comparing a list of air conditioner unit sales supplied by the marketing firm GfK and of advertising on the internet against the list of models included in the Energy Rating database in order to uncover potentially unregistered product. The search was extended to air conditioners Internet websites and other supply outlets to look for unregistered models.

A number of unregistered models were found and relevant suppliers were contacted. An ongoing dialogue commenced and actions may be taken against suppliers of unregistered stock.

This audit was considered successful by regulators because a number of previously unknown suppliers were contacted and made aware of labelling and energy efficiency requirements. The main sanction used against electrical equipment retailers is infringement notices. During the 2005-2006 financial year, Australian energy regulators concentrated on using educative approaches to retailers explaining their responsibilities in relation to labelled appliances.

A similar audit for white goods targeting dryers, washing machines, dishwashers, refrigerators and freezers is to be undertaken during 2007. A further audit will be conducted in 2007 for air conditioners and at that time sanctions other than discussion and correspondence with regulators will be used where instances of non-compliance are detected.

7.2.3.2 The European Union

The EU market surveillance is based on Article 3 of directive 94/2/EC, Member States shall take all necessary measures to ensure that all suppliers and dealers established in their territory fulfil their obligations under this Directive.

Starting 1996, the European Commission DG TREN promoted under the SAVE programme three monitoring studies to evaluate the impact of the EU legislation on the market transformation of cold appliances and energy consumption under the leadership of the French Agency ADEME- Agence

de l'Environnement et le Maîtrise de l'Énergie (ADEME, 1998[57]; ADEME, 2000[58]; ADEME, 2001[59]). No other major studies or reports on the overall implementation of the labelling scheme and the efficiency requirements in the EU have been promoted or prepared. Some more recent projects developed in the framework of the SAVE-II[60] and the Intelligent Energy Europe[61] programmes have addressed the implementation of the energy labelling scheme in groups of member States.

Single Member States have developed market surveillance activities at national level in a discontinue way over the years. For example, the 2001 document "Evaluating the Implementation of the Energy Consumption Labelling Ordinance", Research Project on behalf of the German Federal Ministry of Economics and Technology[62] states the energy labelling implementation in Germany, or the document "Ten Years of Energy Labelling of Domestic Appliances 1995–2005"[63] of the Swedish Energy Agency stating the conclusion after ten years and showing also the result of appliance testing from one single test:

- 101 cold appliances, 15 deviated more than allowed (14,9%).
- 19 ovens, 2 deviated more than allowed (10,5%).
- 28 dishwashers, 13 deviated more than allowed (46,4%).
- 48 washing machines, 20 deviated more than allowed (41,7%).
- 14 tumble dryers, 2 deviated more than allowed (14,3%).

since only the Step 1 of the two stage verification procedure of the labelling scheme has been completed, it is not possible to draw conclusions about the actual compliance rate.

The CECED Voluntary Commitment on Reducing Energy Consumption of **Household Refrigerators, Freezers and their Combinations** (2002-2010), foresee a monitoring and reporting actions. In particular, the monitoring system of the Commitment supervises both the fulfilment of the conditions and the progress in energy saving resulting from the Commitment itself. The compliance with the targets is based on data that are declared on the energy label for household refrigerating appliances (according to the energy labelling Directive).
A Notary monitors on an annual basis the results achieved by the Commitment, in terms of an overall production weighted energy consumption figure, calculated on the basis of the complete production/ import range in the EU of all participants. Participants to the Commitment are responsible for the accuracy of the data communicated to the Notary and for this purpose, they commit themselves to have such data validated by an independent (responsible) auditor. Each participant remains responsible for the data declared on the label and communicated to CECED, which will ensure that the information is passed consistently in the database.
As far as the reporting is concerned, the Notary collects on a confidential basis from each manufacturer the production weighted energy efficiency index and the total production quantity for

[57] ADEME, Monitoring of energy efficiency trends of European domestic refrigeration appliances: final report, PW Consulting for ADEME on behalf of the European Commission, 1998.
[58] ADEME, Monitoring of energy efficiency trends of refrigerators, freezers, washing machines and washer-dryers in the EU, Final Report, PW Consulting for ADEME on behalf of the European Commission, 2000.
[59] ADEME, Monitoring of energy efficiency trends of refrigerators, freezers, washing machines, washer-dryers and household lamps in the EU, Final Report, PW Consulting for ADEME on behalf of the European Commission, 2001.
[60] SAVE project "Energy Labels - Making a Greener Choice", contract 4.1031/Z/01-024/2001, 2004.
[61] IEE project "CEECAP – Implementing EU Appliance Policy in Central and Eastern Europe project", http://www.ceecap.org/cntnt/ceecap/library .
[62] Fraunhofer ISI, "Evaluating the Implementation of the Energy Consumption Labelling Ordinance", Executive Summary, Research Project on behalf of the German Federal Ministry of Economics and Technology, No. 28/00, March 2001.
[63]The Swedish Energy Agency, Ten Years of Energy Labelling of Domestic Appliances 1995–2005, ER 2006:18.

each product category and for each energy efficiency class. The Notary will provide CECED with an aggregated summary and anonymous ranking of the participants.
CECED collects a database that contains technical data of all models of household refrigerating appliances placed on the Community market by all the participants. For each single model the data mandatory on the energy label are given. The database is available to the European Commission, national authorities and, for study purposes, to experts appointed by them. The copyright is owned by CECED.
Based on the data provided, CECED submits each calendar year starting from 01.01.2003 to the European Commission a report including the following information:

- on the base of the Notary summary:
  - the overall production weighted energy efficiency index;
  - a histogram of production weighted energy efficiency index for each efficiency classes and product category;
  - the ranking of the production weighted energy efficiency indexes of the participants in an anonymous way;

- on the base of the CECED technical database:
  - the respective share of each product category
  - some charts showing the trend in the technology

The annual report will be made available to the public free of charge.

A similar procedure is foreseen also for the "Second Voluntary Commitment on Reducing Energy Consumption of Domestic **Washing Machines** (2002-2008)" and the "Voluntary Commitment on Reducing Energy Consumption of Household **Dishwashers** (2000-2004)".

7.3 SUBTASK 7.3: THE BUSINESS AS USUAL SCENARIO

The definition of the Business as Usual (BaU) scenario for the wash appliances is based on qualitative assumptions rather then factual evidences.

It is worth remembering that the notable technological progress and the high energy efficiency gains achieved by this manufacturing sector during the last 10-12 years are entirely due to the effective mandatory and voluntary policies and measures enforced or promoted by the European Commission and the Members States.

This does not mean that, without these policies, the sector would have not improved the energy efficiency of its products, but there is no evidence to which extent this could have been achieved and what technological innovation would have resulted. Actually, significant improvements of the energy efficiency were realised during the '80s and the beginning of the '90s (see Table 7.13[64] showing the average annual energy consumption for wash appliances starting from 1950) but at that time the energy efficiency and technological improvement potentials were high and the energy savings relatively easy to obtain. Today any further improvement is more difficult to achieve for the household appliances industry and needs to be justified by the market demand.

[64] Source: CECED

Table 7.13: Unitary energy consumption of washing machines

Year	Average energy consumption (kWh/cycle)	Number of cycles (cycle/year)
1953-1981	3,250	277
1982-1992	1,830	256
1993-1996	1,350	251
1997	1,177	251
1998-1999	1,177	245
2000	1,081	245
2001-2002	1,081	245
2003-2004	1,081	234
2005	0,997	234

All this leads to the assumption that, without further policy measures (the latest industry voluntary commitment on washing machines will end in 2008), a very little or even no additional energy efficiency improvement is expected for these appliances. Possible hypothesis are:

- for dishwashers, the A class (i.e. the LLCC model) will reach 100% of the market in year 2015. No other new energy efficiency classes entries are envisaged during this period;
- for washing machines, being the specific energy consumption of the LLCC model in the range of the "A+" class, it is reasonable to envisage that this class will spread into the market in the next decade (probably around year 2020). This means that the A and A+ classes will dominate the market during the next decade and the A+ class (named here LLCC), will reach 100% in year 2020.

These scenario assumption are presented in Tables 7.14 and 7.15 and in Figures 7.11 and 7.12 that show the market transformation trend respectively for washing machines and dishwashers. In the lower rows of the Tables the average energy consumption per kg of load (for the washing machines only), per cycle and per year are shown. It is worth noting that the overall annual stock and average energy consumptions include the standby mode consumption, hypothesised in 11,8 kWh/year for the washing machines and in 12,4 kWh/year for the dishwashers.

Table 7.14: BaU Scenario for washing machines, energy efficiency classes trend in 2005-2030

Year	A+ (%)	A (%)	B (%)	C (%)	Tot. (%)
2005	38	52	6	4	100
2009	55	45	0	0	100
2014	70	30	0	0	100
2019	10	0	0	0	100
2025	100%	0	0	0	100
2030	100	0	0	0	100
Energy consumption (kWh/kg)	0,17	0,19	0,23	0,27	--
Energy consumption (kWh/cycle)	0,91	1,02	1,23	1,45	--
Energy consumption (kWh/y)	212	236	283	330	--

Table 7.15: BaU Scenario for dishwashers, energy efficiency classes trend in 2005-2030

Year	A (%)	B (%)	C (%)	Tot. (%)
2005	91	8	2	100
2009	97	3	0	100
2014	100	0	0	100
2019	100	0	0	100
2025	100	0	0	100
2030	100	0	0	100
Energy consumption (kWh/cycle)	1,06	1,26	1,45	--
Energy consumption (kWh/y)	309	364	420	--

Figure 7.11: Market transformation for washing machines, BaU Scenario **(percentage of models in each class are shown)**

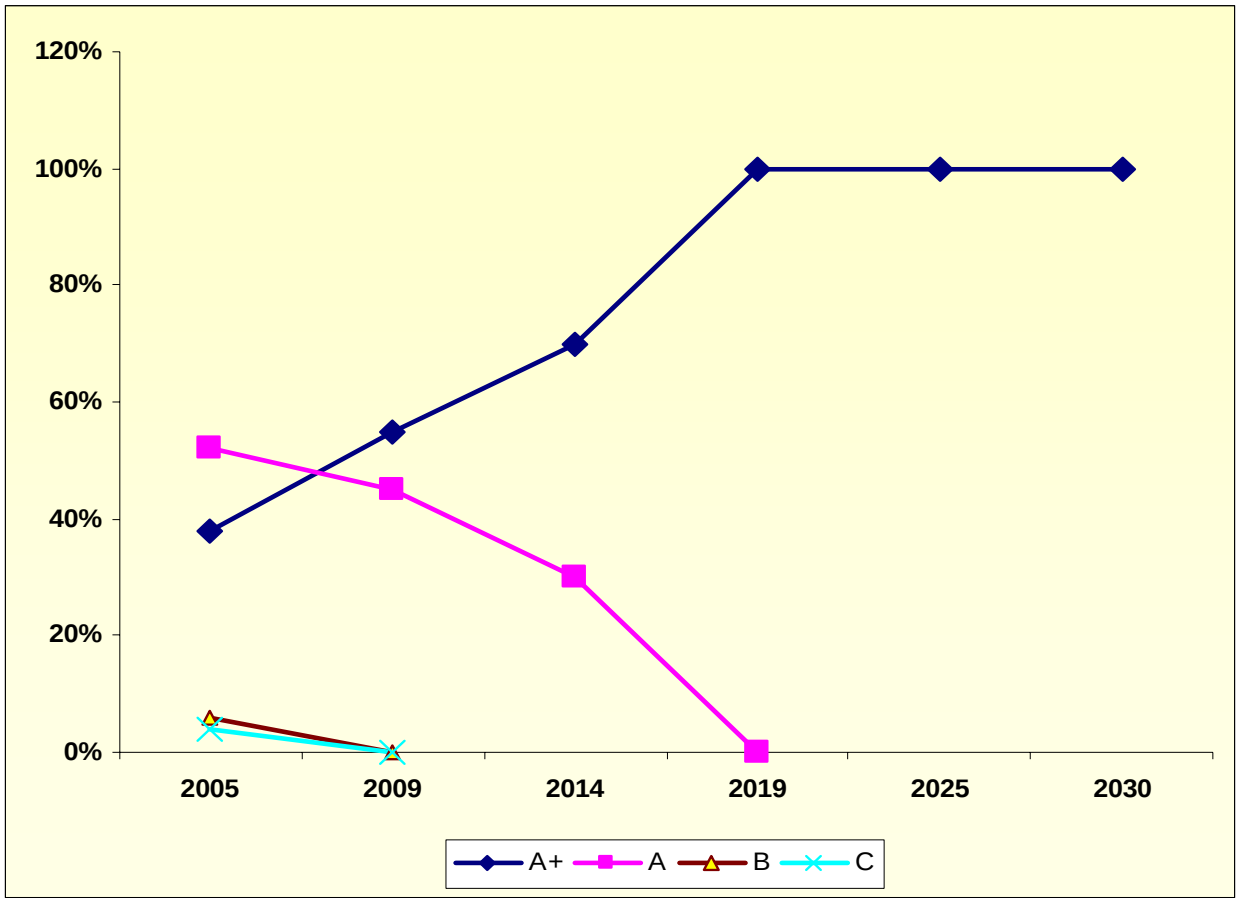
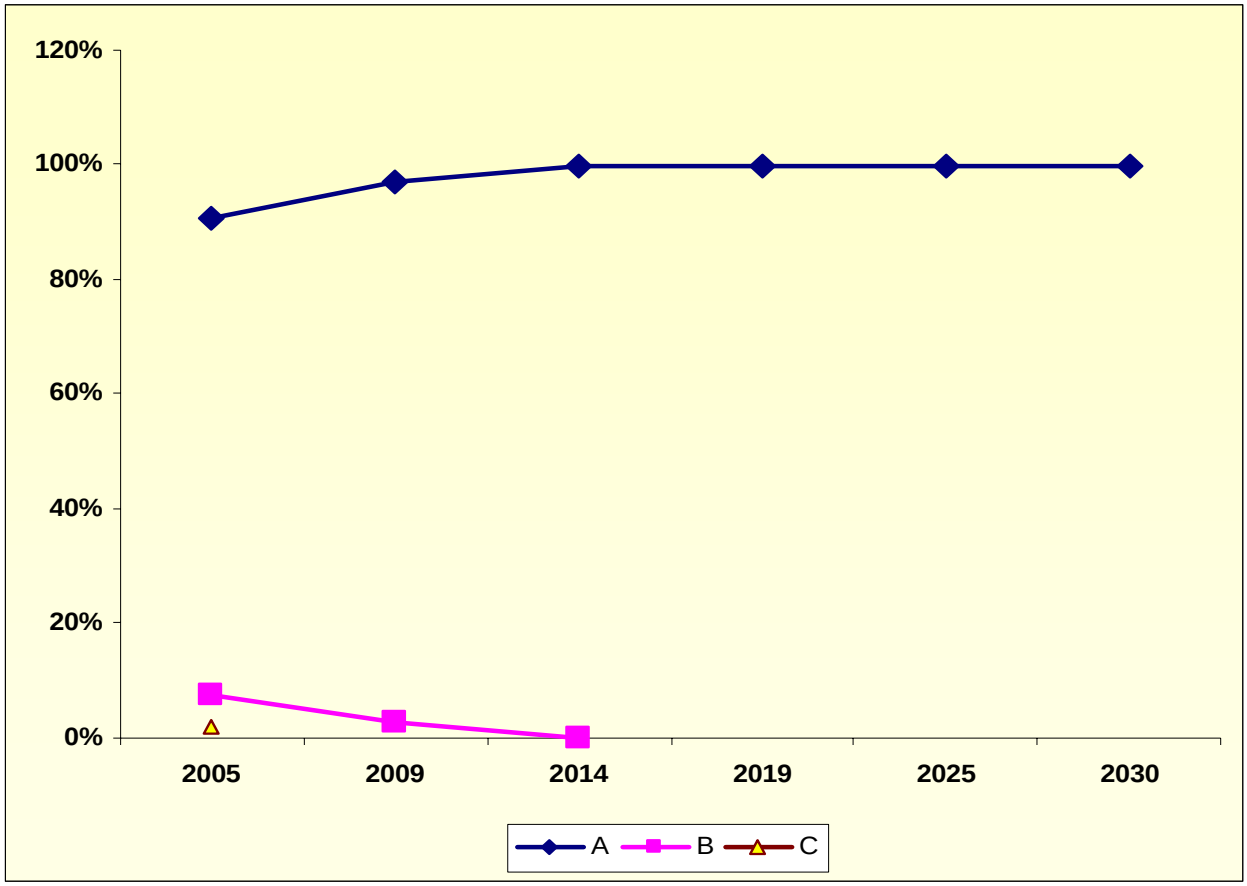


***Figure 7.12: Market transformation for dishwashers, BaU Scenario* (percentage of models in each class are shown)**



Tables 7.16-7.18 and Figures 7.13-7.15 for washing machines and Tables 7.19-7.21 and Figures 7.16-7.18 for dishwashers, show the appliance stock, the stock energy consumption and the average energy consumption trends for the years 1990-2020 in accordance with the BAU Scenario assumptions and the stock growth rates provided by the stock model described in Task 2.

As far as **washing machines** are concerned, the stock energy consumption (Figure 7.14) shows a peak in 1995, decreases steadily until 2010 and then slowly increases again due to the household growth rate (the washing machine ownership is estimated to saturate at 90% around the year 2005). This trend, clearly showing the effect of the policies implemented during the past decade, is consistent with the average energy consumption values that stop decreasing around 2015. Due to the ownership rate saturation (96% for EU15 at 2020 and 92% for EU10 in the same year), to keep the stock energy consumption at least constant, the average energy consumption per unit should decrease steadily at a rate at least equal to the household number growth rate.

Figure 7.16 and 7.17 show respectively the appliance stock and the stock energy consumption trends for **dishwashers**. For EU15 it is assumed that the ownership reaches 60% in year 2020, while the for EU10 the situation is different but available data are less reliable. From the assessment carried out within the SACHA[65] project during the second half of the '90s (see Task 2) very few or even no dishwashers were installed in these countries in 1995. But the sales of this product, although concentrated in few countries, are lively, with +50% in three years in four Eastern

[65] The SACHA 1 and SACHA 2 projects, developed under the DG TREN SAVE-I programme in 1995-1998, evaluated the refrigerators and washing machines state of the art in seven Central and Eastern European countries, including former Accession Countries.

European countries. Therefore a rapid penetration of dishwashers in new Member States in East Europe can be expected, with an estimated ownership of 20% in 2020.

Due to the combined effect of the households' number growth and the increase in ownership the dishwasher stock is still sharply increasing and despite a strong decrease of the unitary energy consumption (see Figure 7.16) the stock energy consumption, especially in Eastern Member States increases rather steadily.

Table 7.16: Washing machine stock trend in the EU countries in 1990-2030, BaU Scenario (million of units)

Years	Stock		
	EU 25	EU 15	EU 10
1990	122	109	12,8
1995	141	124	16,5
2000	157	136	20,2
2005	167	143	24,1
2009	177	151	26,3
2014	188	160	27,9
2019	197	169	28,6
2025	208	179	29,5
2030	217	187	30,2

Table 7.17: Stock energy consumption trend for washing machines in EU countries in 1990-2030, BaU Scenario (GWh/year)

Years	**Energy consumption**		
	EU 25	EU 15	EU 10
1990	52 092	46 527	5 565
1995	54 857	48 368	6 489
2000	52 400	45 465	6 935
2005	47 704	40 553	7 151
2009	45 356	38 348	7 008
2014	44 188	37 456	6 732
2019	44 261	37 730	6 531
2025	45 120	38 667	6 454
2030	46 502	39 998	6 504

Table 7.18: Average energy consumption trend for washing machines in EU countries in 1990-2030, BaU Scenario (kWh/year)

Years	Average energy consumption		
	EU 25	EU 15	EU 10
1990	427	427	434
1995	389	389	394
2000	335	333	343
2005	285	283	296
2009	256	254	266
2014	235	234	242
2019	224	224	228
2025	217	217	219
2030	214	214	215

Figure 7.13: ***Washing machines stock trend in the EU countries in 1990-2030, BaU Scenario (million of units)***

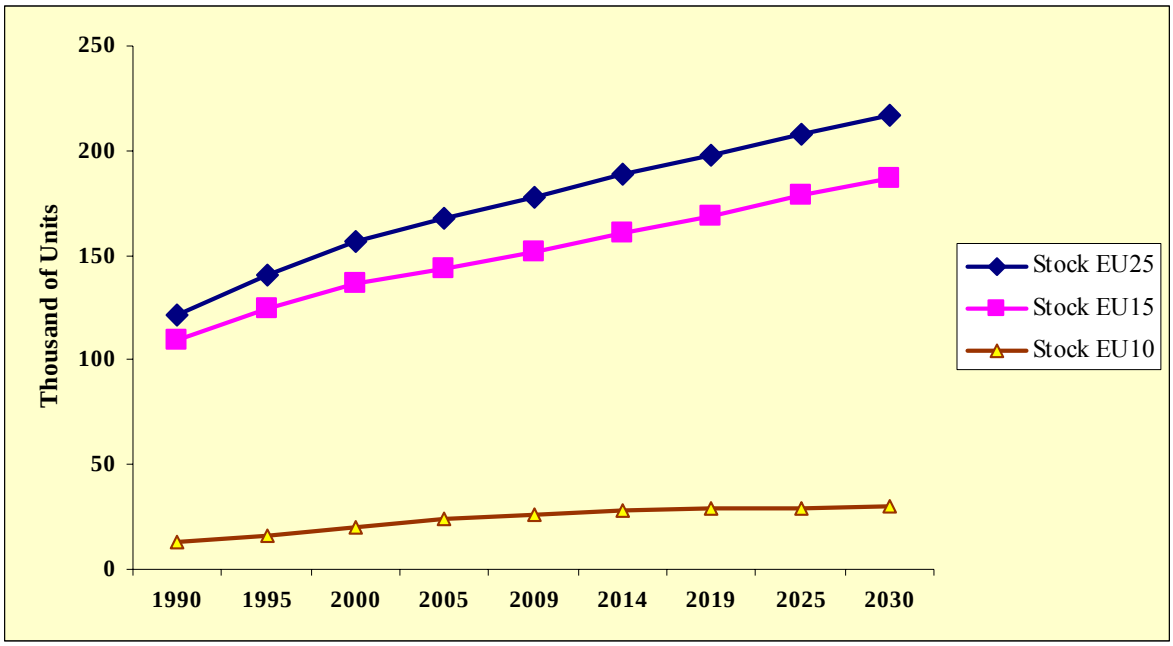


Figure 7.14: ***Stock energy consumption trend for washing machines in EU countries in 1990-2030, BaU Scenario (GWh/year)***

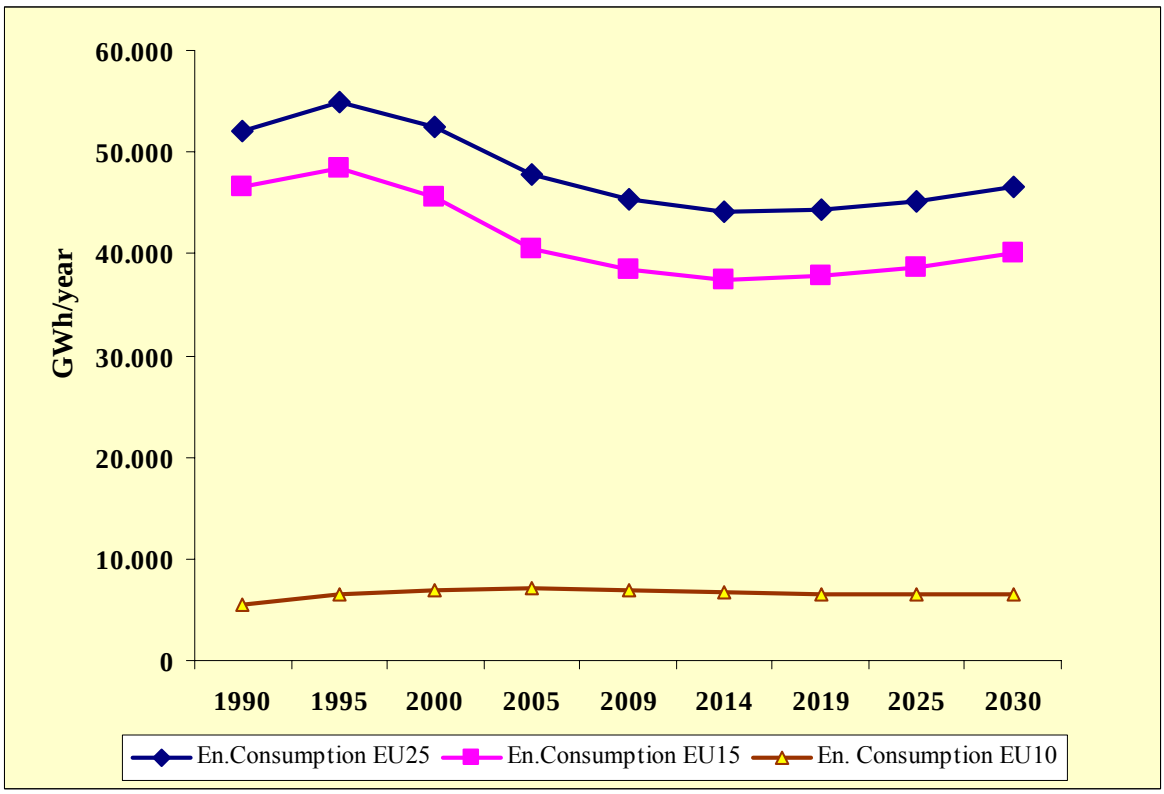


Figure 7.15: ***Average energy consumption trend for washing machines in EU countries in 1990-2030, BaU Scenario*** **(kWh/year)**

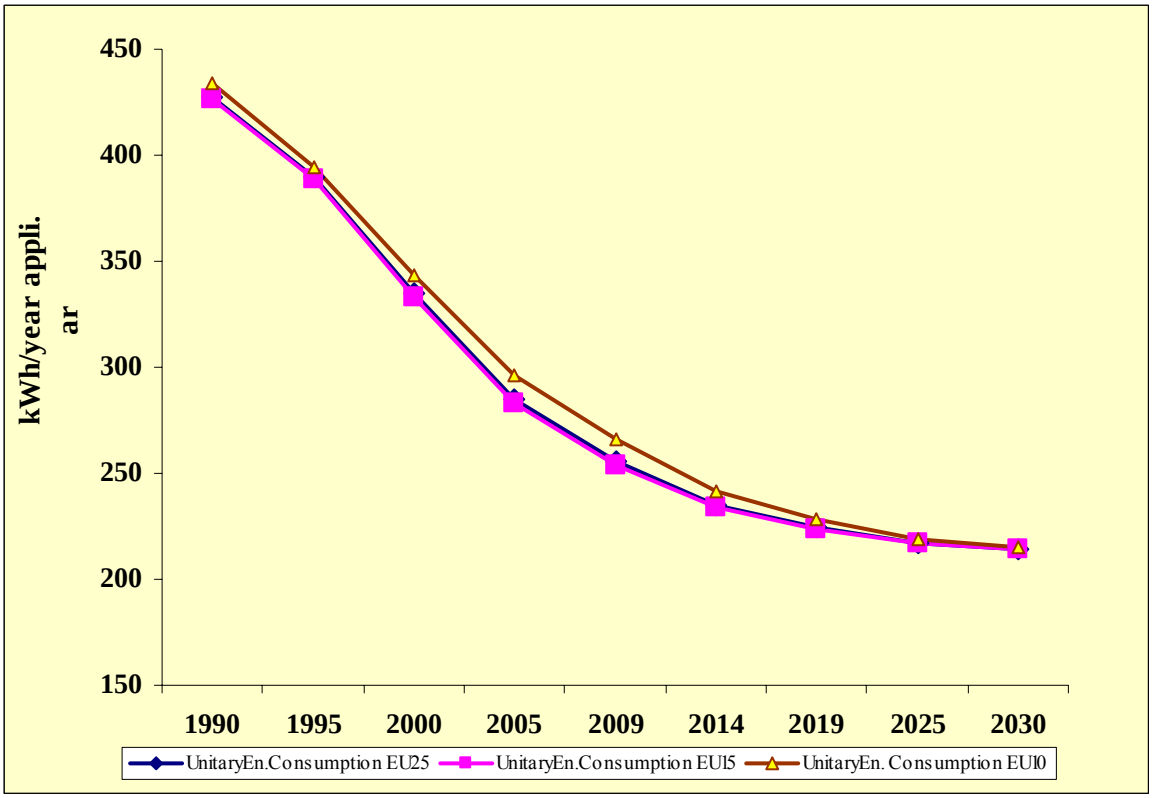


Table 7.19: Dishwasher stock trend in the EU countries in 1990-2030, BaU Scenario (million of units)

Years	Stock		
	EU 25	EU 15	EU 10
1990	36	36	0,00
1995	47	47	0,13
2000	58	57	0,54
2005	69	68	1,28
2009	81	79	2,11
2014	96	92	3,43
2019	111	106	5,06
2025	131	123	7,44
2030	149	139	9,78

Table 7.20: Stock energy consumption trend for dishwashers in EU countries in 1990-2030, BaU Scenario (GWh/year)

Years	Energy consumption		
	EU 25	EU 15	EU 10
1990	23 190	23 190	0
1995	27 456	27 390	67
2000	29 678	29 436	242
2005	29 907	29 407	500
2009	30 372	29 623	749
2014	31 865	30 737	1 127
2019	34 993	33 399	1 593
2025	40 421	38 118	2 303
2030	45 981	42 961	3 020

Table 7.21: Average energy consumption trend for dishwashers in EU countries in 1990-2030, BaU Scenario (kWh/year)

Years	Unitary energy consumption		
	EU 25	EU 15	EU 10
1990	644	644	--
1995	587	587	525
2000	512	513	448
2005	434	435	392
2009	376	377	355
2014	334	334	328
2019	315	315	315
2025	309	309	310
2030	309	309	309

Figure 7.16: *Dishwashers trend in the EU countries in 1990-2030, BaU Scenario (million of units)*

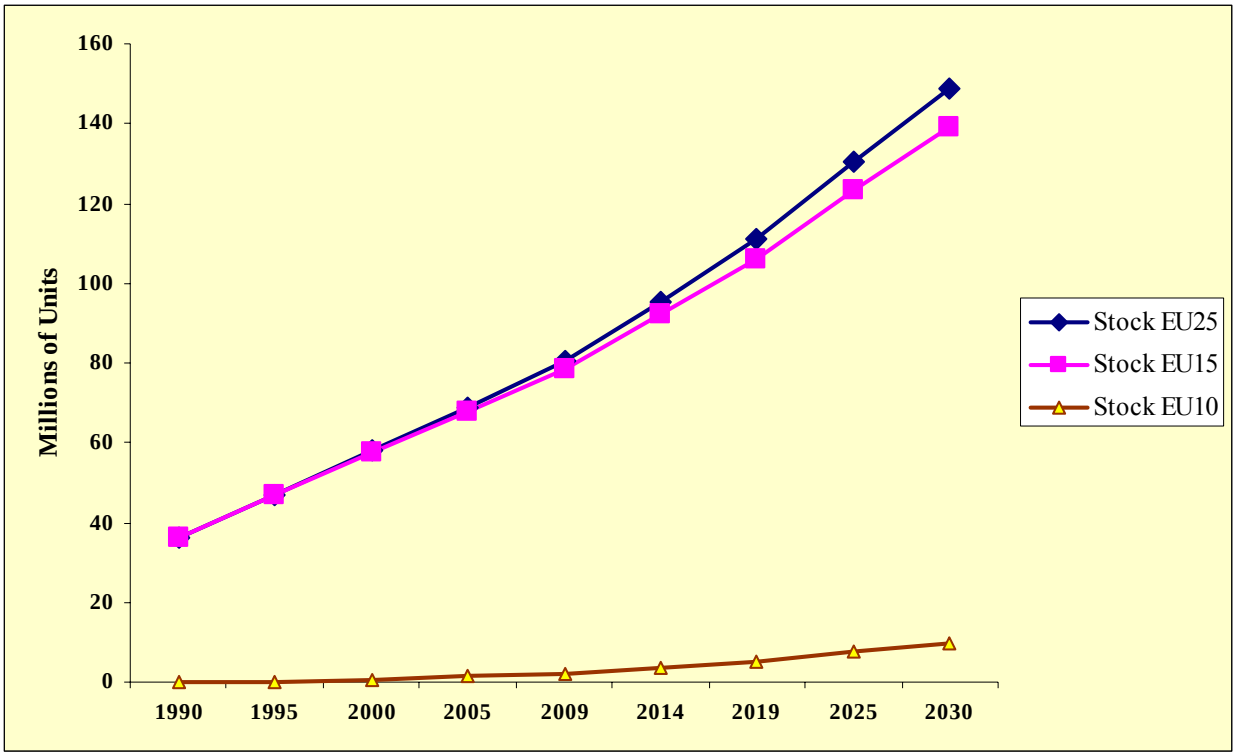


Figure 7.17 ***Stock energy consumption trend for dishwashers in EU countries in 1990-2030, BaU Scenario (GWh/year)***

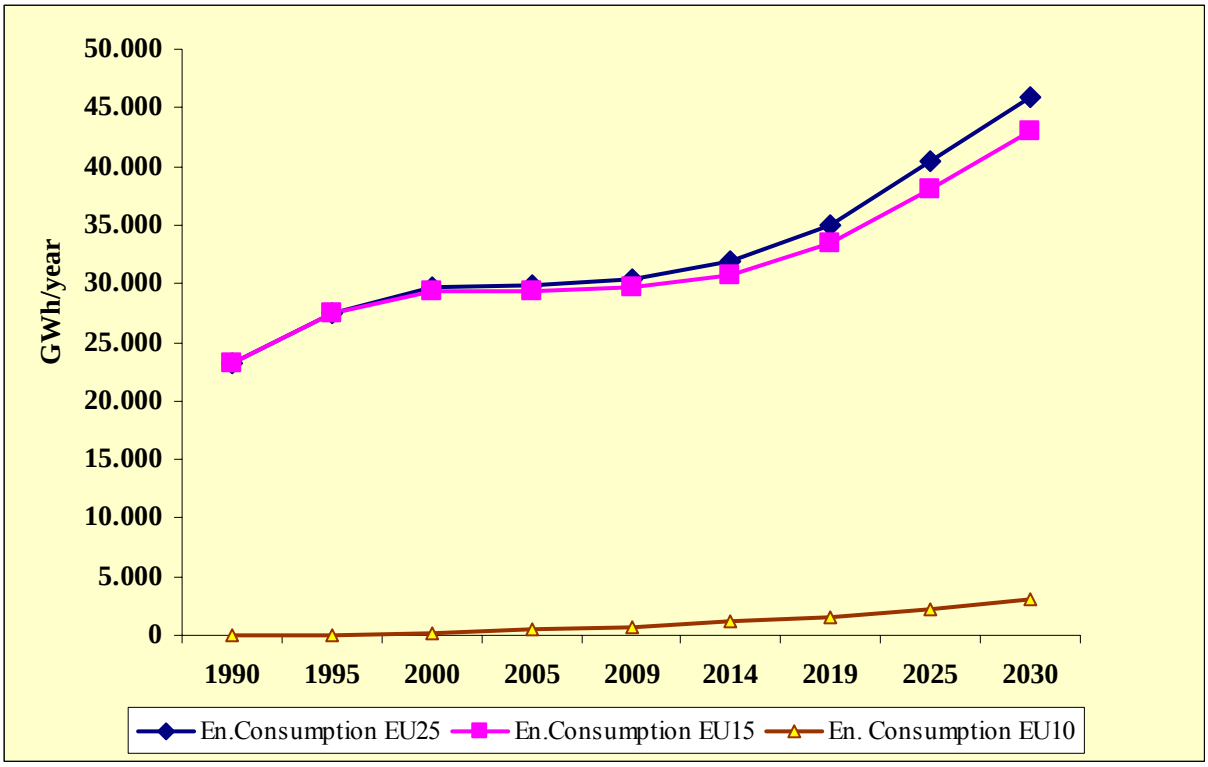
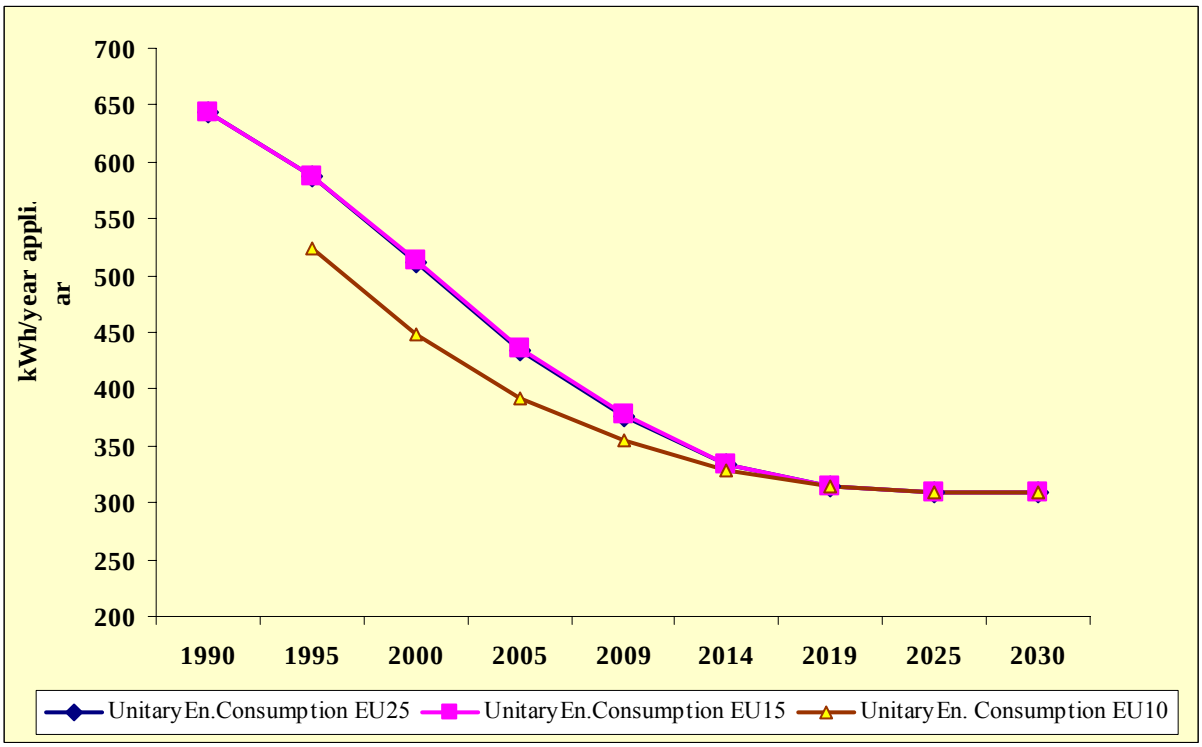


Figure 7.18 ***Average energy consumption trend for dishwashers in EU countries in 1990-2030, BaU Scenario* (kWh/year)**



7.4 SUBTASK 7.4: MANUFACTURERS IMPACT ANALYSIS

The impact analysis on manufacturers will be run using the E-GRIM model, developed by ENEA in the framework of previous SAVE projects and already successfully applied in the analysis of the WASH-2 project.

Cost data used in the NPV and Life Cycle Cost methods is further disaggregated and used as input in E-GRIM (European Government Regulatory Impact Model) model. Quantitative market data, industry structure, consumers' habits provided by previous phases of the study or by literature will be used to establish a framework to describe the linkages of the market and the technological improvement. E-GRIM model is expressly designed to allow the analysis of the effects of a single policy measure upon a single product. By combining multiple iterations it is also possible to analyse multiple products with policy measures taking effects over a period of time and/or multiple policy measures on the same product. The program simulates the sales, all main elements of cost and the cash flow, each year for fifteen years and then determines the present value of those cash flows without policy measure – the Base case – and with policy measure – the Policy Measure case. Output consists in the complete cash flow calculations, summary statistics, and graphs of major variables, including net cash flow for industry and for consumers (due to electricity savings), employment, investments required and impact on profits.

Average values to be used as input to E-GRIM model is presented at the sector level in terms of the "typical manufacturer".

7.4.1 The E-GRIM model

The white goods appliance market is essentially one of low growth and substitution among models, favouring higher efficiency categories, the only exception being air conditioners, a relative latecomer to the European market. Overall unit sales growth are usually between one or two percent, whereas new models gain market share relatively rapidly. In this context a new type of E-GRIM was developed incorporating dual production lines: one for the newer, higher share penetration model and a second for the typical model being substituted. For simplicity, both lines are assumed to be within the same facility of one million units nominal capacity. One more unit of sales (and production) of the higher penetration model corresponds to one less unit of sales and production of the typical substituted model. For more complex situations, additional growth rates above the substitution rates can be introduced, relaxing the assumption of constant production capacity, allowing capacity to grow slightly.

The dual production line model of E-GRIM was first introduced in a study for CECED in 2006[66] and subsequently in 2007[67]. It results in more realistic representation of the industrial dynamics because it explicitly considers the losses due to substitution that inevitably occur within industry and normally within the same firm. Only in the situation of a firm rapidly gaining market share in the new models over the other firms can this substitution be partially avoided within the firm. The traditional single-line production model overestimates cash flows and profits in this context, not subtracting the substituted cash flows lost. Fortunately the margin of the newer higher penetration

[66] Mebane, William (November 2006) *Final Report on Production Tax Credits*, site: www.ceced.org (see Statements and Press Info)

[67] Mebane, William and Piccino, Emanuele (2007), *New Policy Instruments for Energy Efficient Home Appliances in Europe,* 9th IAEE European Energy Conference, Energy Markets and Sustainability in a Larger Europe, Florence, Italy

models is greater than that on the older models and after substitution there remain profits. This is consistent with the practice of product life cycles, introducing the newer higher margin product with gradually decreasing price and margins over time.

The original GRIM was developed by Arthur D. Little and subsequently modified by ENEA and William Mebane for an European context[68]. It has been utilized in several studies for industry and the European Commission[69].

The primary purpose of the method is to simulate the impact of changes in policy due to the introduction of new or improved technologies that modify the cost of manufacturing. The impact of these changes are simulated by the model through annual projections of the profit/loss and cash flow statements of a production facility, projected forward in time for fifteen years.. It is this cost structure and along with the evolution of prices that determine the future cash flows. Policies introduce changes in these inputs and the resulting outputs and cash flows can be compared to base case.

Since the energy savings and price savings are known between a base case product and an improved product, the various impacts for consumers can be estimated. Similarly changes in value added, manufacturers' profits and income tax can be calculated for new products. These changes impact on the national government where the production facility is located, and these impacts on government revenues may be estimated

7.4.2 Impact Analysis

The more general aspects of the impact analysis are presented here. Instead the specific data input and results regarding the base case, the LLCC and BAT for washing machines and dishwashers are given successively together with their corresponding scenarios.

7.4.2.1 General Input Data

The most single group of important set of inputs is undoubtedly the structure of the production costs. Unfortunately there are not detailed income statements available for many of the producers and the ones available often involve other products. The cost structure also is not available for different appliances or for different models within the same appliance group. Often this reflects the industrial reality where it is difficult to follow costs at a detailed and rapidly evolving level of production. Therefore over the years we have developed a consensus model of costs, which is retained by industry to fairly accurately represent the cost structure of a large plant of one million units of nominal capacity. The cost assumptions have been reviewed by industry representatives recently as part of this task.

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[68] Arthur D. Little, Inc. of Cambridge, Massachusetts developed the original model. It was modified and upgraded by ENEA on March 11, 1997 and subsequently modified by William M. Mebane on July 26, 2006.

[69] E-GRIM has been utilized in the following studies:

- ISIS/ENEA, Study of the Environmental Impact of Dishwashers, promoted by CECED, September 2005.
- Enhancing the Government Regulatory Energy Measures Impact and Diffusion Speed Appraisal Method (E-GRIDS), project number NNE5-2001-00147, contract number ENG1-CT2001-80550, 2002.
- Government Regulatory Energy Measures Impact and Diffusion Speed Appraisal Method (GRIDS), project number NNE5-1999-00657, contract number ENK6-CT-1999-00016, 2001.
- Proposal for the Revision of Energy Labelling and the 2nd Stage of Minimum Energy Efficiency Standards for Domestic Refrigerators and Freezers and their Combinations, contract number XVII/4.1031/Z/98-269, 2000.
- Revision of energy labelling & targets washing machines (clothes), contract number XVII/4.1031/Z/98-091, 2000.

These costs are presented in Table 7.22 and shown on the assumption page of every simulation of the E-GRIM.

Table 7.22: General Cost Assumptions

Income Tax Rate	48%
Working Capital	18% of Revenue
Sales, General and Admin. (SG&A)	10% of Revenue
Research and Development	2,5% of Revenue
Ordinary Depreciation	4,3% of Revenue
Ordinary Capital Expenditures	4,5 % of Revenue
Variable Overhead as % of Total Overhead	60%
Total Unit Manufacturing Cost	about 78% of revenue
Within the Unit Manufacturing Costs:	
Materials and Components	72%
Labour	15%
Overhead (only variable part)	7%
Depreciation	6%
Total	100%

Usually we have a net income of between 2 and 6% of revenue depending on the model and price levels.

For example, applying this structure of costs to the washing machine LLCC model the outcome of Figure 7.19 results.
Notice that net income is not net cash flow, which is shown for the above example as a percent of sales.

Net Income:	7,19%
Depreciation	4,30%
Change in Working Capital	-1,11%
Total (Cash Flows from Operations)	10,38%

From this we subtract cash used in investments:

Extra Productivity capital expenditure	0
Ordinary Capital Expenditures	-4,50%
Extra Conversion Capital Expenditures (for example, an ad hoc marketing campaign)	0
Total Cash Used In Investment	-4,50%
Net Cash Flow	5,80%

It so happens that this is the first and most profitable year in the simulation. A strong negative impact of prices in the case of washing machines brings these profits down. Average cash flow and net income margins are 2 and 3 percent lower that that shown above.

As suggested, one of the most important data input is the appliance price trend. These trends have been analyzed over the latest available 8 years and are reported in Table 7.23.

Figure 7.19: Example of composition of Industry Costs Washing Machine LLCC Model, year 2007

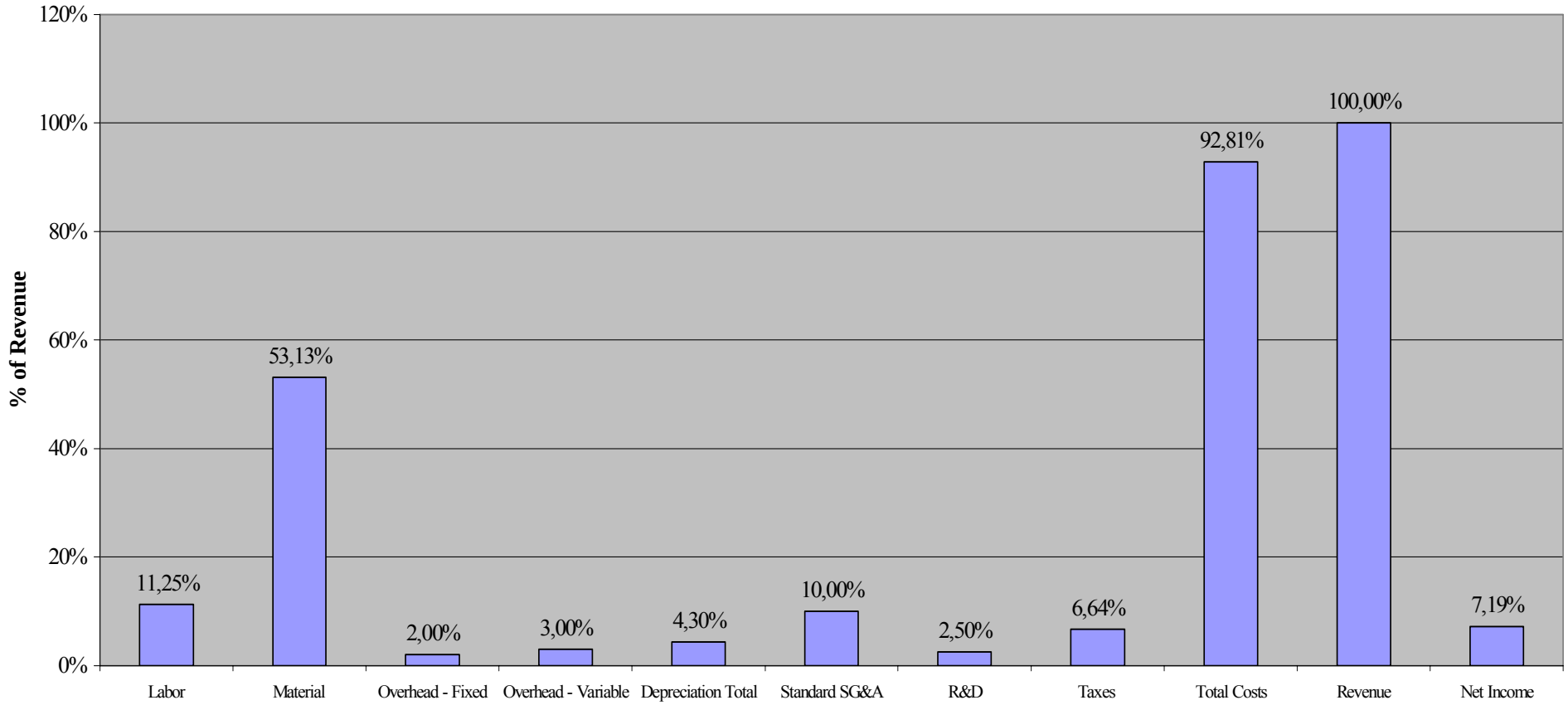


Table 7.23: Real Price Growth of Appliances in Europe

Real Price Growth (1996-2004, Source: GfK)										
Appliance/Data	Country:									
	Austria	Belgium	Germany	Spain	France	Great Britain	Italy	Netherlands	Sweden	
Refrigerators										
Real Price, 1996	532,8338703	566,3930263	526,7301793	570,159144	512,1198398	375,8941111	418,9888412	537,7363588	713,061262	
Sales * 1000, 1996	203	272,9	2559,2	862	1562,4	1761,7	774,4	486,6	115,7	8597,9
	12,5804296	17,97748949	156,783386	57,16246783	93,06179854	77,02027885	37,73769858	30,4333049	9,595504485	492,3523583
Real Price, 2004	460,2620873	491,4491177	436,2766235	519,4741337	495,2822413	505,3400139	456,6635709	400,6570273	622,1368576	
Sales, 2004	219290,2457	314658,9158	2448339,72	1279777,695	2122244,399	2711370,182	1485652,152	494875,7549	197110,8162	11273319,88
	8,953084565	13,71724108	94,75056129	58,97210553	93,23872414	121,5404033	60,18131519	17,5880265	10,87788736	479,819349
									Ratio 2004/1996	0,974544634
								% decrease in 8 years		0,025455366
							Refrigerators Annual Price Growth:			-0,003217931
Washing Machines										
Real Price, 1996	730,679358	765,4887567	772,3900528	449,6679959	575,5683155	494,8901758	428,565729	782,7187546	753,8076198	
Sales * 1000, 1996	187	208,3	1977,5	964,8	1708,4	1817,8	1145,9	401,8	91	8502,5
	16,07021934	18,75346169	179,6414383	51,0249553	115,6484458	105,8055115	57,75871436	36,98869693	8,067802811	589,7592461
Real Price, 2004	552,3884656	594,2049788	506,021695	644,6829427	393,2977434	483,3249826	471,1059306	445,7067093	573,025708	
Sales, 2004	217530,2319	266720,624	2225274,997	1406644,64	2089027,873	2717126,812	1453263,414	507287,988	187303,8784	11070180,46
	10,85449253	14,31654374	101,7180732	81,9173463	74,21829764	118,6299784	61,84551514	20,4243879	9,695409932	493,6200448
									Ratio 2004/1996	0,836985682
								% decrease in 8 years		0,163014318
							Washing Machine Annual Price Growth:			-0,021997976
Freezers										
Real Price, 1996	521,5926494	470,2778461	494,6394751	337,8720853	396,5529733	298,0462183	319,6286303	426,2693687	588,558502	
Sales, 1996	47840	43009	418725	40651	226244	189922	82002	53013	34529	1135935
	21,96691919	17,80575463	182,3325403	12,09121837	78,98139497	49,8316663	23,07366789	19,89358374	17,89040439	423,8671498
Real Price, 2004	394,9810871	434,4190221	350,8892083	322,8991454	404,1354721	378,1123786	271,1807008	308,0327134	339,4571126	
Sales, 2004	96877,17883	136585,3415	898414,7617	137434,8129	618152,8707	970442,922	320555,2355	183951,6251	106197,6127	3468612,361
	11,03168917	17,10634233	90,88477225	12,79404529	72,02231793	105,7876878	25,06143217	16,33596156	10,39307112	361,4173196
									Ratio 2004/1996	0,852666501
								% decrease in 8 years		0,147333499
							Freezers Annual Price Growth:			-0,019726189
							Refr+WM+ Freez. Annual Price Growth:			-0,013288408
								(weighted by sales, GfK data)		
							EU25 Large Appliance Price Index Growth:			-0,008
								(1996-2006, EU official data)		

GfK gathered price data for the latest available years for the above countries. The percent change in the average, weighted by sales, was computed for the period 1996-2004. As shown this results in real price declines of 0,032%/year, 1,97%, and 2,19% for refrigerators, freezers, and washing machines respectively. This is a very strong negative growth rate for real prices of washing machines. For dishwashers the EU25 average of -0,8%/year is used. As a check the average price decline for these three appliances is calculated weighting again by sales and compared to the EU25 large appliance price index. The three-appliance average is -1,3%/year compared to -0,8%/year for the EU25 appliance index, which appears reasonable.

7.4.2.2 Other General Assumptions

The base year is 2007, the year of announcement of a policy is 2008 and the first year of the policy implementation is 2009. Including the first year of the policy, 15 years of production are simulated ending in 2023. Since the last appliance sold in year 2023 has a fifteen-year lifetime that produces savings through year 2038, which is the last year simulated for consumers.

As in the original version of E-GRIM, it is assumed that the normal activities of production including the normal level of capital investment, assumed to be 4,5% of sales, produces the historic increase in labour productivity of 1,5% per year. This increase of labour productivity may come through automation or relocation of facilities. It is applied to direct labour and variable overheads in both the BAU and policy scenarios. There is also an option to increase these types of investments.

The real discount rate of 5% is used. This compares with a real risk free discount rate of 2 to 3% in Europe (for long term government bonds for example) plus a very low risk premium in keeping with the social aspects of public policy.

In these simulations the Base Case or business as usual scenario (BAU) is defined as a continuation of the affects of present policies through year 2008, then from year 2009 and forward the relative quota of sales and production remain constant. No new policies are introduced and producers keep their quotas constant. Instead the policy scenario, here called ‘Scenario Evolution’ represents a possible tendency of the quotas without a well-defined instrument on the part of the governments, European Commission or producers to achieve that new tendency. It is an exploration on the production side to see the implication of achieving such a new tendency without the extra costs in promotion to achieve it, in terms of extra marketing costs, a production tax scheme or EC policy. More detailed policy analysis will be made subsequently in Task 7.

In the dual production model depreciation is treated as a more rapidly changing variable than usual. This is believed to better represent the cost of conversion, which will involve more re-tooling costs with a shorter lifetime (typically 5 years). Essentially depreciation is a lagged amount of capital expenditures for each production line.

7.4.2.3 General Output Information

Starting from the first year, a profit/loss and cash flow statement is projected forward for 15 years based on all the various cost and price assumptions. For each year a complete profit/loss and cash flow statement is available. In the case of the dual production model this applies to each line of production and a summary of the profits, taxes and cash flow for the combination of both lines, that is the entire production facility. Thus for the 15 year period we have all the key production variables: units shipped, manufacturer’s price, revenue, all the major costs, the profit before taxes, the corporate taxes, net profits, depreciation, change in working capital, operating cash flow, capital

investments, net (or free) cash flow. These may be displayed in table or graphic form. A key summary variable for the manufacturers' is the net present value (or discounted value) of the net cash flows. This is industry value that has been added over the years and is used as a summary comparison of policies.

The model calculates the various impacts on consumers assuming that all the models produced are sold, assuming zero change in inventories in the long run. Consumers' purchases, and the difference in the price between the newer and the substituted model are calculated. This difference is the investment cost for the relative energy saving between the two models, as hypothesized in the LCC optimization in Task 6. Economic savings, electricity savings and avoided carbon dioxide emissions are calculated as a result of sales and use by the consumer for each year through 2038, after the last product sold has exhausted its average lifespan.

A new feature was introduced in E-GRIM for estimating the changes in cash flows of a government that introduces production tax credits. This is a new type of policy instrument currently being utilized by the US government to promote high efficiency appliances that appears to be more effective than traditional rebates (or reduction in value added tax) and costs less for the government.

7.4.3 Impact Analysis and Results for Washing Machines

From Task 6, Tables 6.31 and 6.32, we have the characteristic of each of the three models of washing machine (Table 7.24)

Table 7.24: Characteristics of the Washing Machine Models

Model	Energy consumption (kWh/cycle)	Energy consumption (kWh/kg)	Water consumption (litre/cycle)	Manufacturer Price (€)	Consumer Price (€)
BAT	0,855	0,1596	38,7	180	540,8
LLCC	0,900	0,168	38,7	153	459,7
Base	0,998	0,186	50,7	148	443,5

7.4.3.1 Formulation of preliminary Scenarios for washing machines

Let us consider the evolution of washing machine energy efficiency classes given in Task 2 and disaggregating where necessary for models in years 2003, 2004 and 2005. For year 2008 an estimate for a continuation of the affects of the present policies for the 5,36 kg machine (defined in Task 5) is made as shown in Table 7.25.

Table 7.25: Trend (2003-2008) of Market Quota (%) by model type for washing machines

WM models	Energy consumption (kWh/cycle)	2003 (%)	2004 (%)	2005 (%)	2008 (%)
BAT	0,855	0	0	1	2
LLCC	0,900	0	21	37	55
Base case	0,998	18	67	53	35
Energy efficiency class B	--	11	6	5	4
Energy efficiency class C	--	9	5	4	4
Energy efficiency class D	--	2	1	0	0

At the factory level, two sets of hypotheses are made:
1) maximizing the quota of the LLCC
2) rapid introduction of BAT.

Within each set we have the BAU and Evolution Scenarios. The factory is simulated with two production lines.

In the first case we can imagine a producer who has a little over half of his production in the LLCC model and desires to produce a maximum amount in the future, phasing out the base model production.

Instead, the second case represents a manufacturer who is already fully producing the LLCC model and just introducing the BAT model. He wishes to bring them to a 50%/50% capacity in the future. In both hypotheses the Business-as-Usual (BAU) scenario is represented by a fixed continuation of the 2008 production quotas (Table 7.26).

Table 7.26: Production hypotheses for washing machines

Hypothesis Set	Model	Factory capacity (%)		
		2008	2023 BAU	2023 Evolution
Maximum quota LLCC	LLCC	55	55	100
	Base	45	45	0
Fast introduction of BAT	BAT	5	5	50
	Base	95	95	50

The Evolution Scenario is a representation of the producers' wishes without the introduction of specific policy instruments to achieve the desired changes in production. Only the costs of production are included, not even extra costs of a marketing campaign for promoting the desired changes. Policy will be fully studied subsequently.

7.4.3.2 Inputs and results of washing machine hypothesis set: 'Maximum Quota LLCC'

The input data for the base case model production line is as shown in Table 7.27.

In this first hypothesis, for the Base Case Model we have hypothesized a manufacturing (unit) cost of 116 €, or about 80% of manufacturing price of 145 €. The more detailed manufacturing costs are as given above. Notice that a very strong decrease in real prices is input at 2,0%/year, near the recent historic average of minus 2,2%/year as reported earlier.

The data assumptions and input for the second production line with the LLCC model costs are illustrated in Table 7.28.

Notice that the shipments of BAU and Evolution Scenarios are specifically included, along the distribution/retail mark-up given as 3 and an input of water savings per year estimated at 9,77 € (2,64 m^3 x 3,7 €/m^3). Again the real price decline is given as -2,0%/year, as illustrated in Figure 7.20.

A similar trend is working on the base model prices. The resulting cash flows are seen in Figure 7.21 for the BAU scenario.

Table 7.27: Input for the Washing Machine Base Model

Assumptions Page for				
Wash Mach LLCC & Base (base prod line) July 07 check				
Scenario Description	Base Model			
Base Year	2007	*Beginning year for analytical purposes*		
Announcement Year	2008	*Year in which the announcement is made*		
Policy Measure Year	2009	*Year in which the policy measure takes effect*		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	145,00	*(EURO)*	Price Grow. UPMY	-2,0%
Base Year Unit Sales	0,950	*(million)*	Price Grow. APMY	-2,0%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%			
			Tax Credit (Ū)	0
			El. Savings (kWh/yr)	0
			Electr.Price (Ū/kWhr)	0,17

0	Base Model Year 2007	Policy Measure Case Year 2009	Sens. Anal. of Manufacturing Costs	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	84,00	0,00	0%	0%
Labor / Unit	18,00	0,00	0%	0%
Overhead / Unit	8,00	0,00	0%	0%
Depreciation / Unit	6,24	0,00		
Total/ Unit	116,24	-		

Hypothetical Full Price Increase (Policy Measure Case Only)	0,00
Percent of H. F. Price Increase Recovered by Manufacturers	100,00%
Manufacturers' Price Increase	0,00

Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10	0	0%	0%
Tooling	5	0	0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%

Table 7.28: Input for the Washing Machine LLCC Model

Assumptions Page for				
Situation Studied	**Wash Mach LLCC &BASE Ver July 07**			
Situation Studied in Base Prod.	**Wash Mach LLCC & Base (base prod line) July 07 check**			
	Wash Mach LLCC & Base (base prod line) July 07 check			
Base Year	2007			
Announcement Year	2008	***Year in which the announcement is made***		
Policy Measure Year	2009	***Year in which the policy measure takes effect***		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	160,00	*(EURO)*	Price Grow. UPMY	-2,0%
Base Year Unit Sales	0,050	*(million)*	Price Grow. APMY	-2,000%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%		Dist. Mark-up	3,00
			Tax Credit (Ū)	0
			El. Savings (kWh/yr)	21,56
			Electr.Price (Ū/kWhr)	0,17
			Water Savings (Ū/yr)	9,77
	BAT Case	**Policy Measure Case**		
0	**Year 2007**	**Year 2009**	**Sens. Anal. of Manufacturing Costs**	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	**85,00**	0,00	0%	0%
Labor / Unit	**18,00**	0,00	0%	0%
Overhead / Unit	**8,00**	0,00	0%	0%
Depreciation / Unit	6,88	0,00		
Total/ Unit	117,88	-		
Hypothetical Full Price Increase (Policy Measure Case Only)		0,00		
Percent of H. F. Price Increase Recovered by Manufacturers		100,00%		
Manufacturers' Price Increase		0,00		
Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10		0%	0%
Tooling	5		0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%
	Shipments BAU Scenario	**Shipments Evolution Scenario**		
(Year)	*(%)*	*(%)*		
2007	**48,00%**	**48,00%**		
2008	**52,00%**	**52,00%**		
2009	**55,00%**	**56,00%**		
2010	55,00%	**62,00%**		
2011	55,00%	**68,00%**		
2012	55,00%	**74,00%**		
2013	55,00%	**79,00%**		
2014	55,00%	**84,00%**		
2015	55,00%	**88,00%**		
2016	55,00%	**93,00%**		
2017	55,00%	**96,00%**		
2018	55,00%	**98,00%**		
2019	55,00%	**99,00%**		
2020	55,00%	**100,00%**		
2021	55,00%	**100,00%**		
2022	55,00%	**100,00%**		
2023	55,00%	**100,00%**		

Figure 7.20: Real Manufacturer's Price of the LLCC Model Washing Machine

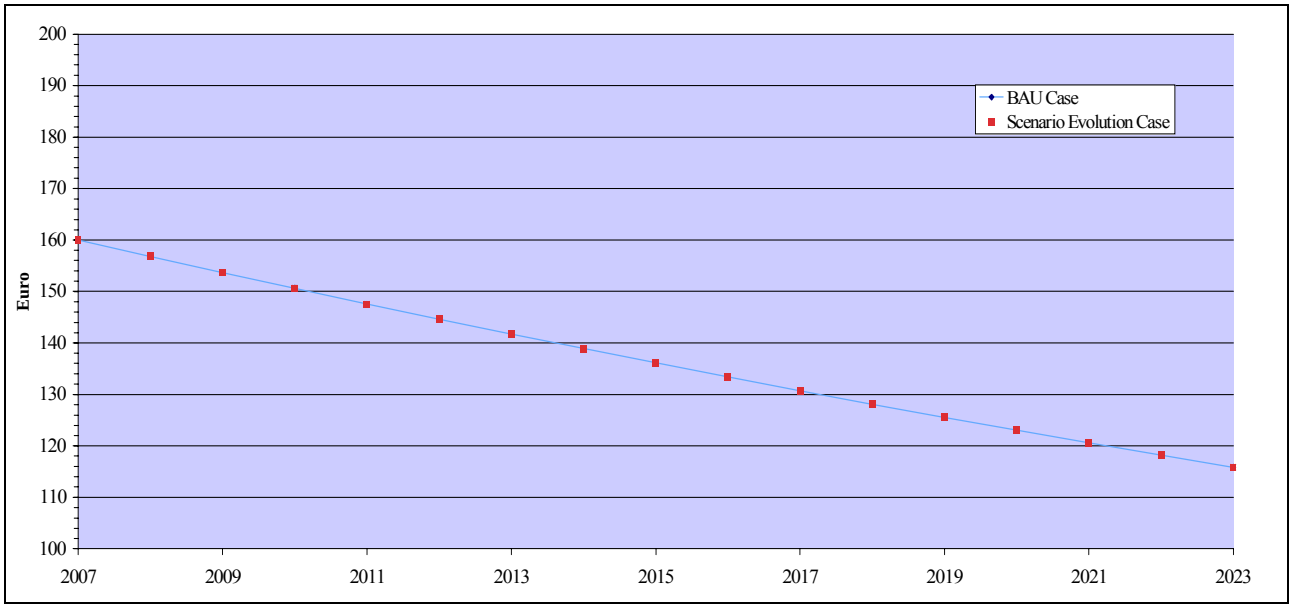
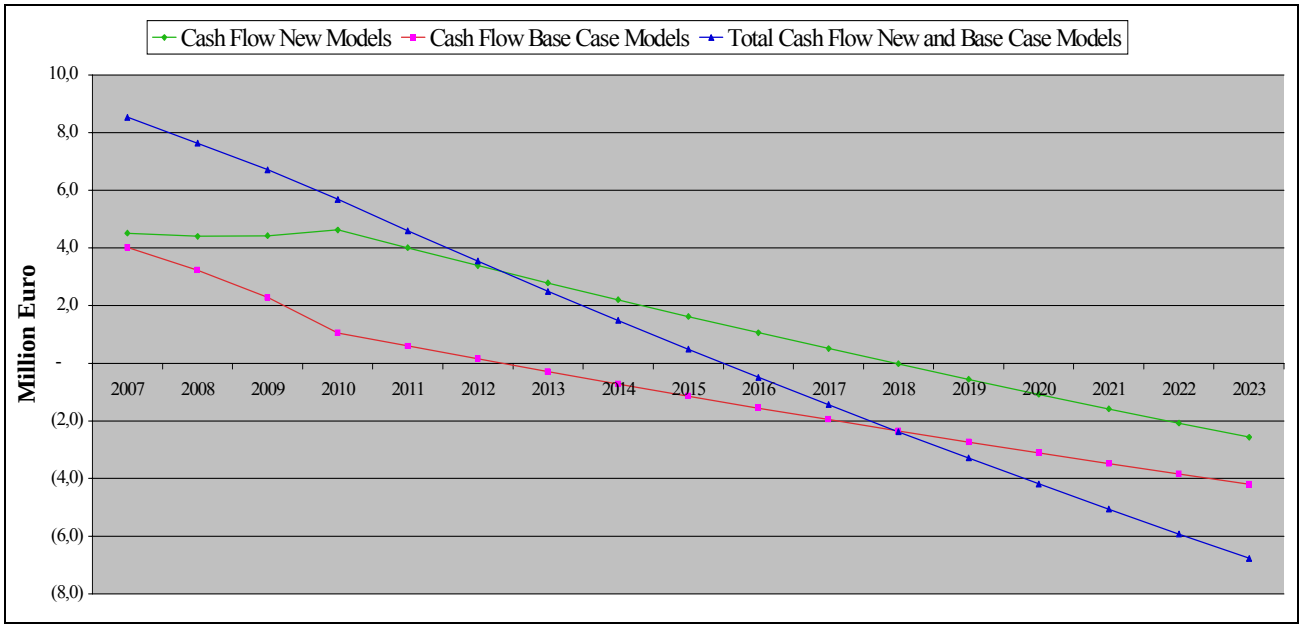


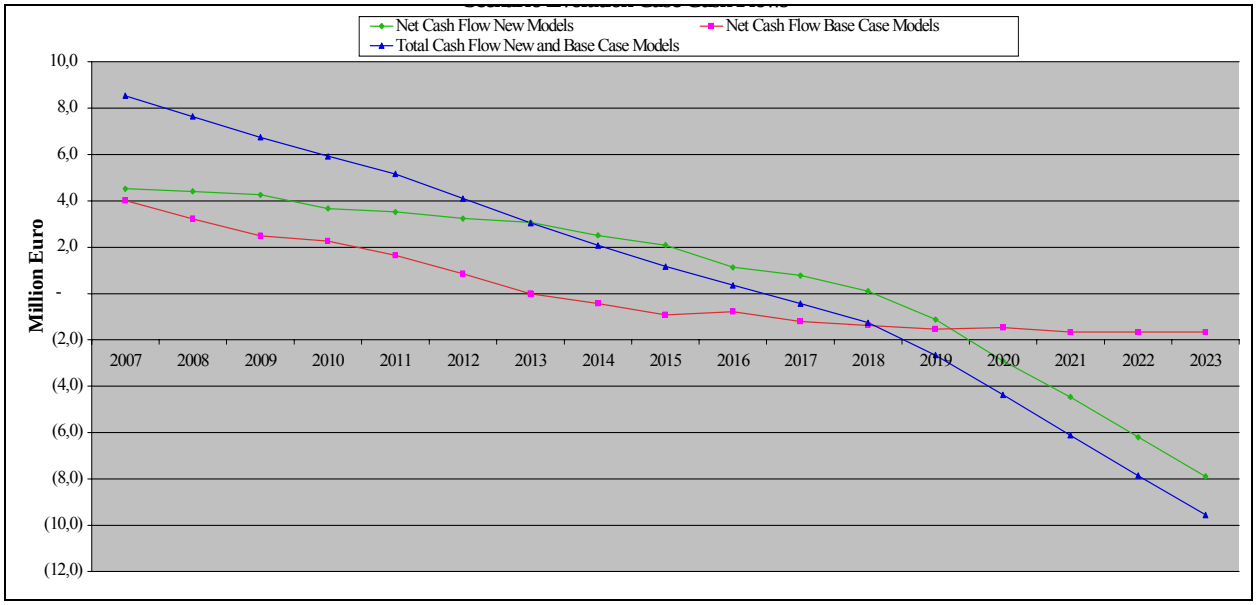
Figure 7.21: Base Model and LLCC Model (New Model) Cash Flow in the BAU



The initial years are more profitable. The LLCC production line in the beginning (year 2007) has a 5% net cash flow margin, that of the base model slightly less because it is an early product. In fact the LLCC cash flow increases while the LLCC production quota is rising. Once the quota is fixed in the BAU scenario (in 2009) then the LLCC cash flow begins to decline shortly thereafter. This is due to the dramatic impact of the price decreases. At some year around 2017 it is no longer profitable to produce.

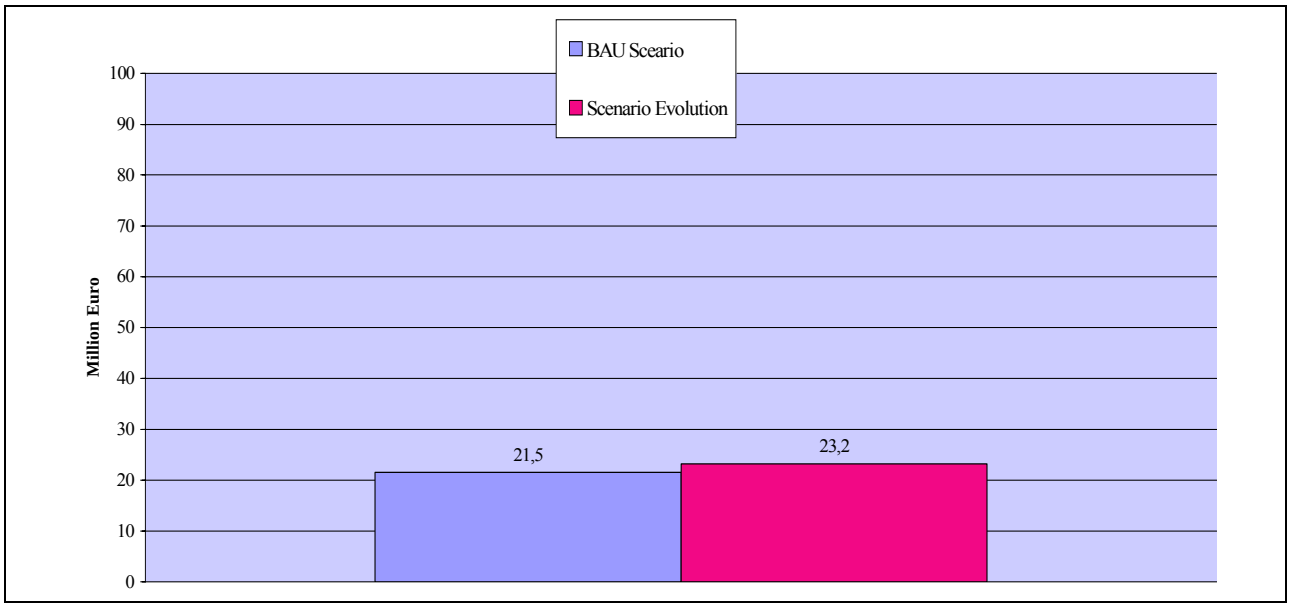
Turning to the Evolution Scenario matters are not that much different, primarily because there is not much difference in the cost structure of the two models. The LLCC is slightly more profitable, but taking into consideration the substitution impacts, which this model does, this difference is minimal. The cash flows in the Evolution Scenario are illustrated in Figure 7.22.

Figure 7.22: Cash Flows in the Evolution Scenario of the Base Model and LLCC Model Lines of Production



In the midyears, between 2011 and 2016, the cash flows of the LLCC model are slightly higher than those of the previous BAU scenario as the quota of the LLCC rise. Once the LLCC capacity reaches 100%, the price impact is seen in full. It is interesting to see the net present value of the total cash flows, called industry value, between the BAU and Evolution scenarios (Figure 7.23).

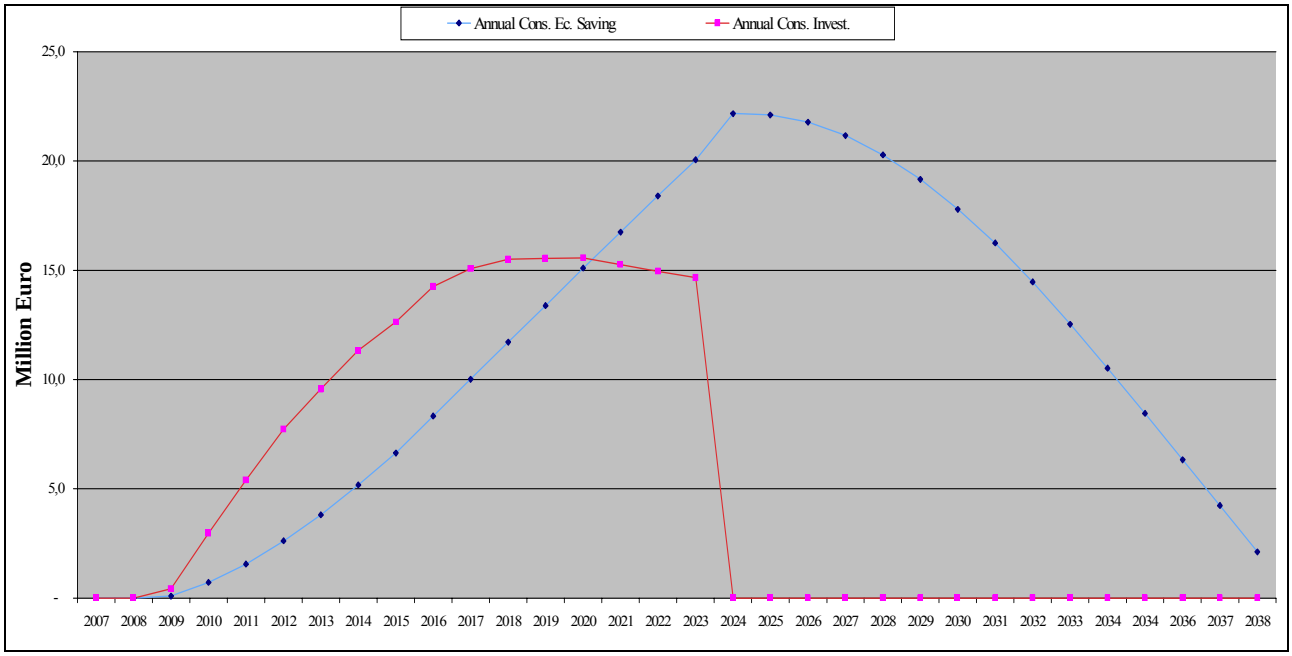
Figure 7.23: Industry Value in the BAU and Evolution Scenarios



First, the industry value is quite low in an absolute sense; 20 million Euro in 15 years of production is quite small, considering the cost of a one million-unit plant. Also in the latter years the plant is accumulating losses. This also rings a cost reduction warning, which is not explored here. Second, there is almost no difference in the industry value between the two scenarios. Converting from the base case to the LLCC model helps very marginally in front of the onslaught of such rapid price deterioration.

From the consumers' point of view matters are encouraging. The change in model has a relatively low price difference, which is declining in time, and there are significant water savings between the two models (12 litre/cycle). The payback time is 4,4 years. The annual investments (difference in consumer prices) and economic savings are shown in Figure 7.24. The consumers' discounted net benefits are some 40 million Euro, double that of industry.

Figure 7.24: Consumers' Investments and Benefits (electricity and water) in the Evolution Scenario



7.4.3.3 Inputs and results of washing machine hypothesis set: 'Accelerated Introduction of BAT'

Turning to the next hypothesis set of washing machines with a fast introduction of BAT, the input data for the BAT line of production is shown in Table 7.29.

Notice that the conversion to 50% occurs in four years, from 2009 to 2012, more rapidly than originally hypothesized. This is important to show the substitution impact in the early stages. The price decline is dramatic as usual at -2,0% per year and as a result the initial cash flow margins are set seemingly high. The BAT manufacturing initial price is set at 200 € with the manufacturing unit costs at 137 €.
The other line is characterized by a LLCC initial manufacturer's price of 153 € and a production cost of 121 €. In the BAU scenario this produces a cash flow margin of the BAT line of production above 7% in the first five years, but an average of 4,8% for the period. The LLCC line has an early margin around 3%, which goes to a negative -1,8% for the period, under the impact of strong price declines.

As a whole in the BAU scenario, where the quotas are fixed, there is a strong linear decline in cash flows as illustrated in Figure 7.25. In the Evolution Scenario we see more clearly the dynamics of substitution between the models and the relentless impact of rapidly declining prices (Figure 7.26).

Table 7.29: Input Data for BAT Production Line

Assumptions Page for				
Situation Studied	**Wash Mach BAT & LLCC (BAT Prod Line)**			
Situation Studied in Base Prod.	**Wash Mach BAT & LLCC (LLCC prod line)**			
	Wash Mach BAT & LLCC (LLCC prod line)			
Base Year	2007			
Announcement Year	2008	***Year in which the announcement is made***		
Policy Measure Year	2009	***Year in which the policy measure takes effect***		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	200,00	*(EURO)*	Price Grow. UPMY	-2,0%
Base Year Unit Sales	0,050	*(million)*	Price Grow. APMY	-2,000%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%		Dist. Mark-up	3,00
			Tax Credit (Ū)	0
			El. Savings (kWh/yr)	9,9
			Electr.Price (Ū/kWhr)	0,17
			Water Savings (Ū/yr)	0
	BAT Case	**Policy Measure Case**		
0	**Year 2007**	**Year 2009**	**Sens. Anal. of Manufacturing Costs**	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	**99,00**	0,00	0%	0%
Labor / Unit	**20,00**	0,00	0%	0%
Overhead / Unit	**9,00**	0,00	0%	0%
Depreciation / Unit	8,60	0,00		
Total/ Unit	136,60	-		
Hypothetical Full Price Increase (Policy Measure Case Only)		0,00		
Percent of H. F. Price Increase Recovered by Manufacturers		100,00%		
Manufacturers' Price Increase		0,00		
Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10		0%	0%
Tooling	5		0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%
	Shipments BAU Scenario	**Shipments Evolution Scenario**		
(Year)	*(%)*	*(%)*		
2007	**4,00%**	**4,00%**		
2008	**5,00%**	**5,00%**		
2009	**5,00%**	**10,00%**		
2010	5,00%	**20,00%**		
2011	5,00%	**35,00%**		
2012	5,00%	**50,00%**		
2013	5,00%	**50,00%**		
2014	5,00%	**50,00%**		
2015	5,00%	**50,00%**		
2016	5,00%	**50,00%**		
2017	5,00%	**50,00%**		
2018	5,00%	**50,00%**		
2019	5,00%	**50,00%**		
2020	5,00%	**50,00%**		
2021	5,00%	**50,00%**		
2022	5,00%	**50,00%**		
2023	5,00%	**50,00%**		

Figure 7.25: Washing machine (BAT= New Production Line and LLCC=Base Production Line) Cash Flows in the Business-As-Usual Scenario

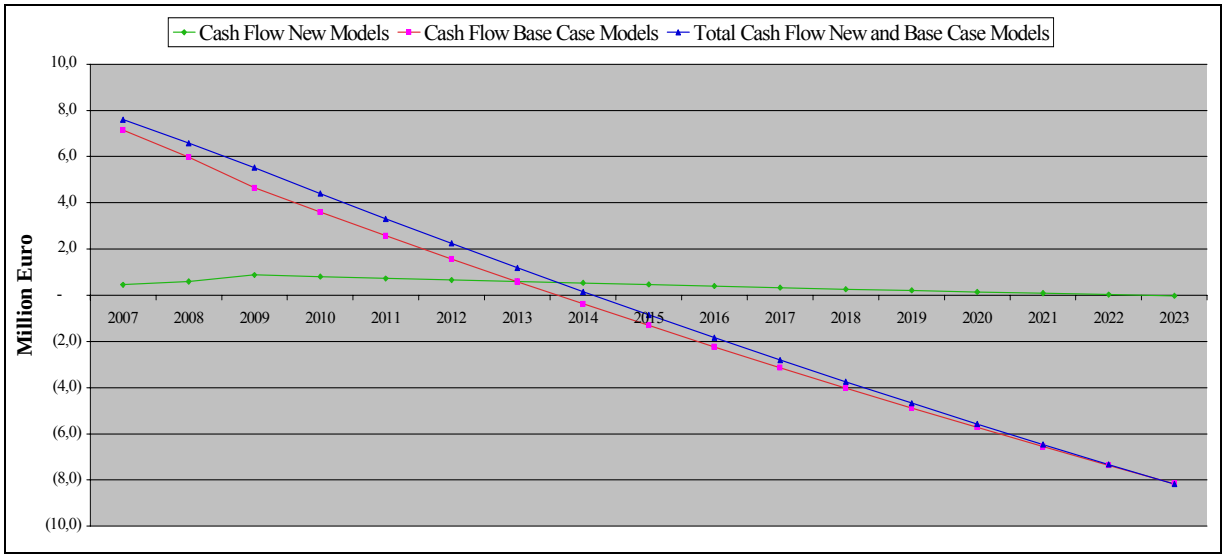
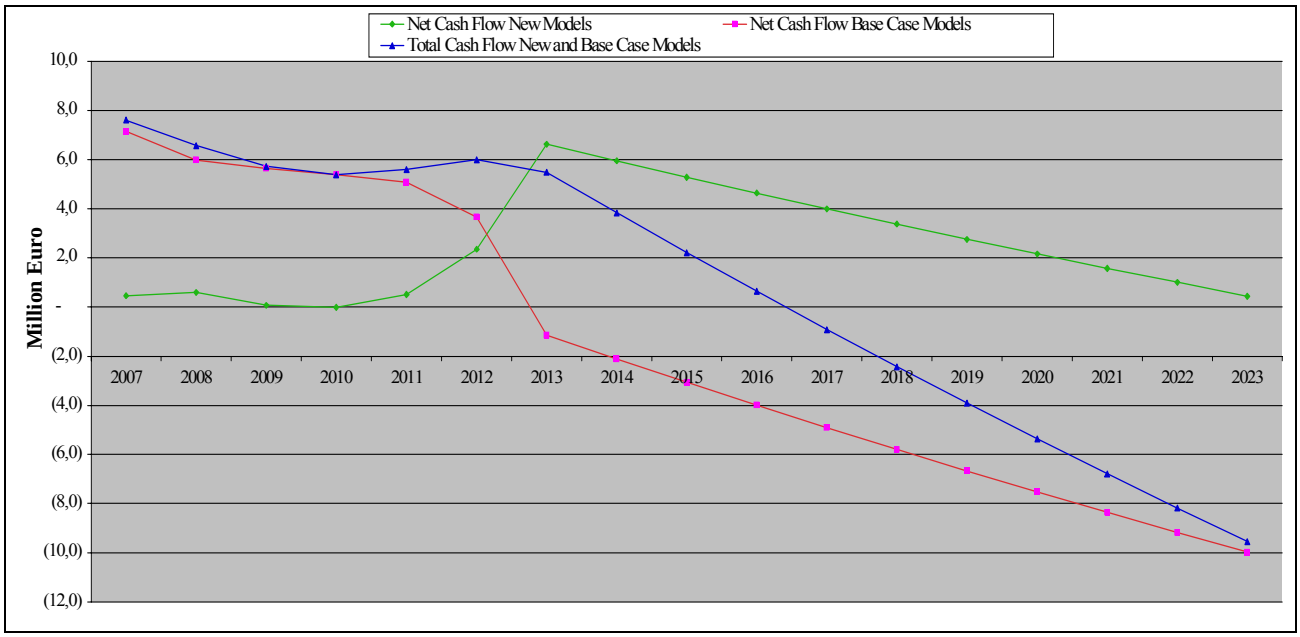


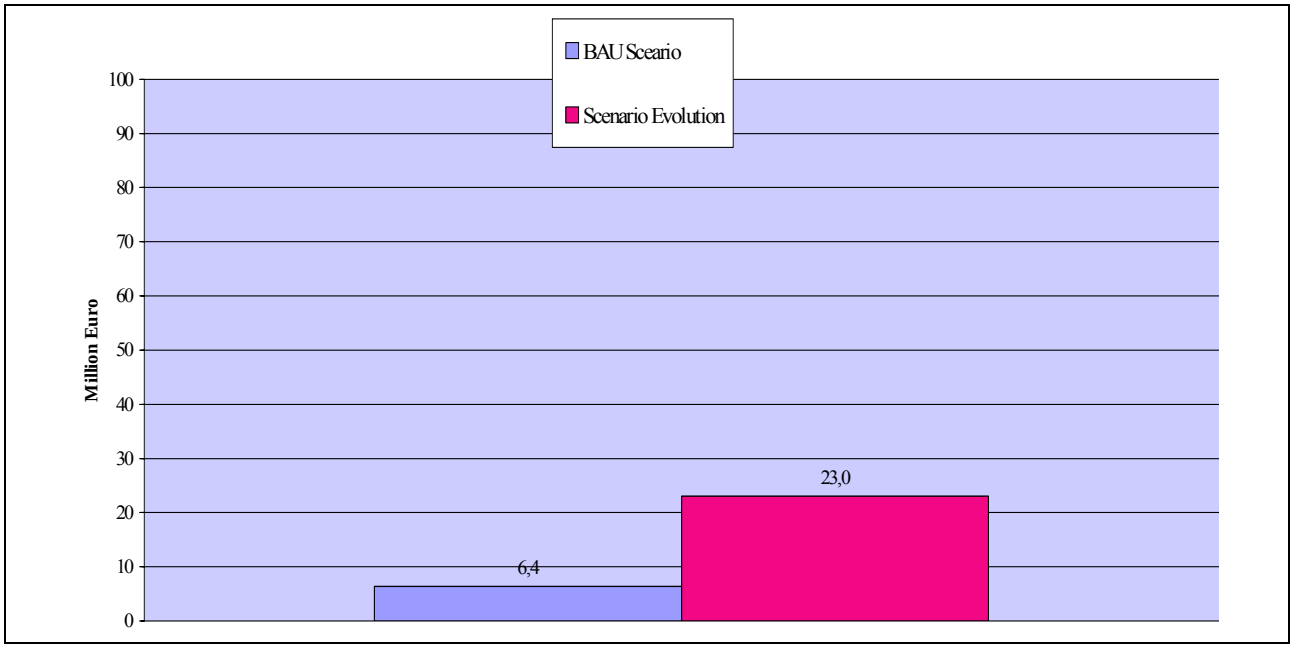
Figure 7.26: Washing machine (BAT= New Production Line and LLCC=Base Production Line) Cash Flows in the Evolution Scenario



Events go as desired up until 2012: the net cash flow of BAT increases while that of LLCC decreases and the total cash flow even begins to rise between 2010 and 2012.

In fact, in 2012 the maximum quota for BAT at 50% and the maximum value of the total net cash flow is reached (Figure 7.27); from then onward the price takes over. Clearly it would be helpful to continue the increase in the production quota for BAT, market permitting.

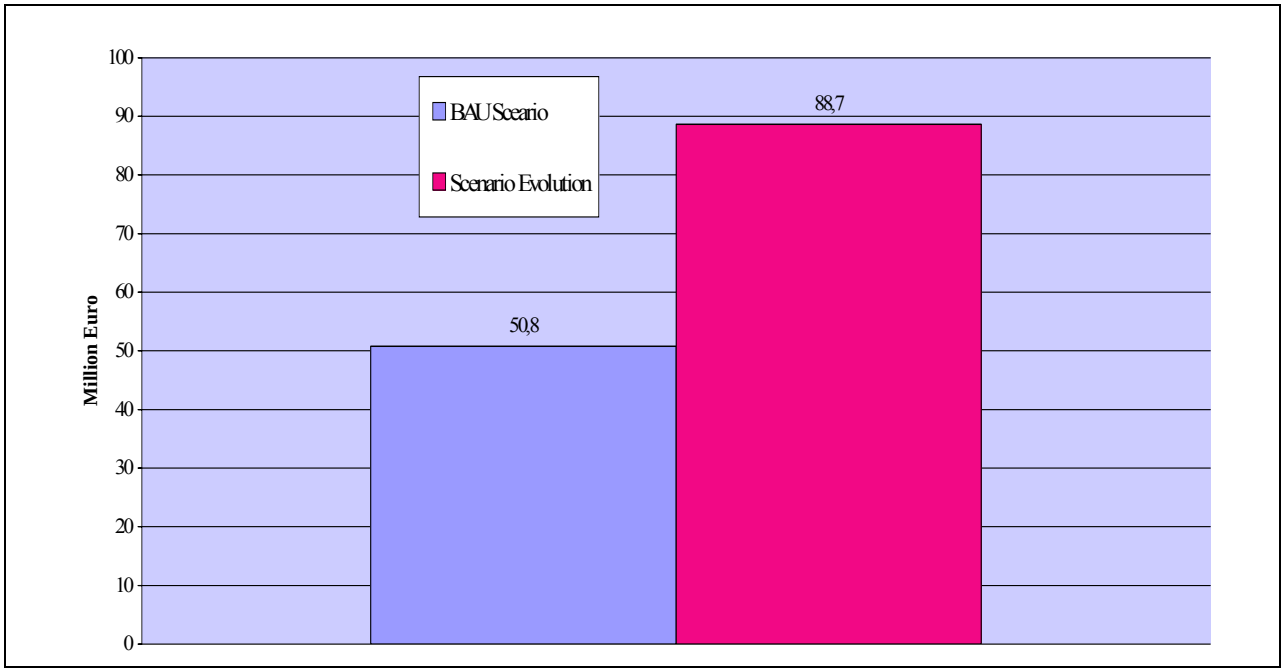
Figure 7.27: Washing machine Industry Value (NPV of Total Cash Flows) in BAU and Evolution Scenarios (Hypothesis of Accelerated BAT Introduction)



Under these circumstances what are the levels of the industry value under the two scenarios?

Again the absolute values are low, and the price affect reduces the overall values and the difference in the industry values under the two scenarios. We can show this, in an experiment reducing the real price decline to one percent/year as illustrated in Figure 7.28.

Figure 7.28: Industry Values (NPV of Total Cash Flows) under A One-Percent Real Price Decline



This is a new world! The total industrial values have quadrupled and the absolute difference between the two scenarios, the advantage of quickly introducing the BAT model, has gone from 17 to 38 million Euro.

The strategic emphasis for manufacturers of washing machines is still on differentiating the product in order to defend prices and on lowering costs.

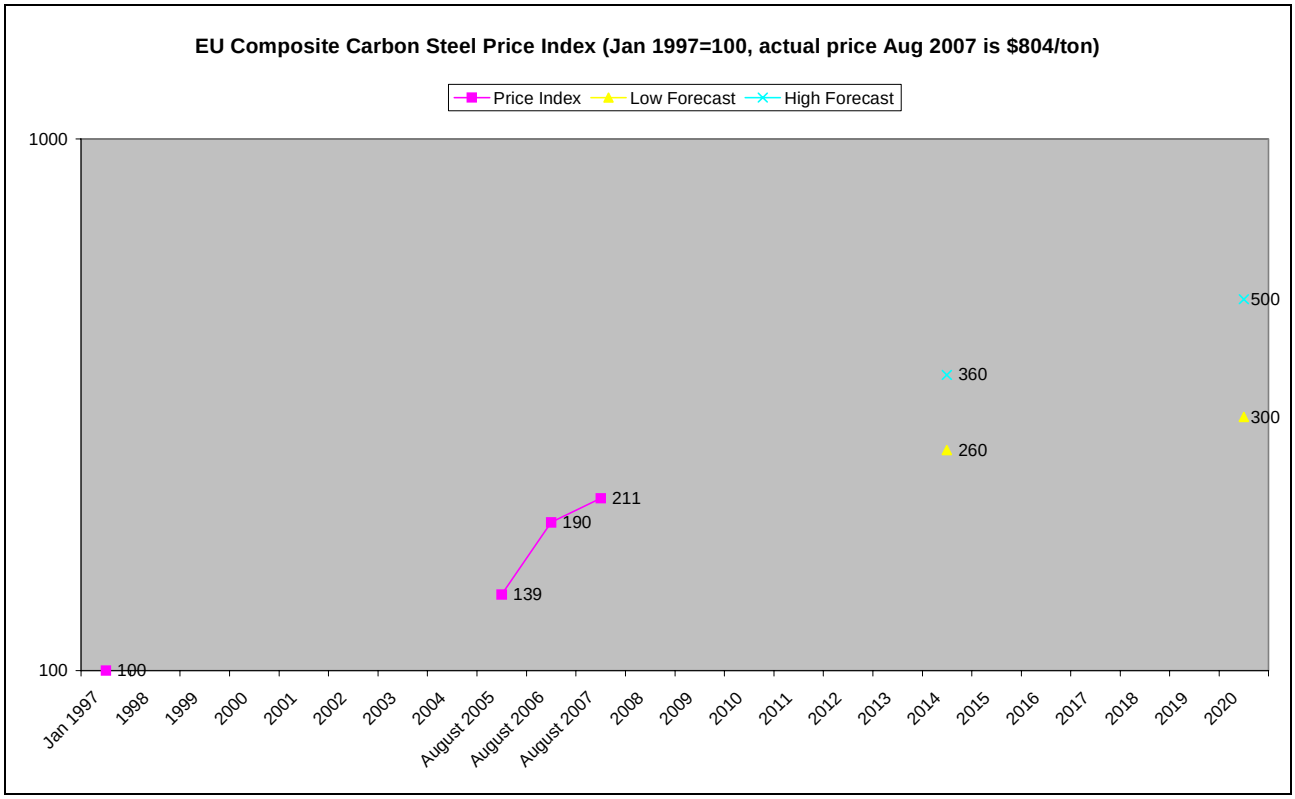
In contrast for the consumer, purchasing a BAT washing machines instead of a LLCC one, results in a small savings in electricity, valued at about 2€ per year and no savings in water. The difference in consumer price is around 80 € due to the high marginal cost of the additional technology and high mark-up in the distribution/retail sector given at 300% (consumer price = 300% manufacturer price). Clearly the informed consumer will purchase the BAT also for other reasons than electricity savings.

7.4.3.4 Cost sensitivity analysis and conclusions regarding washing machines

Price sensitivity was seen for the individual models and hypothesis. Here the sensitivity to cost changes in the base case and then in some instances the LLCC and BAT cases are analysed.

Steel prices[70] have risen dramatically recently as shown for the EU in Figure 7.29. The index has doubled in the last ten years, suggesting that it will at least do so in the next decade, given the very strong infrastructure demand in the developing world.

Figure 7.29: EU steel price trend



Using this conservative estimate we have a mid-period index price of 310, which would correspond to 1.181 € or € 844 € per ton. This represents a 270 €/ton increase over today's prices. The metal composition of the base case washing machine, as reported in Task 5, is shown in Table 7.30.

[70] Source: MPS Co., U.K.

Table 7.30: Metal composition of the base case washing machine

Ferrous Metal Composition of Washing Machine Base Model (kg.)	
Cast Iron	6,214
Iron	4,978
Total Cast Iron and Iron	11,192
Stainless Steel	1,939
Stainless Steel Sheet	0,564
Steel	12,521
Steel Strip	6,145
Total Steel	**21,169**
Total	**32,361**

With 21,2 kg of steel used to make the washing machine, the above represents a materials price increase of 5,70€ per unit or an increase in unit manufacturing cost by the same amount. Using a conservative one-third of the price increase for iron and cast iron adds 1,00€ for a total of 6,70€/unit. Electricity consumption during assembly is on the average 29 kWh/unit. Assuming that the price increases in the order of 0,02 to 0,04 €/kWh, this represents a 0,58 to 1,16 €/unit increase.

How much might we reasonably gain from extra labour productivity investments?

Let us assume that they still have a reasonable rate of return of between 3 and 5 years of payback time, beginning with 3 in the early years and ending at 5 years in the last. Let us assume we can add an extra 1,5% reduction in labour cost per year, that is we go from the usual historical 1,5% to its double 3,0%/year. In the case of the base case and LLCC hypothesis, the new Evolution Scenario, which contains this new productivity investment, the net present value of cash flow increases from 34,5 to 37,0 million Euro, a 2,5 million Euro increase. This in itself could offer some further limited financial advantage to manufacturers. The cost of labour can be brought down by automation or other means, but these have costs and the overall trade-off leads to these relative modest benefits.

With the BAT and LLCC production hypothesis, the productivity improvement is slightly greater with a 3,7 million Euro increase.

Compared to the potential increase in steel and ferrous metal prices however the labour productivity does not compensate the difference. On an undiscounted basis the 2,5 million Euro in productivity gains becomes about 3,4 million Euro and divided by the roughly 10 million units produced over the period, amounts to 0,34 € savings per unit, compared to possible increase in the cost of steel and iron from 5,70€ to 6,70 €, not to mention electricity cost increases. For the BAT and LLCC production, the equivalent is 0,50 €.

Could some of the component costs come down? Some of the largest items are the motor and pumps. The steel in these items has already been accounted for, but there might be labour cost savings in their production or some learning curve phenomenon. Suppose that the motor/pumps cost to the manufacturers is 50 €/unit about one-third of the materials and components total. In order to compensate for these possible cost changes due increase in steel prices, electricity prices and productivity investments by the washing machine producer, this would require cost reductions due to further automation or learning on the part of motor/pump producers in the order of 5,90 € to 7,40 €/unit, 12 to15% of their price.

This overall cost analysis may be summarised in Table 7.31.

Table 7.31: Sensitivity analysis of key costs for washing machine (changes mid-period)

Source	Estimated Impact on Average Unit Cost (€/unit)
Steel Price Increase	+5,70 to + 6,70
Electricity Price Gains	+0,58 to +1,16
Labour Productivity	-0.34 to -0,50
Component Maker Productivity Or Learning Efforts	Not estimated.

In general, these simulations for washing machines illustrate that:

1) **There is a high degree of sensitivity in cash flow due to price.** This is because price acts directly on revenues, cash flow is a difference equation (revenue minus costs) and the historic level of profit margin in the household appliance sector is low, from the 3 to 5%. To not overestimate these effects the fixed costs have been assumed to be a minimum.

2) **In the specific context of severe and continued decline in real prices (-2,0%/year), that have historically characterised the washing machine market, rather low levels of industry value are generated in both the BAU and Evolution scenario.** This is true despite an increase in labour productivity of 1,5% per year, which is applied in the simulation. Industry value is slightly greater with the BAT model due to higher value added.

3) Evidently there is a l**ack of pricing power on the part of the appliance producers**. Few large distributors in given geographic areas may exert a greater concentration of power, not allowing the household appliance producers much flexibility in pricing. Almost no producer has direct sales through Internet, although some distributors are beginning this.

4) **Also in this context of strong price decline, differences in margins of the products (2% here) have less impact on the improvement in industry values between the BAU and Evolution scenarios.** In the Base model LLCC model hypothesis, the investment in the conversion to more new product capacity is rewarded with a 15% increase in enterprise value over the period, which normally would be considered barely sufficient to cover the financial risks involved in a new investment. In the LLCC BAT case there is more improvement in industry value, but in part was due to the greater difference in margins between the two models.

5) **The sensitivity analysis of costs reveals the strongest cost increases coming from possible gains in steel prices.** Productivity investments within the freezer plant may help, but are an order of magnitude less than possible impact due to steel prices. Possible reductions in the cost of major components are not estimated but they would have to be substantial to offset other gains. If these steel price gains materialize, the washing machine production might be hard pressed to make a profit.

6) **Possible benefits from policy actions, for example production tax credits are yet to be analyzed.** This will be explored in the policy section. Public policy could be aimed at the energy saving products that are the most critical to introduce.

7.4.4 Impact Analysis and Results for Dishwashers

The general inputs and general outputs as outlined previously apply to both wash appliances, washing machines and dishwashers. From Task 6, Table 6.13: we have the characteristics of each model for the 12ps dishwasher (Table 7.32).

Table 7.32: Characteristics of the 12ps dishwasher models

Model	Energy consumption (kWh/cycle)	(EEI)	Water consumption (litre/cycle)	Noise (dBA)	Consumer Price (€)
BAT	0,914	0,554	10.64	50	779,5
LLCC	1,009	0,611	11,0	50	571,1
Base	1,070	0,648	15,2	50	548,4

7.4.4.1 Formulation of preliminary Scenarios for dishwashers

Let us consider the evolution of energy efficiency classes given in Task 2 and disaggregating where necessary for the models in years 2003, 2004 and 2005. For year 2008 an estimate for a continuation of the affects of the present policies is made in Table 7.33.

Table 7.33: Trend (2003-2008) of Market Quota (%) by model type for dishwashers

DW models	Energy consumption (kWh/cycle)	2003 (%)	2004 (%)	2005 (%)	2008 (%)
BAT	0,914	0	0	0,5	1,0
LLCC	1,009	0	0,5	1,0	1,5
Base case	1,070	72,9	80,3	88,7	95,0
Energy efficiency class B	--	17,4	13,3	7,7	2,0
Energy efficiency class C	--	9,1	5,4	2,3	0,5
Energy efficiency class D	--	0,6	0,5	0	0

At the factory level, again two sets of hypothesis (Table 7.34) are made:
1) Maximizing the quota of the LLCC
2) Rapid introduction of BAT.

Within each set we have the BAU and Evolution Scenarios. The factory has only two production lines.

Table 7.34: Production hypotheses for dishwashers

Hypothesis Set	Model	Factory capacity (%)		
		2008	2023 BAU	2023 Evolution
Maximum quota LLCC	LLCC	60	60	100
	Base	40	40	0
Fast introduction of BAT	BAT	1	1	50
	Base	99	99	50

The first hypothesis corresponds to the situation of a producer who is already producing a majority of LLCC models, 60% of capacity, and 40% capacity of the base model, in his large one-million unit plant. He could continue in this manner, the BAU hypothesis, or may explore the possibility of

converting the all of his capacity to LLCC production over the next 5 years.

7.4.4.2 Inputs and results of dishwasher hypothesis set of 'Maximum Quota LLCC'

The input data and assumptions for the LLCC line of production are shown in Table 7.35.

Table 7.35: Inputs for the dishwasher LLCC line of production

Assumptions Page for				
Situation Studied	**Dishwasher LLCC & Base (LLCC Prod Line)**			
Situation Studied in Base Prod.	**Dishwasher LLCC & Base (Base Prod Line)**			
	Dishwasher LLCC & Base (Base Prod Line)			
Base Year	2007			
Announcement Year	2008	***Year in which the announcement is made***		
Policy Measure Year	2009	***Year in which the policy measure takes effect***		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	190,00	*(EURO)*	Price Grow. UPMY	-0,8%
Base Year Unit Sales	0,050	*(million)*	Price Grow. APMY	-0,800%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%		Dist. Mark-up	3,00
			Tax Credit (Ū)	0
			El. Savings (kWh/yr)	17
			Electr.Price (Ū/kWhr)	0,17
			Water Savings (Ū/yr)	4,35
	BAT Case	**Policy Measure Case**		
0	**Year 2007**	**Year 2009**	**Sens. Anal. of Manufacturing Costs**	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	**105,00**	0,00	0%	0%
Labor / Unit	**22,20**	0,00	0%	0%
Overhead / Unit	**10,40**	0,00	0%	0%
Depreciation / Unit	8,17	0,00		
Total/ Unit	145,77	-		
Hypothetical Full Price Increase (Policy Measure Case Only)		0,00		
Percent of H. F. Price Increase Recovered by Manufacturers		100,00%		
Manufacturers' Price Increase		0,00		
Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10		0%	0%
Tooling	5		0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%
	Shipments BAU Scenario	**Shipments Evolution Scenario**		
(Year)	*(%)*	*(%)*		
2007	**57,00%**	**57,00%**		
2008	**60,00%**	**60,00%**		
2009	**60,00%**	**65,00%**		
2010	60,00%	**75,00%**		
2011	60,00%	**85,00%**		
2012	60,00%	**95,00%**		
2013	60,00%	**100,00%**		
2014	60,00%	**100,00%**		
2015	60,00%	**100,00%**		
2016	60,00%	**100,00%**		
2017	60,00%	**100,00%**		
2018	60,00%	**100,00%**		
2019	60,00%	**100,00%**		
2020	60,00%	**100,00%**		
2021	60,00%	**100,00%**		
2022	60,00%	**100,00%**		
2023	60,00%	**100,00%**		

The producer's price is 190 € and the manufacturing cost 147 €/unit which, results in an average cash flow margin of 3,9% for the period in the BAU scenario. A most important input is the real price dynamic that is hypothesized here as -0,8 %/year, the EU25 average for appliances. This is applied to both the LLCC and Base models. As seen energy savings is 0,061 kWh/cycle for 280 cycles per year or 17 kWh/year. Water savings is 4,2 litres/cycle or 1,176 m^3/year valued at 4,35€/year. The inputs for the base model is shown in Table 7.36.

Table 7.36: Inputs for the dishwasher Base Model line of Production

Assumptions Page for Dishwasher LLCC & Base (Base Prod Line)				
Scenario Description	Base Model			
Base Year	2007	*Beginning year for analytical purposes*		
Announcement Year	2008	*Year in which the announcement is made*		
Policy Measure Year	2009	*Year in which the policy measure takes effect*		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	175,00	*(EURO)*	Price Grow. UPMY	-0,8%
Base Year Unit Sales	0,950	*(million)*	Price Grow. APMY	-0,8%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%			
			Tax Credit (Ū)	0
			El. Savings (kWh/yr)	0
			Electr.Price (Ū/kWhr)	0,17

0	Base Model Year 2007	Policy Measure Case Year 2009	Sens. Anal. of Manufacturing Costs	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	103,00	0,00	0%	0%
Labor / Unit	22,00	0,00	0%	0%
Overhead / Unit	10,00	0,00	0%	0%
Depreciation / Unit	7,53	0,00		
Total/ Unit	142,53	-		

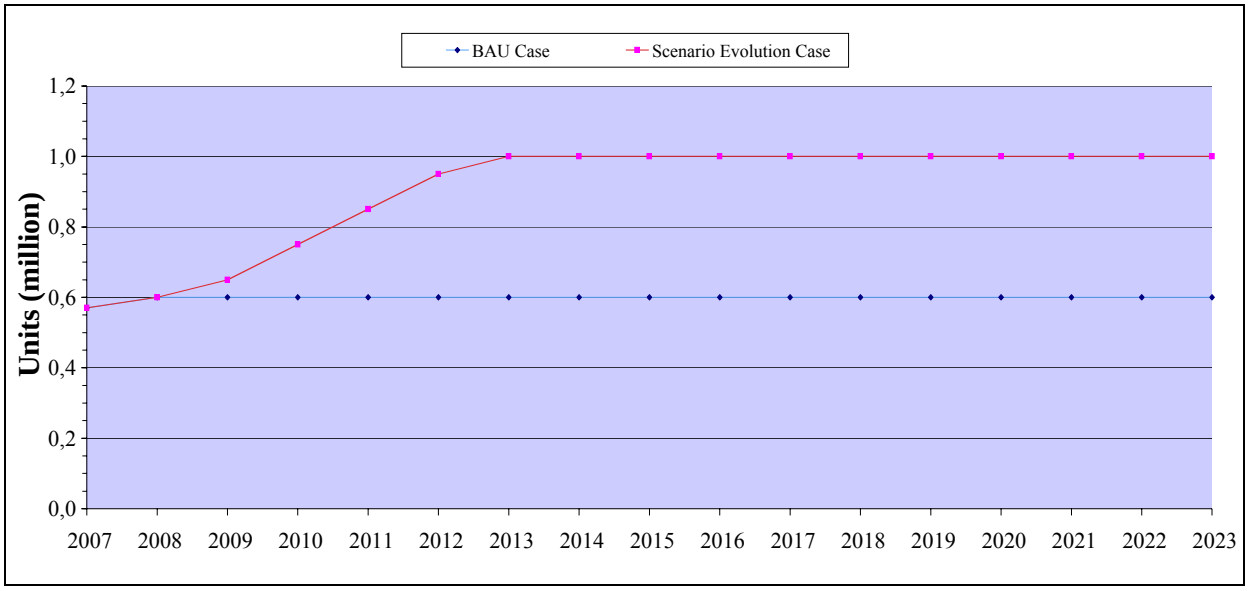
Hypothetical Full Price Increase (Policy Measure Case Only)	0,00
Percent of H. F. Price Increase Recovered by Manufacturers	100,00%
Manufacturers' Price Increase	0,00

Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10	0	0%	0%
Tooling	5	0	0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%

The manufacturer's price is 175 € and the total manufacturing cost reaches 142,5 €, which results in an average net cash flow margin of 1,5% for the base model for the period in the BAU scenario. This is lower than that of the LLCC in keeping with product life cycle dynamics. This is shown on the detailed table giving the calculation of the cash flows for the BAU.

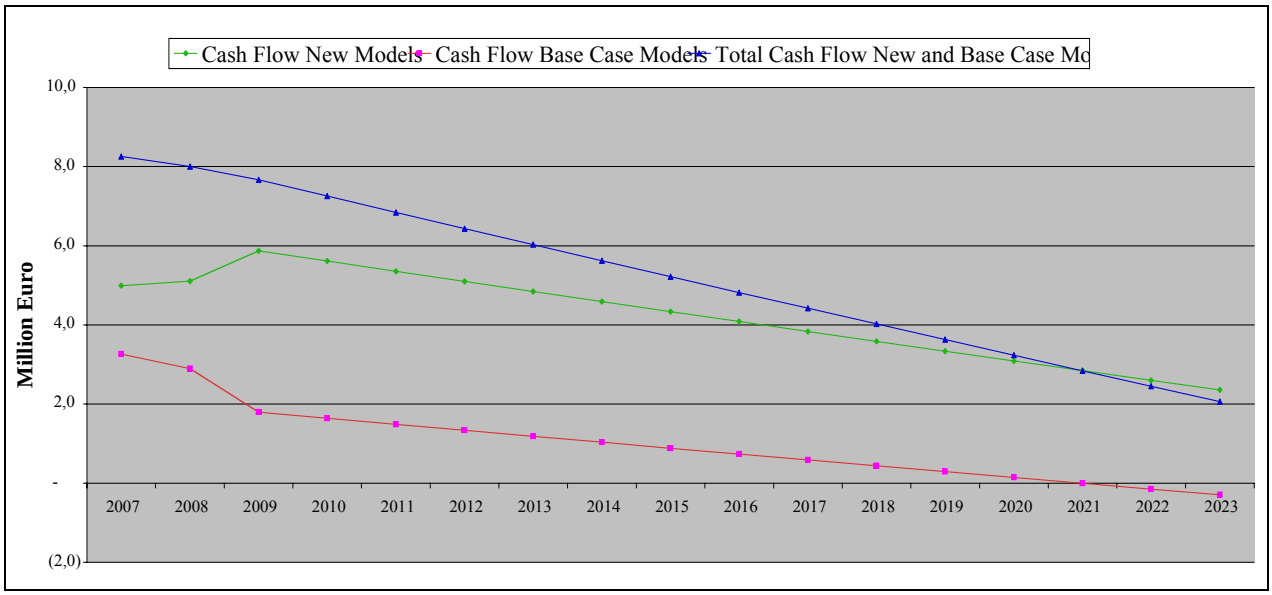
The shipments (and capacity utilization) are shown in Figure 7.30 for the dishwasher LLCC model, as hypothesized in the two scenarios.

Figure 7.30: Shipments of the LLCC dishwasher



In the BAU scenario there are very few surprises with the fixed quotas, as illustrated by the cash flow in Figure 7.31

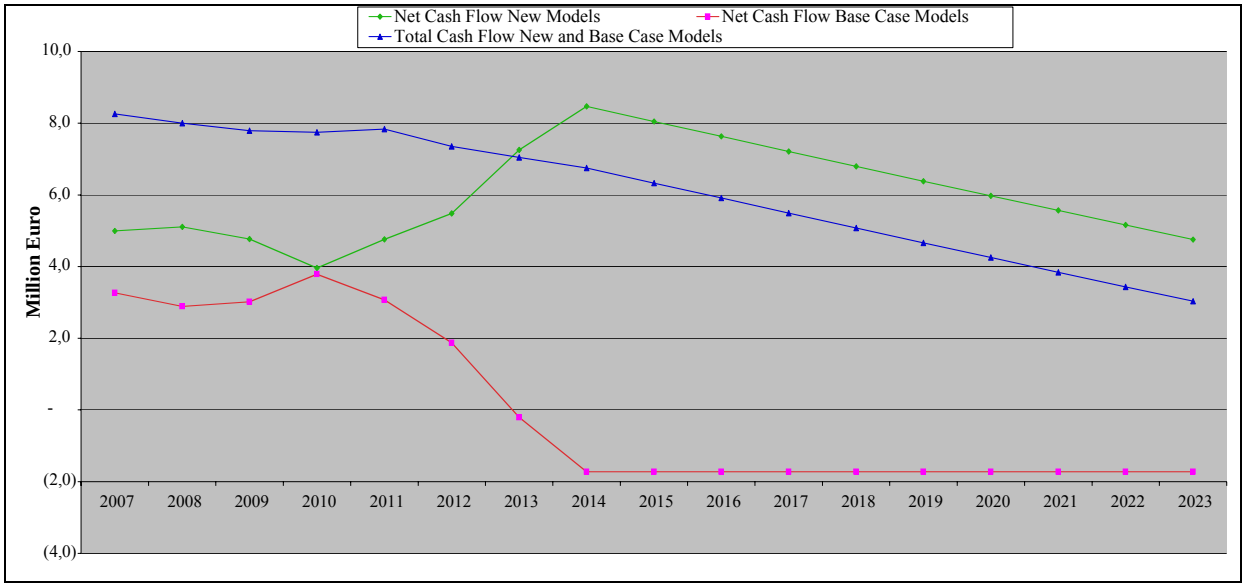
Figure 7.31: Net Cash Flows of the LLCC (New) and Base Model dishwasher in the BAU Scenario



After the initial brief increase in LLCC capacity between 2007 and 2008, the quotas are fixed and there is a gradual decline in cash flows due to the price erosion. Small gains in labour productivity are not sufficient to make the difference.

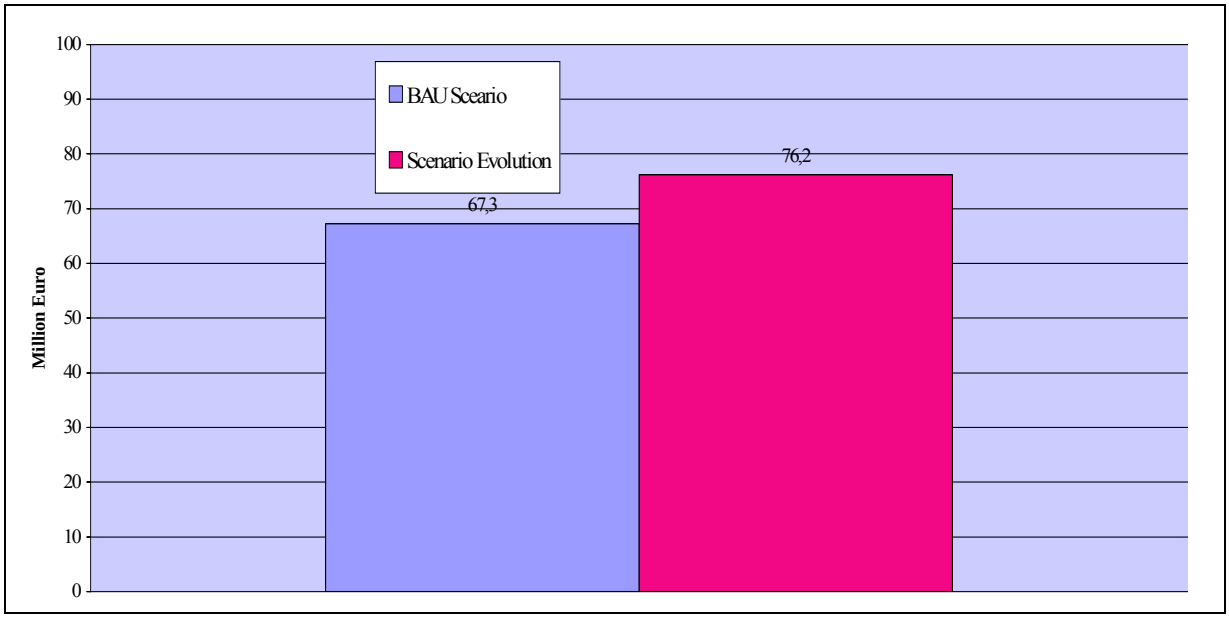
Instead in the Evolution Scenario the dynamics of the substitution between models becomes evident.

Figure 7.32: Net Cash Flows of the LLCC (New) and Base Model Dishwasher in the Evolution Scenario



The new model (LLCC) cash flows increase and those of the base model decrease until the quotas again become fixed in 2014. Beyond that year the price dynamics appear more evident. The net present value of the cash flows (industry value) is given for the two scenarios (Figure 7.33).

Figure 7.33: Industry Value for the Dishwasher (Hypothesis: Max Quota for LLCC)



These substantial absolute values of industry value for dishwashers reflect the more favourable circumstances of moderate price declines of 0,8 %/year compared to the situation of -2,0 %/year in the case of washing machines. The relatively moderate difference between the Evolution and BAU scenario, 9 million Euro, is due to the fact that there are not dramatic price and cost differences between the base and LLCC models.

Even though we introduced a margin of 3,9% for the LLCC model and 1,5% for the base case, this produced only moderate impact, taking into consideration the substitution affect. For the consumer the payback time is about 7 years with an initial difference in consumer price of 45 €.

7.4.4.3 Inputs and results of dishwasher hypothesis set of 'Fast Introduction of BAT'

For the fast introduction of the BAT dishwasher, we have hypothesised a rapid conversion of the production market and production capacity, going from 1% in 2007 to 50% five years later in year 2001, as shown on the input page for BAT (Table 7.37).

Table 7.37: Input parameters for BAT dishwashers

Assumptions Page for				
Situation Studied	**Dishwasher LLCC & Base (LLCC Prod Line)**			
Situation Studied in Base Prod.	**Dishwasher LLCC & Base (Base Prod Line)**			
	Dishwasher LLCC & Base (Base Prod Line)			
Base Year	2007			
Announcement Year	2008	***Year in which the announcement is made***		
Policy Measure Year	2009	***Year in which the policy measure takes effect***		
Tax Rate	48,00%			
Discount Rate for NPV	5,0%			
Inflation Rate	0,0%	*per annum*		
Working Capital	18,00%	*of Revenue*		
Base Year Unit price	262,00	*(EURO)*	Price Grow. UPMY	-0,8%
Base Year Unit Sales	0,050	*(million)*	Price Grow. APMY	-0,800%
Unit Sales Growth Rate	0,0%	*per annum*		
Standard SG&A	10,00%	*of Revenue*	Prod. Base Case	0,015
Research and Development	2,50%	*of Revenue*	Prod. Policy Case	0,015
			Reference Prod.	0,015
Ordinary Depreciation	4,30%	*of Revenue*		
Ordinary Capital Expenditures	-4,50%	*of Revenue*	Price elasticity	-0,4
Variable Overhead as % of Total	60,00%		Dist. Mark-up	3,00
			Tax Credit (€)	0
			El. Savings (kWh/yr)	26,6
			Electr.Price (€/kWhr)	0,17
			Water Savings (€/yr)	0,37
	BAT Case	**Policy Measure Case**		
0	**Year 2007**	**Year 2009**	**Sens. Anal. of Manufacturing Costs**	
Manufacturing Costs	**(Euro)**	**Additional Costs Euro**	**% Below**	**% Above**
Materials / Unit	**140,00**	0,00	0%	0%
Labor / Unit	**30,00**	0,00	0%	0%
Overhead / Unit	**14,00**	0,00	0%	0%
Depreciation / Unit	11,27	0,00		
Total/ Unit	195,27	-		
Hypothetical Full Price Increase (Policy Measure Case Only)		0,00		
Percent of H. F. Price Increase Recovered by Manufacturers		100,00%		
Manufacturers' Price Increase		0,00		
Conversion Costs (Policy Case)	**Useful Life**	**Investment Cost**	**Sens. Anal. Of Conversion Costs**	
Capital Expenditures	*(Years)*	*(EURO 10^6)*	**% Below**	**% Above**
Investment	10		0%	0%
Tooling	5		0%	0%
Design & Marketing Expenses		**Total Expenditures**		
R&D		0		
Marketing		0	0%	0%
	Shipments BAU Scenario	**Shipments Evolution Scenario**		
(Year)	*(%)*	*(%)*		
2007	**1,00%**	**1,00%**		
2008	**1,00%**	**10,00%**		
2009	**1,00%**	**25,00%**		
2010	1,00%	**45,00%**		
2011	1,00%	**50,00%**		
2012	1,00%	**50,00%**		
2013	1,00%	**50,00%**		
2014	1,00%	**50,00%**		
2015	1,00%	**50,00%**		
2016	1,00%	**50,00%**		
2017	1,00%	**50,00%**		
2018	1,00%	**50,00%**		
2019	1,00%	**50,00%**		
2020	1,00%	**50,00%**		

Note that the consumer savings in purchasing a BAT dishwasher, instead of a LLCC model, is limited to 26,6 kWh/year and 0,37 Euro/year in water savings. The difference in consumer price is about 200€.

The manufacturers' unit costs are 195 €/unit with base year manufacturers' price at 262 €. This results in an average cash flow margin of 4,5% for the new BAT model as compared to the 3,9% for the LLCC model production, which is shown in the profit/loss and cash flow statements for the base case scenario shown in Table 7.38.

Table 7.38: Profit/Loss and Cash Flow Statement for dishwasher Base Case Scenario

New (and Base Case)		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Income Statement															
Price/Unit		262,0	259,9	257,8	255,8	253,7	251,7	249,7	247,7	245,7	243,7	241,8	239,8	237,9	236,0
Unit Sales		0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Revenues		2,6	2,6	2,6	2,6	2,5	2,5	2,5	2,5	2,5	2,4	2,4	2,4	2,4	2,4
Cost of Sales															
	Labor	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2
	Material	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4
	Overhead - Fixed	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Overhead - Variable	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Depreciation Productivity Cap. Exp.		-	-	-	-	-	-	-	-	-	-	-	-	-
	Depreciation Ordin. & Convers.	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Depreciation Total	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Selling, General and Administrative															
	Standard SG&A	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
	R&D	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Product Conversion Expense	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit Before Tax		0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,2	0,2	0,2	0,2	0,2
% Profit B.T./ Revenue		13,0%	12,63%	12,28%	11,9%	11,6%	11,20%	10,84%	10,47%	10,09%	9,71%	9,33%	8,94%	8,54%	8,14%
Taxes		0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Net Income Before Financing		0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Cash Flow Statement		**2007**	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Net Income	0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Depreciation	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
	Change in Working Capital	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cash Flows from Operations		0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,2	0,2	0,2	0,2	0,2	0,2	0,2
	Productivity capital expenditure		-	-	-	-	-	-	-	-	-	-	-	-	-
	Ordinary Capital Expenditures	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)
	Conversion Capital Expenditures	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cash Used In Investment		(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)	(0,1)
Average Base Model Margin	**3,9%**	5,15%	4,96%	4,77%	4,58%	4,38%	4,19%	3,99%	3,78%	3,58%	3,37%	3,16%	2,95%	2,74%	2,52%
Cash Flow New Models		0,2	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Cash Flow Base Case Models		9,6	9,2	8,7	8,3	7,9	7,5	7,1	6,7	6,2	5,8	5,4	5,0	4,6	4,2
Total Cash Flow New and Base Case Models		9,8	9,3	8,9	8,5	8,1	7,6	7,2	6,8	6,4	6,0	5,5	5,1	4,7	4,3
Average New Model Margin	**4,5%**	6,69%	6,51%	6,33%	6,15%	5,96%	5,77%	5,58%	5,39%	5,19%	4,99%	4,79%	4,59%	4,39%	4,18%
Present Value Factor		1,000	0,952	0,907	0,864	0,823	0,784	0,746	0,711	0,677	0,645	0,614	0,585	0,557	0,530
Discounted Cash Flow		9,8	8,9	8,1	7,3	6,6	6,0	5,4	4,8	4,3	3,8	3,4	3,0	2,6	2,3
Total Cash Flow as % of Revenue	3,9%	5,2%	5,0%	4,8%	4,6%	4,4%	4,2%	4,0%	3,8%	3,6%	3,4%	3,2%	3,0%	2,8%	2,5%
Industry Value (Net Present V.)	**76,3**														

The cash flows of the base case with the constant production shares of one and 99% for BAT and LLCC models respectively display a constant decline as in Figure 7.34.

Instead, in the Evolution Scenario there is a strong substitution of BAT for LLCC models reaching 50% with five years (Figure 7.35).

Figure 7.34: Net Cash Flow for BAU Scenario of BAT(new) and LLCC(base) dishwasher models

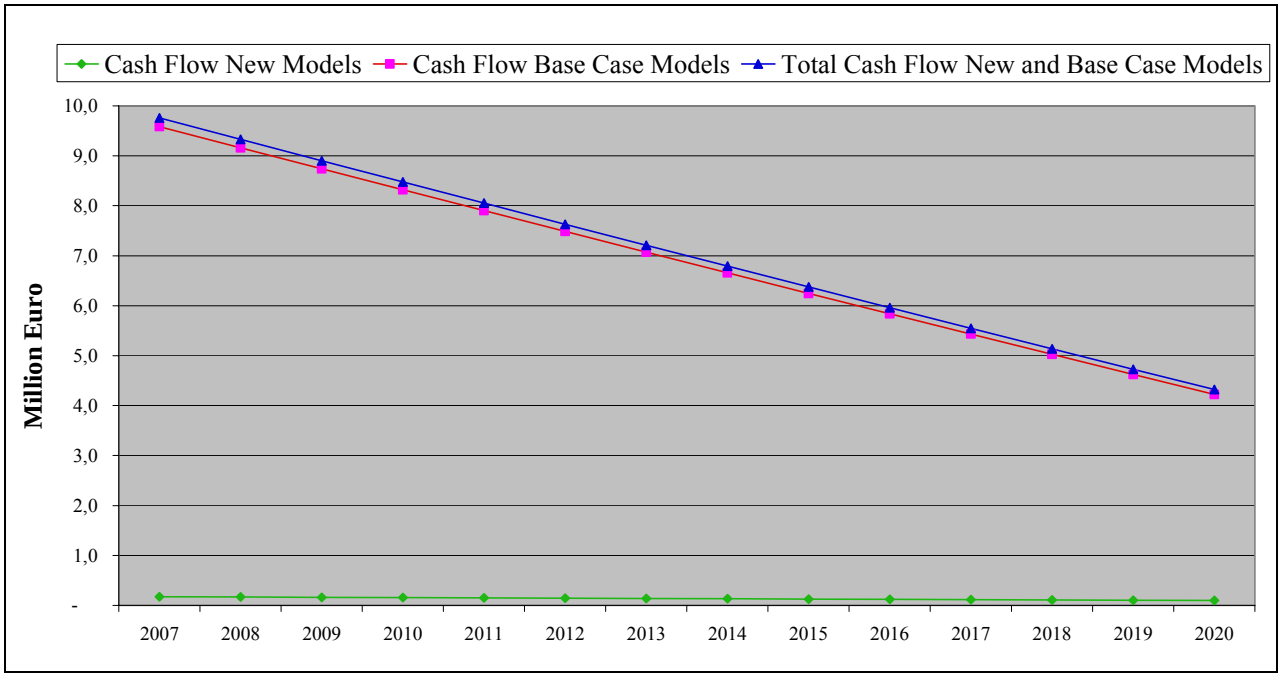
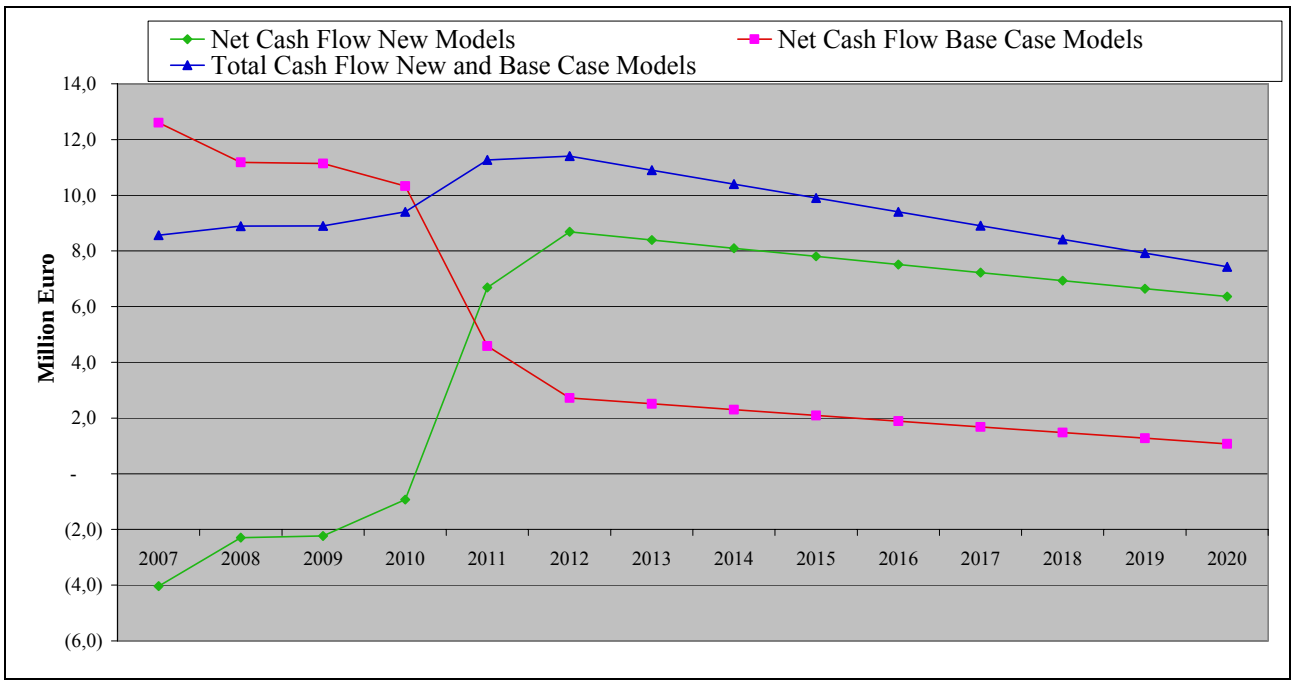
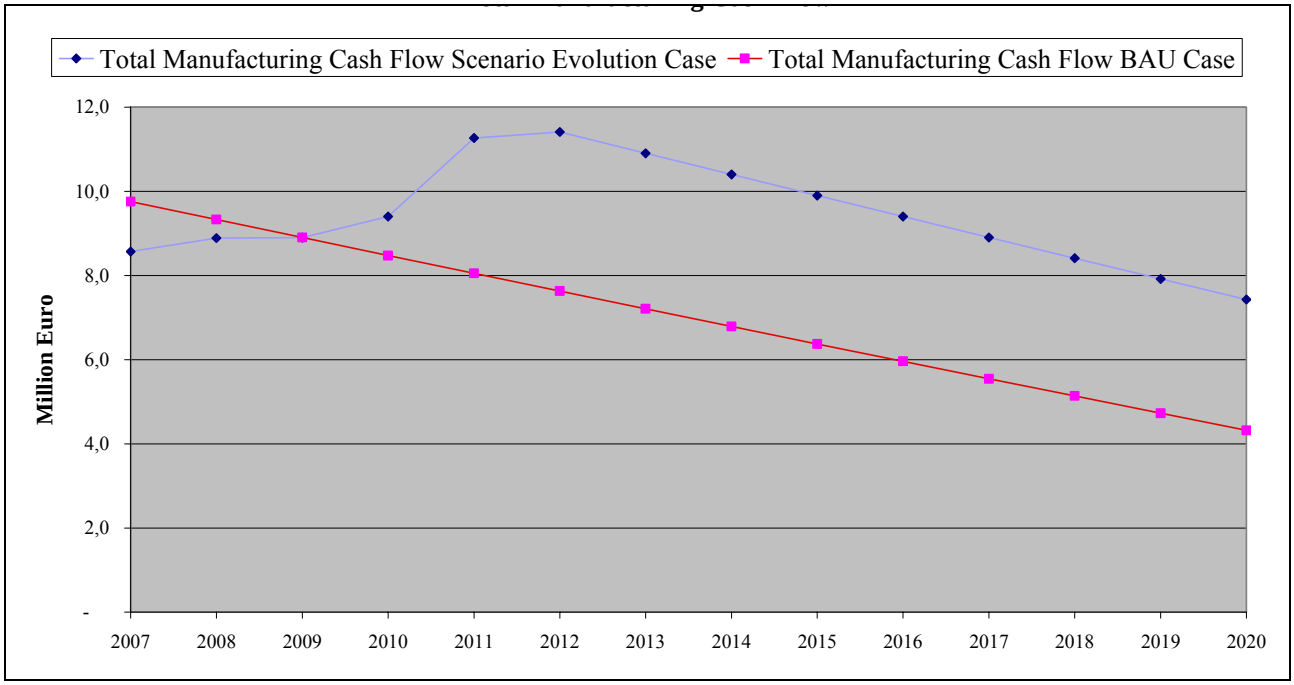


Figure 7.35: Net Cash Flow for Evolution Scenario of BAT(new) and LLCC(base) dishwasher models



The cash flow margin is highest for the newer BAT model and the overall cash flow (blue line in Figure 7.36) reaches a peak in the years 2011-2012, when the BAT reaches the maximum quota, and subsequently the total cash flows gradually decline. Total cash flows are higher in the evolution than BAU scenario.

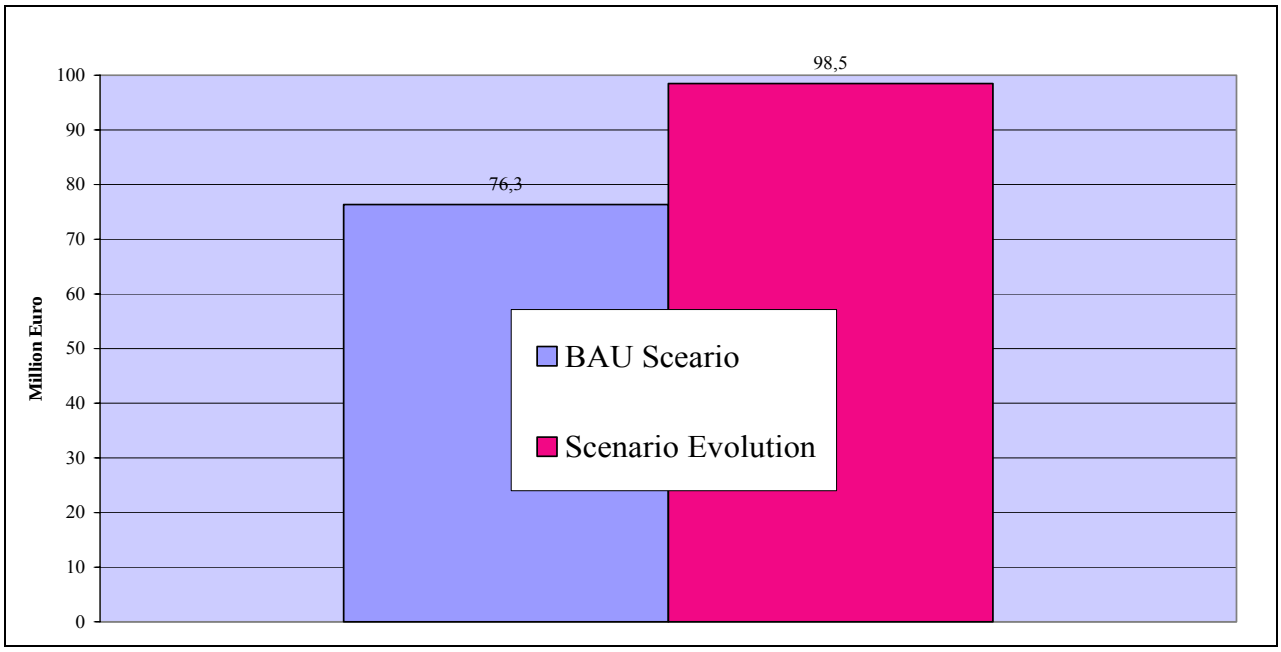
Figure 7.36: Total Net Cash Flows in the BAU and Evolution Scenario of dishwasher models



This produces a increase in the discounted net cash flow between the two scenarios (Figure 7.37). The absolute amounts of the industry value are substantial, which is consistent with the initial margins around four percent and a relative mild real price decrease of 0,8% per year. The difference between the two values, 22 million Euro is due to the slightly higher margin for BAT models coupled with their rapid penetration.

Instead for the consumer as previously indicated the benefits relative to the difference in price results in a payback time of 44 years. Again the consumer must be purchasing the BAT model for additional reasons.

Figure 7.37: Present Value of Net Cash Flows in the BAU and Evolution Scenario of dishwasher models



7.4.4.4 Cost Sensitivity Analysis and Conclusions regarding Dishwashers

The same cost factors that were considered in the case of washing machine are analyzed for dishwashers. The ferrous metal composition of the 12 place setting dishwashers is presented in Table 7.39.

Table 7.39: Ferrous Metal Composition of 12 ps dishwasher Base Model

Material	kg
Galvanized Steel	0,403
Iron	2,303
Total Iron and Galv. Steel	**2,706**
Mixed & Plastic	0,967
Prepainted Steel	1,269
Stainless Steel	8,691
Steel	6,536
Steel Strip	7,097
Total Steel	**23,593**
Total	**27,266**

The rising cost of steel is also a preoccupation for relative large amount contained in these units.

Using the same hypothesis of increase in the price of steel of 0,27 €/kg., with 23,6 kg of steel used to make the 12ps dishwasher, this represents a materials price increase of 6,37 € per unit or an increase in unit manufacturing cost by the same amount. Using a conservative one-third of the price increase for iron and galvanized steel adds 0,24 € for a total of 6,61 €/unit.

Electricity consumption during assembly is on the average 17 kWh/unit. Assuming that the price increases in the order of 0,02 € to 0,04 €/kWh, this represents a 0,34 € to 0,68 €/unit increase.

Turning to labour costs, let us examine the possible from additional labour productivity investments. Let us assume that they still have a reasonable rate of return of between 3 and 5 years of payback time, beginning with three in the early years and ending at five years in the last years of investment. The improvements occur gradually over the production period. Let us hypothesize that we can add an *extra* 1,5% percent reduction in labour cost per year, that is we go from the usual historical 1,5% to its double 3,0%/year. This would appear to be a reasonable upper limit.
In the hypothesis of the Base case and LLCC dishwasher, in the new Evolution Scenario, which contains this new productivity investment, the net present value of cash flow increases from 71,2 € to 73,0 million Euro, a 2,8 million Euro increase. This in itself is important and could offer some further financial advantage to manufacturers. The cost of labour can be brought down by automation or other means, but these have capital and the overall trade-off leads to these relative modest benefits. With the LLCC and BAT model hypothesis, the productivity improvement is slightly less with a 2,6 million Euro increase.

Compared to the potential increase in steel and ferrous metal prices however the labour productivity does not compensate the difference. On an undiscounted basis the 2,8 million Euro in productivity gains becomes about 3,8 million Euro and divided by the roughly 10 million units produced over the period, amounts to 0,38 € savings per unit, compared to possible increase in the cost of steel and iron from 6,40 € to 6,60 €, not to mention electricity cost increases. For the LLCC BAT production the equivalent is 0,35 €.

Could some of the component cost come down? Undoubtedly the largest items are the pumps/motors. The steel has already been accounted for, but there might be labour cost savings in the production of pumps/motors or some learning curve phenomenon. Suppose that the pumps/motors cost to the manufacturers is about 40 €/unit. To offset the possible cost changes occurring to the dishwasher producer due to steel prices, electricity prices and reduction in labour costs, this would imply cost reductions due to further automation or learning on the part of pump/motor producers in the order of 6,40 € to 6,90 €/unit, 16 to17% of their price.

Table 7.40: Sensitivity Analysis of Key Costs for dishwashers

Source	Estimated Impact on Average Unit Cost (€/unit)
Steel Price Increase	+6,37 to + 6,61
Electricity Price Gains	+0,34 to +0,68
Labour Productivity	-0,35 to -0,38
Component Maker Productivity or Learning Efforts	Not estimated

In general, these preliminary simulations for dishwashers illustrate that:

1) **There is a high degree of sensitivity in cash flow due to price**. This is because price acts directly on revenues, cash flow is a difference equation (revenue minus costs) and the historic level of profit margin in the household appliance sector is low, from the three to five percent. To not overestimate these effects the fixed costs have been assumed to be a minimum.
2) **In the specific context of moderate decline in real prices (-0,8%/year), that have historically characterised the dishwasher market, substantial levels of industry value are generated in both the BAU and Evolution scenarios**.
3) **Also in this context, differences in margins of the products (from 1,7 to 0,6%) do produce significant differences in industry values of the BAU and Evolution scenarios**. The Base model LLCC model production yielded an improvement of 12%, and the LLCC BAT hypothesis gave an improvement of 29%, for an average of 20%. The margins on a the higher priced BAT model yield greater profits. **In a healthy price environment, market incentives to invest in improved LLCC and BAT model do exist.** Obviously the faster the market moves to higher margin products, and the margins are sustained, the better for the producer.
4) **In all cases, including dishwashers and washing machines, greater potential cash flows exist for the higher value added BAT model, which however has the longest payback time for the consumer**. The payback times are coming from Task 6 and are only slightly changed by the price dynamics of the E-GRIM simulations. Sometimes these returns to the consumer do not have a positive net present value at a real discount rate of five percent.
5) **The cost sensitivity analysis reveals the strongest cost problems coming from possible increases in steel prices.** Productivity investments within the freezer plant may help, but are an order of magnitude less than possible impact due to steel prices. Possible reductions in the cost of major components are not estimated, but they would have to be substantial to offset other gains. If these steel price gains materialize, the dishwasher model profits likely will be compressed.
6) **Possible benefits from policy actions, such as production tax credits are yet to be analyzed**. This will be explored in the policy section. Public policy could be aimed at the most critical products, those energy saving products having the most difficulty of introduction. In this case washing machines would have a higher priority than dishwashers.

7.5 SUBTASK 7.5 - SENSITIVITY ANALYSIS

The sensitivity analysis of the main parameters allows to evaluate the robustness of the analysis outcome.

The sensitivity of the manufacturer impact analysis has been developed in the previous paragraphs. A sensitivity analysis covering the most relevant factors: the price of energy, the production costs and discount rates, was carried out in Task 6 for the standard base cases to check if there are significant changes in results and if the overall LCC conclusions, BATs and BNATs are reliable. The main outcome are here reported.

7.5.1.1 The LCC sensitivity analysis for dishwashers

The Life Cycle Cost sensitivity analysis has been developed for the two average standard base cases, the 9ps and the 12ps machines. The technical and financial assumptions were modified, one at time, to evaluate the impact on the LCC output values. It is worth highlighting that in the sensitivity analysis the application order of the technological options is that resulting as the most profitable for the consumers according to the MNPV analysis for the average standard base case and the basic technical and financial assumptions. The variation of parameters such as the energy and water price and the number of cycles per year might have an influence on the optimum technological option combination (corresponding to the LLCC) and more in general to the options application order, but this more sophisticated sensitivity analysis was not compatible with the time and budget constraints of the study.

The most important result is that in practice the Least Life Cycle Cost point occurs at the same technological option combination when the investigated parameters are varied. In addition, there is no effect on the overall LCC results robustness when the disposal and recycling costs are decreased from 61 € to 10 €.

The second most important outcome of the sensitivity analysis is the large variation of the LCC at the LLCC point due to the combination of technical and economical factors. For the **9ps dishwasher**, when 208 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.033 Euro; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 1.554 Euro, with a difference of 521 Euro. For the **12ps dishwasher** when 208 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.139 Euro; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 1.776 Euro, with a difference of 635 €.

For the 9ps machine, the energy savings going from the average standard base case to the $LLCC_{av}$ are in the range 1,6-2,2 €/year depending on the annual washing cycles, the water savings in the range 2,6-3,6 €/year, for a total of 4,2-5,7 €/year against an increase in purchase price of 23 Euro; the energy savings going from the average standard base case to the BAT_{av} at a noise of 50 dB(A) are in the range 3,7-5,0 €/year and the water savings in the range 2,8-3,8 €/year, for a total of 6,6-8,8 €/year against an increase in purchase price of 173 Euro. When the noise is decrease to 41 dB(A) there is a slight increase of the energy expenses (-0,8-1,1 €/year), while the water savings are in the range 2,8-3,8 €/year, with a price increase of 265 €.

For the 12ps machine the energy savings going from the average standard base case to the $LLCC_{av}$ are in the range 2,2-2,9 €/year depending on the annual washing cycles, the water savings in the range 3,2-4,4 €/year, for a total of 5,4-7,3 €/year against an increase in purchase price of 23 €; the energy savings going from the average standard base case to the BAT_{av} at 50 dB(A) are in the range

5,5-7,4 €/year depending on the annual washing cycles and the water savings in the range 3,5-4,8 €/year, for a total of 9,1-12,2 €/year against an increase in purchase price of 231 €. When the noise is decrease to 41 dB(A) there is no energy savings, while the water savings are in the range 3,5-4,8 €/year, with a price increase of 335 €.

7.5.1.2 The LCC sensitivity analysis for washing machines

The LCC analyses of the standard base case 5,36 washing machine was developed for the three different values of annual washing cycles. The most important result is that the Least Life Cycle Cost point occurs at the same technological option combination when the investigated parameters are varied and as in the case of dishwashers, there is no effect on the overall LCC when the disposal and recycling costs are varied. The second most important outcome of the sensitivity analysis is the large variation of the LCC at the LLCC point due to the combination of technical and economical factors: when 200 washing cycles are run per year, the life cycle cost over a lifetime of 10 years is 1.411 €; on the contrary when the electricity price is 0,25 €/kWh, the life cycle cost over a lifetime of 17 years is 2.162 Euro, with a difference of 751 €.

The energy savings for the $LLCC_{av}$ are in the range 3,3-4,1 €/year depending on the annual washing cycles, the water savings[71] in the range 8,9-10,9 €/year, for a total of 12,2-15,0 €/year against an increase in purchase price of 16 € the energy savings going from the average standard base case to the BAT_{av} are in the range 4,95-6,0 €/year and the water savings in the range 8,9-10,9 €/year, for a total of 13,7-16,8 €/year against an increase in purchase price of 97 €. When the spin speed is increased to 1 600 rpm or when the capacity increases to 6kg the savings decrease and the price increase of 123 €.

7.6 SUBTASK 7.6: HYPOTHESISED POLICY MEASURES FOR WASH APPLIANCES

7.6.1 The Policy Measures Portfolio

7.6.1.1 The mandatory vs. the voluntary approach in Europe

After the first experience in setting minimum efficiency requirements for products, resulting in the issue of directive 96/57/EC for cold appliances and directive 2000/55/EC ballast for fluorescent lamps, a set of five Industry Voluntary Commitments (described in Task 1) have been discussed and agreed upon by the household appliance manufacturers' European industry association, CECED, the European Commission, and Member States.

However, on 21 March 2007 with a Press Release[72], CECED, called for legislative measures to ensure future energy performance standards as an alternative to continued updating of the voluntary agreements that industry introduced a decade ago.

The strategy change was announced after a meeting of the CECED steering committee in Brussels. Patchy government enforcement of the EU's energy labelling scheme, the vehicle whereby energy efficiency information is shared with the public, has undermined industry's ability to go to the next phase of voluntary measures. CECED's voluntary agreements on energy efficiency have delivered

[71] the modification of the rinsing performance (if any) due to the decrease of the water consumption is not known.
[72] "Top Executives Discontinue Voluntary Energy Efficiency Agreements for Large Appliances", Embargo: 17.00 hrs, 21 March 2007, downloadable from http://www.ceced.org.

major performance improvements, estimated to have cut 17 million tons of CO_2 from Europe's emissions tally, equivalent to the carbon output of nine 500 MW thermo-electric power plants.

"European manufacturers are as committed as ever to designing and marketing energy efficient appliances because it is the right thing to do and consumers expect that of us," said CECED President, Magnus Yngen of Electrolux. "But governments must guarantee fair competition by enforcing the law and ensuring that product declarations are genuine–or our investment in high performing products is compromised. The next round of improvements needs to be driven by legislation that applies to all and is enforced on all."

Covering on average 90% of the market for large appliances, CECED's five existing voluntary agreements (for washing machines, refrigerators and freezers, dishwashers and water storage heaters) have been widely recognised as progressive and pro-active. These have required an investment by European manufacturers of €10 billion over the past decade.

"Too many governments are not stopping careless or unscrupulous operators from marketing products that claim better energy efficiency than they actually deliver," says Yngen. "Free-riding must be strongly discouraged. Today we have a very worrisome situation where politicians set rules, expect companies to abide by them and then fail to invest the resources needed to stop the lawbreakers."

To show that market surveillance is not working, the top managers also announced that CECED will launch a one-off market testing programme, using independent laboratories to check products sampled from the market against the performance claims stated on their labels. The results will be made public later this year. The exercise will demonstrate that market surveillance is feasible and not prohibitively expensive for governments. Sampling will cover refrigeration appliances in the market, regardless of source.

7.6.1.2 The extension of the Energy Star programme to household appliances

In 2005 detailed discussions and negotiations were held with the US Environmental Protection Agency and the US Department of Energy. These resulted in an in principle agreement that Australia and New Zealand could set local Energy Star "high efficiency" criteria for products that were sold in the Australasian market (such as white goods where the USA had their own domestic Energy Star criteria), subject to detailed review by EPA and DOE on a product by product basis. On this basis, E3 decided to move towards the use of the Energy Star label as the primary endorsement label for appliances and equipment in Australia and to discontinue TESAW as an endorsement label.

One of the key decisions made at the E3 Stakeholder Working Group meetings in 2005 was that any Energy Star criteria to recognise high efficiency refrigerators and freezers needs to be linked to the star rating system. This is critical as it provides a consistent message with regard to the relative efficiency of products for both program elements (comparative energy label and the Energy Star endorsement label). So in principle, an Energy Star qualification level should be defined in terms of star ratings under the new energy labelling algorithm under preparation by the Australian authorities (see Task 1 for details).

At this stage, no draft Energy Star criteria have been proposed. Further analysis needs to be undertaken to refine the likely criteria and the approval of proposed levels needs to be sought from US authorities prior to their implementation. In fact, setting Energy Star levels that are comparable with or better than US levels (i.e. 10% to 15% better than current 2005 efficiency requirements

levels) and also where 20% to 30% of products on the Australia and New Zealand market can attain the criteria would be ideal. But using these criteria together with the new star rating index could create some mismatches and complications that may need to be examined and resolved. Other issues for implementation that require some consideration are frequency of review of qualification levels and whether there should be any tag or identifier on the Energy Star label used for locally developed high efficiency levels to distinguish this from the standard EPA Energy Star label which is used internationally.

The Energy Star Program, commenced in the USA in 1992, applies to a vast array of products in that country, including equipment, appliances, materials and even buildings. A large part of the US Energy Star program is set up as a domestic endorsement labelling system that works in conjunction with other domestic programs such as minimum efficiency requirements and energy labelling (the Energy Guide) or as a stand-alone program for selected unregulated products. The use of Energy Star as an endorsement of high efficiency products at this stage is used in North America (USA and Canada) only, but neither the US nor the Canadian energy labels have a star rating system or its equivalent categorical rating system (such as the EU labelling scheme) so this potential information miss-match is not an issue there.

If the criteria of the Energy Star and the categorical labelling scheme are the same, and the Energy Star approach calls for a 20% of the models fulfilling the criteria at the time of enforcement, there is little scope is setting this endorsement label.

The justification given by Australia is that Energy Star, as the former TESAW scheme, allows consumer to quickly recognise highly efficient product on the market. But if high efficient dishwashers or washing machines are identified by energy efficiency classes A (and A+), and the label is mandatory on models displayed in shops or offered for sale, high efficient models are immediately recognisable by consumers. An additional Energy Star logo (or any other efficiency mark) is not only useless, but can also create the impression of a poor quality of the categorical labelling scheme, that needs to be supported by the endorsement label to be sure that highly efficient appliances are identified.

7.6.1.3 The standby approach

Two approaches are possible to address the so-called ‘standby’ mode and the other ’low power modes’:

- a “simple” way is to define specific requirements for each single mode(s): once maximum power consumption (in Watt) are enforced the overall machine energy consumption for those modes will depend only from their duration.

- an alternative more global approach is to calculate the energy consumption in each mode (once the power consumption and the duration are measured, but not regulated) and to add it to the on-mode consumption, to calculate the overall appliance energy consumption (annual or per cycle).

7.6.1.4 A new labelling scheme

The possibility of an updated labelling scheme will be addressed. The options of an upgraded A-G scale or as alternative a new categorical label will be discussed and examples given.

7.6.1.5 Specific and generic requirements

The EuP directive calls for the level of energy efficiency or energy consumption in use to be set aiming at the life cycle cost minimum to end-users, taking into account the consequences on other environmental aspects. This will be addressed through the proposal of specific requirements. Also some considerations about noise will be drafted, to evaluate the possibility and the opportunity to set specific requirements on this aspect. If necessary, generic requirements will complement the specific ones.

7.6.1.6 Policy measures for washing temperature different from 60°C and partial load

Possible policy measures addressing resource consumption at washing temperature different from the 60°C cycle are briefly presented along with the constraints deriving from an insufficient standardisation. Elements for a mandate of the European Commission to CENELEC will be also drafted.

7.6.2 The standby approach

As already described, two approaches are possible to address the standby and low power mode consumption: setting mandatory minimum requirements – possibly of a horizontal nature across several appliances - for the identified modes; or their incorporation into the algorithm (a new Energy Efficiency Index) for the energy label. A mixed approach could also be hypothesised.

7.6.2.1 A summary of the EU and worldwide situation

a) Australia and New Zealand

According to an Australian market survey in 2005, there is an important issue regarding washing machines and dishwashers: most European products (which are imported into the Australian market) have an off-switch, which usually disconnects power to most parts of the machines and drops the power consumption close to zero Watts. However to achieve this, the consumer must manually turn the machine off when the cycle has been completed and the load removed. During the intrusive (in-home) survey in 2005 around 40% of the European front load machines were found left on when not in use (i.e. the users did not manually turn the machines off when the washing cycle was completed). This means that the off-mode power consumption for many European machines is probably not all that relevant. A more relevant figure is the end of cycle mode. All non-European (usually top loading, vertical axis) machines automatically revert to off-mode at the end of the cycle, so only off mode measurements for these machines are relevant.

The Standby Power Strategy 2002-2012 contains a wide range of possible policy measures to address excessive standby power. The document sets out the long-term strategy to address excessive standby energy used by consumer appliances and equipment. In particular the report contains:

- the measures that governments will use to address excessive standby;
- the identification of the products to be targeted in the first of three-year rolling plans under the strategy;
- the procedure whereby standby targets will be set for each of the targeted products (Stage 1 targets);
- the sanctions that will apply should suppliers not meet the targets for these products (Stage 2 targets);

– a proposal for the Australian products to meet the ultimate target, of 1 Watt in 2012.

The strategy sets out a number of possible policy tools that were to be considered on a product by product basis as follows:

- Promotion of Energy Star
- Industry Codes of Conduct
- Publication of targets in Australian Standards
- Collection of data for new products
- Publication of standby data for products
- Inclusion of standby into the energy label for selected products
- Introduction of minimum requirements on standby for selected products
- Warning label for products with high standby.

Investigation regarding modes and the inclusion of standby power into the energy label have been concluded for dishwashers and washing machines and these were implemented in late 2005 with a transition period to April 2007. After this date all dishwashers and washing machines will have standby energy consumption included in the energy label value, which will also affect the product star rating.

The initially proposed algorithms for the calculation of the CEC (Comparative Energy Consumption) including standby for wash appliances were:

$$CEC = E_t \times C + [P_d \times 2 \times C + P_e \times 15 \times C + (8760 - T_c \times C - 2 \times C - 15 \times C) \times P_o]$$

where:

- E_t = the cycle energy consumption measured according to the AU/NZS Part 1 standard
- C = is the defined number of cycles per year, 365 for washing machines and dishwashers
- P_d = the measured power (in W) in the "delay start" mode, it is 0 where the appliance does not have a delay start function; the delay start mode is assumed 2 hours where present
- P_e = the measured power (in W) in the "end of programme" mode, it is 0 where the appliance does not have end of programme mode; end of programme mode is assumed for 15 hours when present
- P_o = measured power in off mode (W), for the remaining standby time after delay start and end of programme modes
- T_c = cycle time (in hours).

The value of CEC is in Wh and should be divided by 1000 for use on the energy label. The proposal was subsequently modified, considering only an average of "off mode" and "end of cycle mode" for inclusion into the energy label CEC and deleting the "delay start mode" from the overall standby calculation, to avoid any penalisation of this mode, which was recognised to have a positive impact on the machine use by allowing the delay of the washing cycle to off-peak hours. In addition, the overall standby power is considered 100% the time in "off mode" where the "end of cycle" mode is not present (when products automatically revert to "off" after the end of cycle) [73]:

$$CEC = E_t \times C + [P_s \times (8760 - T_c \times C)]$$

[73] For sake of coherence, the shown algorithm is not the one eventually published in the standard, but is presented in the same form as the previous formula.

where P_s = the average measured standby power, in Watts which is the average of end of cycle mode and off mode, (where this mode is present). Again, the value of CEC is in Wh and should be divided by 1000 for use on the energy label. The new algorithms are in force since 1 April 2007.

b) USA

Also in USA, the latest proposal calls for the introduction of the so called "low power modes" in the calculation of the annual energy consumption of appliances – and therefore subject to the relevant policy measures - since the main goal is save energy and improve efficiency, and not to strictly define in which of the modes this energy should be saved.

Annual standby energy consumption for *dishwashers* and is calculated in kWh per year as:

$S = S_m \times (H_s/1000)$ and
$H_s = H - (N \times L)$

where:

- S_m = measured average standby power (in Watt) and
- H = the total number of hours per year, or 8.766
- N = the representative average dishwasher use of 215 cycle/year
- L = the average of the duration (in hours) of the normal washing cycle, measured for the different types of dishwashers addressed in the test procedure

In order to determine standby power usage, the energy use of each dishwasher in the Energy Star products database was calculated. Since 60% of current qualified products use standby power and the trend for new products is to offer more features that will draw power in the standby mode, comments were required to stakeholders on the value of incorporating a standby power requirement into the new criteria for dishwashers. In addition, DoE is trying to determine whether it is preferable the (a) setting a maximum amount of standby power in terms of Watts or kWh/year or (b) setting the maximum total allowable Energy Star qualified product usage in terms of kWh/year instead of EF.

c) The latest EU proposals

More recently, a working document[74] of the European Commission, circulated and discussed during the second EuP Forum meeting, proposed to set minimum requirements for the 'off-mode' and 'standby mode' of electrical and electronic household and office equipment, depending on energy input from the mains power source, where:

- off mode = a condition where the equipment is connected to the mains power source and provides no function (a mere indication n of the off-mode condition is also considered off-mode

- standby = a condition where the equipment is connected to the mains power source and provides one of more of reactivation functions, information or status display depending on energy input from the mains power source to work as intended

- preheating function, sensor-based safety functions, network reactivation and network integrity functions are not considered as being standby.

[74] Working document on possible ecodesign requirements for standby and off-mode electric power consumption of electrical and electronic household and office equipment, Bruxelles, 19 October 2007

The proposed requirements for off mode and standby are:

a) one year after the implementing measure is enforced:
- any off mode condition ≤ 1W
- standby (reactivation function, with/without mere indication of enabled reactivation function) ≤1W
- standby (information or status display with/without reactivation function) ≤ 2W;

b) three years after the implementing measure is enforced:
- any off mode condition ≤ 0,5 W
- standby (reactivation function, with/without mere indication of enabled reactivation function) ≤ 0,5W
- standby (information or status display with/without reactivation function) ≤ 1W.

In addition, equipment shall offer a *power management* function or a similar function that, after the shortest possible period of time appropriate for the intended use, switches the equipment automatically into a condition with reduced energy consumption when the equipment is not providing the main functions

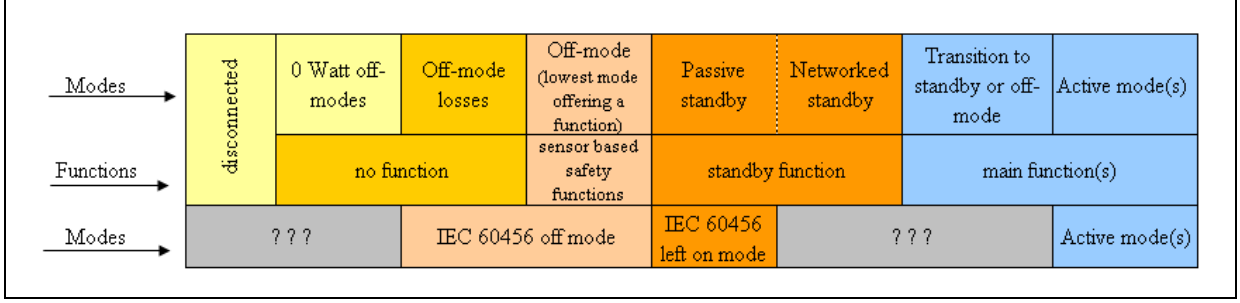
7.6.2.2 Proposed approach for off- and left-on modes

In Task 6 a detailed analysis was developed about the 'low power modes' comparing the draft definitions of the June 2007 draft of IEC 60456 "*Clothes washing machines for household use - Methods for measuring the performance*" 5th Edition with the definitions proposed "Lot 6-Standby and Off-mode losses of EuPs". As conclusion, the definitions given in IEC 60456, 5th edition draft are seen here as being more appropriate for washing machines, considering that they will in a short time be included also in the new edition of the EN 60456 standard:

- *off mode*: is where the product is switched off using appliance controls or switches that are accessible and intended for operation by the user during normal use to attain the lowest power consumption that may persist for an indefinite time while connected to a mains power source and used in accordance with the manufacturer's instructions. Where there are no controls, the washing machine is left to revert to a steady state power consumption of its own accord;
- *left on mode*: is the lowest power consumption mode that may persist for an indefinite time after the completion of the programme and unloading of the machine without any further intervention of the user. In some products this mode may be an equivalent power to off mode.

A compromise solution for an acceptable harmonisation of Lot 6 and the draft IEC 60456 5th Ed. definitions was developed as presented in Figure 7.38.

Figure 7.38: Possible harmonisation of Lot 6 and draft IEC 60456 5th Ed. definitions for wash appliance modes



It is also clear that the possibility to evaluate an overall annual energy consumption and to set a new Energy Efficiency Index based on the global annual energy consumption will be jeopardized when horizontal limits are set for some 'modes', with lower product differentiation, lower consumer choice and no higher savings.

As conclusion, the proposal is to include the 'off-mode' and the 'left-on mode' in a new energy efficiency algorithm within a revised energy labelling scheme and/or the setting of specific requirements.

7.6.3 A revised labelling scheme

7.6.3.1 Manufacturers position

CECED position about a revised labelling is that where technological scope still exits, CECED supports the revision of current labels to allow better market differentiation and the promotion of more efficient appliances. However, when further improvements appear technically not achievable, the label should be substituted by specific efficiency requirements, to avoid the deterioration of the market.

While supporting the label revision, a recent study shows that the modification process of the current label may turn into a very critical phase for manufacturers, retailers and consumers. To avoid that the revision negatively affects manufacturers and the return on their investments, CECED invites authorities to take in great care the concerns of the main stakeholders, in particular avoiding that the revision is carried out as a simple rescale of the current A to G scale. The label is a communication tool towards consumers and retailers; therefore, while discussing label revision any possible reaction or impact on them must always be carefully taken into account.

7.6.3.2 Washing machines

a) Elements to be updated in the present labelling scheme

Elements of the present labelling scheme that should be updated in a revised scheme for washing machines are:

- Energy Efficiency (Index) calculation algorithm: to be amended to include low power modes and to consider the machine annual energy consumption;

- Energy Efficiency Classes: existing thresholds to be amended and new thresholds defined; in addition, the rescaling the present A-G scale or the definition of a new categorisation should be investigated;

- information to be disclosed: information in the label and the fiche to be revised and if necessary amended.

b) The Energy Efficiency (Index) algorithms for the 60°C cotton programme

The opportunity of amending the algorithms in directive 95/12/EC will be discussed. Possible

alternatives are:

i. to calculate the Energy Efficiency Index (EEI) based on the annual energy consumption (in kWh); the EEI is given by the ratio between the energy consumption per cycle of any given appliance and the reference energy consumption of the same appliance;
ii. to use the Energy Consumption (E_c) per washing cycle (in kWh/cycle);
iii. to follow the present approach based on the specific energy consumption 'C' per kg of load.

Off mode and left-on mode power consumption can be added to the three approaches to give an overall value.

To evaluate the average energy consumption (AE_c) of a machine per year, the Energy Consumption (E_c) per cycle should be measured according to the standard and then multiplied for an agreed number of washing cycles per year. The average number of washing cycles per year used in Task 6 is 220 for washing machines.

$AE_c = E_c \times n$ where n = number of washing cycles per year.

The Energy Efficiency Index is the ratio between the energy consumption of a specific appliance and the standard energy consumption (SEC) of that appliance. The standard energy consumption (SEC) can be any agreed reference line. The energy consumption can be addressed through the annual value (AE_c) - with (or without) the low power modes contribution - or through the per cycle consumption:

$EEI = AE_c/SEC$

The overall annual energy consumption including 'low power modes' can be calculated, as shown in Table 7.39, as:
– including *off-mode* and *left-on mode* each working for half of the residual time after 220 washing cycles per year;
– in case a 'power management system' is implemented and *left-on mode* reverts to *off mode* within, lets say, about 1 hour, resulting in the hours in left-on mode hypothesised equal to the number of the annual washing cycles plus the time in off mode.

The contribution of the low power modes to the annual energy consumption is modest, as clearly shown in Table 7.41.

Table 7.41: Methods to calculate the machine energy consumption including low power modes, with and without a power management system

		Energy consumption	Et (cycle duration)	C (number of annual cycles)	off-mode power consumption with safety functions	t1 (oof mode duration)	left-on mode power consumption	t2 (left on duration)	Total annual energy consumption	t2 measured duration	Overall energy consumption per cycle	load capacity	Overall specific energy consumption per cycle	Specific energy consumption per cycle
		Wh/cycle	min	cycle/year	W	min	W	min	kWh/y	min	kWh/cycle	kg	kWh/kg	(dir. 95/12/EC)
without power management		850	240	220	1	236400	3	236400						
	Wh	187000			3940,0		11820,0		525600					
	kWh	187			3,9		11,8		202,76		0,92163636	5	0,1843	0,1700
with power management		850	240	220	1	459600	3	13200	525600	60				
	Wh	187000			7660,0		660		195,32		0,88781818	5	0,1776	
	kWh	187			7,7		0,66							

The formula to calculate the overall AE_c (when the power management is not enforced) is:

$$AE_c = E_c \times C + \{P_s \times [525\,600 - (T_c \times C)]/2 + P_l \times [525\,600 - (T_c \times C)]/2\} / (60 \times 1\,000)$$

which can be also written as:

$$AE_c = E_c \times C + \frac{\left[P_s \times \frac{525.600 - (T_c \times C)}{2 \times 60} + P_1 \times \frac{525.600 - (T_c \times C)}{2 \times 60} \right]}{1.000}$$

where :

- AE_c = annual energy consumption (in kWh)
- E_c = the cycle energy consumption (in kWh)
- C = is the defined number of cycles per year, 220 for washing machines
- P_l = the measured power (in W) in the "left-on mode"
- P_s = measured power in "off-mode" (W)
- T_c = washing cycle time (in minutes)
- 525.600 = total number of minutes in a year (= 60 min/h × 24 h/day × 365 days/year).

When a power management is enforced the formula should be modified to take into consideration the effective duration of the "off-mode" and the "left-on mode" as:

$$AE_c = E_c \times C + \{(P_1 \times T_{Pl} \times C) + P_s \times [525\,600 - (T_c \times C) - (T_{P1} \times C)]\} / (60 \times 1\,000)$$

where T_{P1} is the measured time in "left-on mode" (in minutes).

In addition, the overall low power modes power is considered 100% the time in "off mode" where the "end of cycle" mode is not present (when products automatically revert to "off" after the end of cycle).

The overall annual energy consumption can be used as such to calculate an Energy Efficiency Index, or can be divided by the number of the cycles per year (resulting in an overall consumption per cycle) or by the number of the cycles per year and by the machine load capacity resulting in an overall value of energy consumption per kg load, as in the present directive 95/15/EC.

Starting from 2005 CECED technical database, a set of energy consumption straight lines (Table 7.42) have been calculated through linear regressions for different clusters of load capacity machines, trying to identify models with similar thermodynamic properties. Energy consumption per cycle is expressed as function of the machine load capacity. In addition, the straight line deriving from the 1997 CECED technical database is also added.

Table 7.42: Straight lines and R^2 values for different cluster of washing machines

Load clusters (kg)	Straight line parameters		
	M	**N**	**R^2**
3-4kg	0,0852	0,4286	0,9908
4,5-6kg	**0,0951**	**0,4863**	0,9957
7-9kg	0,2793	-0,7407	0,9911
3-7kg	0,1337	0,2726	0,9816
4,5-7kg	0,1163	0,3785	0,9823
8-9kg	0,2730	-0,6875	0,9837
3-9kg	0,1676	0,0213	0,9344
4,5-6,5 kg, 1997	0,201	0,2213	0,9514

The R^2 value for the different machine clusters has also been calculated. The clusters resulting in the highest R^2 value (best linearity) are presented in Figure 7.39 and have been then considered as thermodynamically similar machines. The three straight lines of the optimum clusters (R^2>0,99) were then compared to evaluate if one line can be used to represent all washing machines: the 4,5-6,5kg load machine cluster has been then selected since it represents about 92,4% of the machines in the 2005 technical database.

When the 4,5-6 kg cluster reference line is used to characterise smaller 3-4 kg load machines, they show a higher efficiency than the actual one. Small capacity machines have lower dimensions compared to the more traditional (L×D×H: 60cm×60cm×85cm) 5-6kg machines: 4kg machines might have a 33cm depth, while 3,5kg machines have (51cm×44cm×69,5cm) dimensions and 3kg machines have (50cm×52cm×67cm) dimensions.

On the contrary, larger capacity machines ≥ 7kg load, result in having a lower energy efficiency than in the present system. Higher capacity machines have dimensions larger than the 5-6kg machines, such as for example: 9kg (68,6cm×78,5cm×96,5cm), 10kg (69cm×79cm×97cm), although 7kg and 8kg machines are on the market with dimensions close to standard ones, for example: (60cm×64cm×84,2cm) for a 8kg machine or with standard dimensions. Unfortunately the CECED technical database does not provide the machine dimensions.

Machine with a load capacity ≤4kg represent 2,04% of the models in the 2005 technical database; machine with a load capacity ≥7kg represent 5,5% of the machine models in 2005, with 7kg responsible for 3,5%.

The second best choice is to consider the straight line of the cluster 4,5-7kg (Figure 7.40). The 1997 straight lines are presented in Figure 7.41.

b.1) Hypothesis One

When the 4,5-6kg cluster reference line is considered representative of all the models in 2005 database, the average energy consumption ($E_{c,aver}$) per cycle (in kWh/cycle) of an appliance in 2005 can be calculated using the formula:

$E_{c,aver} = 0{,}0951 \times c + 0{,}486$ where c is the machine load capacity in kg.

In Figure 7.42 the $E_{c,aver}$ line is compared with the straight lines of the other machine clusters and with the lines representing energy efficiency class A (directive 95/12/EC), A+ (CECED Voluntary Agreement) and C<0,15 kWh/kg.

The standard energy consumption (SEC) is the straight line parallel to the average 2005 line and matching the reference value of 0,30 kWh/kg for the 5kg machine resulting from the 1996 VhK study[75] (already used in the CECED Industry Commitments for washing machines) or:

$SEC = 0{,}1483 \times c + 0{,}758$ where c is the machine load capacity in kg.

In Figure 7.43 the $E_{c,aver}$ line is compared with the *SEC* line.

[75] Source: Sensitivity Analysis of Energy Efficiency Improvements for Washing Machines carried out by Van Holsteijn en Kemna (NL), (Final Report, April 1996).

Figure 7.39: Optimised energy consumption straight lines and relevant R^2 for different load capacity machines with similar thermodynamic properties in 2005 CECED technical database. Energy consumption per cycle is expressed as function of the machine load capacity

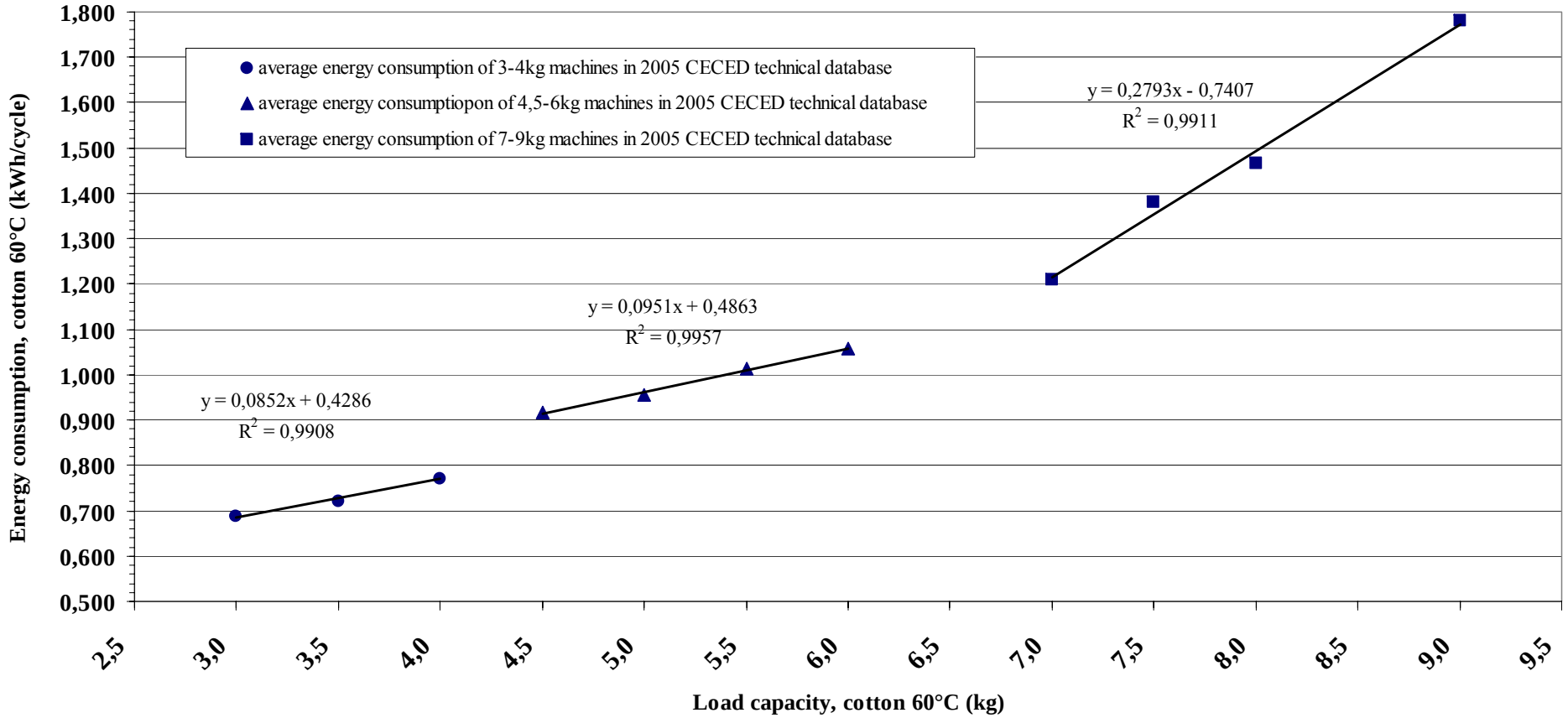


Figure 7.40: Second best choice for the energy consumption straight lines and relevant R^2 for different load capacity machines with similar thermodynamic properties in 2005 CECED technical database. Energy consumption per cycle is expressed as function of the machine load capacity

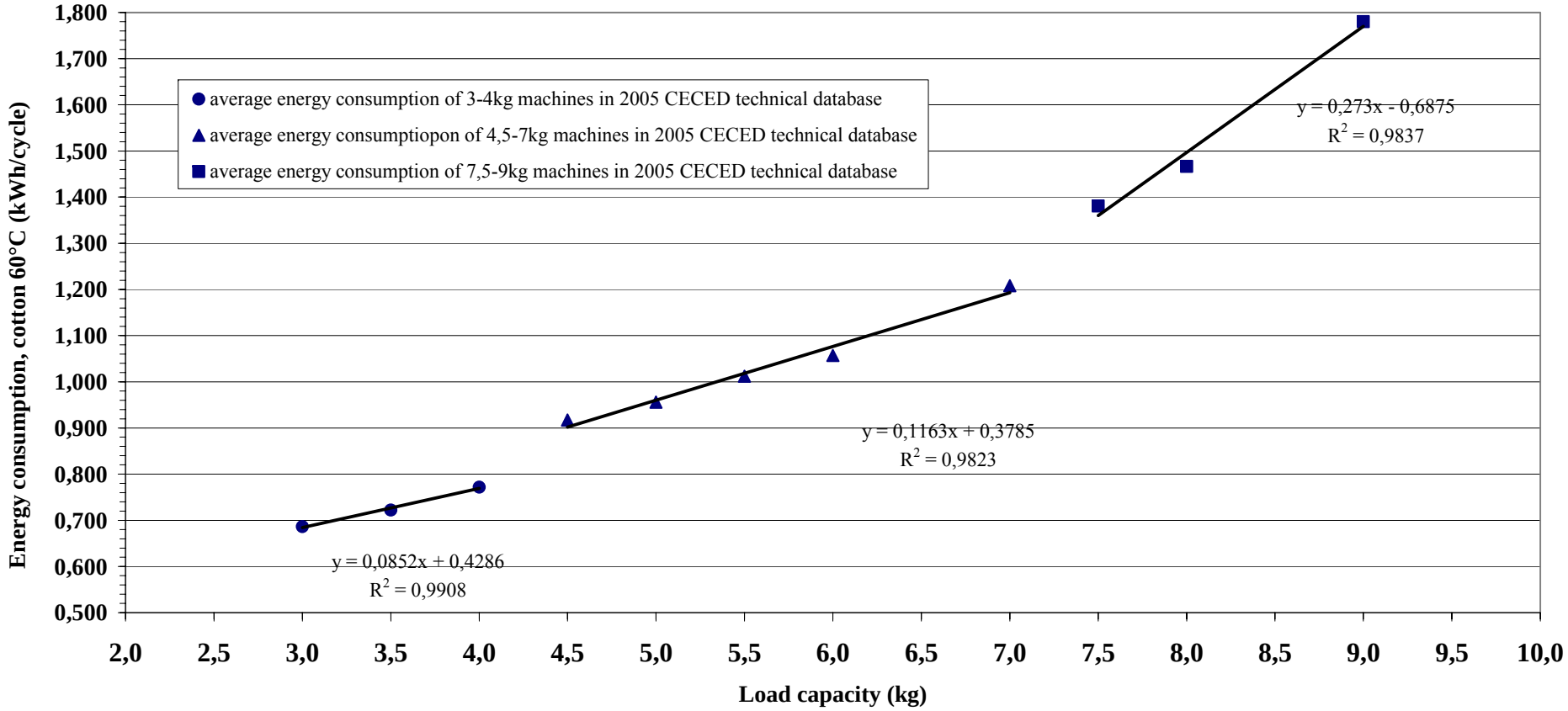


Figure 7.41: Energy consumption straight lines and relevant R^2 for different load capacity machines with similar thermodynamic properties in 1997 CECED technical database. Energy consumption per cycle is expressed as function of the machine load capacity

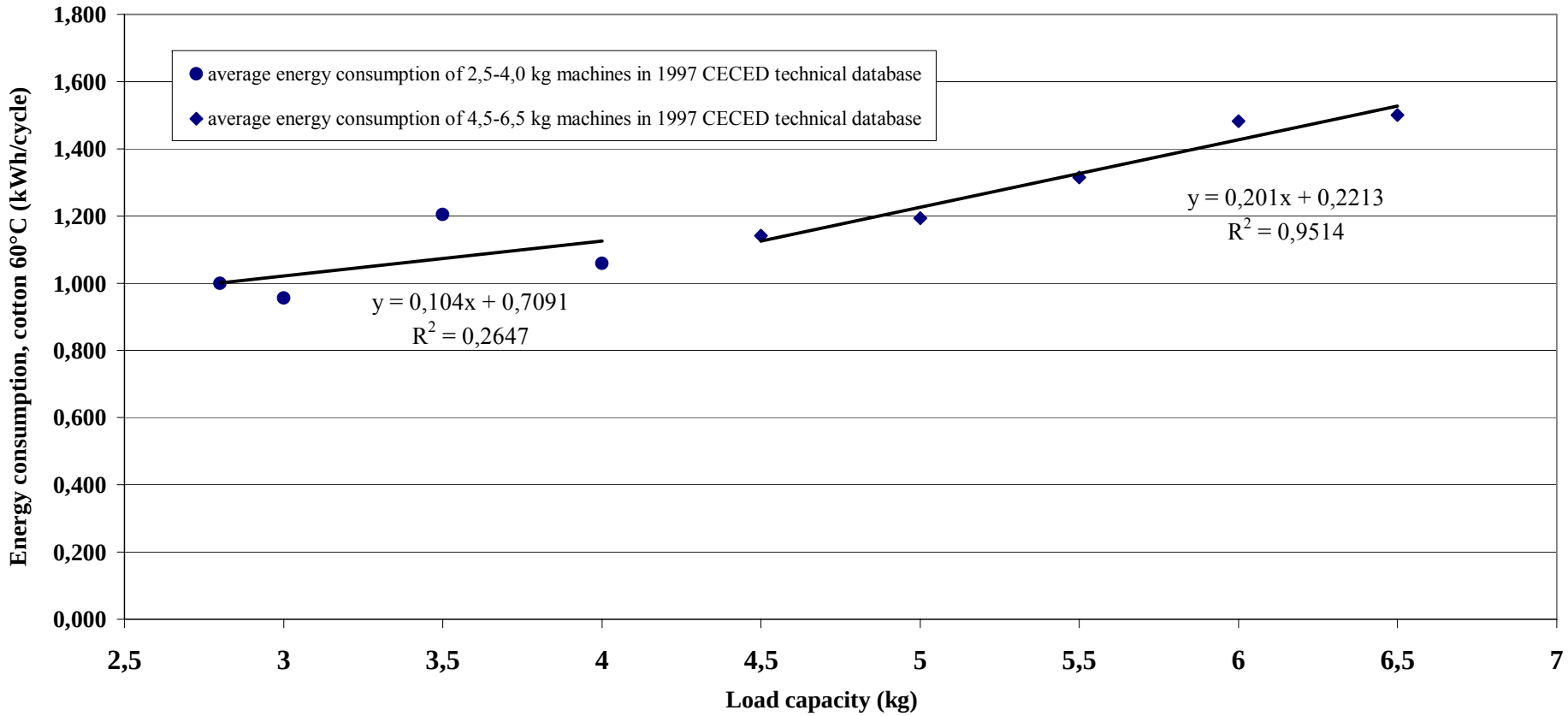


Figure 7.42: Straight lines for energy consumption and 2005 CECED technical database and comparison with the present labelling system, Hypothesis One

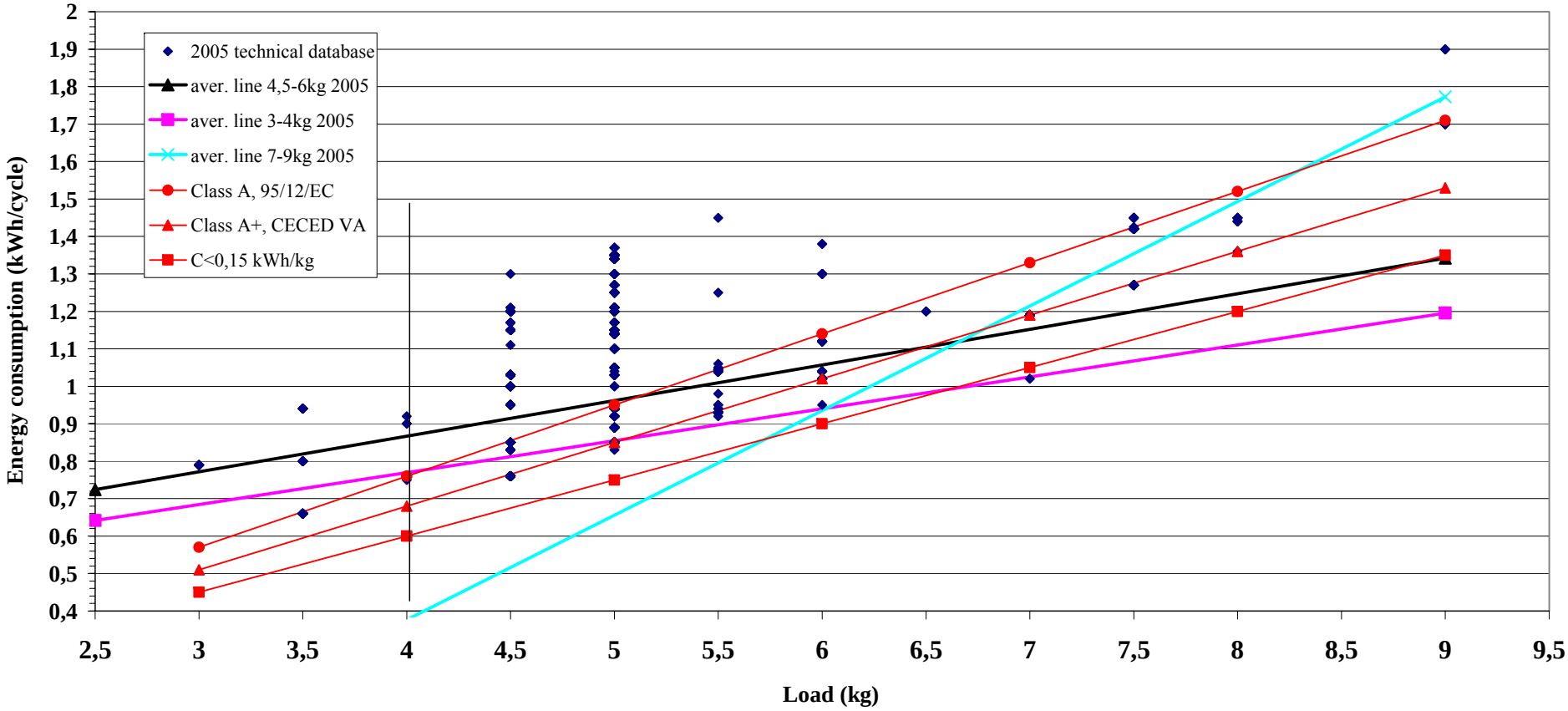
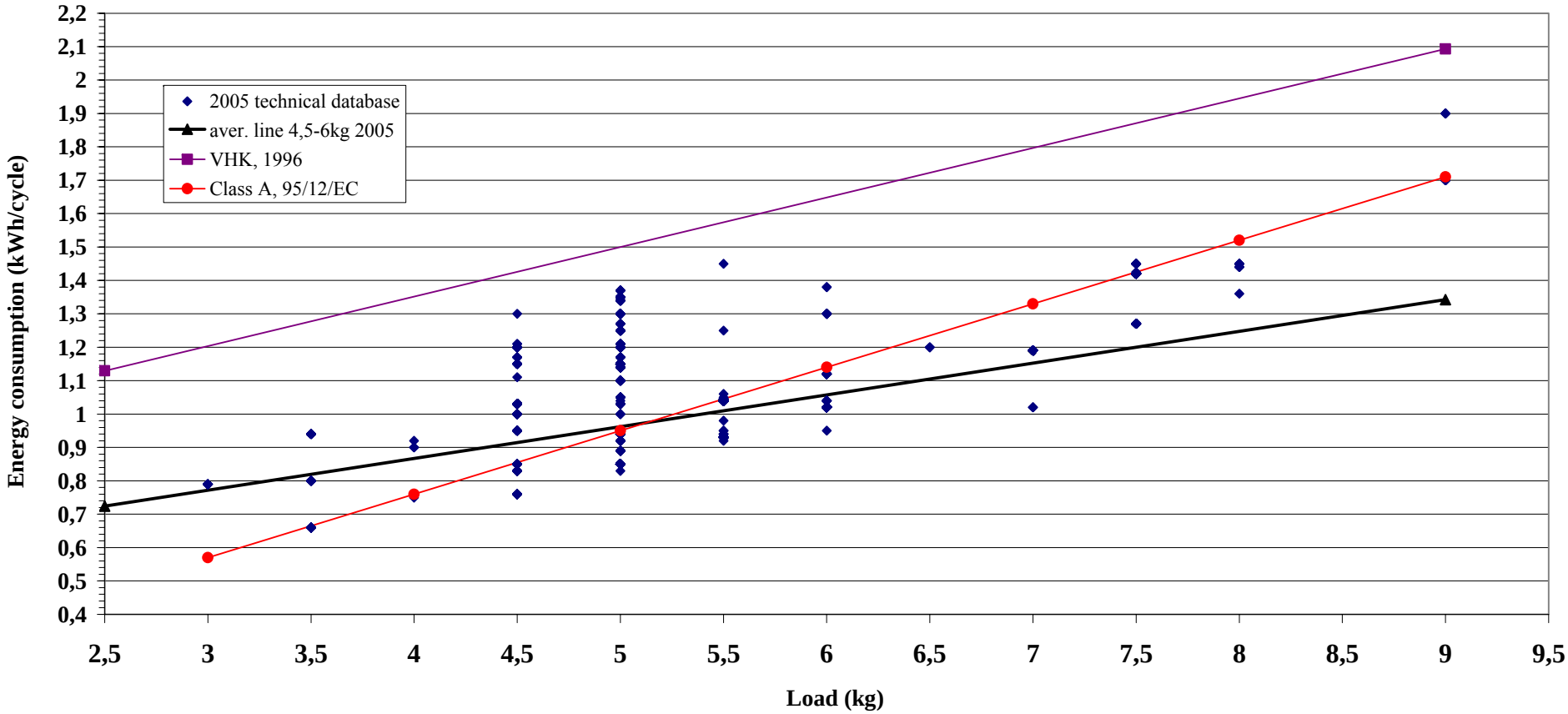


Figure 7.43: Comparison of the $E_{c,aver}$, the SEC and the A class lines with 2005 CECED technical database, Hypothesis One



b.2) Hypothesis Two

When the 4,5-7kg cluster reference line is considered representative of all the models in 2005 database, the average energy consumption ($E_{c,aver}$) per cycle (in kWh/cycle) of an appliance in 2005 can be calculated using the formula:

$E_{c,aver} = 0{,}1163 \times c + 0{,}3785$ where *c* is the machine load capacity in kg.

In Figure 7.44 the $E_{c,aver}$ line is compared with the straight lines of the other machine clusters and with the lines representing energy efficiency class A (directive 95/12/EC), A+ (CECED Voluntary Agreement) and C<0,15 kWh/kg. The standard energy consumption (SEC) matching the reference value of 0,30 kWh/kg for the 5kg machine resulting from the 1996 VhK study is:

$SEC = 0{,}1817 \times c + 0{,}591$ where *c* is the machine load capacity in kg.

In Figure 7.45 the $E_{c,aver}$ line is compared with the *SEC* line and the models in the 2005 technical database.

b.3) Hypothesis Three

As alternative, the 1997 4,5-6,5 kg cluster reference line:

$E_{c,aver,1997} = 0{,}201 \times c + 0{,}2213$ where *c* is the machine load capacity in kg,

can be used to derive the standard energy consumption (SEC) matching the reference value of 0,30 kWh/kg for the 5kg machine resulting from the 1996 VhK study or:

$SEC = 0{,}246 \times c + 0{,}270$ where *c* is the machine load capacity in kg.

In Figure 7.46 the $E_{c,aver,1997}$ line is compared with the *SEC* line and the models in the 2005 technical database.

Under all the three hypothesis, EEI can be calculated as percentage of reduction from the SEC line, or from the same line but considering the annual energy consumption (once the annual or the per cycle energy consumption is known) with or without the Low Power Modes. Since the contribution of the low power modes (see Table 7.40) is modest, the SEC reference line can be still considered representative of the washing machine consumption.

c) The Water Consumption and Efficiency algorithms for the 60°C cotton programme

To complement the energy consumption algorithms, the possibility and opportunity of introducing water efficiency algorithms in the revision of directive 95/12/EC:
(i) to calculate a Water Efficiency Index (WEI) based on the annual water consumption (in m^3)
(ii) to use the Water Consumption (W_c) per washing cycle (in litre/cycle)

is here discussed.

Figure 7.44: Straight lines for energy consumption and 2005 CECED technical database and comparison with the present labelling system, Hypothesis Two

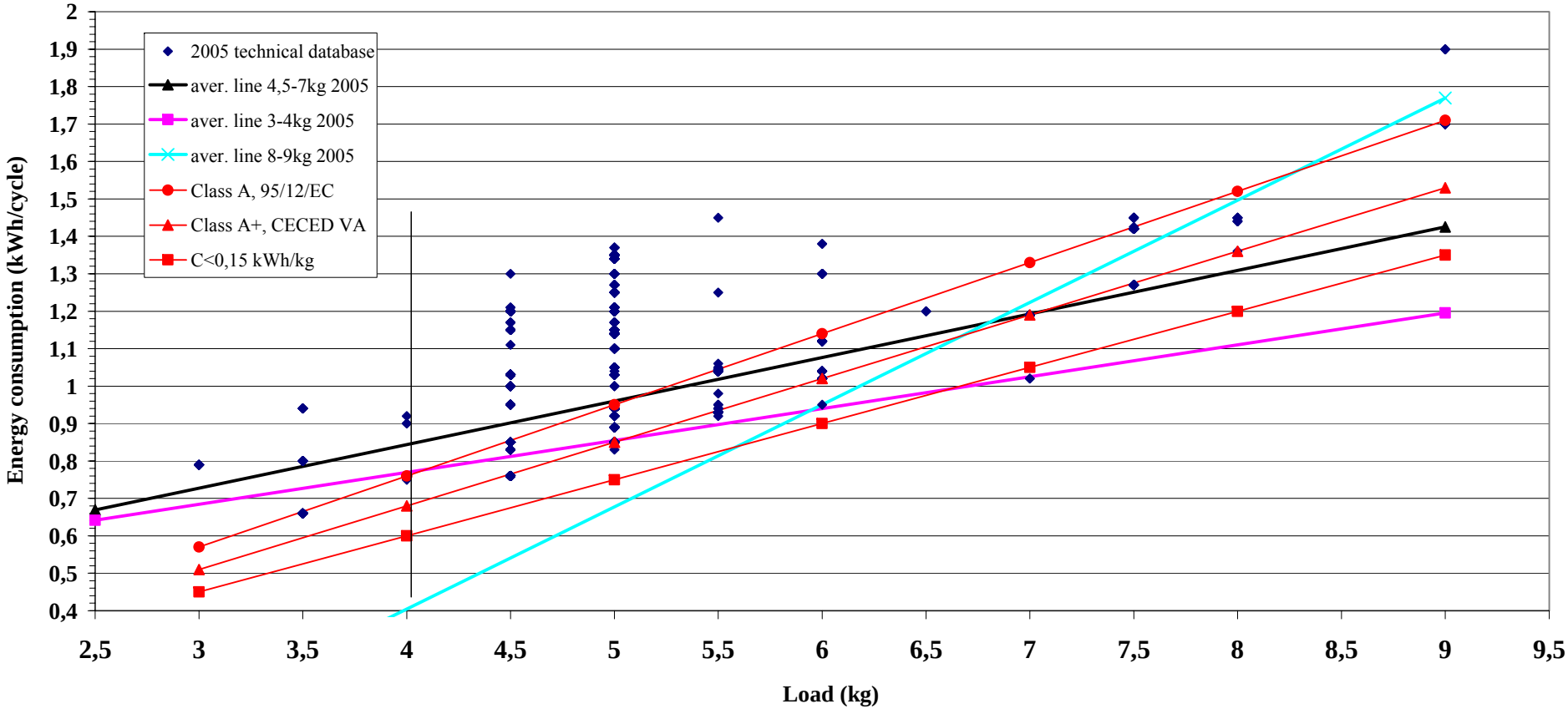


Figure 7.45: Comparison of the $E_{c,aver}$, the SEC and the A class lines with 2005 CECED technical database, Hypothesis Two

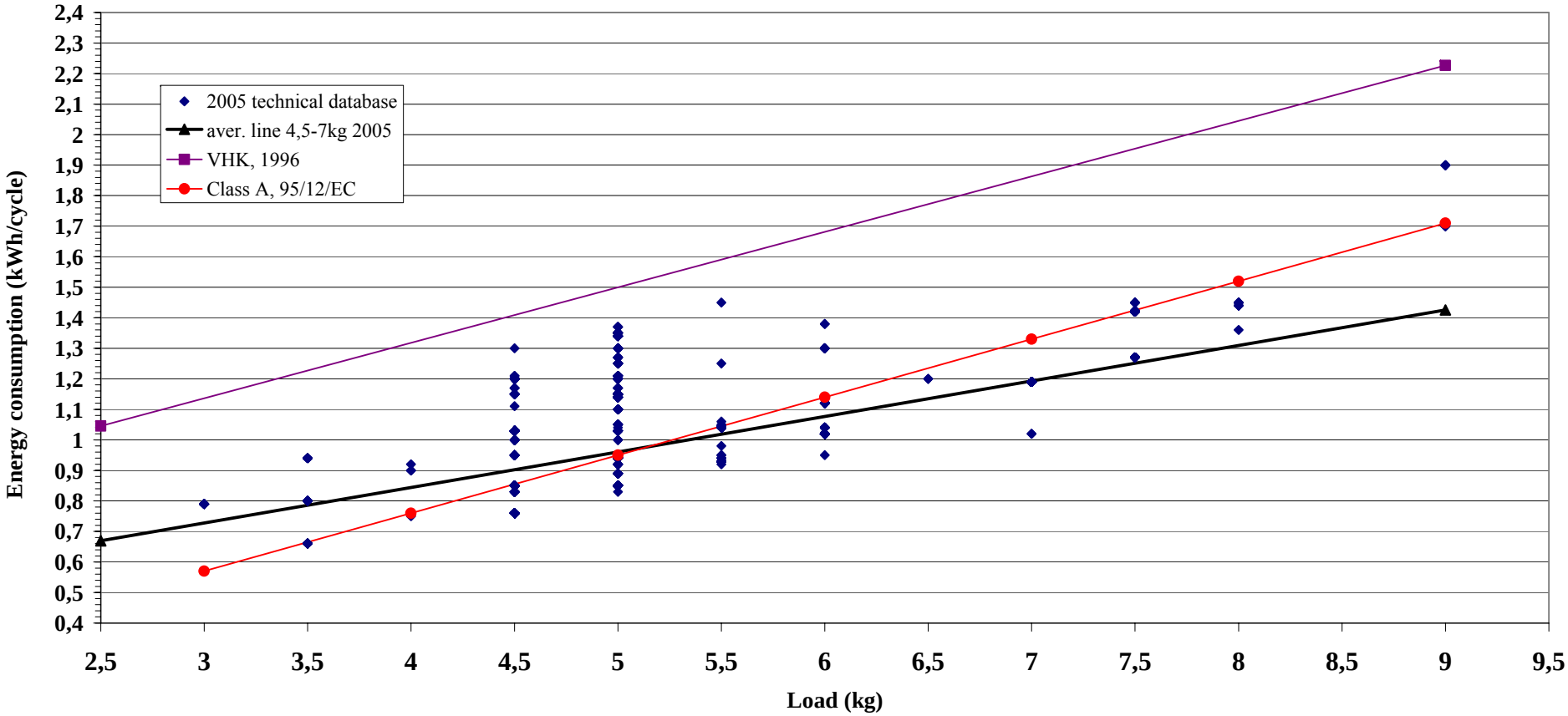
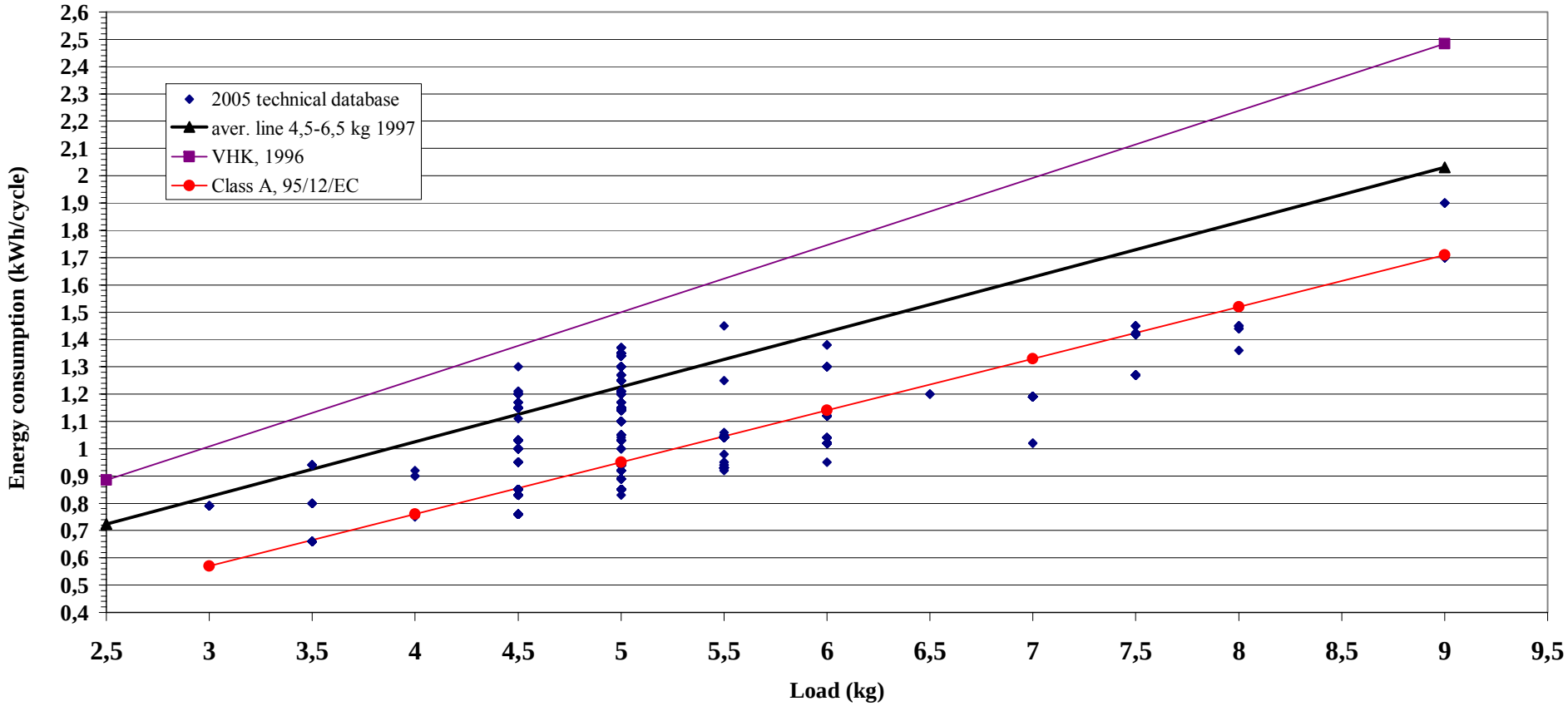


Figure 7.46: Comparison of the 1997 $E_{c,aver}$, the SEC and the A class lines with 2005 CECED technical database, Hypothesis Three



To evaluate the average Water consumption per year (AW_c) of an appliance in 2005 per cycle (in litre/cycle) the Water Consumption (W_c) per cycle should be measured according to the standard and then multiplied for an agreed number of washing cycles per year. The same average number of washing cycles per year already proposed for the energy consumption will be used.

$AW_c = W_c \times n$ where n = number of washing cycles per year.

When considering the average water consumption per cycle as function of the load capacity for the models in 2005 CECED technical database, Figure 7.47 results. The average water consumption $W_{c,aver}$ (in litre/cycle) over the load capacity is represented by the straight line resulting from the linear regression of the average points:

$W_{c,aver} = 5{,}05 \times c + 25{,}1$ where c is the machine load capacity in kg.

For the water consumption, no specific model clusters could be identified from the 2005 CECED technical database, therefore the straight line deriving from the regression of the average values for each load capacity was used, although the R^2 value (R^2=0,7748) is lower than for the energy consumption, but still acceptable.

Once the water consumption per cycle of a model is measured, the average annual consumption is calculated and can be used to calculate a Water Efficiency Index. The water consumption per cycle can be divided by the machine load capacity resulting in water consumption per kg load (similarly to the energy consumption in the present directive 95/15/EC).

The WEI is the ratio between the water consumption of a specific appliance and the standard water consumption of that appliance. The water consumption can be both the annual value and the cycle consumption:

$WEI = AW_c/SWC$

The standard water consumption (SWC) may be represented by a straight line (Figure 7.48) matching the reference value of 18,5 litre/kg for the 5kg machine (equal to 92,5 litre/cycle) resulting from the mentioned 1996 VhK study as the water consumption of the standard base case machine in 1995:

$SWC = 9{,}28 \times c + 46{,}1$ where c is the machine load capacity in kg.

WEI can be calculated as percentage of reduction from this line once the water consumption of the specific model is known.

d) Energy Efficiency Classes: definition and thresholds

It has to be discussed whether a revised A-G scale should be adopted or if a new categorical system is a better approach and whether the present system base on horizontal thresholds for specific energy consumption (in kWh per cycle and per kg of load) should be retained or modified to consider an overall annual energy consumption including low power modes.

Figure 7.47: The average water consumption and regression line for the washing machines in 2005 CECED technical database

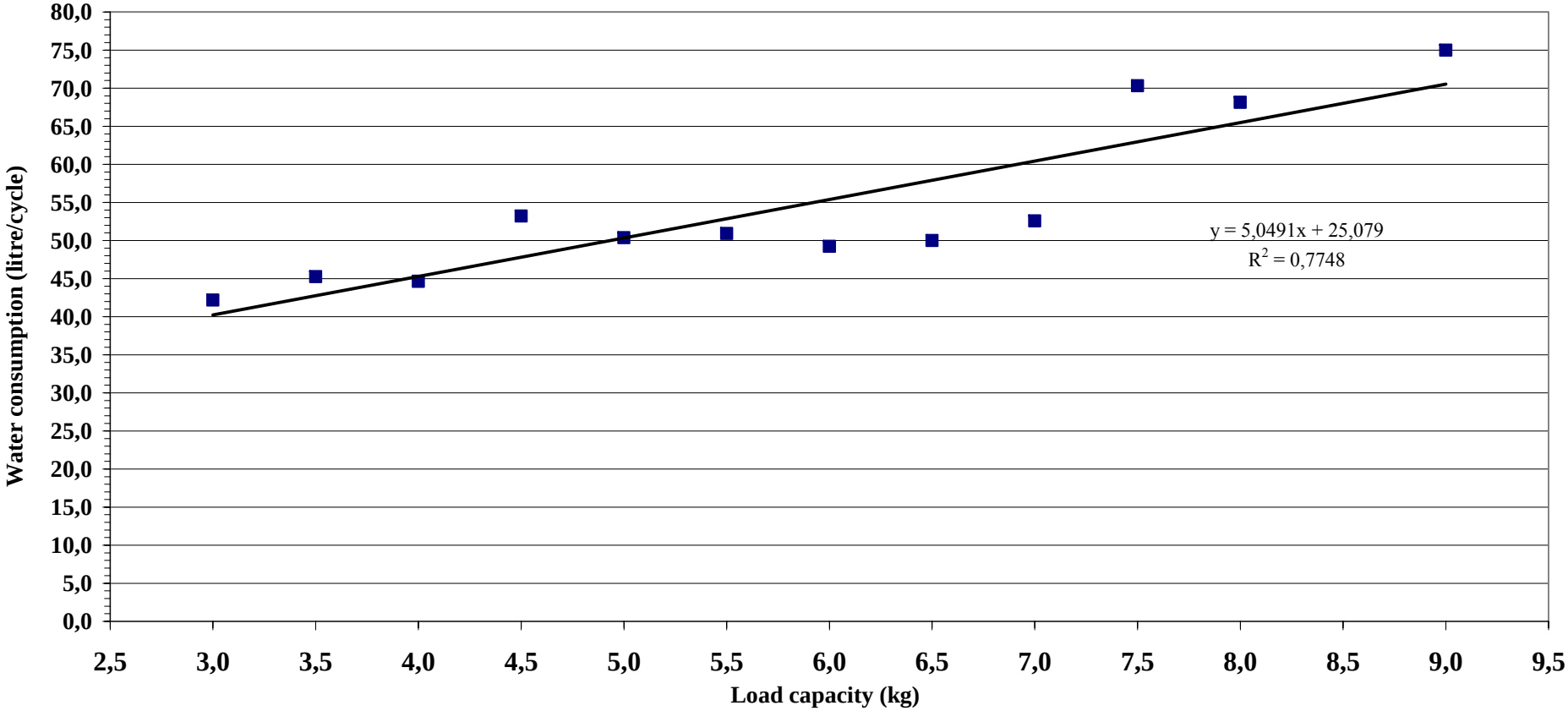
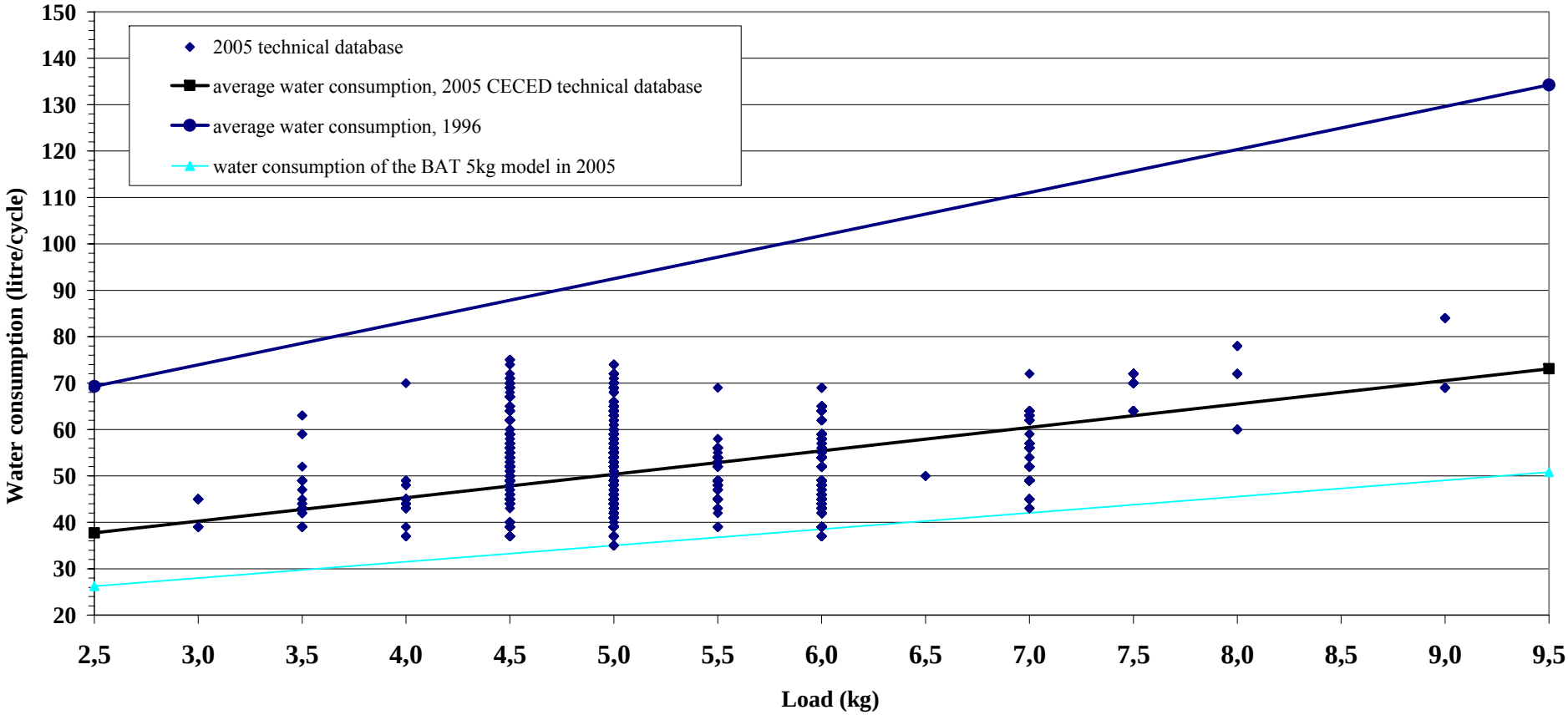


Figure 7.48: Straight lines for water consumption and 2005 CECED technical database



In addition, the value of the classes' thresholds has to be proposed. Again two alternatives are possible:

- retain the existing ones and create new ones on top, following the same pace;
- redesign the entire threshold systems, taking into consideration that the A+ class and threshold was defined in 2003 only through a commercial agreement to address a strong market need.

The present labelling scheme is based on a series of horizontal thresholds of energy consumption per kg of load for the 60°C cotton programme, measured under EN 60456 standard, 3rd edition. It was developed in 1995 when the large majority of the machines had a load capacity of 5kg (see Task 2). In 2003 an industry commercial agreement established a further 17% better threshold to address a strong market need of higher efficiency product identification, after the so called Labelling Committee negatively voted the upgrading of the directive 95/12/EC efficiency classes system. More recently, models with a larger load capacity and with an energy consumption lower than 0,15 kWh/kg appeared on the market, which were named "class A++" from some non-EU manufacturers, trying to exploit as much as possible the effective marketing and communication tool represented by anything related the EU labelling scheme.

The EU energy label is the current format and is not protected by copyright, i.e. the label is not a trademark. Article 7(b) of the framework directive 92/75/EC only provides an indirect and incomplete way to protect the EU energy label, i.e. by Member States taking action when other labels are likely to mislead or confuse.

d.1) Upgrading of the current labelling scheme, with or without A-G rescaling

The energy labelling scheme for washing machines in directive 95/12/EC considers the specific energy consumption in kWh/kg load:

CLASS	ENERGY EFFICIENCY	WASHING PERFORMANCE	WATER EXTRACTION EFFICIENCY
A	$C \leq 0,19$	$P > 1,03$	$D < 45\%$
B	$0,19 < C \leq 0,23$	$1,03 \geq P > 1,00$	$45\% \leq D < 54\%$
C	$0,23 < C \leq 0,27$	$1,00 \geq P > 0,97$	$54\ \% \leq D < 63\%$
D	$0,27 < C \leq 0,31$	$0,97 \geq P > 0,94$	$63\% \leq D < 72\%$
E	$0,31 < C \leq 0,35$	$0,94 \geq P > 0,91$	$72\ \% \leq D < 81\%$
F	$0,35 < C \leq 0,39$	$0,91 \geq P > 0,88$	$81\% \leq D < 90\%$
G	$0,39 < C$	$0,88 \geq P$	$90\% \leq D$

Note: C is the specific energy consumption in kWh/kg load; P is the ratio of the average reflectance of the test machine and the reference machine; D is the residual moisture content in percentage.

A new set of energy efficiency classes going from G to A3 (or as alternative from class 1 to class 10) can be created (Labelling Scheme Option 1), based on specific energy consumption (kWh/kg) thresholds with just a little modification of the current thresholds. As alternative, it is possible to defined a shorter classification from G to A (Labelling Scheme Option 2), as shown in Table 7.43

d.2) New categorical scheme based on annual energy consumption with low power modes

Based on the scale of specific energy consumption in Table 7.43 a set of EEI are created for the 5kg machine taking into consideration that a specific energy consumption of 0,31 kWh/kg (the same value identified in previous paragraph as the consumption of the standard base case in 1996 and used as basis of CECED voluntary commitments for washing machines) is already defined in directive 95/12/EC as threshold between Classes D and E (Table 7.44). If this value is taken as having EEI=100, then the following straight line can be considered as the SEC (under the hypothesis of the 4,5-6kg cluster reference line representative of all washing machine models):

Table 7.43: Comparison of directive 95/12/EC and the updated labelling scheme based on specific energy consumption (kWh/kg) for washing machines

Directive 95/12/EC				**Revised labelling scheme**					
Specific energy consumption (kWh/kg)	EE classes (class)	improvement (units)	improvement (%)	Specific energy consumption (kWh/kg)	improvement (units)	improvement (%)	EE classes **Option 1** (class)		**Option 2** (class)
				C ≤ 0,14	--	--	A3	10	A
C ≤ 0,15		--	--	0,14 < C ≤ 0,16	0,02	12,5	A2	9	B
C ≤ 0,17	A+	0,02	10,5	0,16 < C ≤ 0,18	0,02	11,1	A1	8	C
C ≤ 0,19	A	0,02	17,4	0,18 < C ≤ 0,21	0,03	14,3	A	7	D
0,19 < C ≤ 0,23	B	0,04	14,8	0,21 < C ≤ 0,24	0,03	12,5	B	6	E
0,23 < C ≤ 0,27	C	0,04	12,9	0,24 < C ≤ 0,27	0,03	11,1	C	5	F
0,27 < C ≤ 0,31	D	0,04	11,4	0,27 < C ≤ 0,31	0,04	12,9	D	4	G
0,31 < C ≤ 0,35	E	0,04	10,3	0,31 < C ≤ 0,35	0,04	11,4	E	3	
0,35 < C ≤ 0,39	F	0,04	11,8	0,35 < C ≤ 0,39	0,04	10,3	F	2	
C > 0,39	G	--	--	C > 0,39	--	--	G	1	

$$SEC_{cycle} = 0{,}1532 \times c + 0{,}7836$$

where c is the machine load capacity (in kg) and the energy consumption in kWh per cycle is considered. When the annual energy consumption is instead used, for 220 cycles per year, the following formula results:

$$SEC_{year} = 33{,}7 \times c + 172{,}4$$ where c is the machine load capacity (in kg).

For a 5kg machine, this formula results in (33,7 × 5 + 172,4) = 340,9 kWh/year. When the other specific energy consumption values are considered, the annual energy consumptions and EEIs shown in Table 7.43 are calculated, which are almost overlapping with the value of Table 7.44.

The SEC formula does not take into consideration the low power modes consumption. For example an annual consumption of 11,8 kWh can be calculated for washing machines from Table 7.41 when 'off-mode' power consumption is 1W and 'left-on mode' power consumption is 2W and should be added to the on-mode annual consumption to have the overall annual energy consumption

The EEI of a washing machine, under this new approach, is calculated as the ratio of the overall annual energy consumption (energy consumption for 220 cycles/year plus the low power modes consumption) with the standard energy consumption (calculated through the relevant SEC formula,

which does not include the low power modes). According to the proposed approach, for a 5kg machine no differences will arise in terms of energy efficiency, compared to the current labelling scheme, when the low power modes consumption is not considered. In Table 7.45 a set of energy efficiency classes are proposed: Labelling Scheme Option 3 foreseen a rating system from class G to class A3 (or as alternative from class 1 to class 10) while Labelling Scheme Option 4 foreseen a scale from G to A.

Table 7.44: Calculation at the basis of the upgrading of the washing machine labelling scheme based on EEI and overall annual energy consumption(based on a 5kg washing machine)

Annual energy consumption (kWh/year)		Energy consumption (kWh/cycle)		difference		Specific energy consumption (kWh/kg)		difference		Energy efficiency index (EEI)		difference	
				(%)	(kWh/cycle)			(%)	(n)			(%)	(n)
<154		<0,700		--	--	< 0,14		--	--	< 45,2		--	--
154	176	0,700	0,800	12,5	0,100	0,14	0,16	12,5	0,020	45,2	51,6	12,5	6,5
176	198	0,800	0,900	11,1	0,100	0,16	0,18	11,1	0,020	51,6	58,1	11,1	6,5
198	231	0,900	1,050	14,3	0,150	0,18	0,21	14,3	0,030	58,1	67,7	14,3	9,7
231	264	1,050	1,200	12,5	0,150	0,21	0,24	12,5	0,030	67,7	77,4	12,5	9,7
264	297	1,200	1,350	11,1	0,150	0,24	0,27	11,1	0,030	77,4	87,1	11,1	9,7
297	341	1,350	1,550	12,9	0,200	0,27	**0,31**	12,9	0,040	87,1	**100,0**	12,9	12,9
341	385	1,550	1,750	11,4	0,200	**0,31**	0,35	11,4	0,040	**100,0**	112,9	11,4	12,9
385	429	1,750	1,950	10,3	0,200	0,35	0,39	10,4	0,040	112,9	125,8	10,4	12,9
>429		>1,950		--	--	> 0,39		--	--	>125,8		--	--

Table 7.45: Updated labelling scheme based on EEI and overall annual energy consumption for a 5kg washing machine

Annual energy consumption (kWh/year)		Energy consumption (kWh/cycle)		difference		Specific energy consumption (kWh/kg)		**Energy efficiency index** (EEI)		difference		EE classes		
				(%)	(kWh/cycle)					(%)	(n)	**Option 3** (class)		**Option 4** (class)
<153,4		<0,697		--	--	< 0,139		< 45		--	--	A3	10	A
153,4	177,3	0,697	0,806	13,5	0,108	0,139	0,161	45	52	13,5	7	A2	9	B
177,3	201,1	0,806	0,914	11,9	0,108	0,161	0,183	52	59	11,9	7	A1	8	C
201,1	231,8	0,914	1,054	13,2	0,139	0,183	0,211	59	68	13,2	9	A	7	D
231,8	262,5	1,054	1,193	11,7	0,139	0,211	0,239	68	77	11,7	9	B	6	E
262,5	296,6	1,193	1,348	11,5	0,155	0,239	0,270	77	87	11,5	10	C	5	F
296,6	340,9	1,348	1,550	13,0	0,201	0,270	**0,310**	87	**100**	13,0	**13**	D	4	G
340,9	385,2	1,550	1,751	11,5	0,201	**0,310**	0,350	**100**	113	11,5	13	E	3	
385,2	429,5	1,751	1,952	10,3	0,201	0,350	0,390	113	126	10,3	13	F	2	
>429,5		>1,952		--	--	> 0,390		>126		--	--	G	1	

The effect for other capacity machines is presented in Figure 7.49. In the same Figure the current A, A+ and 'C'≤ 0,15 kWh/kg classes are shown for sake of comparison.

Under the hypothesis of the 4,5-7kg cluster reference line representative of all washing machines, and using the same set of EEIs shown in Table 7.45, if the of 0,31 kWh/kg value is taken as having EEI = 100, then the following line can be considered as the SEC:

$SEC_{cycle} = 0{,}1878 \times c + 0{,}6111$ where c is the machine load capacity (in kg) and the energy consumption in kWh per cycle is considered. When the annual energy consumption is used, for 220 cycles per year, the following formula results:

$SEC_{year} = 41{,}3 \times c + 134{,}4$ where c is the machine load capacity (in kg).

For a 5kg machine, this formula gives (41,3 × 5 + 134,4) = 340,9 kWh/year. When the other specific energy consumption values are considered, the values of the annual energy consumption and EEI shown in previous Table 7.45 are calculated. Again the SEC formula does not take into consideration the low power modes consumption. The same options for the energy labelling classification already presented in Table 7.45 (set of energy efficiency classes from G/class 1 to A3/class10 or from G to A) are also possible when this second SEC reference line is used.

The effect of this approach is presented in Figure 7.50. In the same Figure the current A, A+ and 'C'≤0,15 kWh/kg classes are shown for sake of comparison.

Under the third hypothesis of using the 1997 4,5-6,5kg cluster reference line, and considering again the 0,31 kWh/kg value in Table 7.45 as having EEI = 100, then the following line can be considered as the SEC:

$SEC_{cycle} = 0{,}2541 \times c + 0{,}2794$ where c is the machine load capacity (in kg) and the energy consumption in kWh per cycle is considered. When the annual energy consumption is used, for 220 cycles per year, the following formula results:

$SEC_{year} = 55{,}9 \times c + 61{,}5$ where c is the machine load capacity (in kg).

For a 5kg machine, this formula gives (55,9 × 5 + 61,5) = 341,0 kWh/year. When the other specific energy consumption values are considered, the values of the annual energy consumption and EEI shown in previous Table 7.44 are calculated. Again the SEC formula does not take into consideration the low power modes consumption. The same options for the energy labelling classification already presented in Table 7.45 (set of energy efficiency classes from G/class 1 to A3/class10 or from G to A) are also possible when this second SEC reference line is used.

The effect of this approach is presented in Figure 7.51. In the same Figure the current A, A+ and 'C'≤0,15 kWh/kg classes are shown for sake of comparison.

Figure 7.49: Straight lines for annual energy consumption including low power modes and 2005 CECED technical database (hypothesis of the 4,5-6kg cluster reference)

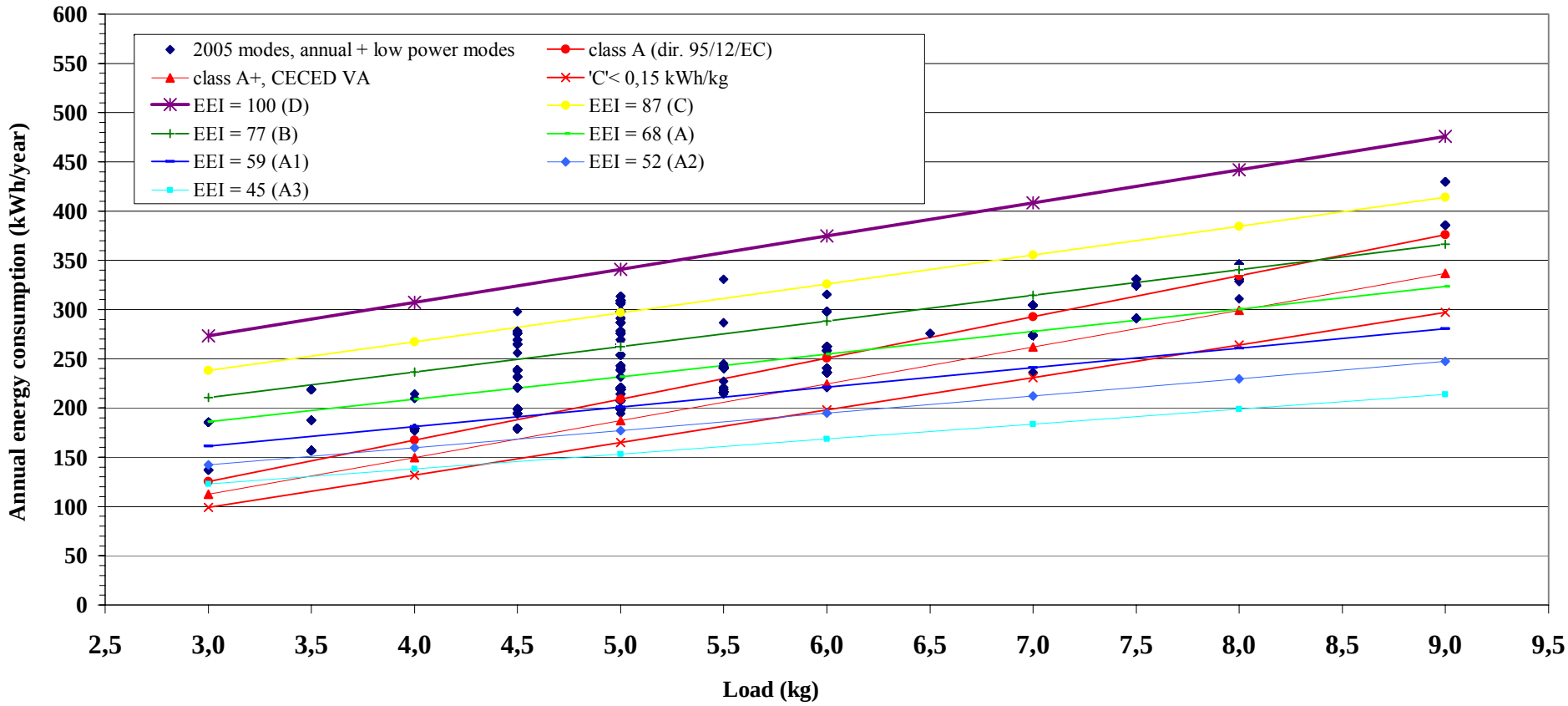


Figure 7.50: Straight lines for annual energy consumption including low power modes and 2005 CECED technical database (hypothesis of the 4,5-7kg cluster reference)

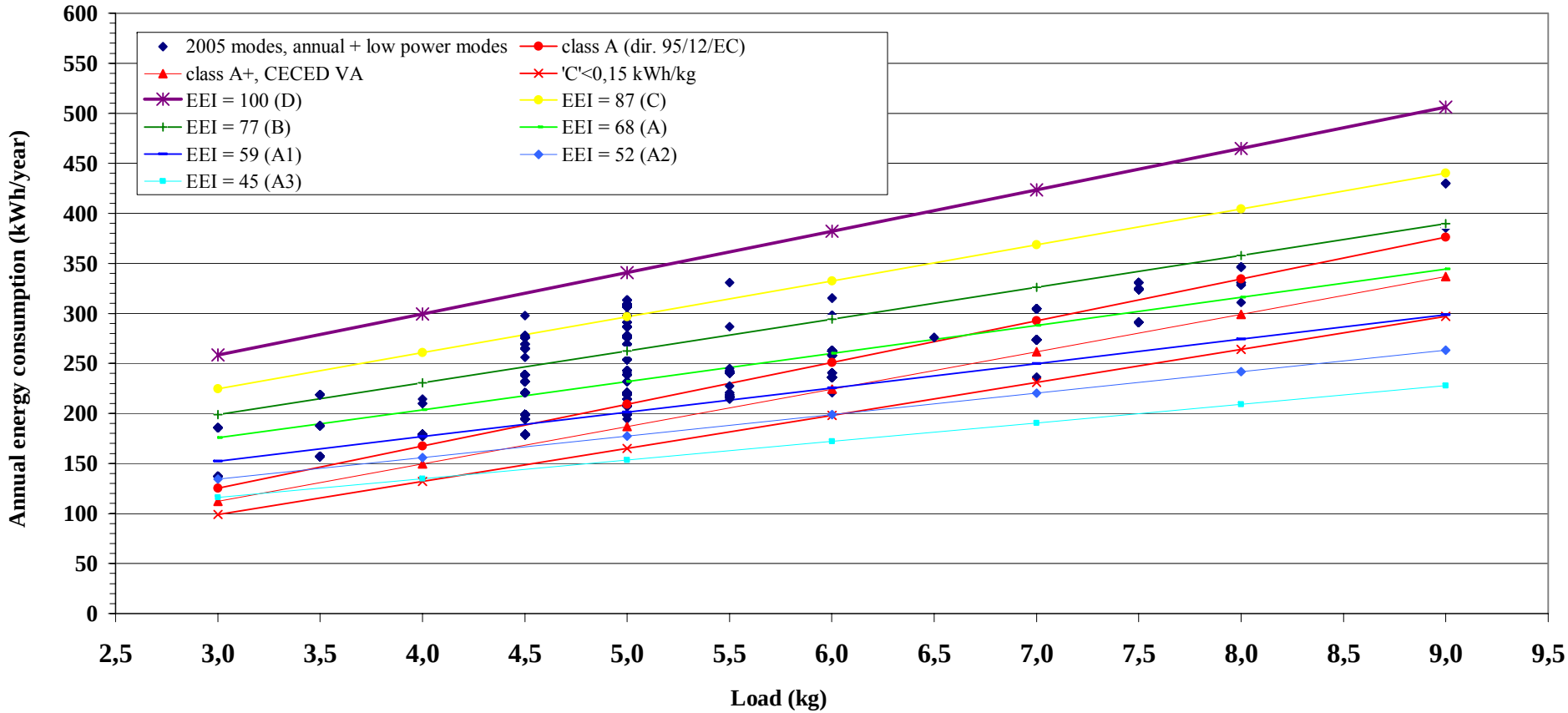
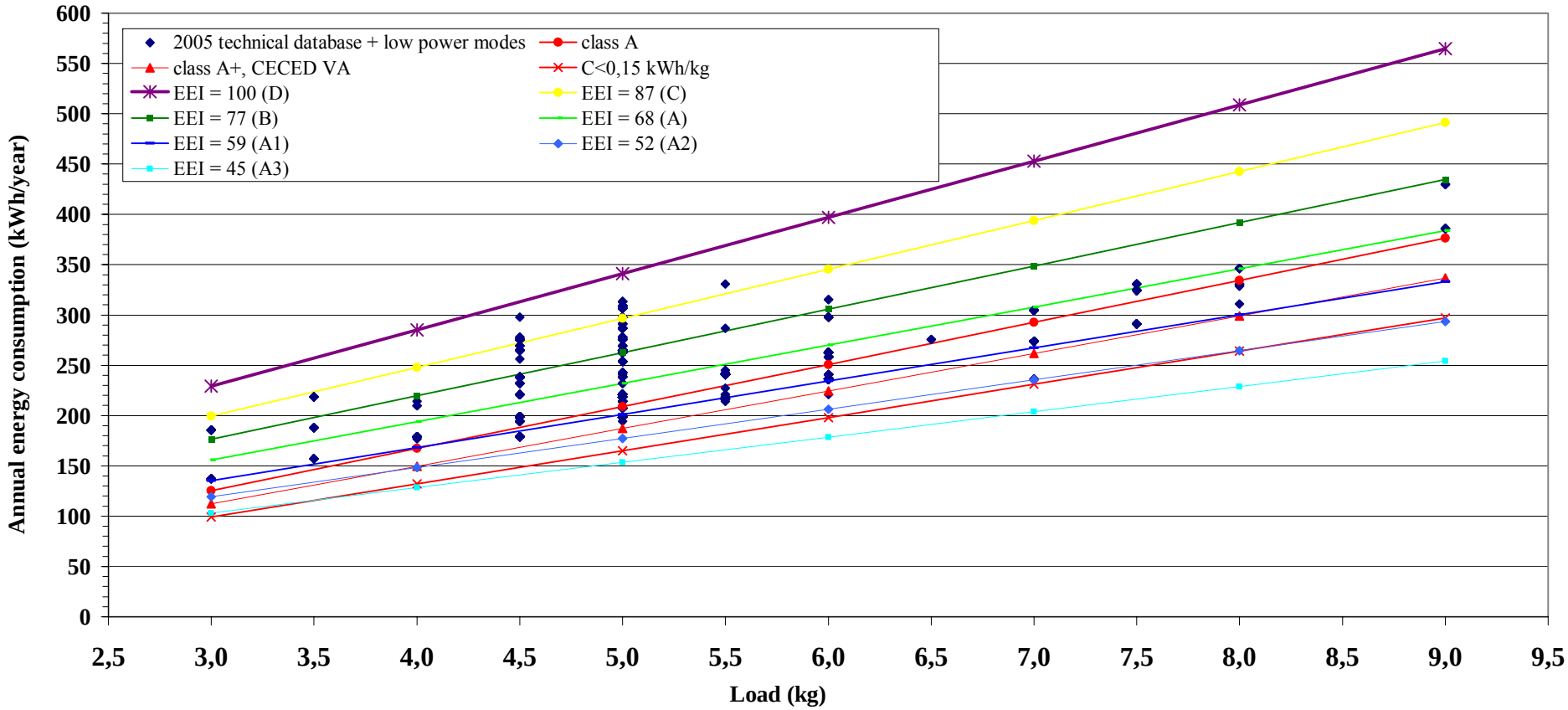


Figure 7.51: Straight lines for annual energy consumption including low power modes and 2005 CECED technical database (hypothesis of the 4,5-6,5kg 1997 cluster reference)



e) Water Efficiency Classes and Rinsing Performance for the 60°C cotton programme

At present the water consumption of a washing machine is only partially addressed by the EU policy measures, since only the indication of the water consumption per cycle has to be indicated in the label.

e.1) Rinsing Performance

There is a strong link is between water consumption and rinsing performance. In fact, in today's machine, water consumption in the (warm) washing phase is already at the minimum due to the associated energy consumption, therefore the water savings can be done only in the rinsing phase or better in the non-warm washing phases.

Most of the machines on the EU market have already the possibility of (one or more) extra rinses, recommended for people with a high sensitive skin or for babies and young children. Although it should be evaluated if the possibility of extra rinse(s) is an actual need (due to a poor rinsing performance known by the manufacturers, which might cause problems is specific social categories) or just a way for product differentiation through an appealing - but basically useless - extra feature (although rinse performance might be improved by increasing the rinse number).

At present in the EU the washing machine rinsing performance is driven by the market (manufacturers and consumers) judgement and - in general - it satisfies the consumer expectations in washing. This does not necessarily mean that the textiles are really "well" rinsed, but no major problems are detected or perceived by consumers.

Latest 2007 data from Australia[76], show that there is a very little influence of the spinning performance (in terms of residual moisture content) - and therefore broadly of the spinning speed - on the washing machine rinsing performance.

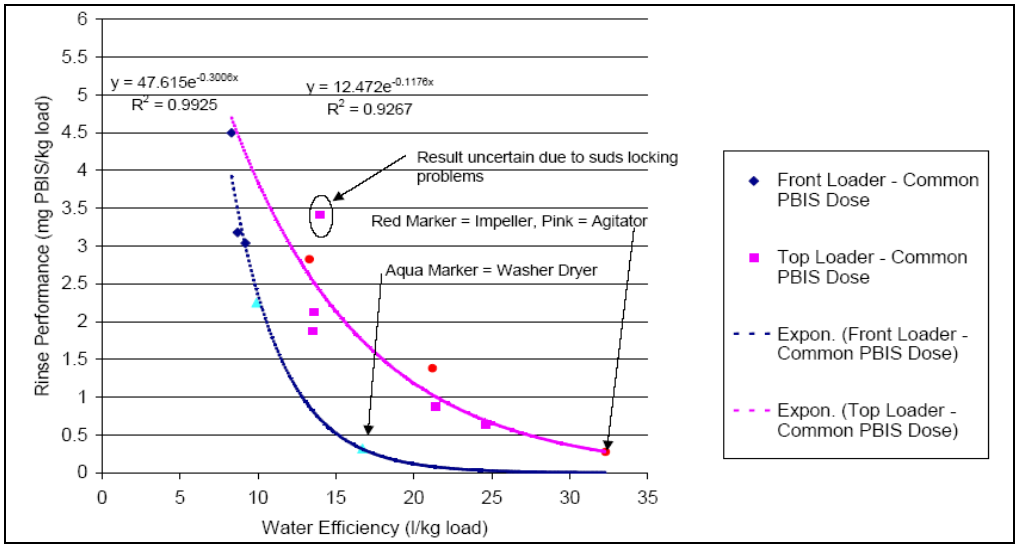
Australia has chosen the PBIS tracer retention method (see Task 1) because two detergents are available in the country and therefore the detection of the surfactant (LAS system) cannot be used, while the alkalinity system is still under investigation. The results of the tests on 8 top loader machines and 5 front loader machines, a representative cross section of the product available in 2004 in the Australian market, including a wide range of water efficiencies are presented in Figure 7.52[77], where the mass of retained PBIS is plotted against the water efficiency (l/kg load). For each data series (front loading machines in blue and washer-dryers in light blue in one series and top loading impeller machines in red and agitator machines in magenta in the other series) an exponential trend line has been fitted. In all cases the fit was good. The trend lines show a clear relationship between water efficiency and rinse performance whereby an increase in water efficiency will result in a decrease in rinse performance. However, for a given water efficiency some significant variation in rinse performance between different models was found.

One of the alternative systems, the LAS system, is based on the detection trough UV spectrophotometry of the surfactant component of the detergents. The alkalinity method, under preparation for the IEC 60456 5th edition, is still not completely satisfactory – due to a too large variation of the results.

[76] Presentation of the Australian expert at the meeting of the IEC SC59D/WG20 held in Milton Keynes (UK), March 2007.

[77] Source: Energy Efficient Strategies, Method for the Determination of Rinse Performance in Clothes Washers, Summary Report, Report for The Department of Environment and Heritage – Australian Federal Government, June 2005

Figure 7.52: Rinse performance (PBIS) vs. water efficiency for a representative sample of washing machines in the Australian market in 2004



e.2) Water Efficiency Classes

Staring from the WEC and W_c values a rating system for water consumption can be hypothesised in term of WEI, based on the annual consumption or the consumption per cycle or per kg of load. However, any attempt to label the water consumption without addressing the rinsing efficiency might result in a reduction of the rinse quality and therefore having a negative impact on consumers.

e.3) Conclusions

Although very likely challenging for suppliers, water (efficiency or consumption) labelling should not be introduced in the EU if rinsing performance labelling or specific requirements are not contemporarily enforced, due to the strong relation between water consumption and rinsing performance (proven in Australia, where the introduction of a rinse performance requirement facilitated the introduction of mandatory water efficiency rating and labelling). Without a policy measure addressing the rinse performance in the EU, higher water efficiency rating could be achieved by reducing rinse quality that may not meet the needs of washing machine users. A specific requirement, addressing a maximum of water consumption per cycle will be proposed.

7.6.3.3 Dishwashers

a) Elements to be updated in the present labelling scheme for dishwashers

The main element of the present labelling scheme that should be updated in a revised scheme for dishwashers is the Energy Efficiency (Index) calculation algorithm: to be amended to include low power modes and to consider the machine annual energy consumption.

b) The Energy Efficiency (Index) algorithms for dishwashers

The opportunity of amending the algorithms in directive 97/12/EC will be discussed. The possible alternative is to calculate a new Energy Efficiency Index (EEI) based on the annual energy consumption (in kWh); the EEI is given by the ratio between the energy consumption per cycle of any given appliance and the reference energy consumption of the same appliance.

The current energy labelling scheme for dishwashers includes the calculation of energy efficiency index (E_I) as the ratio between the actual model energy consumption (C) and the energy consumption of the reference model (C_R) according to the following formulae:

$C_R = 1{,}35 + 0{,}025 \times S$ if $S \geq 10$
$C_R = 0{,}45 + 0{,}09 \times S$ if $S \leq 9$
$E_I = C/C_R$

To evaluate the average energy consumption of a machine per year, the energy consumption per cycle should be multiplied for an agreed number of washing cycles per year. The average number of washing cycles per year used in Task 6 is 280 for washing machines.

The overall annual energy consumption including 'low power modes' can be calculated, as shown in Table 7.45, as:

- including *off-mode* and *left-on mode* each working for half of the residual time after 280 washing cycles per year;
- in case a 'power management system' is implemented and *left-on mode* reverts to *off mode* within, lets say, about 1 hour, resulting in the hours in left-on mode hypothesised equal to the number of the annual washing cycles plus the time in off mode.

The contribution of the low power modes to the annual energy consumption is modest, as clearly shown in Table 7.46.

Table 7.46: Methods to calculate the machine energy consumption including low power modes, with and without a power management system for dishwashers

		Energy consumption	Et (cycle duration)	C (number of annual cycles)	off-mode power consumption with safety functions	t1 (oof mode duration)	left-on mode power consumption	t2 (left on duration)	Total annual energy consumption	t2 measured duration	Overall energy consumption per cycle	load capacity	Energy consumption of the reference model	Energy efficiency index
		Wh/cycle	min	cycle/year	W	min	W	min	kWh/y	min	kWh/cycle	ps	kWh/cycle	(dir. 97/17/EC)
without power management		1050	110	280	1	247400	2	247400						
	Wh	294000			4123,3		8246,7		525600					
	kWh	294			4,1		8,2		306,37		1,09417857	12	1,6500	0,6631
with power management		1050	110	280	1	478000	3	16800	525600	60				
	Wh	294000			7966,7		840		302,8066667		1,08145238	12	1,6500	0,6554
	kWh	294			8,0		0,84							

The formula to calculate the overall AE_c (when the power management is not enforced) is:

$$AE_c = E_t \times C + \{ P_s \times [525\,600 - (T_c \times C)]/2 + P_l \times [525\,600 - (T_c \times C)]/2 \} / (60 \times 1000)$$

where:

- AE_c = annual energy consumption (in kWh)
- E_t = the cycle energy consumption in kWh
- C = is the defined number of cycles per year, 280 for dishwashers
- P_l = the measured power (in W) in the "left-on mode"
- P_s = measured power in "off-mode" (W)
- T_c = washing cycle time (in minutes).
- 525 600 = total number of minutes in a year (= 60 min/h × 24 h/day × 365 days/year).

When a power management is enforced, the formula should be modified to take into consideration the effective duration of the "off-mode" and the "left-on mode" as:

$$AE_c = E_c \times C + \{(P_l \times T_{Pl} \times C) + P_s \times [525\,600 - (T_c \times C) - (T_{Pl} \times C)]\} / (60 \times 1\,000)$$

where T_{Pl} is the measured time in "left-on mode" (in minutes). In addition, the overall low power modes power is considered 100% the time in "off mode" where the "end of cycle" mode is not present (when products automatically revert to "off" after the end of cycle).

When 280 cycles per year are considered, the SEC (standard energy consumption) formulae are derived from C_R according to the place settings number:

$SEC_{\geq 10} = 7 \times ps + 378$ for $ps \geq 10$, where ps is the number of place settings, and

$SEC_{\leq 9} = 25{,}2 \times ps + 126$ for $ps \leq 9$, where ps is the number of place settings.

c) Energy Efficiency Classes: definition and thresholds

c.1) Upgrading of the current labelling scheme, with or without A-G rescaling

The energy efficiency/washing performance/drying performance classes are defined in directive 97/17/EC as:

CLASS	ENERGY EFFICIENCY	WASHING PERFORMANCE	DRYING PERFORMANCE
A	$E_I < 0{,}64$	$P_C > 1{,}12$	$P_D > 1{,}08$
B	$0{,}64 \leq E_I < 0{,}76$	$1{,}12 \geq P_C > 1{,}00$	$1{,}08 \geq P_D > 0{,}93$
C	$0{,}76 \leq E_I < 0{,}88$	$1{,}00 \geq P_C > 0{,}88$	$0{,}93 \geq P_D > 0{,}78$
D	$0{,}88 \leq E_I < 1{,}00$	$0{,}88 \geq P_C > 0{,}76$	$0{,}78 \geq P_D > 0{,}63$
E	$1{,}00 \leq E_I < 1{,}12$	$0{,}76 \geq P_C > 0{,}64$	$0{,}63 \geq P_D > 0{,}48$
F	$1{,}12 \leq E_I < 1{,}24$	$0{,}64 \geq P_C > 0{,}52$	$0{,}48 \geq P_D > 0{,}33$
G	$E_I \geq 1{,}24$	$0{,}52 \geq P_C$	$0{,}33 \geq P_D$

A new set of energy efficiency classes going from class G to class A3 (or as alternative from class 1 to class 10) can be created (Labelling Scheme Option 1), based on E_I (and corresponding energy consumption in kWh/cycle) thresholds with just a little modification of the current thresholds. As alternative, it is possible to define a shorter classification from G to A (Labelling Scheme Option 2), as described in Table 7.47. The new classes have been created with an almost constant improvement (i.e. technological effort) between two classes.

Table 7.47: Comparison of directive 97/17/EC and the updated labelling scheme based on E_I for 12ps dishwashers

Directive 97/17/EC				**Revised labelling scheme**					
Energy Efficiency Index (E_I)	EE classes (class)	improvement (units)	improvement (%)	New Energy Efficiency Index (E_I)	improvement (units)	improvement (%)	EE classes **Option 1** (class)		EE classes **Option 2** (class)
				$E_I < 50$	--	--	A3	10	A
				$50 \leq E_I < 56$	6	10,7	A2	9	B
				$56 \leq E_I < 63$	7	11,1	A1	8	C
$E_I < 0{,}64$	A	--	--	$63 \leq E_I < 71$	8	11,3	A	7	D
$0{,}64 \leq E_I < 0{,}76$	B	12	15,8	$71 \leq E_I < 80$	9	11,3	B	6	E
$0{,}76 \leq E_I < 0{,}88$	C	12	13,6	$80 \leq E_I < 90$	10	11,1	C	5	F

$0,88 \le E_I < 1,00$	D	12	12,0	$90 \le E_I < 100$	10	10,0	D	4	G
$1,00 \le E_I < 1,12$	E	12	10,7	$100 \le E_I < 112$	12	10,7	E	3	
$1,12 \le E_I < 1,24$	F	12	9,7	$112 \le E_I < 124$	12	9,7	F	2	
$E_I \ge 1,24$	G	--	--	$E_I \ge 124$	--	--	G	1	

c.2) New categorical scheme based on annual energy consumption with low power modes

Based on the new scale of E_I in the fourth column of Table 7.46, where $E_I = 100$ corresponds to an energy consumption per cycle of 1,650 kWh for 12 dishwashers (representative of machines ≥10ps) and 1,260 kWh for 9ps dishwashers (representative of machines ≤9ps) the before identified SEC straight lines for 280 washing cycles per year:

$$SEC_{\ge 10} = 7 \times ps + 378 \qquad \text{for } ps \ge 10$$
$$SEC_{\le 9} = 25,2 \times ps + 126 \qquad \text{for } ps \le 9$$

can be considered as reference lines with $E_I = 100$ and thresholds between Classes D and E (Tables 7.47 and 7.48).

For a 12ps machine, the first formula results in $(7 \times 12 + 378) = 462$ kWh/year; for a 9ps machine the second formula results in $(25,2 \times 9 + 126) = 428,4$ kWh/year. When other specific energy consumption values are considered, the values of the annual energy consumption and EEI shown in Table 7.47 are calculated. The SEC formulae do not take into consideration the low power modes consumption. For example, an annual consumption of 12,4 kWh can be calculated from Table 7.45 when off-mode power consumption is 1W and left-on mode power consumption is 2 W and should be added to the on-mode annual consumption.

The EEI of a dishwasher, under this new approach, is calculated as the ratio of the overall annual energy consumption (energy consumption for 280 cycles/year plus the low power modes consumption) with the standard energy consumption (calculated for each place setting category with the relevant SEC formula which does not includes the low power modes).

The effects of the new labelling system on the models in the CECED 2005 technical database is shown in Figure 7.53: for each mode, the energy consumption per cycle has been multiplied by 280 and then 16,kWh have been added. For sake of comparison, the line representing the current class A is also shown in the Figure. Classes B and C are common to the current and the new labelling scheme.

Similarly to the washing machines, in Tables 7.48 and 7.49 a set of energy efficiency classes are proposed: Labelling Scheme Option 3 foresees a rating system from class G to class A3 (or as alternative from class 1 to class 10), while Labelling Scheme Option 4 foresees a scale from class G to class A.

d) Water efficiency classes

Water consumption is only partially addressed in directive 97/17/EC, since only the indication of the water consumption per cycle has to be indicated in the label.

Starting from the WEC and W_c values a rating system for water consumption could be hypothesised in term of WEI, based on the annual consumption. However, since the water consumption per cycle is already modest for dishwashers, going from 20 litres to 9 litres per cycle for a 12ps machine

(with an average of 15,2 litre/cycle) and the washing performance might be affected by a further reduction in the water use, the introduction of a water label should be carefully evaluated in terms of effective benefits and potential negative impact on consumers.

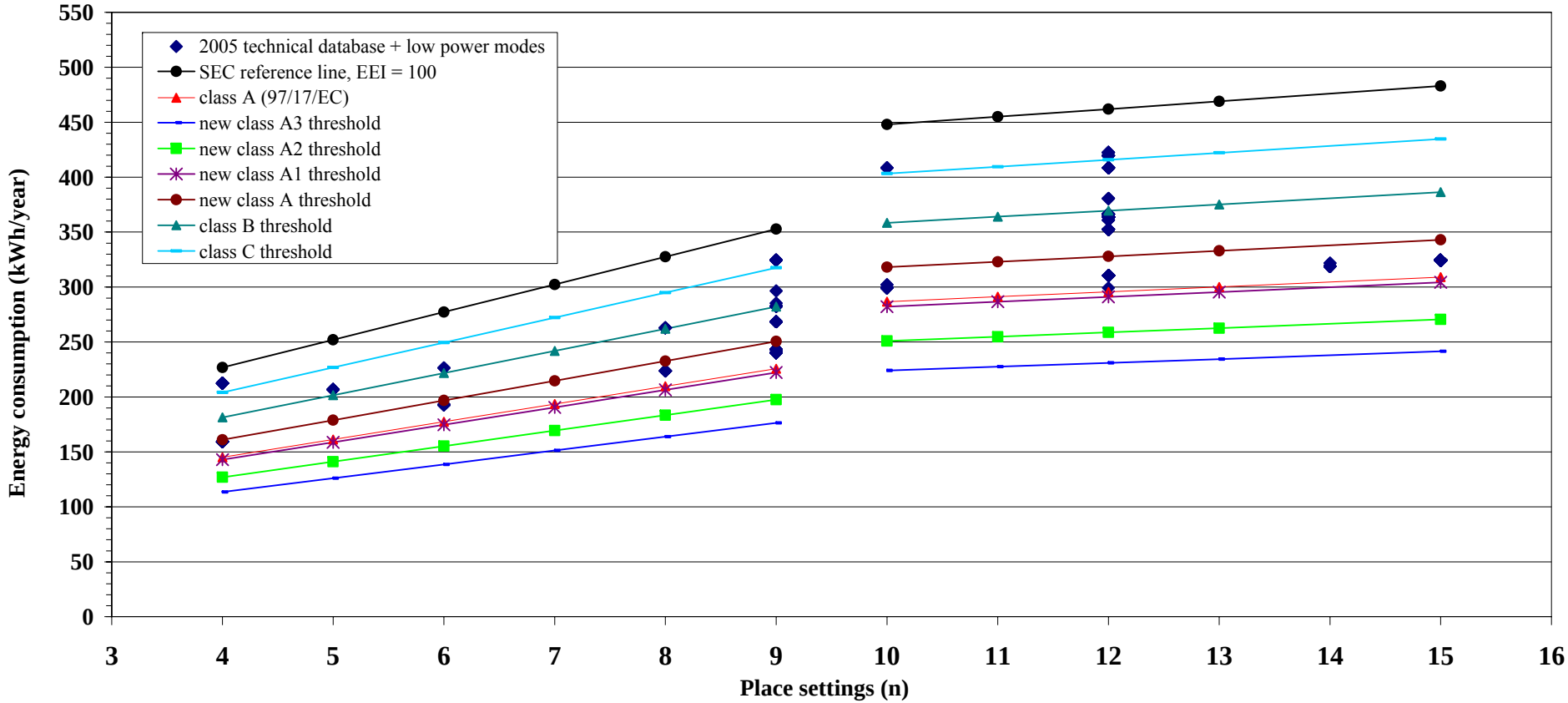
Table 7.48: Comparison of directive 97/17/EC and the updated labelling scheme based on annual energy consumption including low power modes for 12ps dishwashers

E_I directive 97/17/EC		Difference		E_I, new		Difference		Energy consumption		Annual energy consumption		New labelling scheme Energy Efficiency classes		
												Option 3		**Option 4**
(%)	(%)	(n)	(%)	(%)	(%)	(n)	(%)	(kWh/cycle)		(kWh/year)		(class)		(class)
				<50		--	--	< 0,825		< 231		A3	10	A
				50	56	6	10,7	0,825	0,924	231	259	A2	9	B
				56	63	7	11,1	0,924	1,040	259	291	A1	8	C
<64		--	--	63	71	8	11,3	1,040	1,172	291	328	A	7	D
64	76	12	15,8	71	80	9	11,3	1,172	1,320	328	370	B	6	E
76	88	12	13,6	80	90	10	11,1	1,320	1,485	370	416	C	5	F
88	100	12	12,0	90	**100**	10	10,0	1,485	**1,650**	416	**462**	D	4	G
100	112	12	10,7	**100**	112	12	10,7	**1,650**	1,848	**462**	517	E	3	
112	124	12	9,7	112	124	12	9,7	1,848	2,046	517	573	F	2	
>124		--	--	>124		--	--	>2,046		> 573		G	1	

Table 7.49: Comparison of directive 97/17/EC and the updated labelling scheme based on annual energy consumption including low power modes for 9ps dishwashers

E_I directive 97/17/EC		Difference		E_I, new		Difference		Energy consumption		Annual energy consumption		New labelling scheme Energy Efficiency classes		
												Option 3		**Option 4**
(%)	(%)	(n)	(%)	(%)	(%)	(n)	(%)	(kWh/cycle)		(kWh/year)		(class)		(class)
				<50		--	--	< 0,630		< 176		A3	10	A
				50	56	6	10,7	0,630	0,706	176	198	A2	9	B
				56	63	7	11,1	0,706	0,794	198	222	A1	8	C
<64		--	--	63	71	8	11,3	0,794	0,895	222	250	A	7	D
64	76	12	15,8	71	80	9	11,3	0,895	1,008	250	282	B	6	E
76	88	12	13,6	80	90	10	11,1	1,008	1,134	282	318	C	5	F
88	100	12	12,0	90	**100**	10	10,0	1,134	1,260	318	353	D	4	G
100	112	12	10,7	**100**	112	12	10,7	**1,260**	1,411	**353**	395	E	3	
112	124	12	9,7	112	124	12	9,7	1,411	1,562	395	437	F	2	
>124		--	--	>124		--	--	>1,562		> 437		G	1	

Figure 7.53: Energy consumption of dishwashers in 2005 CECED technical database



7.6.4 Specific requirements

The main question when proposing specific requirements for energy (and water) efficiency or consumption is whether the elements included in CECED Industry Commitments should be at the basis of the requirements or if a different system should be put in place.

To avoid any potential confusion, it is proposed that the new energy efficiency requirements are set in terms of maximum Energy Efficiency Index value, which indirectly defines a maximum annual energy consumption. This approach allows us:

- to set an univocal energy index and corresponding consumption value for a given model,
- to phase out an energy efficiency class (of the labelling scheme) when setting a minimum efficiency requirement (should the phase-out EEI value corresponding to a labelling class threshold, which is a recommended choice); the market control will be facilitated because no residual models in a labelling class will be present on the market,
- to put in place a 'dynamic' approach for the phase-out of less efficient products, implicitly given by the sequence of the labelling energy efficiency classes, and
- to reinforce the synergy – and therefore the effectiveness – between the labelling system and the eco-design energy efficiency/consumption requirements.

The main criterion for setting a specific requirement is that the product classification and the energy efficiency calculation algorithms are the same as the new labelling scheme.

7.6.4.1 Washing machines (for the 60°C cotton programme)

a) Washing performance

Minimum washing performance B (or even A). This requirement is set more to avoid that tightening the energy consumption efficiency classes might result in a decrease of the washing performance.

b) Water consumption

Maximum water consumption $W_{c,max}$ per cycle given by the formula:

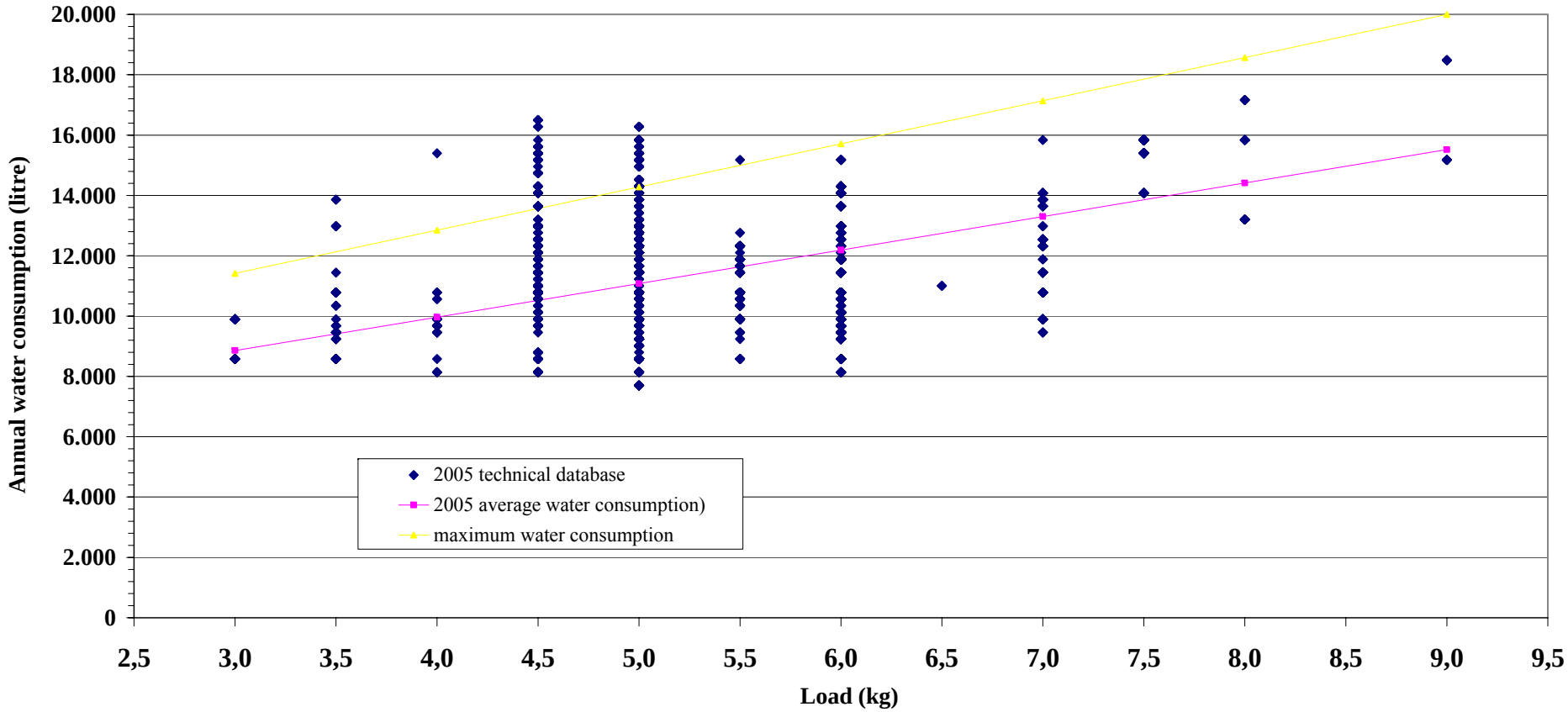
$$W_{c,\max} \leq 6{,}5 \times c + 32{,}4$$

Where *c* is the machine load capacity. The limit corresponds to a 65 litre consumption per cycle for a 5kg washing machine. A preliminary analysis showed that 299 models, essential belonging to energy efficiency class C will be phased-out, corresponding to about 5% of the 2005 CECED technical database (Figure 7.54).

c) Energy consumption

If the new labelling system based on the overall annual energy consumption (including the low power modes) is implemented, the pulling effect of the new label should be sufficient to drive the market. However, if considered necessary, the phase out of the class C models from 01.01.2009 can be considered: about 560 models (of the 2005 technical database) will be involved.

Figure 7.54: Maximum and average annual water consumption per washing machine load capacity



If the current labelling scheme is updated by adding some classes on top (Labelling Scheme Options 1 and 2), then a maximum energy consumption of 0,19 kWh/kg is proposed, with a possible exemption for machines with a load capacity ≤ 3kg. This means that the models belonging to the present class B (532 models) will be phased out starting 01.01.2009.

d) Spinning speed

As analysed in details in Task 6, due to the strong dependence of the energy consumption of the 'washing + drying' system on the laundry residual moisture content and contemporarily on the dryer ownership and use any specific requirement addressing minimum spinning speed or maximum residual moisture content has been found a sub-optimal solution. No specific requirement is therefore proposed.

7.6.4.2 Dishwashers

a) Washing performance

Minimum washing performance B. This requirement is set to avoid that tightening the energy efficiency classes might result in a decrease of the present washing performance.

b) Drying performance

Minimum drying performance C. This requirement is set to avoid that tightening the energy efficiency classes might result in a decrease of the drying performance. [*alternative*: minimum drying performance B: only 242 models (or 5,7%) in the 2005 database will be phased-out].

c) Energy consumption

If the new labelling system based on the annual energy consumption including the low power modes (Energy Labelling Options 3 and 4) is implemented the pulling effect of the new label is considered sufficient to drive the market. However, if necessary the phase-out of class B models can be considered (resulting in the phase-out of 335 models for ≥10ps machines and 121 ≤9ps machines from the 2005 technical database).

If on the contrary the present labelling scheme is updated by adding some classes on top (Energy Labelling Options 1 and 2), then a requirement of E_I ≥0,63 starting 01.01.2009 for the ≥10ps machines and E_I ≥0,71 starting 01.01.2009 for the ≤9ps machines. This means that the models belonging to the present class B (≥10ps) or C (≤9ps) will be phased out. In total, it is expected that more than one hundred models of the 2005 database will be phased out only for the energy efficiency parameter.

d) Noise

Although noise is an important element for the consumer comfort, and to allow washing cycles during the night, the decrease from 50 dB(A) to 41 dB(A) will increase the dishwasher energy consumption of about 125 Wh/cycle for a 9ps machine and of about 150 Wh/cycle for a 12ps machine and as discussed in Task 6. Therefore the setting of a maximum noise level should be carefully evaluated against the increase in the energy consumption and the possible savings when washing tableware during night off-peak hours.

7.6.5 Policy measure for washing cycles at temperature different from 60°C and partial load

7.6.5.1 The energy consumption and energy efficiency

In 2007 CECED proposed a new approach to determine the energy consumption of washing machines, which takes into account the needs of a new test procedure closer to consumer behaviour. This method foreseen a series of 7 test runs: 3 runs at 60°C plus 2 runs at 60°C and partial load plus other 2 runs at 40°C and partial load (with a reduced detergent dosage). CECED identified also pros and cons of this new method:

	Positive	Negative	Comment
Test with 3+2+2 runs	Increased differentiation Closer to users washing habits Fits into current test scheme of EN60456	Increased variation possible due to 3 different program settings averaged	More information about performance under different conditions: partial load, reduced temperature and reduced dosage
40°C	Label information on an additional & more consumer relevant cycle	Relative error on specific energy consumption increases compared to 60°C	Will stimulate optimization of the 40°C cycle
Partial load	Identifies machines, with same energy consumption at partial & full load	New parameter increasing the total number of tests from 5 runs to 7 runs, but fits with test procedure in EN60456	Will push for a better temperature control, load detection & load adjusted consumption
65% detergent	Reduce the impact of detergent on washing performance	Additional adjustment for detergent dosage	Current dosage covers factors influenced by washing machine

Three test conditions (different temperatures, different loads and different detergent amounts) instead of one will give a significant increase of information about the performance of the machines with a consequent better product differentiation and machines tested closer to real consumer behaviour. In addition, under the assumption of equal reproducibility in the three test conditions no precision is lost when going from testing procedure of current standard (1 treatment, 5 runs) to proposed method (3 treatments, 7 runs).

Following this approach, the energy consumption (in kWh) per cycle of the washing machine models is calculated through the formula:

$$E_c = (3 \times E_{c,60} + 2 \times E_{c,60½} + 2 \times E_{c,40½})/7$$

where:

- $E_{c,60}$ = energy consumption of the 60°C cotton full load cycle
- $E_{c,60½}$ = energy consumption of the 60°C cotton half load cycle
- $E_{c,40½}$ = energy consumption of the 40°C cotton half load cycle.

CECED asked also the Commission to issue a mandate to CENELEC to prepare the new standard on basis of the proposed 3+2+2 test procedure in parallel to the procedure for the implementation of the new IEC 60456 5th Ed (under preparation by IEC, seek Task 1).

In the transition period it would be possible to calculate the energy consumption of the washing machines models on the basis of the consumption of the 60°C cotton cycle at full load according to

the following equation:

$E_c = [3 \times E_{c,60} + 2 \times (a \times E_{c,60}) + 2 \times (b \times E_{c,60})]/7$

where the multiplying factors *a* and *b* can be initially set at a = 0,80 (or 80% of the energy consumption at 60°C cotton cycle) and b = 0,64 (or 80% of the consumption at 40°C). These values were assumed taking into consideration the few known energy consumption values for the different washing cycles (40°C cotton programme and half load for the 60°C cotton) presented in Task 3.

The previous formula will allow to put in place a new labelling system based on the new proposed 3 treatments and 7 runs approach while waiting for the new standard be defined.

When considering the annual energy consumption (AE_c), it is calculated considering 220 washing cycles per year:

$AE_c = E_c \times n$

or, when considering the contribution of the low power modes (when the power management is not enforced), as:

$AE_c = E_c \times C + \{P_s \times [525\,600 - (T_c \times C)]/2 + P_l \times [525\,600 - (T_c \times C)]/2\} / (60 \times 1\,000)$

where :

- AE_c = annual energy consumption (in kWh)
- E_c = calculated washing cycle energy consumption in kWh
- C = defined number of cycles per year, 220 for washing machines
- P_l = measured power (in W) in the "left-on mode"
- P_s = measured power in "off-mode" (W)
- T_c = washing cycle time (in minutes).
- 525.600 = total number of minutes in a year (= 60 min/h × 24 h/day × 365 days/year).

The average washing time T_c for the 3 treatments and 5 runs is given by :

$T_c = (3 \times T_{c,60} + 2 \times T_{c,60½} + 2 \times T_{c,40½})/7$

where:

- $T_{c,60}$ = washing cycle time of the 60°C cotton full load cycle (in minutes)
- $T_{c,60½}$ = washing cycle time of the 60°C cotton half load cycle (in minutes)
- $T_{c,40½}$ = washing cycle time of the 40°C cotton half load cycle (in minutes)

an in the interim period could be considered equal to the washing time of the 60°C cotton full load cycle: $T_c = T_{c,60}$; P_l and P_s are the same for all the washing temperatures and loads.

When a power management is enforced the formula should be modified to take into consideration the effective duration of the "off-mode" and the "left-on mode" as:

$AE_c = E_c \times C + \{(P_l \times T_{Pl} \times C) + P_s \times [525\,600 - (T_c \times C) - (T_{P1} \times C)]\} / (60 \times 1\,000)$

where T_{P1} is the measured time in "left-on mode" (in minutes) which is considered same for all the washing temperatures and loads.

Once AE_c - including low power modes - is known, the Energy Efficiency Index (EEI) is then calculated for each washing machine model as the ratio between the annual energy consumption and the standard energy consumption (EEI = AE_c/SEC) of that model, where the SEC can be any agreed reference line as in three hypothesis previously defined for the 60°C cotton cycle. The new three straight lines can be derived from the three lines for the 60°C washing cycle by calculating new m_1 and q_1 values from the previous m and q values as:

$m_1 = [3 \times m_{60} + 2 \times (a \times m_{60}) + 2 \times (b \times m_{60})]/7 = [3 \times m_{60} + 2 \times (0,8 \times m_{60}) + 2 \times (0,64 \times m_{60})]/7$
$q_1 = [3 \times q_{60} + 2 \times (a \times q_{60}) + 2 \times (b \times q_{60})]/7 = [3 \times q_{60} + 2 \times (0,8 \times q_{60}) + 2 \times (0,64 \times q_{60})]/7$

The resulting straight lines formulae are:

- Hypothesis one: the SEC line is derived from the 4,5-6kg machine cluster of the 2005 CECED technical database:

  (1) $SEC_{year} = 28,3 \times c + 144,8$ where c is the machine load capacity in kg.

- Hypothesis two: the SEC line is derived from the 4,5-7kg machine cluster of the 2005 CECED technical database:

  (2) $SEC_{year} = 34,7 \times c + 112,9$ where c is the machine load capacity in kg.

- Hypothesis three: the SEC line is derived from the 4,5-6,5kg machine cluster of the 1997 CECED technical database:

  (3) $SEC_{year} = 47,0 \times c + 51,7$ where c is the machine load capacity in kg.

The position of the three SEC lines compared to the models in the 2005 CECED technical database is presented in Figure 7.55. The energy consumption of the 60°C cotton full load washing cycle of 2005 washing machines has been recalculated following the formula:

$E_c = [3 \times E_{c,60} + 2 \times (0,8 \times E_{c,60}) + 2 \times (0,64 \times E_{c,60})]/7$

to evaluate the impact of the new '3+2+2 approach'. The present class C threshold (recalculated following the same approach) has been added for comparison.

In Table 7.50 a proposal is presented for a new labelling scheme based on EEI and overall annual energy consumption of the combination of 60°C and 40°C washing cycles. Also for this scheme a set of energy efficiency classes are proposed in the same Table: Labelling Scheme Option 3 foreseen a rating system from class G to class A3 (or as alternative from class 1 to class 10) while Labelling Scheme Option 4 foreseen a scale from G to A.

The impact of the adoption of the three SEC lines is presented in Figures 7.56-7.58.

7.6.5.2 The washing performance and the water extraction efficiency

The **water extraction efficiency** depends mainly from the amount of water used in the rinsing phases, the number of intermediate spinning phases and the spinning speed of the final spinning. It

Figure 7.55: Recalculated annual energy consumption per washing machine load capacity for the models in 2005 CECED technical database and comparison with the three hypothesised SEC lines

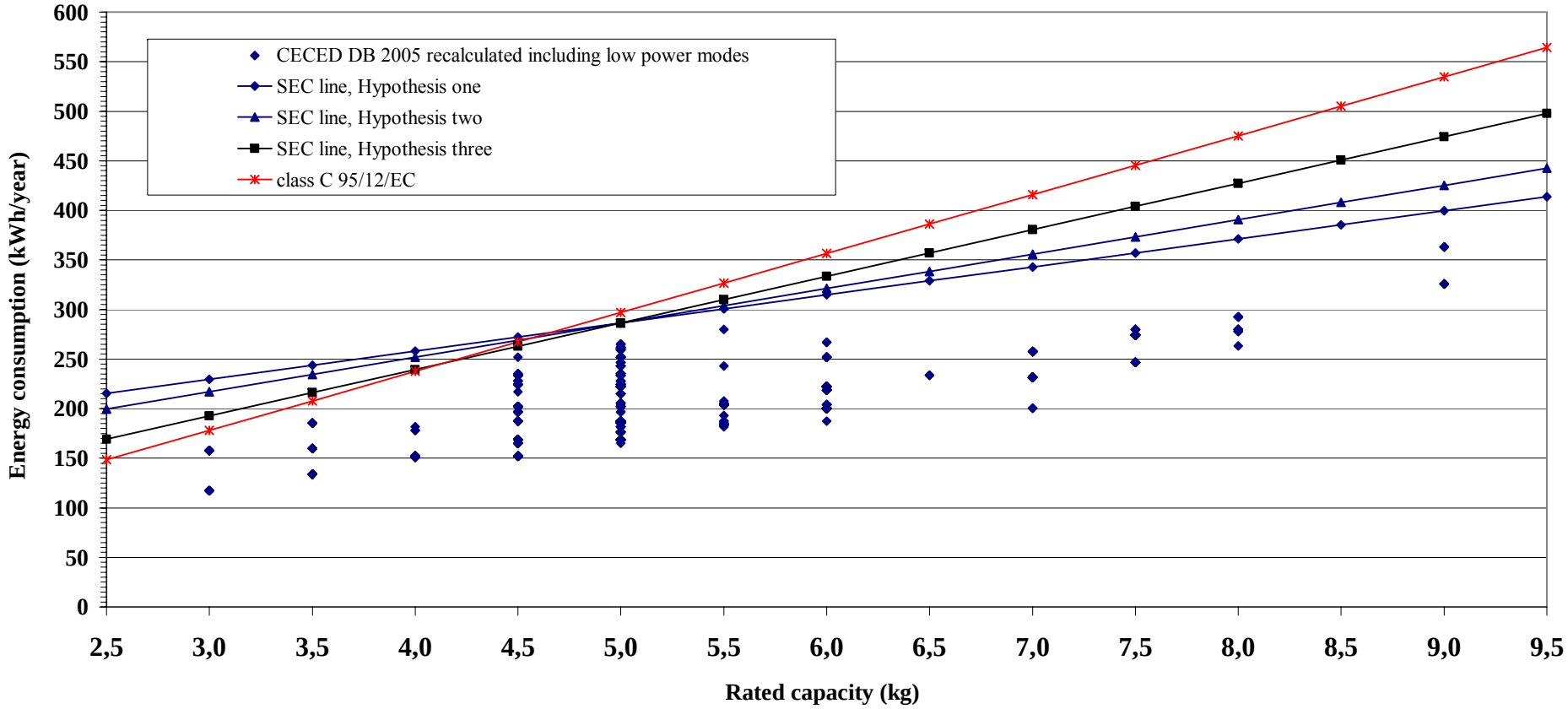


Table 7.50: Proposed labelling scheme based on EEI and overall annual energy consumption for a 5kg washing machine and a combination of 60°C and 40°C cotton cycles

Annual energy consumption (kWh/year)		Energy consumption (kWh/cycle)		difference		Specific energy consumption (kWh/kg)		**Energy efficiency index** (EEI)		difference		EE classes		
				(%)	(kWh/cycle)					(%)	(n)	**Option 3** (class)		**Option 4** (class)
<129		<0,586		--	--	< 0,117		< 45		--	--	A3	10	A
129	149	0,586	0,678	13,5	0,091	0,117	0,136	45	52	13,5	7	A2	9	B
149	169	0,678	0,769	11,9	0,091	0,136	0,154	52	59	11,9	7	A1	8	C
169	195	0,769	0,886	13,2	0,117	0,154	0,177	59	68	13,2	9	A	7	D
195	221	0,886	1,003	11,7	0,117	0,177	0,201	68	77	11,7	9	B	6	E
221	249	1,003	1,134	11,5	0,130	0,201	0,227	77	87	11,5	10	C	5	F
249	287	1,134	1,303	13,0	0,169	0,227	0,261	87	**100**	13,0	13	D	4	G
287	324	1,303	1,473	11,5	0,169	0,261	0,295	**100**	113	11,5	13	E	3	
324	361	1,473	1,642	10,3	0,091	0,295	0,328	113	126	10,3	13	F	2	
>361		>1,642		--	--	> 0,328		>126		--	--	G	1	

Figure 7.56: Recalculated annual energy consumption per load capacity for the models in 2005 CECED technical database and comparison with the EEI and SEC lines (hypothesis one)

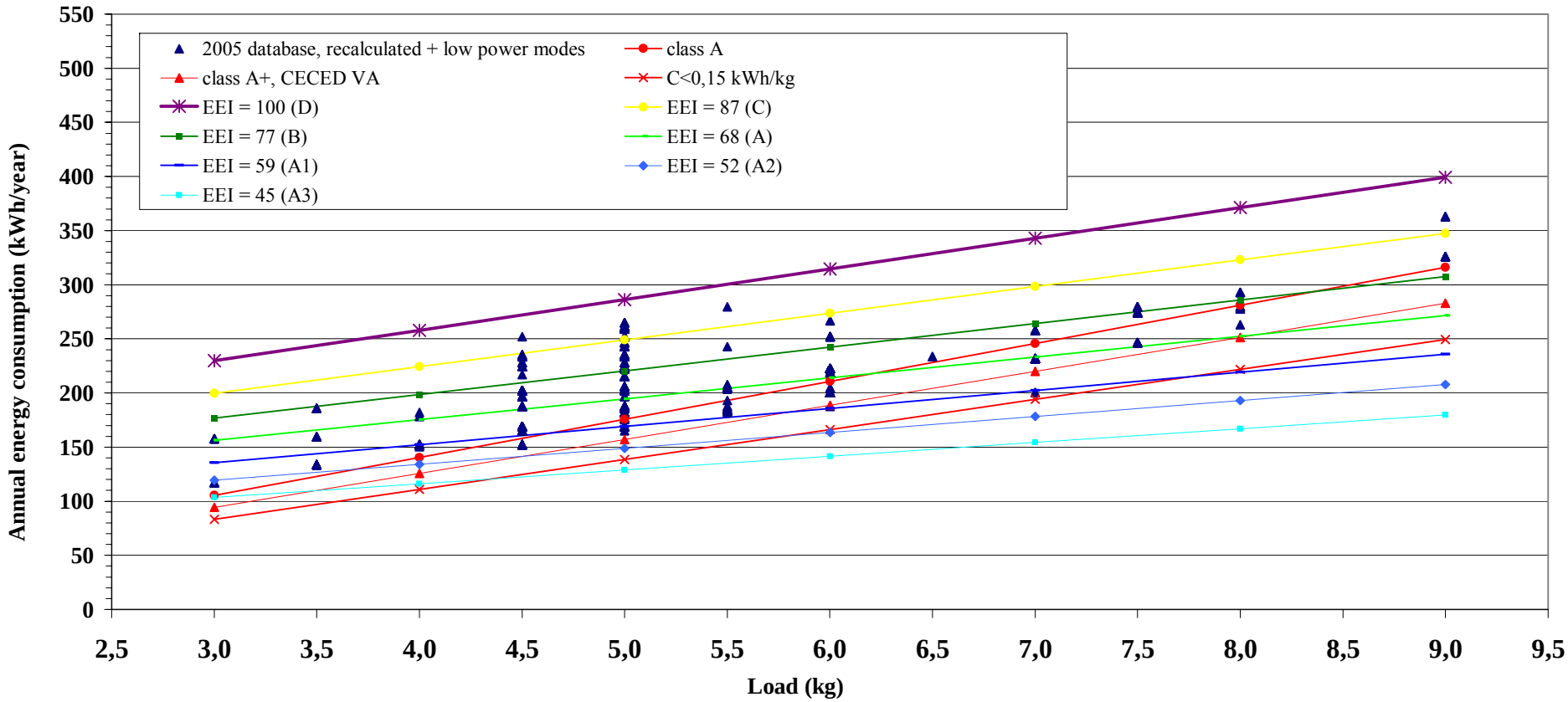


Figure 7.57: Recalculated annual energy consumption per load capacity for the models in 2005 CECED technical database and comparison with the EEI and SEC lines (hypothesis two)

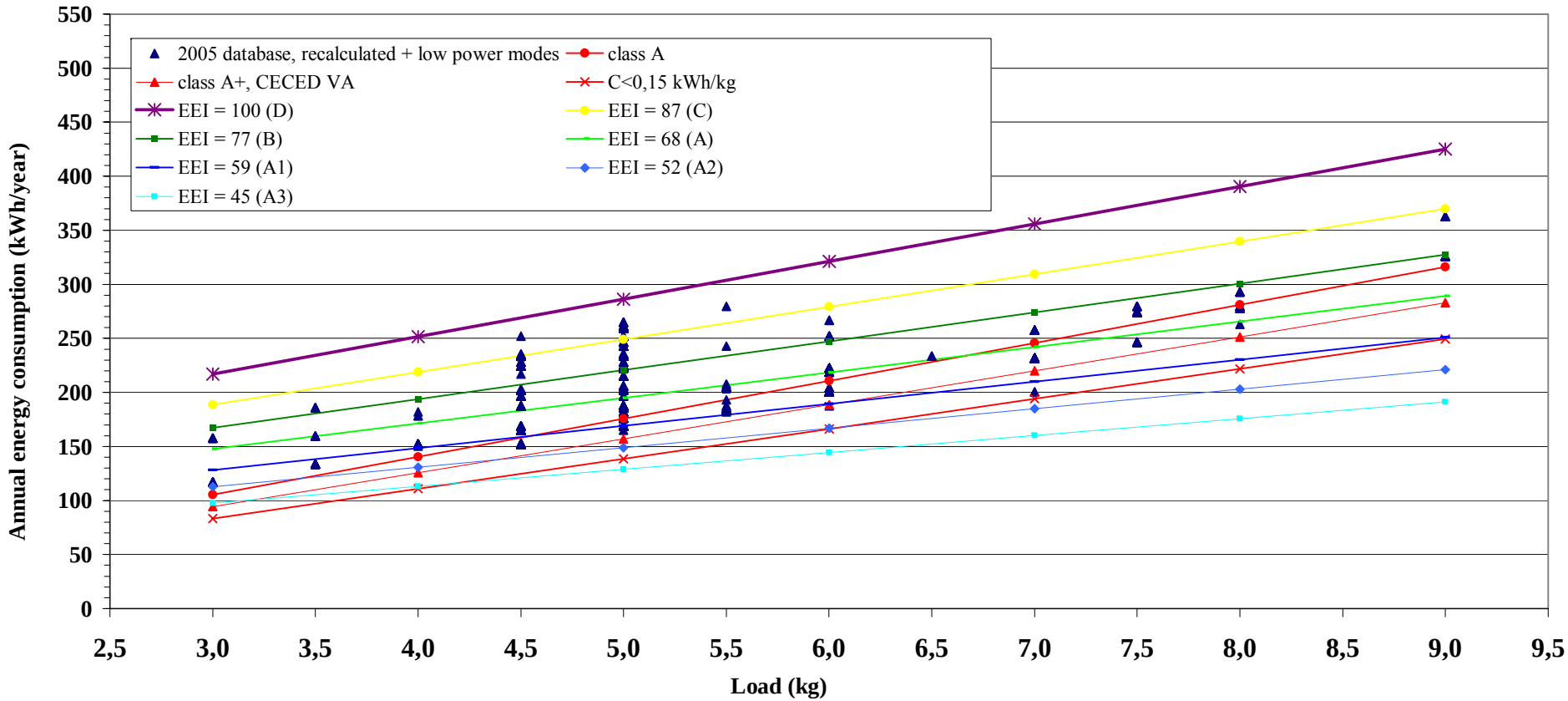
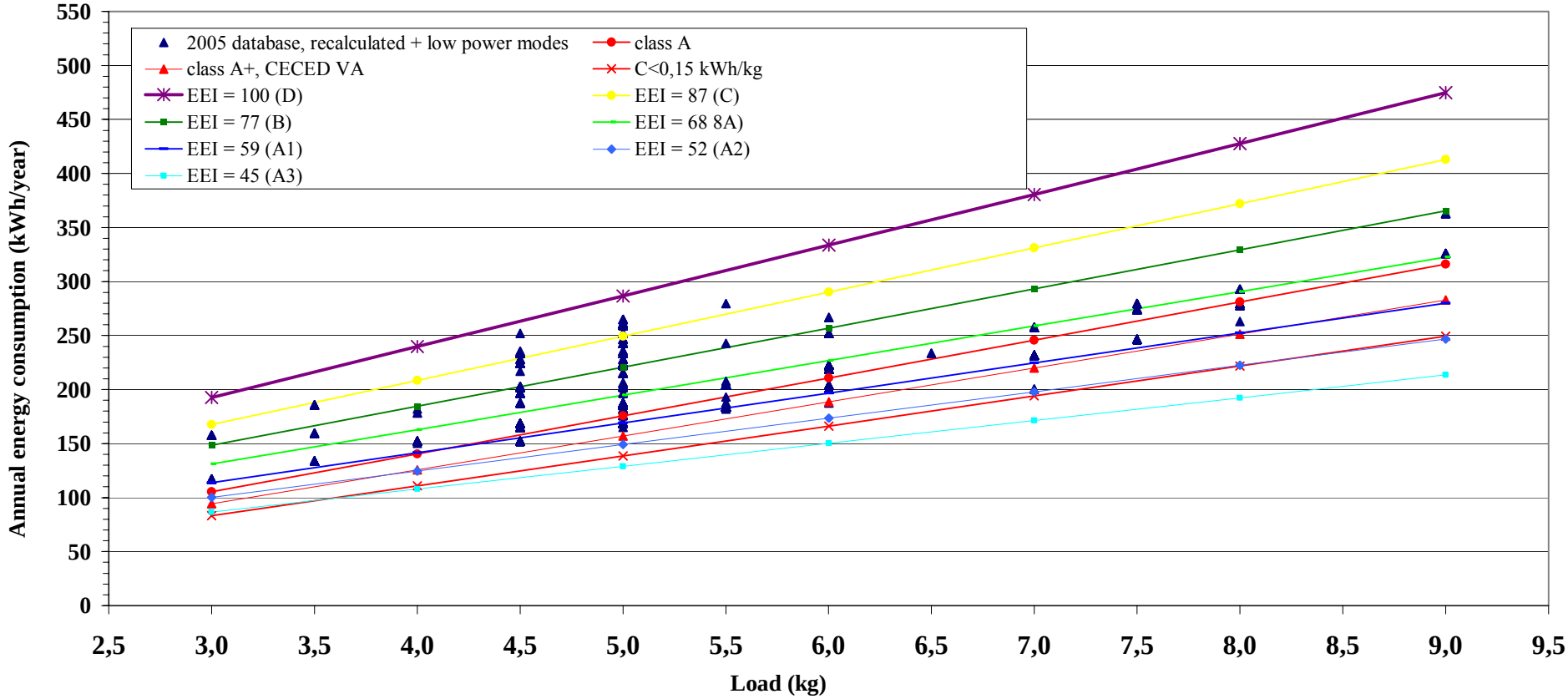


Figure 7.58: Recalculated annual energy consumption per load capacity for the models in 2005 CECED technical database and comparison with the EEI and SEC lines (hypothesis three)



is mostly independent from the washing temperature. Therefore the thresholds of the spinning efficiency classes in directive 95/12/EC:

CLASS (95/12/EC)	WATER EXTRACTION EFFICIENCY
A	$D < 45\%$
B	$45\% \leq D < 54\%$
C	$54\% \leq D < 63\%$
D	$63\% \leq D < 72\%$
E	$72\% \leq D < 81\%$
F	$81\% \leq D < 90\%$
G	$90\% \leq D$

do not need any upgrading or recalculation when the '3+2+2 approach' is followed. The overall residual moisture content "D_c" of the laundry can be calculated as the weighted average of the 7 runs:

$$D_c = (3 \times D_{60} + 2 \times D_{60½} + 2 \times D_{40½})/7$$

where:
- D_{60} = residual moisture content of the 60°C cotton full load cycle (in percentage)
- $D_{60½}$ = residual moisture content of the 60°C cotton half load cycle (in percentage)
- $D_{40½}$ = residual moisture content of the 40°C cotton half load cycle (in percentage)

In the transition period the D_{60} value can be can be considered. This will force manufacturers to achieve the same water extraction efficiency at lower temperature and partial load.

The same is proposed for the **washing performance**. Again there are no reasons to modify the satisfactory values of the "P" parameter in directive 95/12/EC:

CLASS (95/12/EC)	WASHING PERFORMANCE
A	$P > 1{,}03$
B	$1{,}03 \geq P > 1{,}00$
C	$1{,}00 \geq P > 0{,}97$
D	$0{,}97 \geq P > 0{,}94$
E	$0{,}94 \geq P > 0{,}91$
F	$0{,}91 \geq P > 0{,}88$
G	$0{,}88 \geq P$

The overall washing performance "P_c" can be calculated as the weighted average of the 7 runs:

$$P_c = (3 \times P_{60} + 2 \times P_{60½} + 2 \times P_{40½})/7$$

where:
- P_{60} = washing performance of the 60°C cotton full load cycle (in percentage)
- $P_{60½}$ = washing performance of the 60°C cotton half load cycle (in percentage)
- $P_{40½}$ = washing performance of the 40°C cotton half load cycle (in percentage)

In the transition period the P_{60} value can be can be considered. This will force manufacturers to achieve the same good washing performance at lower temperature and partial load.

The name of the washing performance and the water extraction efficiency classes should be adapted to the new classification adopted for the energy efficiency classes.

7.6.5.3 Specific requirements

a) Washing performance

Minimum washing performance B (or even A). This requirement is set more to avoid that tightening the energy consumption efficiency classes might result in a decrease of the washing performance.

b) Water consumption

For the 60°C cotton full load cycle a maximum water consumption $W_{c,max}$ per cycle given by the formula:

$$W_{c,\max,60} \leq 6{,}5 \times c + 32{,}4$$

has been proposed, where *c* is the machine load capacity. The limit corresponds to a 65 litre consumption per cycle for a 5kg washing machine and the 60°C cotton full load cycle. The same value is proposed **for each of the three considered cycles** also for the '3+2+2 approach', at least for the transitional period, since very poor information is available on the water consumption at lower washing temperature and partial load.

c) Energy consumption

If the new labelling system based on the overall annual energy consumption (including the low power modes) is implemented, the pulling effect of the new label should be sufficient to drive the market. However, if considered necessary, the phase out of the class C models from 01.01.2009 can be considered: about 500-550 models (of the recalculated 2005 technical database) will be involved, the exact number depending on the selected SEC line and the low power modes energy consumption.

d) Spinning speed

As analysed in details in Task 6, due to the strong dependence of the energy consumption of the 'washing + drying' system on the laundry residual moisture content and contemporarily on the dryer ownership and use any specific requirement addressing minimum spinning speed or maximum residual moisture content has been found a sub-optimal solution. No specific requirement is therefore proposed.

7.6.6 Generic requirements

Some possible requirements are described, along with considerations about positive and negative aspects of their implementation:

- dishwashers and washing machines: clear indication of the programme(s) used for the energy labelling on the machine and default setting of this programme for a 'normal' cycle (dishwashers) and for the cotton 60°C cycle (washing machines). For washing machines, when a combination of programmes is applied (60°C and 40°C cycles) this indication should be given for all used programmes;
- prevention of the detergent over-dosage: mainly for washing machines. The optimum detergent dosage depends mainly on the used detergent formulation (for example. liquid, pearls, tabs, compact powder or traditional powder) and chemical composition, the water hardness, the user selected washing temperature, the amount of laundry and the amount of soil on it. Some instructions for the consumer on detergent dosing are shown on the detergent package but there is a common understanding that consumers tend to overdose the detergent thinking to achieve a better washing performance. Although hardly the washing machine is involved in the final used decision about dosage, some help might be given by indicating (for example with a line) some volumes of the dispenser;
- mandatory presence of a hard switch: although this requirement could apparently solve the issue of the consumption in the so called standby mode (when the machine is disconnected from the mains there is no energy consumption) some consideration about the real effectiveness of this requirement should be highlighted:
  - real use of the hard-switch by the consumer: if the machine is not switched-off then the hard switch is useless;
  - need of maintaining basic safety functions, which are deactivated when the appliance is switched-off through the hard switch;
  - consistency with the presence of a power management system: under the assumption that the power consumption in the left-on-mode is higher than in off-mode, if power management is taking care of the left-on-mode consumption (automatically reverting the machine to the off-mode after a certain period) the importance of the hard switch is lower the lower is the off-mode power consumption.
    A brief analysis for the washing machine standard base case shows that the annual energy savings, under the conservative hypothesis that (i) the hard switch is actually used 50% of the time the machine is in low power modes, and (ii) the power consumption in low power modes is as indicated by stakeholders in EuP Lot 6 (Table 7.51), is in the range of 8,9-11,2 kWh/year (Table 7.52) when Consumer Organisations data are considered and of 4,4-5,5 kWh/year when CECED date are instead used. This savings has to be considered against the measurement tolerance of the on-mode energy consumption (about 22 kWh/year following the before discussed proposal).
    The effectiveness of this requirement should be also considered in respect with the proposed new energy efficiency algorithm considering the annual energy consumption including low power modes.

Table 7.51: Low-power mode power consumptions for washing machines and dishwashers

Modes (definition)	**Average real life power consumption**	
	CECED (W)	Consumer Organisations (W)
delay-start	2,5	4,3

left-on mode[1]	1,6	3,3
off mode[2] with functions	1	2
off-mode[3] no functions	0,5	0,6

[1]considered equal to the end-of-cycle mode power consumption
[2]Lot 14 estimates
[3]as defined in EuP Lot 6 study, i.e. without (safety) functions.

- mandatory presence of a power management: basically the appliance is automatically reverted from the left on-mode to the lowest possible power (off-mode) after a certain time. To be checked for inconsistency with the use of a hard switch. From Table 7.52 the difference in savings with or without a power management system (in addition to the hard switch) is estimated in 1,1-2,3 kWh/year depending on the input values of power consumption.
  Also the effectiveness of this requirement should be also considered in respect with the proposed new energy efficiency algorithm considering the annual energy consumption including low power modes.

Table 7.52: Estimated annual energy savings in low power modes for washing machines and dishwashers when a hard switch is used 50% of the time

	min/h	W	Wh	kWh	%
measurement tolerance (energy consumption)					10
on-mode energy consumption per cycle			0,998		
on-mode energy consumption per year				219,6	
minutes in on mode	19.800				
minutes in a year	525.600				
hours in low power modes (no power management)	8.430				
hours in left-on-mode (3 hours per cycle)	660				
power consumption in left-on mode		3,3			
hours in off mode	7.770				
power consumption in off-mode		2			
percentage of time the machine is "hard switched"					50
annual energy consumption in low power modes (no power management)			22.340	22,3	
annual saved energy consumption in low power modes (no power management)				**11,2**	
annual energy consumption in low power modes (with power management)			17.718	17,7	
annual saved energy consumption in low power modes (with power management)				**8,9**	

7.6.7 Compliance assessment and verification procedures for wash appliances

7.6.7.1 The possible sources of appliance non compliance

According to a recently pamphlet by Alan Maier, Senior Executive Editor, and published by the US Home Energy Magazine Online[78], several unrelated matters related to compliance with energy efficiency regulations. These incidents illustrate that compliance - or failure to comply - with a regulation is not always objective. Indeed, one could say that there is a spectrum of "compliance." An insidious, new form of non-compliance has recently emerged. Thanks to microprocessor controls, some appliances now recognize when they are being tested and switch into a low-energy mode. According to Consumer Reports, this appears to be the case with a new refrigerator from a large Asian manufacturer, which inexplicably switches-off some operations when the ambient temperature approaches the testing temperature and when doors haven't been opened for a while. These measures cut enough electricity use to qualify the unit for Energy Star endorsement and sales-enhancing utility rebate programs. But it is not alone; other refrigerator manufacturers became so adept at circumventing the test that actual electricity use of refrigerators in a country was typically twice as high as the labels claimed; the government changed the test procedure to make it harder to circumvent. Many appliance manufacturers (and importers) might poised to adopt the same approach. The competent Authorities should be on the alert.
A more subtle form of non-compliance occurs when manufacturers misrepresent the capacity of their products and efficiency, which is described in terms of energy use per unit of capacity, might thus overstated.
Finally, there are cases where the energy-saving claims are partly true for example, under certain conditions. The motor controllers did save electricity when motors were oversized or the voltage delivered was unnecessarily high. Here the problem is agreeing on appropriate test conditions. Reasonable people may disagree on these conditions, so compliance is less clear-cut.

These stories show that compliance is not a simple yes-no decision. It begins with clear regulations. But it must be followed by vigilance, intelligence, and, occasionally, Solomon-like decisions.

7.6.7.2 The verification limits and verification tolerance

In a recently published MTP document[79], it is stated that when tested, an individual cold appliance sample is permitted by the standard to be 15% worse on energy consumption, while the eco-labelling directive, which adopts the same EN 153 standard as the energy labelling directive in fact does not permit any 15% tolerance.

This is the most common misunderstanding that has originated the never ending discussion about a (too large) permitted tolerance in the EU legislation. In fact, a general confusion has always been made between the compliance of the declared values of a model with the regulation(s) criteria (in general threshold values or lines) and the compliance assessment in the verification procedure.

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[78] Source: Alan Meier, http://www.homeenergy.org/blog.php?id=18&blog_title=January/February_2007_Editorial-Compliance:_Following_the_Letter_(and_the_Spirit)_of_the_Law. The document has been adapted to better 'comply' with the spirit of this EuP study by omitting manufacturers and Countries names.
[79] Source: BNC07: Domestic cold appliance EC Energy Label revision, Version 1.5, 05 October 2007, downloadable from http://www.mtprog.org .

A clarification is needed. The EU legislation about household appliances (both energy labelling schemes and efficiency requirements, where existing) **does not permit any declaration tolerance; i.e. all units of a same model shall comply with the set criteria**. An example of 'declaration tolerance' can be found for example in the Australian standard for cold appliances, which specifies an allowable tolerance of 3% on the measurement of the volume (note that the precise rule depends on the compartment volume).

The EU legislation is more stringent than for example the mentioned Australian regulations, since for cold appliance minimum requirements the latter requires, at 90% confidence, that the mean (of all the units of a same model) does not exceed the requirements level and mean energy.

A different issue is the **verification tolerance** or **verification limit**, that is the maximum permitted variation between the supplier's declared value and the measured value resulting from a test developed in a Laboratory under a verification procedure. This 'verification tolerance or verification limit' should not be interpreted as an allowed tolerance on the original declaration used to support the compliance with a regulation. More in detail:

- a '**verification limit**' (usually larger than a verification tolerance) includes allowances for elements such as production variability, measurement accuracy and uncertainties;
- a '**verification tolerance**' is intended to take care only of the known margin of error or uncertainty in the measurement procedure for a particular test method (no production variability is considered).

Only when Government certified laboratories are used for the compliance assessment both the verification limit and the verification tolerance can be kept at a real minimum (2-3% for the latter, but higher in the specific case of the energy consumption of cold appliances) because the laboratory error is known and under strict control.

Following the above definitions, in the EU legislation a verification limit (which includes production variability) of 15% is assumed on a single sample and a 10% on a sample of 3 units of the same model.

The application of verification limits or verification tolerance means that the models a consumer buys is not necessarily as the declared one, but at a lower extent when a lower verification tolerance is used. The solution proposed by the before mentioned MTP document that, the laboratories' own measurement tolerance aside, a 'zero tolerance' (in our discussion a zero production variability) Energy Label is possible, but the claimed benefit for consumers as the Energy Label scheme that a B-energy consuming appliances would be B-declared is unfortunately unattainable, since there will be always "border line" appliances that will comply with a different (worse) energy efficiency class when tested.

The benefit of adopting a lower verification tolerance is that the difference of between the declared and the measured energy consumption will be at maximum as great as the verification tolerance. But on the other side a lower verification tolerance can be applied only under the condition that the margin of error or uncertainty in the measurement procedure (the reproducibility of the measurement method including the laboratory error) for the testing Laboratories is kept under strict control. This is possible only under if a system of certified Laboratories is put in place.

As far as the claim that the EU eco-label does not permit any 15% tolerance, again a major misunderstanding occurred. The eco-label Decisions related to household appliances describe only the procedure for the declaration of the measured values: the reports of at least three measurements of energy consumption made according to EN 153 and the test guidelines as detailed in CECED's

Operational Code shall be presented; the arithmetic mean of these measurements shall be less or equal to the energy efficiency ecolabel requirement; the value declared on the energy label shall not be lower than this mean value, and the energy efficiency class indicated on the energy label shall correspond to this mean value. In simpler words this means that 3 units of a same models are tested, and the average of the three measured values is declared on the energy label, while at present the energy labelling schemes foreseen that only one unit of a model is tested.

The before mentioned MTP document stated also that "when challenged by the Trading Standards Office, manufacturers will sometime declare a fault on the appliance 'that one is not functioning as designed' or state that model is no longer available". Although a fault of a model may always happen, the misuse of this loop-hole can be avoided by imposing (as already in force in Australia) that the onus is on the manufacturer/importer to provide evidence that a defect capable of affecting the test results does exist; furthermore, it must be demonstrated that the "defect" is peculiar to the test unit alone and not common to other samples of the stock of the appliance. But this has nothing to share with the setting of a larger/stricter verification limits or verification tolerance.

7.6.7.3 The verification error sources

Very little information is generally available on the different factors that impact on the verification process. In addition, the way of explaining the differences in test results may also somehow differ.

According to the latest Australian experience[80], typically, differences in the test results represent the outcome of several different types of factors that can be classified into two general categories: (i) random errors, and (ii) systematic errors:

- **Random Errors**: random errors are the kinds of errors that are caused by natural variations in materials, human factors, fluctuations in power input etc. Such errors may cause measurements of appliance energy consumption or performance to deviate from the true or "design" level. A key feature of random errors is that they are just as likely to be positive as they are to be negative and over many measurements they average out to be zero. The main sources of random error in the verification process are:

  - Production Variability: all production processes are subject to random fluctuations as a result of manufacturing tolerances, variations in input materials, power fluctuations, human factors etc. These variations in the production process may cause different units of the same model to have slightly different average energy consumption or performance levels. This random error describes the differences in the average energy consumption and/or performance values of different units of the same model due to production variability;
  - Performance Variability: in addition, the same individual unit may perform differently on different occasions under test; e.g. a pressure switch may terminate fill volume to a different amount each time, even under identical test conditions. Performance variability is often related to the quality of components used in an appliance but it can also be a reflection of the complexity of the process being tested and of the test assessment (e.g. hand soiling of dishes and the subsequent visual assessment of washing performance of a dishwasher). This type of error affects a test's repeatability.
  - Random Measurement Error: if the performance of a single unit is tested twice, in the same laboratory, and using exactly the same equipment and the same staff, then, in addition to the

[80] Source: NAEEEC, Statistical Basis for the Determination of Check testing Validity Criteria, Report prepared by: Professor R. Bartels, University of Sydney, L. Harrington, Energy Efficient Strategies, original Report: January 1999, updated and corrected: February 2004, downloadable from http://www.energyrating.gov.au.

performance variability, there will be some variability in the test results due to random variations in testing equipment, measurement procedure, human factors, etc. This type of error also affects a test's repeatability.

It is difficult to separate out the error due to performance variability from the random measurement error. Hence the joint impact of these two errors (out of the three identified random errors) is referred to as the '***test repeatability error***'. In conclusion it can be affirmed that the random error is given by the sum of 'production variability' and 'test repeatability error'.

- **Systematic Errors (measurement errors)**: systematic errors are not completely random. These errors may have some pattern in them: for example, a bias in a series of measurements leading to an overstatement (or understatement) of the true measure. Such errors can be caused by differences in measuring equipment, calibration errors, differences in procedures between laboratories etc. For the verification process purposes, the sources of systematic error can be classified into two categories:

  - Calibration Errors: equipment that is not properly calibrated can lead to systematic errors in the measurement of energy consumption or performance levels. Calibration errors cannot be detected in the verification testing procedure since they are confounded with laboratory-specific factors, such as types of metering equipment, different operating procedures etc. For the verification procedure purposes, it can be assumed that calibration errors are adequately addressed by a laboratory Accreditation Procedure. For electrical energy consumption, the calibration error is usually less than 2% (typically 1% or better). However, for products such as washing machines, much of the energy is embodied in hot water drawn into the machine, which means that calibration errors in water temperature measurement and water volume will also contribute to energy errors. For other products such as refrigerators and air conditioners, calibration errors in air temperature measurement can have a large effect on the measurement of energy consumption and performance actually delivered;
  - Inter-Laboratory Variability: performance measurements taken in one laboratory can differ systematically from those taken in another laboratory due to differences in equipment, operating procedures and staff. An estimate of the size of the errors introduced due to inter-laboratory variability can be obtained through a program of Round Robin Tests in which two or more laboratories all carry out tests on the same unit. Estimates of inter-laboratory variability, if established through round robin tests, will include any calibration errors present.

A summary of the different errors occurring during a verification procedure is shown in Figure 7.59.

Only limited information is available on the relative sizes of the errors introduced in the verification measurements due to production variability or test repeatability. More data are available on the combined variability caused by production variability and test repeatability. Table 7.53 summarises some of the available information in relation to the energy consumption of a number of products in the energy labelling program in Australia and New Zealand. These data have been derived from energy labelling applications where 3 different units of the same model are tested in the same laboratory.

A somehow different description on how to express uncertainty in standardisation is presented in Annex A.

Figure 7.59: Possible errors affecting the verification procedure of energy consumption and performance values

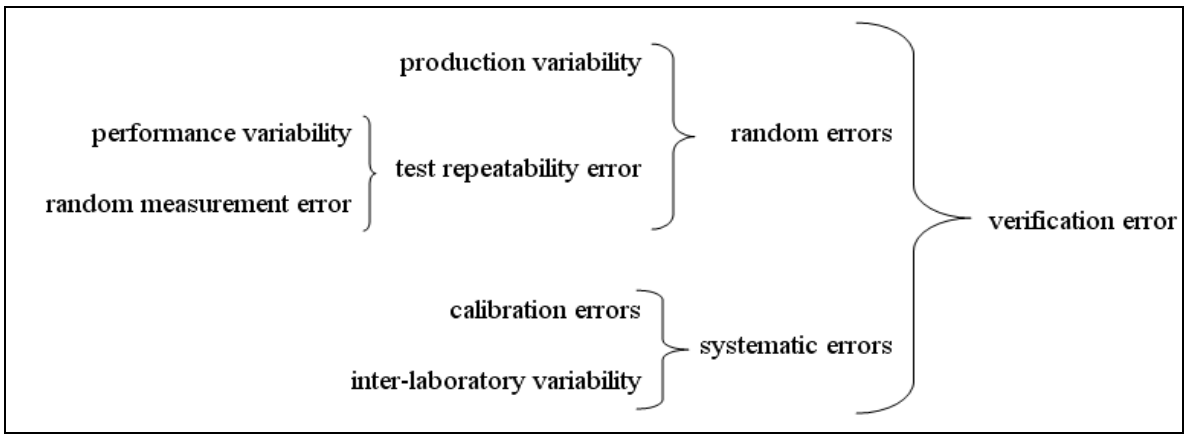


Table 7.53: Variability in the measurement of the energy consumption for selected household appliances in Australia

Product	*Average Standard Deviation*[1]	*Maximum Difference from Average*[2]	*Number of Models*
Refrigerator	25 kWh (3.2%)	125 kWh (18%)	1006
Air conditioning (cooling EER)	0.028 (1.0%)	0.25 (9.2%)	2188
Air conditioning (heating COP)	0.033 (1.1%)	0.39 (12.8%)	1469
Clothes Washer (warm wash)	18.9 kWh (4.5%)	102 kWh (23%)	490
Clothes Washer (cold wash)	3.4 kWh (2.9%)	41 kWh (24%)	232
Clothes Dryer	6.1 kWh (1.5%)	40 kWh (6.9%)	114
Dishwasher (cold connect)	8.7 kWh (2.1%)	51 kWh (9.1%)	369

Notes:
1. sample standard deviation of 3 units is used to calculate this value. The standard deviations are also measured as a percentage of the sample mean. This is also known as the 'coefficient of variation'. Measuring standard deviations as percentages allows one to make comparisons across different models and different appliance types. The numbers shown are the average of these absolute and relative sample standard deviations across the different models for which 3 measurements were available for 3 different units of the same model.
2. The maximum difference is calculated as the absolute difference between the most extreme unit in the sample of three from the mean of the three. In most of these cases (which are generally very unrepresentative) it appears that 3 very different units were tested (or in some cases 1 unit was very different from the other 2). Specific investigations would be required to ascertain why such large variations were produced in these isolated cases. The minimum difference between all 3 units was zero for all products.

7.6.7.4 A possible verification procedure for wash appliance

In Table 7.54 the measurement errors identified in the previous paragraph are listed according to their source. Taking into consideration the pragmatic Australian experience, although the test method followed in the country is sometimes non comparable with the European standards, the measurement variability can be divided into three components:

- variability due to the production, which is in charge of the manufacturers and can be controlled and possibly reduced adopting better manufacturing processes, quality control systems, etc;

- variability of the test method, which can not be modified once the standard in defined, but that might be reduced through the improvement of the test method by the standardisation bodies;

- variability due to the testing Laboratories errors, which can be controlled and kept to the minimum in qualified laboratories.

Table 7.54: Verification errors and relevant sources

error source / error type	MANUFACTURERS	TEST METHOD	TESTING LABORATORIES
production variability	**X**		
performance variability		**X**	
random measurement error		**X**	
calibration error			**X**
inter-laboratory variability			**X**

The present 15% tolerance allowed in the verification procedure for the energy consumption can be therefore broadly divided into three 5% components: 5% due to the manufacturing process, 5% due to the test method and finally another 5% due to the Laboratory errors.

Manufacturers have the full control of the first 5% only, but not on the other two, which represent the reproducibility of the measurement method and the variability of the testing laboratories.

The quality of the production process, which in turn is reflected in a more stable – or less variable – performance characteristics (including the energy consumption) of the produced units of the same model, should be considered part of the overall appliance 'performance' and should be taken into consideration when setting policy measures. The measurement method reproducibility and Laboratory error should be included in the verification tolerance.

Taking into consideration the discussed allocation of verification errors, a double approach is proposed, according to whether the verification involves a qualified or in a non-qualified testing Laboratory: As example of this new approach, for the energy consumption it is proposed that:

- when the verification in done **in a non-qualified laboratory**: the value measured on one randomly selected wash appliance shall not be greater than the rated value by more than 10%. If the result of the test carried out on the first refrigerating appliance is greater than the rated value plus 10% the test shall be carried out on a further three randomly selected refrigerating appliances. The arithmetic mean of the three refrigerating appliances shall be equal to or less than the rated value plus 10%
- when the verification in done **in a qualified laboratory**: the tolerance value can be different (lower) than the value for non-qualified laboratories provided that technical evidence is given on the laboratory ability to reduce such value.

The verification tolerance values for the other measured parameters for both dishwashers (cleaning performance, drying performance and cycle time) and washing machines (washing performance, spin extraction, programme duration, spin speed should be modified following the same approach.

This approach (i) internalises in any case the appliances production variability in the measured energy/water consumption and (ii) sets a different value for the verification tolerance depending if the appliances are tested in qualified or non-qualified laboratories.

No different specific verification scheme is deemed necessary for the verification of the specific requirements compared to the labelling scheme declarations.

It is recommended that the verification tolerances are verified and if necessary modified according to the results of specific Round Robin Test(s) that the Commission should promote and fund either

within the existing EU programmes or through the delivering of mandates to the relevant standardisation bodies.

In addition, a system of qualified laboratories should be put in place by the Commission, taking into account the experience achieved at European and other countries level, such as the Australian one. It is also suggested that a further mandate is given to the standardisation bodies to define the criteria and the procedure for the laboratories qualification since this is a critical issue to assure that the lowest possible verification tolerance is pursued.

For the selection criteria for the verification of appliance models two approaches are possible:
- the 'random type selection': a certain number of appliances are randomly selected from the market and tested. The resulting failure rate gives the almost exact picture of the investigated market, but the resources to be used are maximised;
- the 'maximum failure selection': the selection criteria are set as to maximise the failure rate (i.e. the non complying models). The outcome is not representative of the market situation, but the use of the available resources is optimised.

7.6.8 The Effect of the Proposed Policy Measures on Wash Appliances in 2005

7.6.8.1 Washing machines

a) Policies for the 60°C cotton full load cycle

The effect of the application of Labelling Scheme Option 1, which implies the rescaling of the present scheme based on the specific energy consumption (in kWh/kg) and the reduction of the verification tolerance of 5%. The latter effect is simulated in the worse case scenario by increasing the energy consumption of 5% (i.e. under the hypothesis that for all the models in the technical database the relevant manufacturers had used part of the verification tolerance to declare a better energy efficiency). The major outcome of the analysis of the 2005 models distribution in the energy efficiency classes (Table 7.55) is that the present and the rescaled schemes are practically identical. In the new energy labelling two empty classes are created on top. If specific requirements encompassing the phase out of class B are considered, 532 washing machines models are involved.

When the new approach, based on the calculation of the overall annual energy consumption including the low power modes and the creation of a Energy Efficiency Index system, is applied, the effect on the models of the 2005 CECED technical database is presented in Table 7.56. The three hypotheses about the SEC reference line are presented. When only the overall annual energy consumption is considered, the models disaggregation in the new energy efficiency classes is not dramatically different from the rescaling of the present labelling scheme since about one thousand models are still in class A1 (and more than one hundred in class A2) and no models belonging to the present class A are downgraded. When hypothesis two and three are considered more than two thousand models are classified as A1, but very few models belong to class A2. When the addition of low power modes consumption and the effect of a 5% reduction of the verification tolerance are considered the number of the higher efficiency models decreases, more dramatically under hypothesis three, but few models are downgraded below class A.

The impact on each load capacity is analysed in Tables 7.57-7.59 for the same three hypothesis. Hypothesis one has the strongest impact on high load capacity washing machines, which are less favoured compared to the present labelling system, while hypothesis three has the lowest impact on such machines.

Table 7.55: Effects of the combined proposed policy measures (energy labelling Option 1 + specific requirements) on washing machine models in 2005 CECED technical database (60°C cotton full load cycle)

Labelling scheme 95/12/EC			New labelling scheme		EE class threshold rescaling		Rescaling and 5% verification tolerance reduction	
(class)	(n)	(%)	(class)	(class)	(n)	(%)	(n)	(%)
--	--	--	**A3**	**10**	0	0	0	0
--	--	--	**A2**	**9**	3	0,1	2	0,04
(A+)	1 953	37,6	**A1**	**8**	2 006	38,6	1 951	37,6
A	2 704	52,1	**A**	**7**	2 690	51,8	2 707	52,1
B	323	6,2	**B**	**6**	309	6,0	314	6,0
C	211	4,1	**C**	**5**	183	3,5	94	1,8
D	1	0,0	**D**	**4**	1	0,02	124	2,4
E	0	0	**E**	**3**	0	0	0	0
F	0	0	**F**	**2**	0	0	0	0
G	0	0	**G**	**1**	0	0	0	0
Total	5 192	100	Total		5 192	100	5 192	100

Table 7.56: Effects of the combined proposed policy measures (energy labelling Option 3, using the reference line in hypothesis one, two and three) on washing machine models in 2005 CECED technical database (60°C cotton full load cycle)

New labelling scheme		Hypothesis 1 (4,5-6kg reference line)						Hypothesis 2 (4,5-7 kg reference line)						Hypothesis 3 (4,5-6,5 kg 1997 ref. line)					
EE Classes		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction	
(class)	(class)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
A3	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	**9**	115	2,2	8	0,2	0	0	8	0,2	0	0	0	0	2	0,04	0	0	0	0
A1	**8**	976	18,8	748	14,4	115	2,2	2 104	40,5	722	13,9	117	2,3	2 064	39,8	741	14,3	3	0,1
A	**7**	3 535	68,1	3 362	64,8	3 660	70,5	2 500	48,2	3 431	66,1	3.805	73,3	2 629	50,6	3 902	75,2	3 945	76,0
B	**6**	360	6,9	684	13,2	851	16,4	380	7,3	658	12,7	789	15,2	294	5,7	171	3,3	754	14,5
C	**5**	164	3,2	311	6,0	406	7,8	162	3,1	306	5,9	323	6,2	166	3,2	253	4,9	316	6,1
D	**4**	42	0,8	79	1,5	160	3,1	38	0,7	75	1,4	158	3,0	37	0,7	125	2,4	174	3,4
E	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100

Table 7.57: Effects of the policy measures (energy labelling Option 3, hypothesis one) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
(class)	(class)	**3,0** (n)	**3,5** (n)	**4,0** (n)	**4,5** (n)	**5,0** (n)	**5,5** (n)	**6,0** (n)	**6,5** (n)	**7,0** (n)	**7,5** (n)	**8,0** (n)	**9,0** (n)	(n)	(%)
Annual energy consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**									2				2	0,0
A1	**8**	8	37	34	84	623	70	1 031		154	22	1		2 064	39,8
A	**7**				247	1 670	178	430	2	26	57	13	6	2 629	50,6
B	**6**	9	7	3	82	178	1	10					4	294	5,7
C	**5**		8		67	90	1							166	3,2
D	**4**				1	36								37	0,7
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**	8												8	0,2
A1	**8**		37	34	70	604		1		2				748	14,4
A	**7**	9	7		247	1.668	247	1.030		154				3.362	64,8
B	**6**		8	3	96	36	1	430	2	26	73	9		684	13,2
C	**5**				67	216	1	10			6	5	6	311	6,0
D	**4**				1	73	1						4	79	1,5
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8	37		70									115	2,2
A	**7**		7	34	247	2 269	70	1 031		2				3 660	70,5
B	**6**	9		3	28	24	178	430	2	154	22	1		851	16,4
C	**5**		8		81	206	1	8		26	57	13	6	406	7,8
D	**4**				55	98	1	2					4	160	3,1
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

Table 7.58: Effects of the policy measures (energy labelling Option 3, hypothesis two) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
		3,0	**3,5**	**4,0**	**4,5**	**5,0**	**5,5**	**6,0**	**6,5**	**7,0**	**7,5**	**8,0**	**9,0**		
(class)	(class)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(%)
Annual energy consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**	8												8	0,2
A1	**8**		37	34	317	623	69	1 022		2				2 104	40,5
A	**7**	9	7	3	14	1 670	179	439	2	154	22	1		2 500	48,2
B	**6**		8		83	178	1	8		26	57	13	6	380	7,3
C	**5**				66	90		2					4	162	3,1
D	**4**				1	36	1							38	0,7
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8	37		70	604		1		2				722	13,9
A	**7**		7	34	247	1 668	248	1 050		154	22	1		3 431	66,1
B	**6**	9		3	96	36		410	2	26	57	13	6	658	12,7
C	**5**		8		67	216	1	10					4	306	5,9
D	**4**				1	73	1							75	1,4
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8	37		70					2				117	2,3
A	**7**			34	247	2 269	70	1 031		154				3 805	73,3
B	**6**	9	7	3	28	24	178	430	2	26	73	9		789	15,2
C	**5**		8		81	206	1	10			6	5	6	323	6,2
D	**4**				55	98	1						4	158	3,0
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

Table 7.59: Effects of the policy measures (energy labelling Option 3, hypothesis three) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
(class)	(class)	**3,0** (n)	**3,5** (n)	**4,0** (n)	**4,5** (n)	**5,0** (n)	**5,5** (n)	**6,0** (n)	**6,5** (n)	**7,0** (n)	**7,5** (n)	**8,0** (n)	**9,0** (n)	(n)	(%)
Annual energy consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**									2				2	0,04
A1	**8**	8	37	34	84	623	70	1 031		154	22	1		2 064	39,8
A	**7**				247	1 670	178	430	2	26	57	13	6	2 629	50,6
B	**6**	9	7	3	82	178	1	10					4	294	5,7
C	**5**		8		67	90	1							166	3,2
D	**4**				1	36								37	0,7
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**				70	604	64	1		2				741	14,3
A	**7**	8	37	34	247	1 668	184	1 460	2	180	73	9		3 902	75,2
B	**6**		7	3	96	36		8			6	5	10	171	3,3
C	**5**	9	8		17	216	1	2						253	4,9
D	**4**				51	73	1							125	2,4
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (60°C cotton full load cycle)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**							1		2				3	0,1
A	**7**	8	37	34	317	2 269	70	1 030		154	22	4		3 945	76,0
B	**6**		7		14	24	178	430	2	26	57	10	6	754	14,5
C	**5**	9		3	83	206	1	10					4	316	6,1
D	**4**		8		67	98	1							174	3,4
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

b) Policies for lower washing temperatures and partial load

When the '3+2+2 approach' is selected, the overall effect of the three SEC line hypotheses is shown in Table 7.60. As expected, the outcome is the same as when only the 60°C cotton full load cycle is considered, because the simulation is based on the energy consumption of the 60°C cotton cycle and the low power models consumption has been considered the same for all models.

The effect on each load capacity is analysed in Tables 7.61-7.63 for the three SEC hypotheses. It should be highlighted that when evaluation the energy efficiency class of each model the relevant EEI has not been rounded to the closest integer. Therefore the models classification could be (slightly) modified by the rounding rules, which shall be defined in the implementing measure.

7.6.8.2 Dishwashers

The effect of the combined proposed policy measures (Energy Labelling Option 3 + specific requirements) on dishwasher models in 2005 CECED technical database is presented in Table 7.64. When the low power modes consumption is added and the 5% decrease of the verification tolerance is taken into consideration the 2005 models disaggregation in the new energy efficiency classes is similar with the present labelling scheme for the first 7 classes and three new and empty classes are on top.

7.6.9 The Effect of Other measures

The effect of other measures: early replacement, subsidies and incentives to manufacturers, studied or run in EU and non-European countries are briefly summarised to evaluate the possible benefits for a EU-wide application within the eco-design framework.

7.6.9.1 Early replacement

It has been proved that replacement of old appliances with new efficient ones would represent a good answer to the efforts of the EU towards reducing CO_2 emissions. Therefore, CECED invites authorities to set up policies encouraging earlier and better replacement of our appliances, to promote the penetration of existing energy efficiency appliances.

Today's products have very low running costs compared to old generation ones, and consumers could make significant saving by replacing a ten year old appliance with a state-of-the-art one. Yet, despite this and despite our efforts as an industry to promote this message, the transformation is not taking place, and consumers are not accelerating the replacement of the old products. Some 188 million obsolete and energy inefficient appliances are still used in European households. 22 millions tonnes of CO_2 emissions could be avoided by replacing them with new efficient products. Therefore, there is need that governments push for the early replacement of inefficient appliances and educate consumer to buy only most efficient ones. Initiatives in this direction can provide more significant results than chasing the residual energy efficiency improvement.

In 2005 the German Öko-Institut analysed the environmental and economic impact of the accelerated replacement of domestic appliances. The goal of the study, commissioned by CECED was to compare the impact of the substitution of installed appliances of different age with the purchase (and use) of new models on the market in 2005, considering both environmental and

Table 7.60: Effects of the combined proposed policy measures (energy labelling Option 3, using the reference line in hypothesis one, two and three) on washing machine models in 2005 CECED technical database (3+2+2 approach)

New labelling scheme		Hypothesis 1 (4,5-6kg reference line)						Hypothesis 2 (4,5-7 kg reference line)						Hypothesis 3 (4,5-6,5 kg 1997 ref. line)					
EE Classes		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction		Annual energy consumption		+ low power modes consumption		& 5% verification tolerance reduction	
(class)	(class)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
A3	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	**9**	115	2,2	0	0	0	0	8	0,15	0	0	0	0	2	0,04	0	0	0	0
A1	**8**	976	18,8	115	2,2	8	0,15	2 104	40,5	117	2,3	8	0,15	2 064	39,8	3	0,06	2	0,04
A	**7**	3 535	68,1	3 660	70,5	1 083	20,9	2 500	48,2	3 805	73,3	2 104	40,5	2 629	50,6	4 142	79,8	2 031	39,1
B	**6**	360	6,9	919	17,7	3 512	67,6	380	7,3	789	15,2	2 481	47,8	294	5,7	559	10,8	2 654	51,1
C	**5**	164	3,2	342	6,6	382	7,4	162	3,1	323	6,2	398	7,7	166	3,2	314	6,0	293	5,6
D	**4**	42	0,81	156	3,0	200	3,9	38	0,73	158	3,0	195	3,8	37	0,71	174	3,4	206	4,0
E	**3**	0	0	0	0	7	0,13	0	0	0	0	6	0,12	0	0	0	0	6	0,12
F	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100	5 192	100

Table 7.61: Effects of the policy measures (energy labelling Option 3, hypothesis one) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
(class)	(class)	**3,0** (n)	**3,5** (n)	**4,0** (n)	**4,5** (n)	**5,0** (n)	**5,5** (n)	**6,0** (n)	**6,5** (n)	**7,0** (n)	**7,5** (n)	**8,0** (n)	**9,0** (n)	(n)	(%)
Annual energy consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**	8	37		70									115	2,2
A1	**8**			34	247	623	69	1		2				976	18,8
A	**7**	9	7	3	28	1 670	179	1 460	2	154	22	1		3 535	68,1
B	**6**		8		69	178	1	8		26	57	13		360	6,9
C	**5**				66	90		2					6	164	3,2
D	**4**				1	36	1						4	42	0,81
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8	37		70									115	2,2
A	**7**		7	34	247	2 269	70	1.031		2				3 660	70,5
B	**6**	9		3	96	24	178	430	2	154	22	1		919	17,7
C	**5**		8		17	206	1	8		26	57	13	6	342	6,6
D	**4**				51	98	1	2					4	156	3,0
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8												8	0,15
A	**7**		37	34	317	623	69	1		2				1 083	20,9
B	**6**	9	7	3	14	1 661	179	1 460	2	154	22	1		3 512	67,6
C	**5**		8		83	187		8		26	57	13		382	7,4
D	**4**				66	121	1	2					10	200	3,9
E	**3**				1	5	1							7	0,13
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

Table 7.62: Effects of the policy measures (energy labelling Option 3, hypothesis two) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
(class)	(class)	**3,0** (n)	**3,5** (n)	**4,0** (n)	**4,5** (n)	**5,0** (n)	**5,5** (n)	**6,0** (n)	**6,5** (n)	**7,0** (n)	**7,5** (n)	**8,0** (n)	**9,0** (n)	(n)	(%)
Annual energy consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**	8												8	0,15
A1	**8**		37	34	317	623	69	1 022		2				2 104	40,5
A	**7**	9	7	3	14	1 670	179	439	2	154	22	1		2 500	48,2
B	**6**		8		83	178	1	8		26	57	13	6	380	7,3
C	**5**				66	90		2					4	162	3,1
D	**4**				1	36	1							38	0,73
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8	37		70					2				117	2,3
A	**7**			34	247	2 269	70	1 031		154				3 805	73,3
B	**6**	9	7	3	28	24	178	430	2	26	73	9		789	15,2
C	**5**		8		81	206	1	10			6	5	6	323	6,2
D	**4**				55	98	1						4	158	3,0
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**	8												8	0,15
A	**7**		37	34	317	623	69	1 022		2				2 104	40,5
B	**6**		7	2	14	1 661	179	439	2	154	22	1		2 481	47,8
C	**5**	9	8	1	82	187	1	8		26	57	13	6	398	7,7
D	**4**				67	121	1	2					4	195	3,8
E	**3**				1	5								6	0,12
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

Table 7.63: Effects of the policy measures (energy labelling Option 3, hypothesis three) by load capacity on washing machine models in 2005 CECED technical database

Labelling scheme EE Classes		Load capacity (kg)												Total models	
(class)	(class)	**3,0** (n)	**3,5** (n)	**4,0** (n)	**4,5** (n)	**5,0** (n)	**5,5** (n)	**6,0** (n)	**6,5** (n)	**7,0** (n)	**7,5** (n)	**8,0** (n)	**9,0** (n)	(n)	(%)
Annual energy consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**									2				2	0,04
A1	**8**	8	37	34	84	623	70	1 031		154	22	1		2 064	39,8
A	**7**				247	1 670	178	430	2	26	57	13	6	2 629	50,6
B	**6**	9	7	3	82	178	1	10					4	294	5,7
C	**5**		8		67	90	1							166	3,2
D	**4**				1	36								37	0,71
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**							1		2				3	0,06
A	**7**	8	37	34	317	2 269	240	1 050	2	154	22	9		4 142	79,8
B	**6**		7	2	14	24	8	410		26	57	5	6	559	10,8
C	**5**	9		1	83	206	1	10					4	314	6,0
D	**4**		8		67	98	1							174	3,4
E	**3**													0	0
F	**2**													0	0
G	**1**													0	0
Annual energy consumption + low power modes consumption & 5% verification tolerance reduction (3+2+2 approach)															
A3	**10**													0	0
A2	**9**													0	0
A1	**8**									2				2	0,04
A	**7**	8	37	1	84	623	70	1 031		154	22	1		2 031	39,1
B	**6**			33	247	1 662	178	430	2	26	57	13	6	2 654	51,1
C	**5**		7	3	82	186	1	10					4	293	5,6
D	**4**	9	8		67	121	1							206	4,0
E	**3**				1	5								6	0,12
F	**2**													0	0
G	**1**													0	0
Total		**17**	**52**	**37**	**481**	**2 597**	**250**	**1 471**	**2**	**182**	**79**	**14**	**10**	**5 192**	**100**

Table 7.64: Effects of the combined proposed policy measures (energy labelling Option 3 + specific requirements) on dishwasher models in 2005 CECED technical database

Energy efficiency classes		Dishwasher scenarios																	
		Annual energy consumption						+ low power modes consumption						& 5% verification tolerance reduction					
		all dishwashers		≤9ps		≥10ps		all dishwashers		≤9ps		≥10ps		all dishwashers		≤9ps		≥10ps	
(class)	(class)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
A3	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2	**9**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1	**8**	489	11,3	437	73,1	52	1,4	0	0	0	0	0	0	0	0	0	0	0	0
A	**7**	3 433	79,1	76	12,7	3.357	89,7	3 898	89,8	489	81,8	3 409	91,1	3 886	89,5	477	79,8	3 409	91,1
B	**6**	314	7,2	46	7,7	268	7,2	331	7,6	68	11,4	263	7,0	65	1,5	36	6,0	29	0,8
C	**5**	106	2,4	39	6,5	67	1,8	67	1,5	2	0,3	65	1,7	285	6,6	46	7,7	239	6,4
D	**4**	0	0	0	0	0	0	46	1,1	39	6,5	7	0,2	106	2,4	39	6,5	67	1,8
E	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		4 342	100	598	100	3 744	100	4 342	100	598	100	3 744	100	4 342	100	598	100	3 744	100

economic aspects[81]. The goal of the study was to consider whether it makes sense to further use an old washing machine or is it better to buy a new one.

According to GfK the average useful life of installed washing machine in Germany was 12,9 years in 2003. More than 16% of the washing machines in stock were older than 13 years and even washing machines older than 25 years can be found in households. The age distribution of the washing machines in EU9 and selected countries in 2003 is presented in Table 7.65[82].

Table 7.65: Age of the washing machines in Europe and selected countries in 2003

Countries	after 2002 (%)	2002 (%)	1998-2001 (%)	1993-1997 (%)	1992 and older (%)
EU9	6	8	34	27	25
Germany	2	33	21	16	28
Great Britain	6	11	43	24	16
France	8	9	36	26	21
Italy	1	7	31	28	33
Spain	6	10	33	26	25
The Netherlands	5	8	36	29	22
Sweden	7	7	29	25	32
Austria	4	8	30	28	30

This questions had been tackled in a very simplified way in a previous study developed by the same institute, to get a first impression on the issue of accelerated replacement. At that time it was assumed that the new washing machine was bought in 2004 and thus all environmental impacts through production and the acquisition costs occur at once in 2004. For all washing machines (installed and the new models) it was assumed that they would not break within the next ten years (the time period which was regarded). Thus it was investigated, if and when the environmental impacts through production and the purchasing price of a new washing machine are paid back through the lower energy and water consumptions. The consumption values from 1985 to 1991 were taken from Stiftung Warentest (average figures for the 90°C cotton program) and the values from 1996 were taken from CECED database (average figures for the 60°C cotton program). The values for 1995 were interpolated, the values for the other washing programs were calculated according to a fix ratio. No modification of the initial performance due machine ageing or system changes (such as detergents formulation) was considered. The use of driers was included in the calculations, assuming that driers were used during the whole year for 80% of the annual laundry. The influence of inclusion/exclusion of drier was then analysed as sensitivity (use for only half percent of the year or no use at all).

In the second study, some new elements were added: the costs were discounted, failure rates of installed washing machines were considered through the environmental impacts and costs for repairs or through substitution of older washing machines within the regarded time period.

[81] Source: I. Rüdenauer, C. Gensch,, Eco-Efficiency Analysis of Washing machines. Refinement of Task 4: Further use versus substitution of washing machines in stock. Final report commissioned by: European Committee of Domestic Equipment Manufacturers (CECED), Öko-Institut e.V., Freiburg, 18 March 2005.

[82] Source: Per un uso razionale dell'energia, Apparecchi Elettrodomestici, February 2006, pp. 94-96

Although the authors clearly stated that the study results are valid under the assumptions made and only for Germany, due to the different parameters that strongly depend on the country or climatic conditions such as:

- use of electric tumble driers: the use of driers might not be necessary in countries with other climatic conditions
- electricity supply: the primary energy sources are different in most countries
- consumer behaviour, washing habits,

some useful general indications can be drawn. The answer to the previous question depends on the individual evaluation of the time span, which is acceptable for the environmental and economic payback time. In the study a 5 period is considered acceptable to justify the substitution for both the environmental and the economic payback.

In practice the decision to substitute the washing machine is probably determined by other reasons like the break-down of the existing machine, which would make a repair necessary, or the move to another accommodation. Against the defined payback period of 5 years the following conclusion can be drawn:

- considering the Cumulated Energy Demand, the substitution of washing machines of the years 1985, 1990 and 1995 with a new model is justified. The payback time is approximately 2, 3 and 5 years respectively;
- considering the Global Warming Potential, only the substitution of washing machines of 1985 and 1990 with a new model is justified. The payback time is approximately 3 and 5 years respectively. Washing machines of 1995 have a payback time of approximately 8 years;
- considering the total environmental burden (expressed in environmental points calculated with EcoGrade), only the substitution of washing machines of 1985 is justified, with a payback period of approximately 4 years. Washing machines of 1995 and 2000 present a payback time longer than 10 years;
- considering the economic aspect, for all of the considered washing machines the payback time is longer than the accepted 5 years. Even in case of the 19-year-old washing machine it takes up to 6 years before the savings equal the additional purchasing price.

7.6.9.2 Subsidies

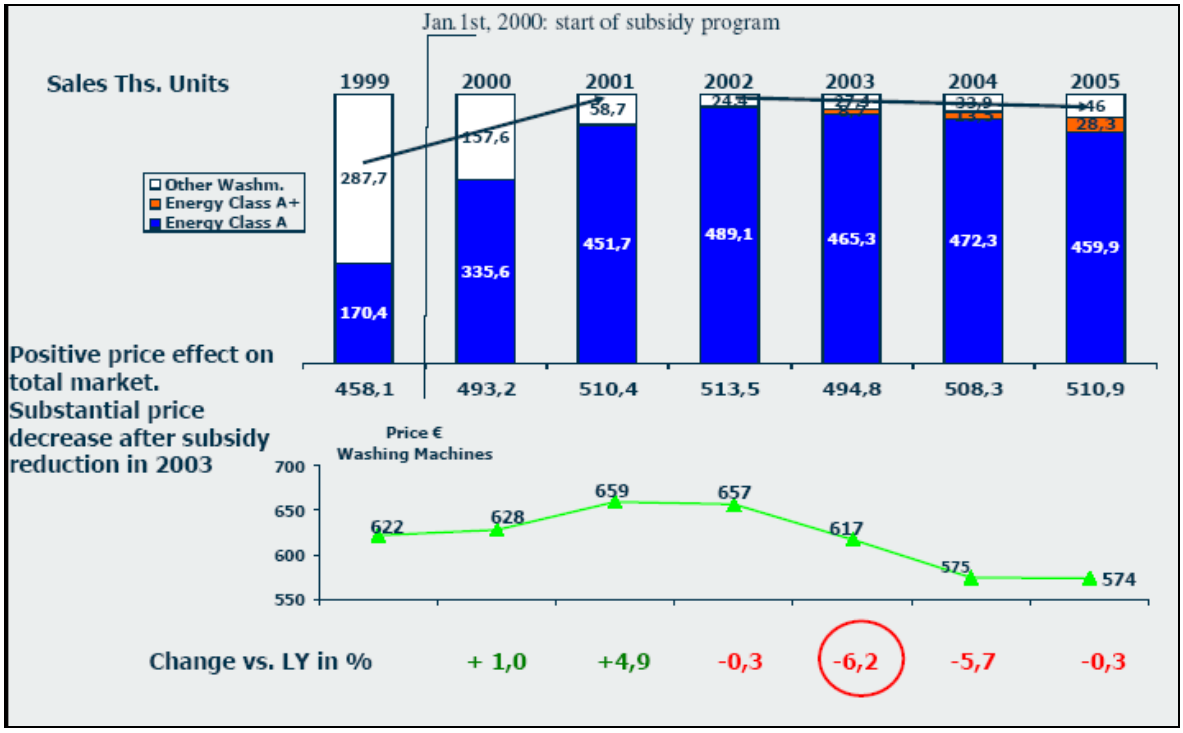
Economic incentives in the form of rebate schemes or tax deduction have been enforced in The Netherlands[83,84]. From the beginning the energy label in the Netherlands had a strong relation with the following energy policy instruments: the MAP (Environmental Action Plan from 1991 to 2000) and the EPR (Energy Premium Regulation from 2000 to 2003). Only a MAP or EPR subsidy could be received when the appliance had an A class label. The EPR started in 2000 and aimed to stimulate households to take energy saving measures and to buy energy efficient appliances. Until October 2003, consumers could get an EPR subsidy for appliances with an energy efficiency class A. For some appliances additional conditions where set to receive the subsidy.

[83] Source: Maxim Luttmer, Evaluation of Labelling of Appliances in the Netherlands, Case Study executed within the framework of the AID-EE project, FINAL DRAFT, contract number EIE-2003-114, April 2006.
[84] Source: "Evaluation of the Netherlands energy efficiency subsidy scheme EPR", Tax Office/Centre for process- and product development, 21 June 2002. English summary by VHK, René Kemna, 8 October 2002. Original title "Rapportage van Onderzoeksbevindingen in Het Kader van de Evaluatie van de Energiepremieregeling, Belastingdienst/Centrum voor proces- en productont-wikkeling, 21 juni 2002

The introduction of the EPR has led to an enormous growth of the supply of A labelled appliances. The market share of A class washing machines grew from 40 to 71% over the 1999-2000 period and 26% to 55% for refrigerators. This increase is most likely due to the EPR and has led to a situation where retailers very often advice their customers to buy an A class appliance as the best on offer.

The effect of the subsidy scheme for washing machines has been specifically studied by GfK[85]. The EPR scheme positively affected the increase the share of the higher efficiency machines and an increase of the average machine price (see the increase in the sales and price of the A and A+ washing machines in Figure 7.60) in the period 1999-2002, followed by a decrease in 2003 when the subsidy ended.

Figure 7.60: The effect of the Dutch subsidy scheme for washing machines in 1999-2005

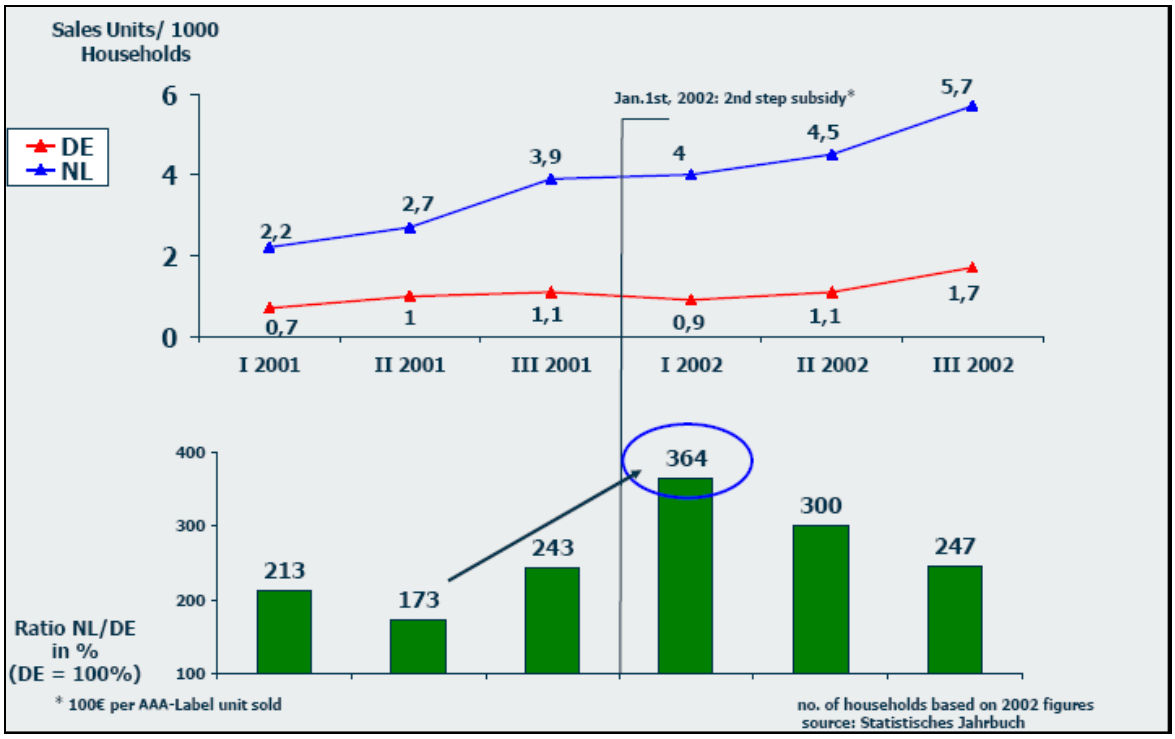


In Figure 7.61, a comparison between the Dutch and the German market for washing machines in 2001 and 2002 is presented, where the effect of the subsidy can be appreciated from the difference in the units sold per 1000 households in the two countries.

Savings on CO_2 emissions were calculated for each EPR-item, using reference situations proposed by the Energie Onderzoek Centrum Nederland (ECN). The total calculated emission saving over 2000 and 2001 amounted to 210 333 ton (the total CO_2 saving over the lifetime of the appliances that were bought with an EPR-subsidy was not calculated), due to insulation-measures 30%, glazing 18%, PV systems 18% and condensing CH boilers 15%. Refrigerators/freezers plus washing machines contributed for 15%, although they took up 46% of funds. The savings did not lead to a general decrease of residential energy consumption: between 1999 and 2000 the average electricity consumption per household rose from 3 165 kWh to 3 197 kWh.

[85] Source: Source: Friedemann Stoeckle, Trends of major domestic appliances sales in the various phases of energy efficiency legislation in Europe, EEDAL 06, London, June 2006.

Figure 7.61: Comparison between the Dutch and the German market for washing machines in 2001 and 2002



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A further example of subsidy scheme comes from, UK. In the UK the more efficient white goods products - cold appliances, washing machines and dishwashers - have been subsidised by power supply firms which are required to promote energy efficient products to consumers by the Energy Efficiency Commitment (EEC) as part of a range of activities to reduce energy consumption. The promotion of products has taken several forms, including subsidising products at point of sale to consumers and replacing old products in some low income homes. The scheme is administered by Ofgem[86], but is a Defra[87] initiative. The EEC scheme has run in two phases - 2002 to 2005 and 2005 to 2008. In 2008 it will be replaced by the Carbon Emissions Reduction Target, but it likely to continue to promote some white goods.

7.6.9.3 Tax incentives to manufacturers

Direct manufacturer subsidies to cover the incremental costs of producing more-efficient appliances have not been tried in Europe to date, but they are implemented in the USA (see Task 1).

Were it possible to introduce a similar tax subsidy in the EU, it could produce substantial positive

[86] For information see: http://www.ofgem.gov.uk/Sustainability/Environmnt/EnergyEff/Pages/EnergyEff.aspx .
[87] For information see: http://www.defra.gov.uk/environment/climatechange/uk/household/eec/index.htm

improvements in the average efficiency of new appliances and far higher efficiency levels could reasonably be requested without any fear of serious negative impacts for industry or consumers. The existence of a mark-up factor between manufacturing cost and final price suggests it is more cost-effective to deliver subsidies directly to manufacturers (assemblers and component suppliers alike) than to deliver them in the form of rebates; however, there are some complications:

- the legality of direct tax credits has to be established as they contravene state aid regulations. Unfortunately the recent guidelines on state aid for the environment makes it clear that investments for products (as opposed to processes) that bring about energy and environmental benefits in their use, are still not included in state aid[88]. This rules out manufacturing tax credit for the time being;
- production of wash appliances in the EU occurs mainly in some countries and yet the products are consumed throughout the EU and beyond. Unless the main producer Member States were to offer unilateral subsidies for the production of higher-efficiency products, an agreement between net producer and net importer Member States may be needed regarding an equitable funding mechanism. The benefits of production tax grants, which may include price reductions or increased marketing go to all the consumer Member States; however, any increase in profits would come home to the producing companies in the producer Member States.

A recent study promoted by CECED addressed the issue[89], but for a different product - cold appliances - although the validity of the overall study outcome can be extended to major household appliances. This study showed how it was necessary to consider all of the three major players involved: producers, consumers and Member State governments in analyzing public incentive policy. The situation examined is that of a consumer who decides to purchase an energy efficiency class A++ refrigerator-freezer instead of a class A model as the result of the marketing campaign associated with production tax credits. In order to capture the substitution effects, a dual production facility (for both class A++ and class A production) is modelled using the E-GRIM method, utilized in several studies for CECED and the European Commission.

Compared to the business as usual base case, the production tax credit resulted in increased discounted cash flows for the manufacturer, zero or neutral cash flows for the government and positive discounted cash flows for the consumer. Surprisingly, for the government, even including the loss in electricity taxes due to energy savings, the cost of the tax credits were almost fully compensated by increased value added taxes and increased corporate income taxes, due the production shift to the more costly and profitable class A++ model. Thus, the production tax credit can result in essentially positive cash flows for all three major stakeholders.

A comparison was made with the traditional policy of rebate. Under assumptions quite favourable to rebates, it was found that government cash flows are significantly negative and consumer benefits disproportionately high, due to the fact that rebate schemes cannot identify and eliminate free riders, those who would have purchased in any case the higher efficiency model.

In general production tax credits are more cost effective for governments with respect to rebates and lower value added taxes. The production tax credits are based upon tax credits for *only those units produced above an established historic level of production and sales*, which is the level associated with those that would have purchased the improved model anyway. Thus it eliminates free riders,

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[88] Source: "State aid: guidelines on state aid for the environment– frequently asked questions", Europe Press Releases, MEMO/08/31, 23/01/2008.

[89] Also see, "New Policy Instruments for Energy Efficient Home Appliances In Europe: Production Tax Credits", 9th IAEE European Energy Conference: Energy Markets and Sustainability in a Larger Europe, June 12, 2007, Florence, Italy

which is very important for promoting a product that already has an initial market share. Also if the government is not successful in the incentive policy it pays nothing. Instead in the rebate scheme, it pays everyone even though the historic sales may not have been reached.

The second reason tax grants can be more effective is that if the grant is used to lower prices at the production stage this has a greater impact on retail prices because of the high distributor/retailer mark-up, typical of the household goods sector. One hundred Euro less in terms of production prices implies two to three hundred Euro less at consumer prices.

The entire program of Energy Using Products is hindered if the EU financial policy can only address energy process improvement. Other major trading nations such as the United States do not suffer such limitations.

7.7 SUBTASK 7.7: EU POLICY SCENARIOS AND TARGETS

An attempt to model the policy measures (a mix of specific requirements and a revised energy labelling scheme) described in Subtask 7.6 is here developed, aimed at evaluating the overall energy impact at EU level[90]. To this end, the analysis of the possible market penetration trends of the energy efficiency classes in the Business as Usual (BaU) scenario developed in Subtask 7.3 is used as reference. The new energy efficiency classes hypothesised for the revised labelling scheme are evaluated and the resulting energy efficiency potential when compared to the BaU scenario are discussed.

7.7.1 Summary of the Policy Scenarios

In Subtask 7.6 a comprehensive policy measures portfolio has been discussed and, among the different alternatives, a new labelling scheme to substitute and improve the existing one has been suggested and analysed. Moreover possible complementary policy measures addressing resource consumption at washing temperature different from 60°C has been presented, taking into account the constraints deriving from an insufficient standardisation. Finally a proposal to introduce the standby and low power mode consumption in the formulation of the new energy policies has been brought forward.

In the mentioned revised labelling scheme, the new energy efficiency classes could be named either through letters (from G to A3) or numbers (from 1 to 10). Just for sake of a better comparison with the current situation, energy efficiency classes will be indicated only with letters in the followings. This should not be interpreted as preference or commitment towards this specific option. The final layout of a possible revised labelling scheme will be defined by the Regulatory Committee managing the EU energy labelling scheme.

7.7.1.1 Washing machines

For washing machines, the Energy Efficiency Indexes and the average energy consumption values defined for the revised labelling scheme presented in Table 7.45 are considered. The evolution of the market penetration of the new energy efficiency classes of the Revised Labelling scheme Scenario is shown in Table 7.66 and Figure 7.62. In the upper rows of Table 7.66 the new

[90] In this modelling exercise the absorption refrigerators are not taken into account.

hypothesises energy efficiency classes are presented, while in the lower part of the Table the corresponding Energy Efficiency Index and the average energy consumption per kg, per cycle and year for each energy efficiency class are given. As in the BaU also in this scenario the average annual energy consumption includes the standby consumption, hypothesised in 11,8 kWh/year. It is worth noting that in general the standby consumption accounts for about 6% of washing machines average annual energy consumption for laundry washing.

Table 7.66: Energy efficiency class trend in the Revised Labelling scheme Scenario for washing machines

New labelling classes	A3	A2	A1	A	B	C	Tot.
Year	(%)	(%)	(%)	(%)	(%)	(%)	(%)
2005	--	--	40	51	6	4	100
2009	--	10	65	25	0	0	100
2014	1	25	69	5	0	0	100
2019	10	65	25	0	0	0	100
2025	20	70	10	0	0	0	100
2030	40	58	10	0	0	0	100
EEI	<45	<52	<59	<68	<77	<87	--
Energy consumption (kWh/kg)	0,14	0,16	0,17	0,19	0,23	0,26	
Energy consumption (kWh/cycle)	0,75	0,86	0,91	1,02	1,21	1,40	
Energy consumption (kWh/y)	164	190	201	224	265	307	
Energy consumption including stand-by (kWh/y)	176	202	213	235	277	319	

Figure 7.62: Energy efficiency class trend in the Revised Labelling scheme Scenario for washing machines

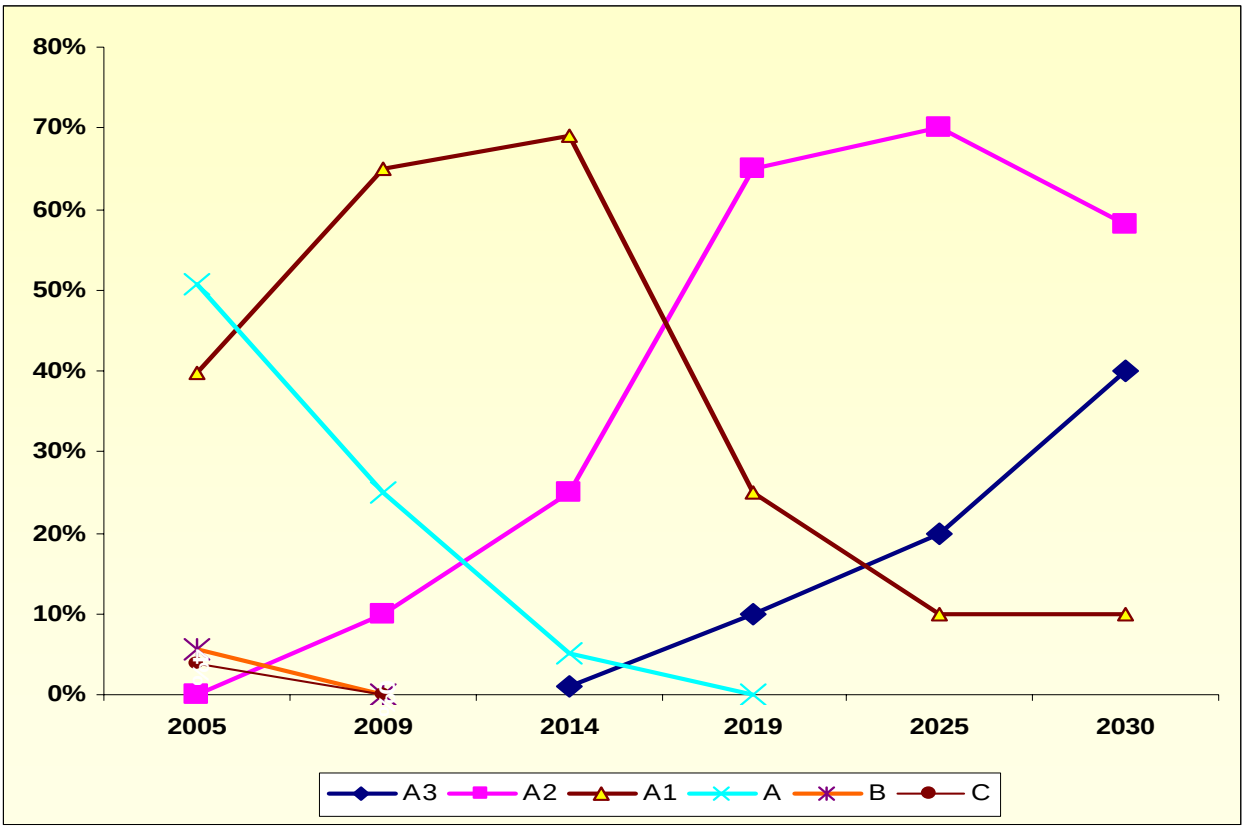


Table 7.67 and Figure 7.63 show the stock energy consumption trends for EU25, EU15 and EU10 countries in this Scenario. The shape of the energy consumption curves is very similar than in the BaU Scenario (see Subtask 7.3) even if here the introduction on the market of the more energy efficient models seems to better counterbalance the energy consumption increase due to the raise of the washing machines stock. This effect is better highlighted in Table 7.68 and Figure 7.64, where it is shown the unitary consumption. In this case the slope corresponding to the years 2005-2030 decreases more rapidly than that of the BaU scenario.

Table 7.69 shows the comparison of the energy consumption trend under the Revised Labelling scheme Scenario and under the hypothesis the washing cycles are carried out at lower temperature and partial load, considering a series of 7 test runs: 3 runs at 60°C plus 2 runs at 60°C and partial load plus other 2 runs at 40°C and partial load (with a reduced detergent dosage). It is worth noting in this case the significant savings achieved at lower temperature (and partial load) washing.

Table 7.67: Stock energy consumption for washing machines under the Revised Labelling scheme Scenario

Year	**Stock energy consumption** (GWh)		
	EU25	EU15	EU10
1990	52 092	46 527	5 565
1995	54 857	48 368	6 489
2000	52 400	45 465	6 935
2005	47 704	40 553	7 151
2009	45 283	38 283	7 000
2014	43 695	37 019	6 676
2019	43 121	36 724	6 397
2025	43 152	36 947	6 205
2030	43 692	37 548	6 145

Figure 7.63: Stock energy consumption for washing machines under the Revised Labelling scheme Scenario

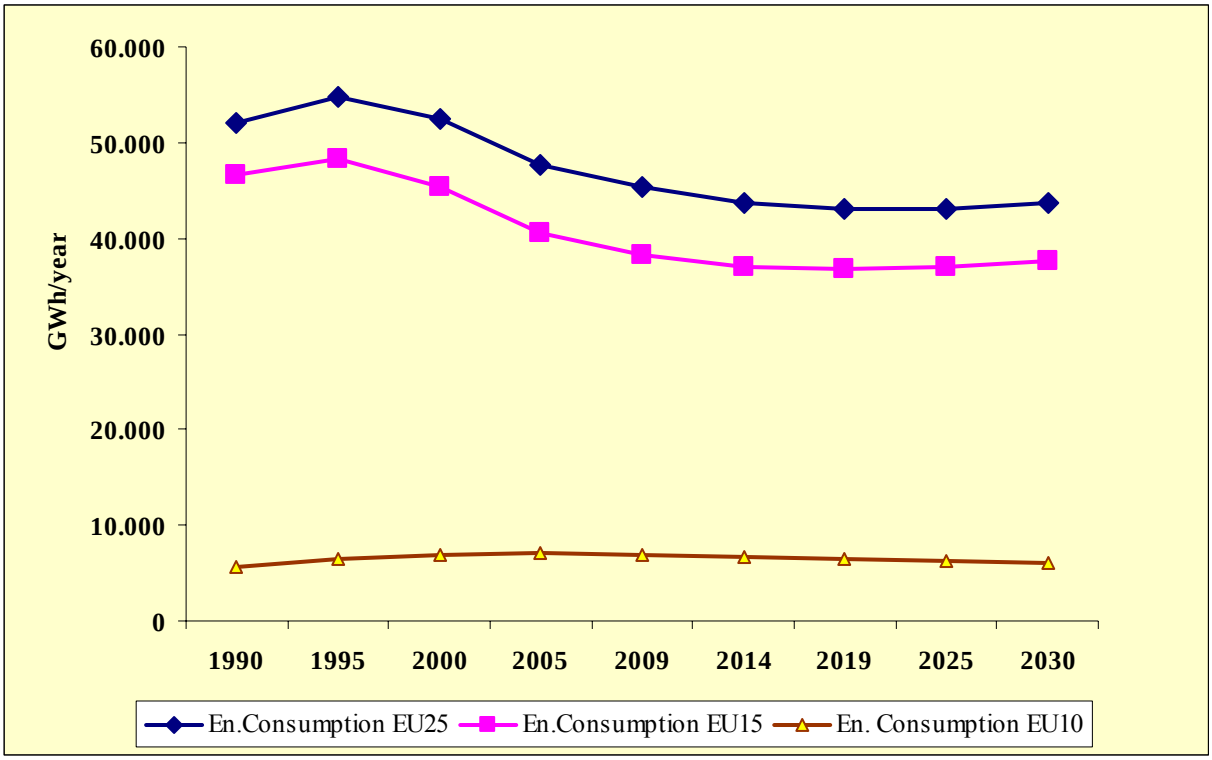


Table 7.68: Average unitary annual energy consumption for washing machines under the Revised Labelling scheme Scenario

Year	**Average annual energy consumption** (kWh/year unit)		
	EU 25	EU 15	EU 10
2005	285	283	296
2009	255	253	266
2014	232	231	240
2019	219	218	224
2025	207	207	210
2030	201	201	203

Figure 7.64: Average unitary annual energy consumption for washing machines under the Revised Labelling scheme Scenarios

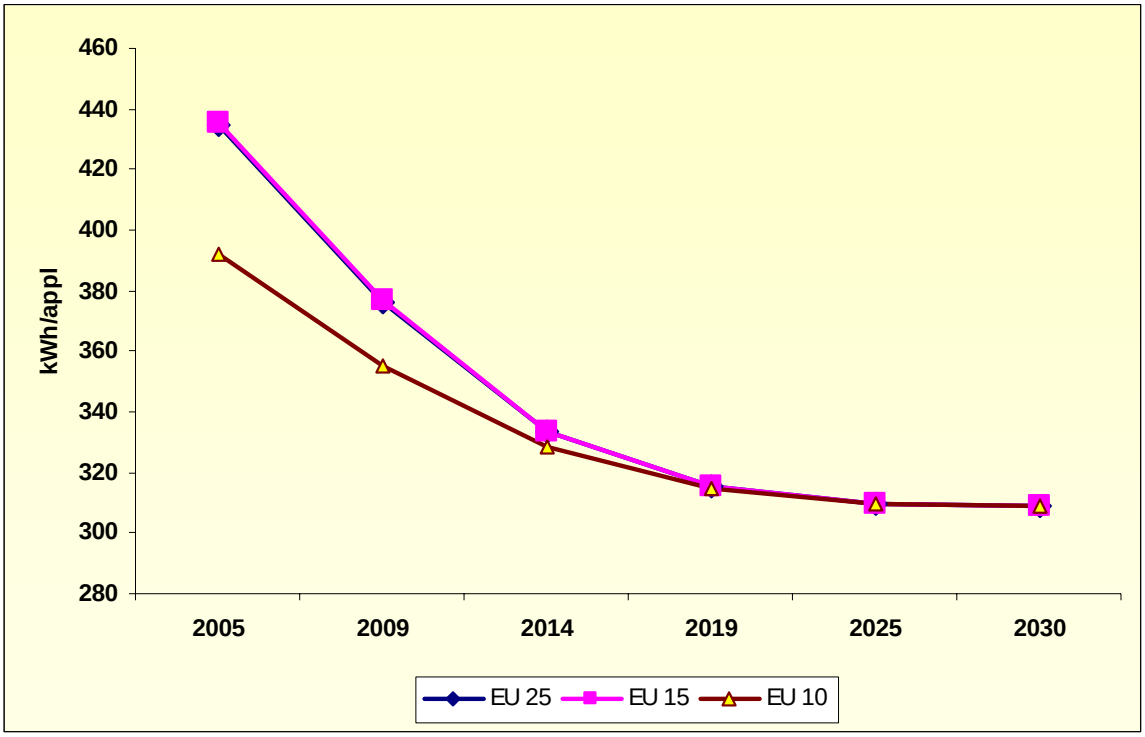


Table 7.69: Energy consumption for washing machines under the Revised Labelling scheme Scenario and the low temperature/partial load conditions for EU25

Year	**Stock energy consumption** (GWh)		
	Revised Labelling Scenario	Low temperature/partial load	Difference
2005	47 704	47 241	463
2009	45 283	42 842	2 441
2014	43 695	39 067	4 628
2019	43 121	37 143	5 978
2025	43 152	36 767	6 385
2030	43 692	37 265	6 428

7.7.1.2 Dishwashers

As in the case of washing machines, also for dishwashers the market penetration trend and the corresponding impact on the energy consumption have been calculated for the Revised Labelling scheme Scenario.

The market penetration rates of the new energy efficiency classes are shown in Table 7.70 and Figure 7.65. In the upper rows of the Table, the new classes are illustrated along with the corresponding Energy Efficiency Indexes. As in the BaU Scenario the average annual energy consumption includes the standby consumption, hypothesised to be 12,4 kWh/year. In general, also for dishwashers, the standby consumption accounts for about 4% of the annual energy consumption for dish washing.

Table 7.70: Energy efficiency class trend in the Revised Labelling scheme Scenario for dishwashers

New labelling classes	**A3**	**A2**	**A1**	**A**	**B**	**C**	Tot.
Year	(%)	(%)	(%)	(%)	(%)	(%)	(%)
2005	--	--	11	79	7	2	100
2009	--	15	70	15	0	0	100
2014	1	39	55	5	0	0	100
2019	3	46	50	1	0	0	100
2025	6	69	25	0	0	0	100
2030	15	80	5	0	0	0	100
EEI	<50	<56	<63	<71	<80	<90	--
Energy consumption (kWh/cycle)	0,83	0,93	1,04	1,17	1,32	1,49	--
Energy consumption (kWh/y)	231	259	292	329	370	416	--
Energy consumption including stand by (kWh/y)	244	272	304	341	383	429	

Figure 7.65: Energy efficiency class trend in the Revised Labelling scheme Scenario for dishwashers

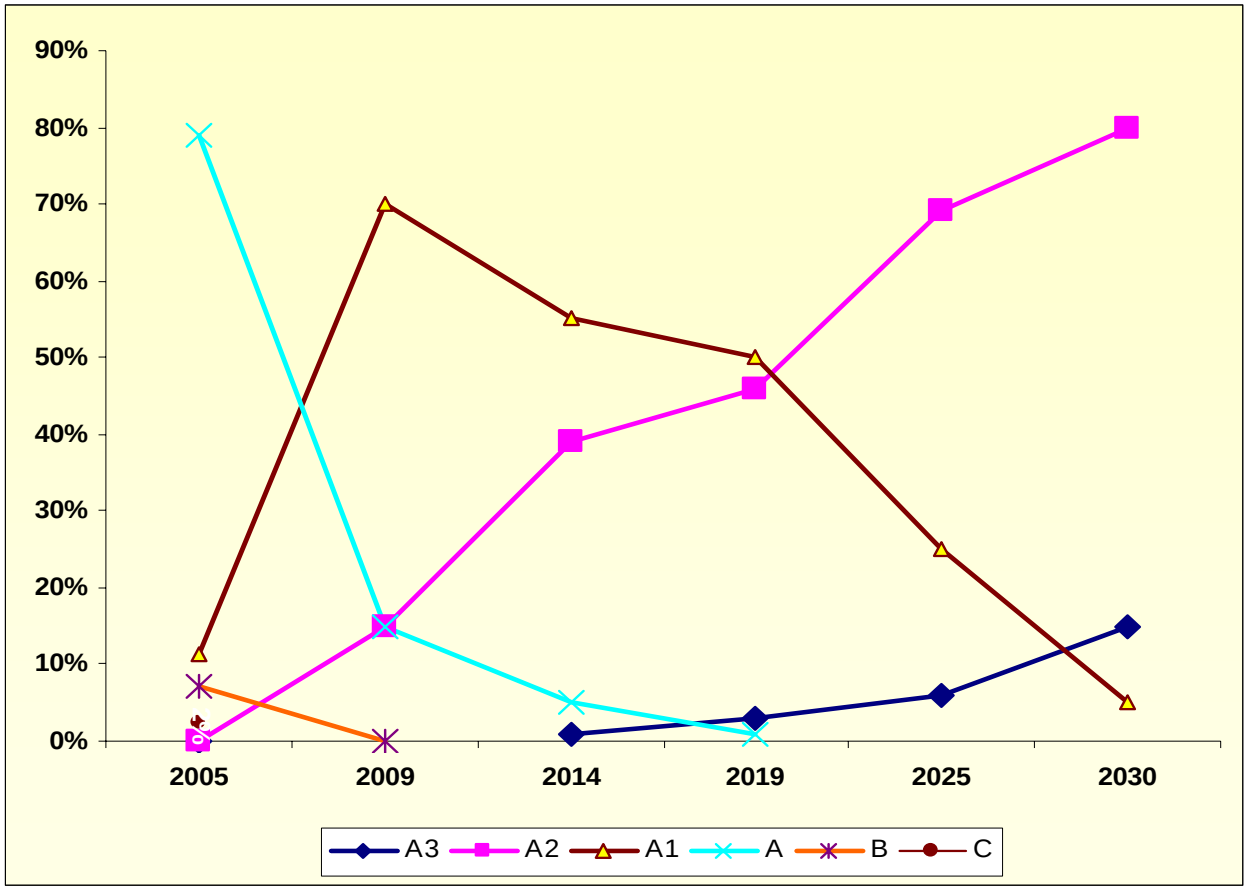


Table 7.71 and Figure 7.66 show the stock energy consumption trends of the EU25, EU15 and EU10 countries under the Revised labelling scheme Scenario. The shape of the energy consumption curves is similar than in the BaU Scenario, even if also for dishwashers the introduction in the market of the more energy efficient models does not prevent the increase of the overall energy consumption, due to the contemporary steadily raise of the dishwashers stock starting from 2014 (see Subtask 7.3).

Nonetheless the slope of the average annual energy consumption curve (see Table 7.72 and Figure 7.67) decrease steadily after 2014 (which presents an asymptotic trend under the BaU Scenario). Unfortunately, the improvement in energy efficiency is not sufficient to counterbalance the contemporary raise in the dishwashers stock. Finally it is worth noting that the average annual energy consumptions for EU15 and EU10 converge to a common value.

Table 7.71: Stock energy consumption for dishwashers under the Revised Labelling scheme Scenario

Years	**Stock energy consumption** (GWh)		
	EU25	EU15	EU10
1990	23 190	23 190	--
1995	27 456	27 390	67
2000	29 678	29 436	242
2005	29 907	29 407	500
2009	30 297	29 551	746
2014	31 342	30 237	1 105
2019	33 710	32 179	1 531
2025	38 001	35 837	2 163
2030	42 221	39 449	2 772

Figure 7.66: Stock energy consumption for dishwashers under the Revised Labelling scheme Scenario

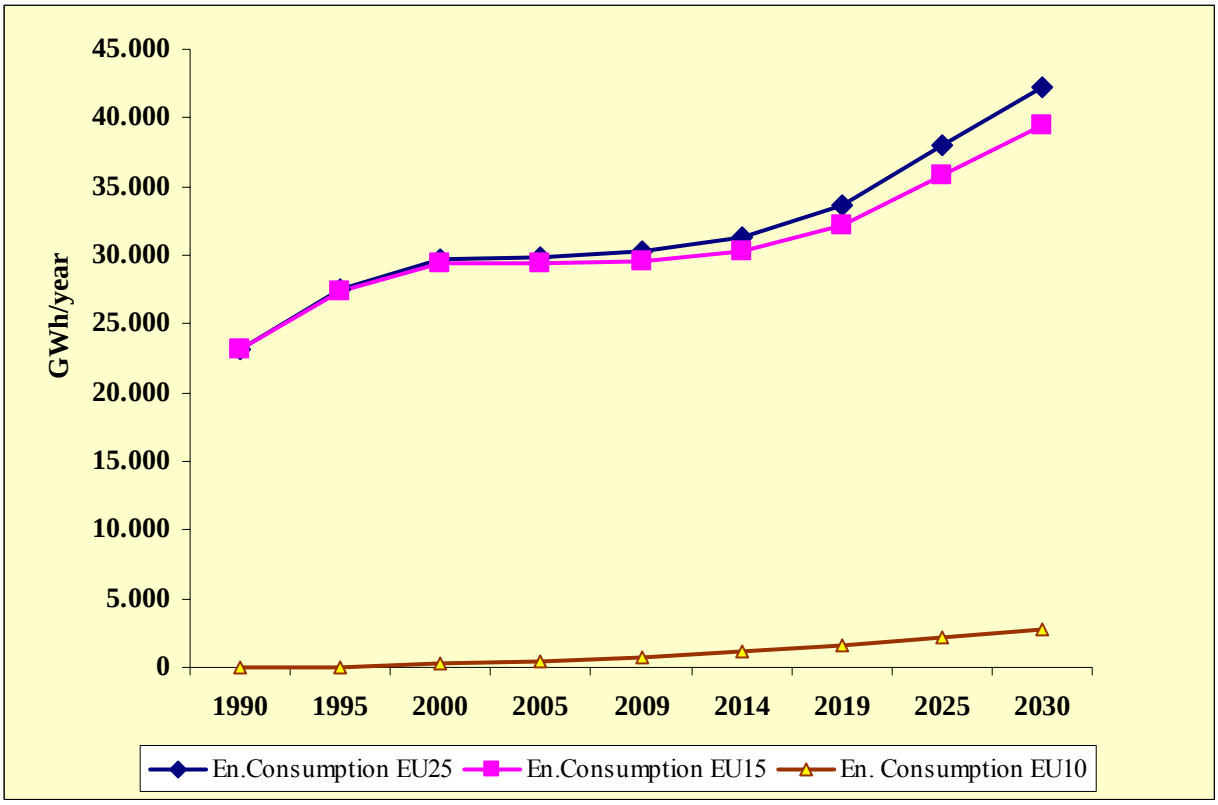
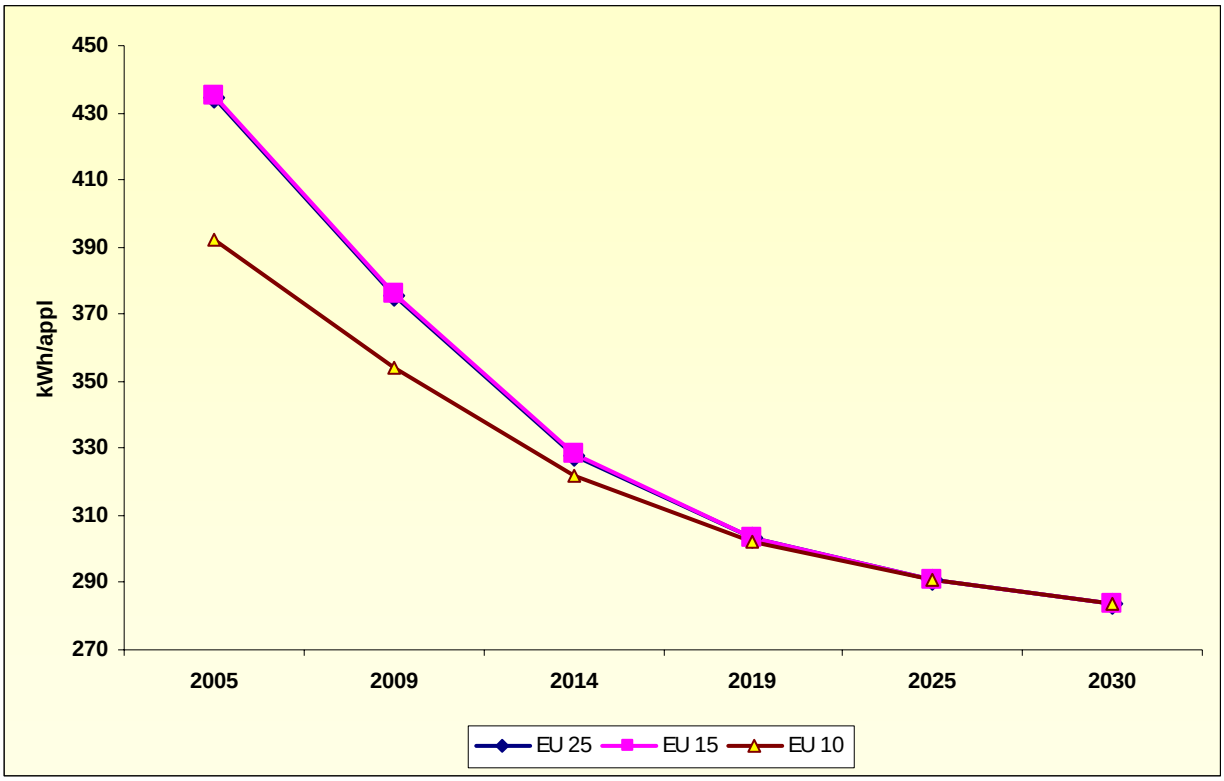


Table 7.72: Average annual energy consumption for dishwashers under the Revised Labelling scheme Scenario

Year	**Average annual energy consumption** (kWh/year unit)		
	EU25	EU15	EU10
2005	434	435	392
2009	376	376	354
2014	328	328	322
2019	304	304	302
2025	291	291	291
2030	283	283	283

Figure 7.67: Average annual energy consumption for dishwashers under the Revised Labelling scheme Scenario



7.7.2 The impact of Policy Scenarios on the EU wash appliance energy consumption

Table 7.73 and Figure 7.68 show the energy consumption forecast of the BaU and Revised Labelling scheme Scenarios for washing machines in EU25 countries. The same data are presented in Table 7.74 and Figure 7.69 for dishwashers. For both products, the impact of the policy Scenarios - compared to the BaU – show a steadily decrease of the stock energy consumption after 2014 due to the introduction of more performing models in the European market.

The energy savings potential of the Revised Labelling scheme Scenario, compared to the BaU, is highlighted and compared for both products in Table 7.75. The achievable savings are in the order of about 2,6% (or 1 140 GWh) for washing machines and about 3,7% (or 1 283 GWh) for dishwashers in 2019, to reach at a maximum of about 6% and 8% (or 2 810 GWh and 3 759 GWh) respectively in 2030, when the best performing (and still not available in the market) washing technologies are expected to dominate the market.

Table 7.73: Comparison of the stock energy consumption by the BaU and the Revised Labelling scheme Scenarios for washing machines in EU25 countries

Year	**Stock energy consumption** (GWh/year)		
	BaU Scenario	Revised Labelling Scenario	Difference
2005	47 704	47 704	0
2009	45 356	45 283	73
2014	44 188	43 695	493
2019	44 261	43 121	1 140
2025	45 120	43 152	1 968
2030	46 502	43 692	2 810

Figure 7.68: Comparison of the stock energy consumption by the BaU and the Revised Labelling scheme Scenarios for washing machines in EU25 countries

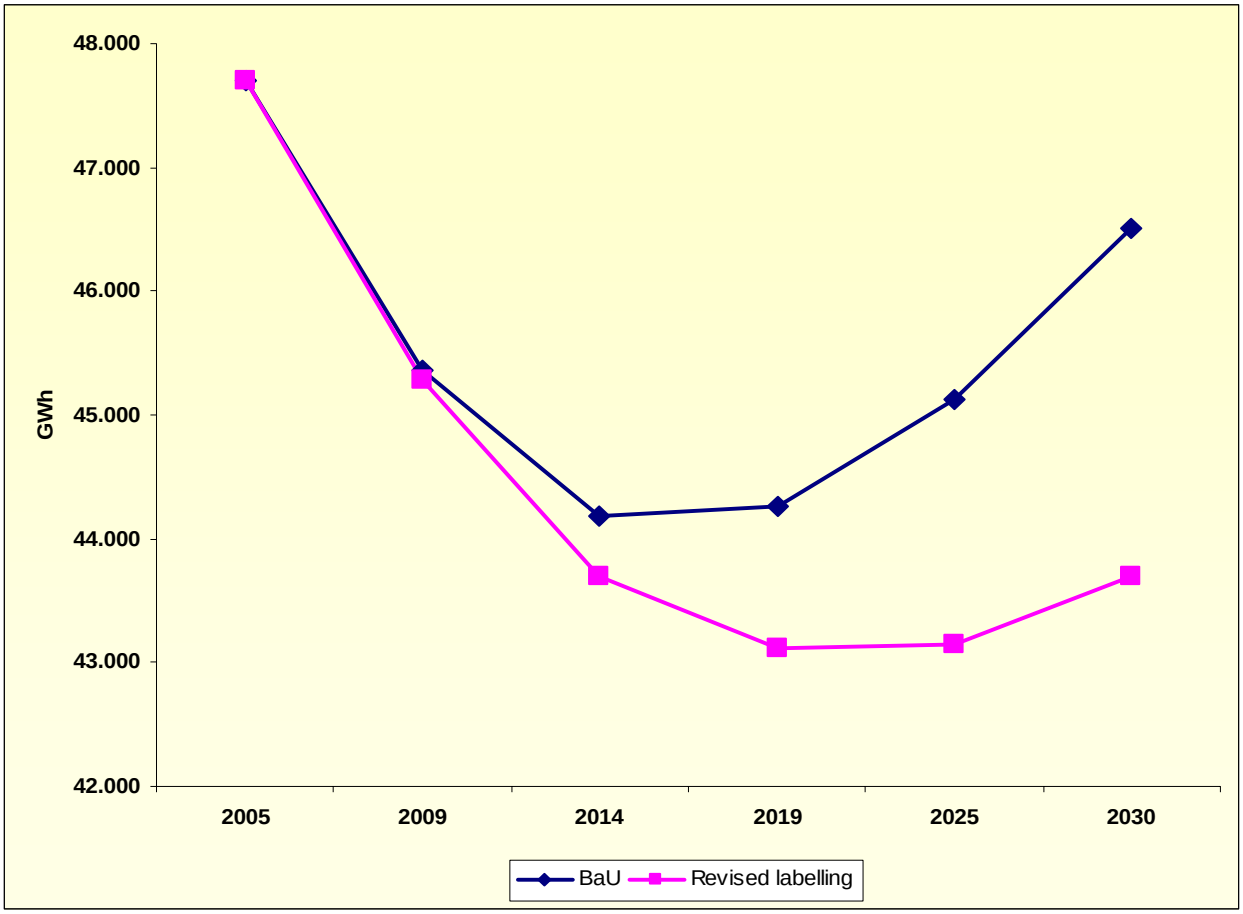


Table 7.74: Comparison of the stock energy consumption by the BaU and the Revised Labelling scheme Scenarios for dishwashers in EU25 countries

Year	**Stock energy consumption** (GWh/year)		
	BaU Scenario	Revised Labelling Scenario	Difference
2005	29 907	29 907	0
2009	30 372	30 297	75
2014	31 865	31 342	522
2019	34 993	33 710	1 283
2025	40 421	38 001	2 420
2030	45 81	42 221	3 759

Figure 7.69: Comparison of the stock energy consumption by the BaU and the Revised Labelling scheme Scenarios for dishwashers in EU25 countries

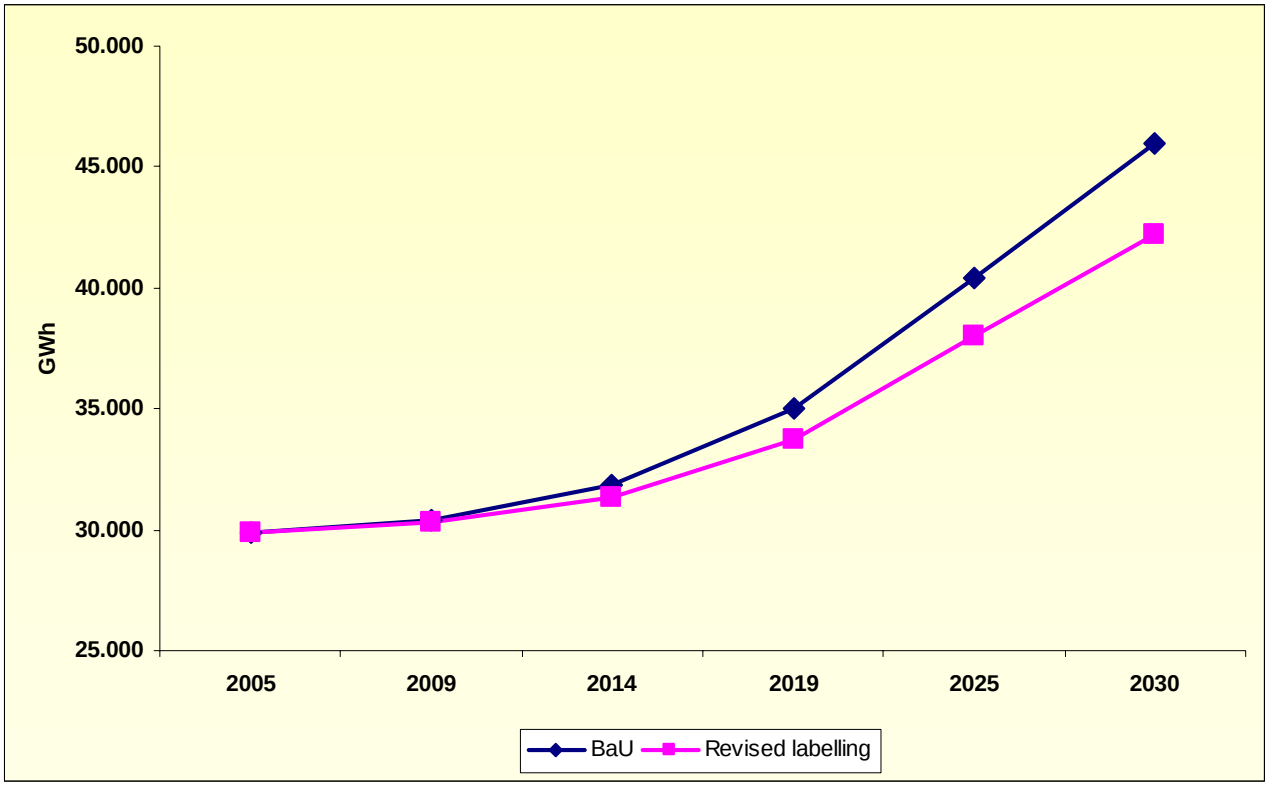


Table 7.75: Energy savings potential for washing machines and dishwashers in EU25 countries

Year	Energy savings potential			
	WASHING MACHINES		DISHWASHERS	
	(GWh)	(%)	(GWh)	(%)
2005	0	0,0	0	0,0
2009	73	0,2	75	0,2
2014	493	1,1	522	1,6
2019	1.140	2,6	1.283	3,7
2025	1.968	4,4	2.420	6,0
2030	2.810	6,0	3.759	8,2

Finally in Table 7.77 and Figures 7.70 (for washing machines) and 7.71 (for dishwashers) show the average annual energy consumption trends for the two wash appliances in EU25 countries. In particular, the average annual energy consumption per unit:

- for washing machines: in 2005 is close to the average consumption of the current class B, to decrease in 2019 to the average value of the current class A, and to target in 2030 a value slightly lower the current class A+ average consumption;

- for dishwashers: in 2005 is slightly lower than the current class C threshold, to decrease in 2019 to a value that is between the current classes A and B, and to target in 2030 a value close to the current A+ class average consumption.

Table 7.76: Average annual energy consumption by policy scenarios for washing machines and dishwashers in EU25 countries

Year	**Average annual energy consumption** (GWh/year unit)			
	WASHING MACHINES		**DISHWASHERS**	
	BaU Scenario	Revised Labelling Scenario	BaU Scenario	Revised Labelling Scenario
2005	285	285	285	285
2009	256	255	256	255
2014	235	232	235	232
2019	224	219	224	219
2025	217	207	217	207
2030	214	201	214	201

Figure 7.70: Average annual energy consumption by policy scenarios for washing machines in EU25 countries

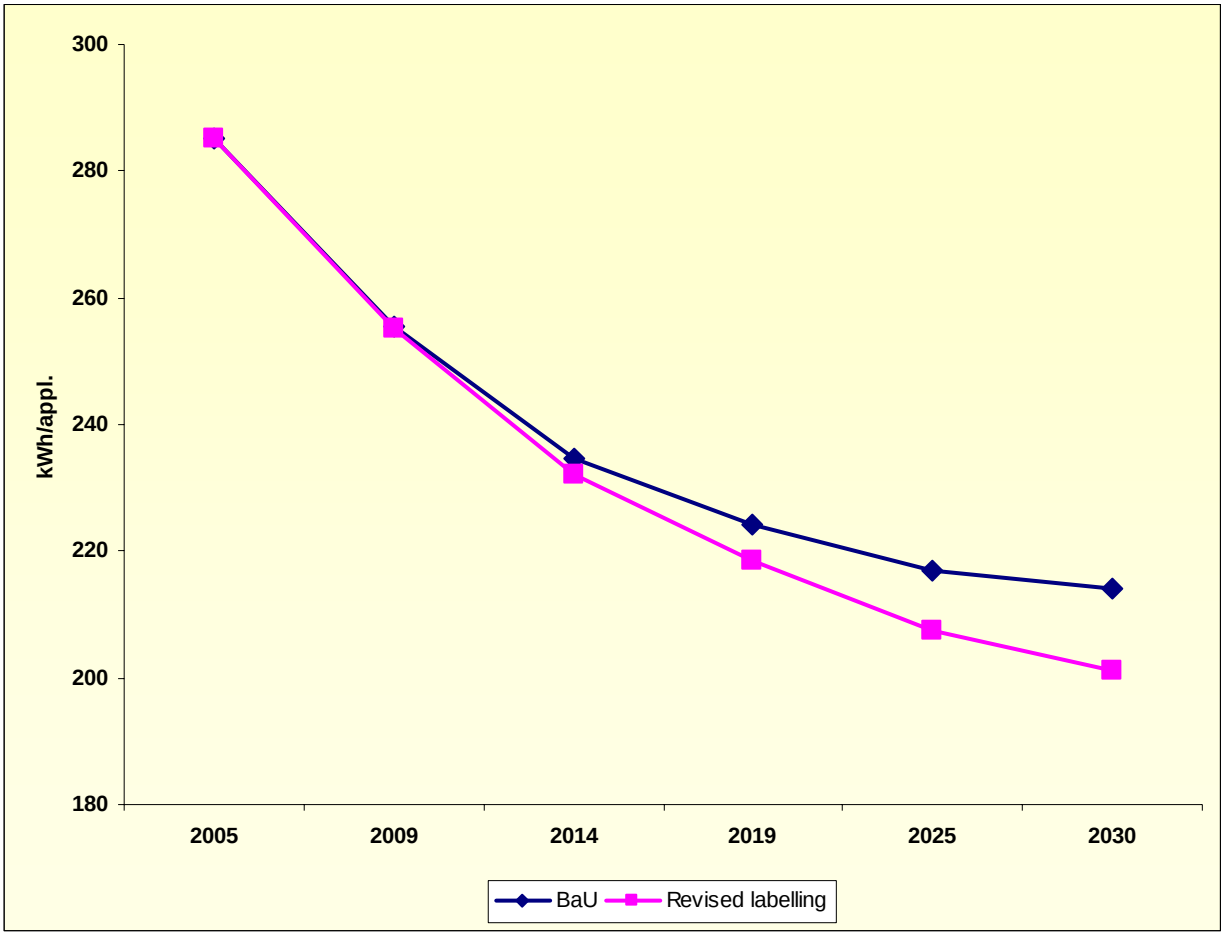
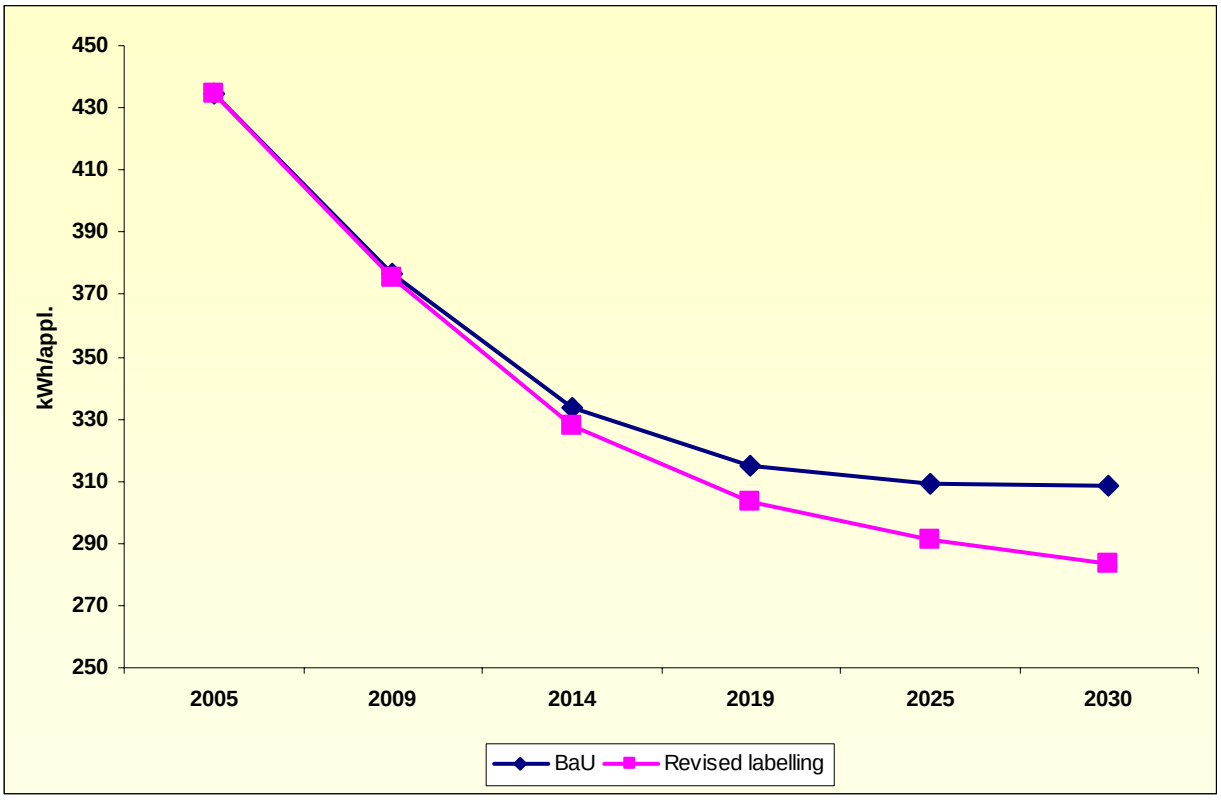


Figure 7.71: Average annual energy consumption by policy scenarios for dishwashers in EU25 countries



7.8 ANNEX A: UNCERTAINTY IN STANDARDISATION

7.8.1 The uncertainty in measurements

Uncertainty reporting is essential to ensure measured data are interpreted in a correct way. Especially when data of measurements are to be compared between laboratories or when normative requirements are set up, it is necessary to know the uncertainty with which data can be measured.

The current international view of how to express uncertainty in measurement is the "Guide to the Expression of Uncertainty in Measurement" (called in short GUM), Ed.1, prepared by BIPM/IEC/IFCC/ISO/IUPAC/IUPAP/OIML in 1995.

In general, the result of a measurement is only an approximation or estimate of the value of the specific quantity subject to measurement, that is, the *measurand*, and thus the result is complete only when accompanied by a quantitative statement of its uncertainty. The uncertainty of the result of a measurement generally consists of several components which, may be grouped into two categories according to the method used to estimate their numerical values:

A. those which are evaluated by statistical methods,
B. those that are evaluated by other means.

There is not always a simple correspondence between the classification of uncertainty components into categories A and B and the commonly used classification of uncertainty components as "random" and "systematic" (described in Subtask 7.6). The nature of an uncertainty component is conditioned by the use made of the corresponding quantity, that is, on how that quantity appears in the mathematical model that describes the measurement process. When the corresponding quantity is used in a different way, a "random" component may become a "systematic" component and vice-versa. Thus the terms "random uncertainty" and "systematic uncertainty" can be misleading when generally applied. An alternative nomenclature that might be used is:

component of uncertainty arising from a random effect
component of uncertainty arising from a systematic effect,

where a random effect is one that gives rise to a possible random error in the current measurement process and a systematic effect is one that gives rise to a possible systematic error in the current measurement process. In principle, an uncertainty component arising from a systematic effect may in some cases be evaluated by 'method A' while in other cases by 'method B', as may be an uncertainty component arising from a random effect.

The difference between *error* and *uncertainty* should always be borne in mind. For example, the result of a measurement after correction can unknowably be very close to the unknown value of the measurand, and thus have negligible error, even though it may have a large uncertainty.

Basic to the GUM approach is representing each component of uncertainty that contributes to the uncertainty of a measurement result by an estimated standard deviation, termed **standard uncertainty** with suggested symbol u_i, and equal to the positive square root of the estimated variance u^2_i.

It follows that an uncertainty component in 'category A' is represented by a statistically estimated standard deviation s_i , equal to the positive square root of the statistically estimated variance s^2_i, and the associated number of degrees of freedom n_i. For such a component the standard uncertainty is $u_i=s_i$.
The evaluation of uncertainty by the statistical analysis of series of observations is termed a **Type A evaluation (of uncertainty)**.

In a similar manner, an uncertainty component in 'category B' is represented by a quantity u_j, which may be considered an approximation to the corresponding standard deviation; it is equal to the positive square root of u^2_j, which may be considered an approximation to the corresponding variance and which is obtained from an assumed probability distribution based on all the available information. Since the quantity u^2_j is treated like a variance and u_j like a standard deviation, for such a component the standard uncertainty is simply u_j.

The evaluation of uncertainty by means other than the statistical analysis of series of observations is termed a **Type B evaluation (of uncertainty)**.

A Type A evaluation of standard uncertainty may be based on any valid statistical method for treating data; a Type B evaluation of standard uncertainty is usually based on scientific judgment using all the relevant information available, which may include: previous measurement data, experience with, or general knowledge of, the behaviour and property of relevant materials and instruments, manufacturer's specifications, data provided in calibration and other reports, including uncertainties assigned to reference data taken from handbooks.

Convert a quoted uncertainty that is a stated multiple of an estimated standard deviation to a standard uncertainty by dividing the quoted uncertainty by the multiplier. Convert a quoted uncertainty that defines a "confidence interval" having a stated level of confidence (such as 95% or 99%) to a standard uncertainty by treating the quoted uncertainty as if a normal distribution had been used to calculate it and dividing it by the appropriate factor for such a distribution. These factors are 1,960 and 2,576 for the two levels of confidence given.

If the quantity in question is modelled by a normal distribution there are no finite limits that will contain 100% of its possible values. However, ±3 standard deviations about the mean of a normal distribution corresponds to 99,73% limits. Thus, if the limits a_- and a_+ of a normally distributed quantity with mean = $(a_+ + a_-)/2$ are considered to contain "almost all" of the possible values of the quantity, that is, approximately 99,73% of them, then $u_j = a/3$, where $a = (a_+ - a_-)/2$.

7.8.2 The combined standard uncertainty

The *combined standard uncertainty* of a measurement result, u_c, is taken to represent the estimated standard deviation of the result. It is obtained by combining the individual standard uncertainties u_i, whether arising from a Type A evaluation or a Type B evaluation, using the law of propagation of uncertainty (also known as "root-sum-of-squares" method) for combining standard deviations. It is assumed that a correction (or correction factor) is applied to compensate for each recognized systematic effect that significantly influences the measurement result and that every effort has been made to identify such effects.

In many practical measurement situations, the probability distribution characterized by the measurement result y and its combined standard uncertainty $u_c(y)$ is approximately normal (Gaussian). When this is the case and $u_c(y)$ itself has negligible uncertainty, $u_c(y)$ defines an interval

$y - u_c(y)$ to $y + u_c(y)$ about the measurement result y within which the value of the measurand Y estimated by y is believed to lie with a level of confidence of approximately 68%. That is, it is believed with an approximate level of confidence of 68% that $y - u_c(y) \leq Y \leq y+u_c(y)$, which is commonly written as $Y = y \pm u_c(y)$.

The term "confidence interval" has a specific definition in statistics and is only applicable to intervals based on u_c when certain conditions are met, including that all components of uncertainty that contribute to u_c be obtained from Type A evaluations. Thus, an interval based on u_c is viewed as encompassing a fraction p of the probability distribution characterized by the measurement result and its combined standard uncertainty, and p is the coverage probability or level of confidence of the interval.

Although the combined standard uncertainty u_c is used to express the uncertainty of many measurement results, for some commercial, industrial, and regulatory applications of such results, what is often required is a measure of uncertainty that defines an interval about the measurement result y within which the value of the measurand Y is confidently believed to lie. The measure of uncertainty intended to meet this requirement is termed **expanded uncertainty**, U, and is obtained by multiplying $u_c(y)$ by a **coverage factor** k. Thus $U = ku_c(y)$ and it is confidently believed that $y - U \leq Y \leq y + U$, which is commonly written as: $Y = y \pm U$.

In general, the value of the coverage factor k is chosen on the basis of the desired level of confidence to be associated with the interval defined by $U = ku_c$. Typically, k is in the range 2 to 3. When the normal distribution applies and u_c has negligible uncertainty, $U = 2u_c$ (i.e., k=2) defines an interval having a level of confidence of approximately 95% and $U = 3u_c$ (i.e., k=3) defines an interval having a level of confidence greater than 99%.

For a quantity z described by a normal distribution with expectation μ_z and standard deviation s, the interval $\mu_z \pm ks$ encompasses 68,27%, 90%, 95,45%, 99% and 99,73% of the distribution for k=1, k=1,645, k=2, k=2,576, and k=3, respectively.

Ideally, one would like to be able to choose a specific value of k that produces an interval corresponding to a well-defined level of confidence p, such as 95% or 99%; equivalently, for a given value of k, one would like to be able to state unequivocally the level of confidence associated with that interval. This is difficult to do in practice because it requires knowing in considerable detail the probability distribution of each quantity upon which the measurand depends and combining those distributions to obtain the distribution of the measurand.

The GUM gives an approximate solution to the problem of how the relation between k and p is to be established. Use expanded uncertainty U to report the results of all measurements other than those for which u_c has traditionally been employed. To be consistent with current international practice, the value of k to be used for calculating U is, by convention, $k = 2$. Values of k other than 2 are only to be used for specific applications dictated by established and documented requirements.

An example of the use of a value of k other than 2 is taking k equal to a t-factor obtained from the t-distribution when u_c has low degrees of freedom in order to meet the dictated requirement of providing a value of $U = ku_c$ that defines an interval having a level of confidence close to 95%.

7.8.3 Accuracy of a measurement method

The current international method for assessing the accuracy of a measurement method is the

standard ISO 5725: *Accuracy (trueness and precision) of measurement methods and results*, Part 1-6, issued in issued 1994 – 1998.

Methods for measuring declared values for energy and other resources consumption must be of sufficient ***accuracy*** to provide confidence to governments, consumers and manufacturers. The term accuracy implies the total displacement of a result from a reference value due to random as well as systematic effects. The accuracy of a test method is expressed in terms of *trueness* and *precision*:

- ***trueness*** refers to the closeness of agreement between the arithmetic mean of a large number of test results and the true or accepted reference values. Trueness assess the various components of bias;
- ***precision*** refers to the closeness of the agreement between test results. Precision is the general term for variability between repeated measurements. The need to consider precision arises because tests performed on presumably identical materials or products in presumably identical circumstances do not, in general, yield identical results. This is attributed to unavoidable random errors inherent in every measurement procedure; the factors that influence the outcome of a measurement cannot all be completely controlled. For instance, the difference between a test result and some specified value may be within the scope of unavoidable random errors, in which case a real deviation from such a specified value has not been established

Accuracy data can be used in various practical situations:
- giving a standard method of calculating the repeatability limit, the reproducibility limit and other limits to be used in examining the test results obtained by a standard measurement method
- providing a way of checking the acceptability of test results obtained under repeatability or reproducibility conditions
- describing how to assess the stability of results within a laboratory over a period of time, and thus providing a method of "quality control" of the operations within a laboratory
- describing how to assess whether a given laboratory is able to use a given standard measurement method in a satisfactory way
- describing how to compare alternative measurement methods.

Two conditions of precision: ***repeatability*** and ***reproducibility*** have been found necessary and useful for describing the variability of a measurement method, where:
- *repeatability*: is precision under repeatability conditions, where independent test results are obtained with the same method, on identical test items, in the same laboratory, by the same operator, using the same equipment, within short intervals of time;
- *reproducibility*: is precision under reproducibility conditions, where test results are obtained with the same method, on identical test items, in different laboratories, with different operators, using different equipment.

The *repeatability* of a test method must be sufficiently accurate for comparative testing, while *reproducibility* must be sufficiently accurate for the determination of values, which are declared, and for checking the declared values.

Many different factors may contribute to the variability of results from a measurement method, including:
- the operator
- the equipment (instrumentation) used
- the calibration of the equipment
- the environmental conditions (temperature, humidity, etc.)

- the time elapsed between measurements.

The variability between measurements performed by different operators and/or different equipment will usually be greater than the variability between measurements carried out within a short interval of time by a single operator using the same equipment. Under repeatability conditions the listed factors are considered constant and do not contribute to the variability, while under reproducibility conditions they vary and do contribute to the variability of test results. Thus *repeatability* and *reproducibility* are the two extremes of precision, the first describing the minimum and the second the maximum variability in results.

The measure of precision usually is expressed in terms of "*imprecision*" and is computed as a standard deviation σ of the test results. Less precision is reflected by a larger standard deviation. However, in statistical practice, where the true value of a standard deviation is not known, it is replaced by an estimate based upon a sample, then the symbol σ is replaced by "s" to denote that it is an estimate. The square of the standard deviation is called the *variance* "S". According to ISO 5725:

- S_L^2 = *between-laboratory variance*; it includes the between operator and between equipment variability
- S_W^2 = *within-laboratory variance*, under repeatability conditions. **Note**: under IEC 61923:1997, within-laboratory variance is the square of the within-laboratory standard deviation indicated as $S_{L,i}$
- S_r^2 = *repeatability variance*; it is the arithmetic mean of the within laboratory variances S_W^2; this arithmetic mean is taken over all those laboratories taking part in the accuracy experiment which remain after outliers have been excluded
- $S_R^2 = (S_L^2 + S_r^2)$ = *reproducibility variance*

From variance values "S" the repeatability (s_r) and the reproducibility (s_R) of the measurement method are derived:

- s_r = repeatability of the test method, is the square root of the *repeatability variance*;
- s_R = reproducibility of the test method, is the square root of the *reproducibility variance*

The 'trueness' of a measurement method is of interest when it is possible to conceive a true value for the property being measured. Although for some measurement methods the true value cannot be known exactly, it may be possible to have an accepted reference value for the property being measured. The trueness of a measurement method can be investigated by comparing the accepted reference value with the level of the results given by the measurement method.

Trueness is normally expressed in term of *bias*. Bias is the difference between the expectation of test results and an accepted reference value. Bias is the total systematic error as contrasted to random error. There may be one or more systematic error components contributing to the bias:

- ***laboratory bias***: the difference between the expectation of the test results from a particular laboratory and an accepted reference value
- ***bias of the measurement method***: the difference between the expectation of test results obtained from all laboratories using that method and an accepted reference value
- ***laboratory component of bias***: the difference between the laboratory bias and the bias of the measurement method.

An accepted reference value is a value that serves as an agreed-upon reference for comparison, and which is derived as:

a) theoretical or established value, based on scientific principles

b) an assigned or certified value, based on experimental work of some national or international organisation
c) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group
d) when a), b) and c) are not available, the expectation of the (measurable) quantity, i.e. the mean of a specified population or measurements.