Washing Machines: Key Criteria for Best Available Technology BAT

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Abstract

Washing machines will reveal new energy consumption results, because of changed standards for testing and labelling, new performance requirements, and because of the market penetration of "new" appliances.

For household laundry washing machines, the updated EU energy label and the Eco-design requirements entered into force by the end of 2010, while the EU measurement standards still are under revision.

Future key parameters of washing machines will be energy and water consumption both for full and partial loads, spin-drying efficiency, availability of a 20°C-cycle and supply for hot fill.

Topten, an independent international programme to create a dynamic benchmark for high-efficient consumer products, carried out a manufacturers' inquiry on the key parameters of their new washing machine models ready to enter the market complying with the new EU energy label requirements. By means of these data Topten selected the actually best-performing household washing machines on the European market and presents them on www.topten.eu. This market research done by Topten in an early stage provides an important and helpful source for policy makers.

The paper outlines key parameters, best available technology, barriers and chances for better washing machines.

Introduction

Over the past few years the energy efficiency and the market penetration of efficient washing machines has increased. In Europe, the regulatory framework has evolved and the enforcement of new regulations for washing machines has started.

We firstly present the European regulations on washing machines (old and new EU Energy label, Eco-design requirements), and the criteria set by The Blue Angel and the EU Ecolabel. Subsequently the key parameters of washing machines are discussed, in particular those influencing energy efficiency, energy consumption and water consumption. The paper then presents the selection criteria of Topten for best performing washing machines available on the European market, the results of the Topten-inquiry with manufacturers on how their washing machines comply with the requirements of the new EU energy label and discusses conclusions for energy policies.
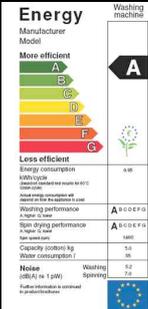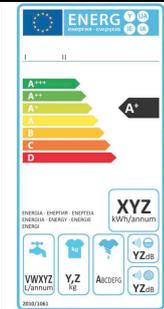
Definition

A household laundry washing machine (in the following washing machine) is understood as an automatic washing machine, which is designed to be used principally for non-professional purposes, which cleans and rinses textiles using water, and which also has a spinning function for water extraction [1].

Regulations

Revised EU Energy Label

The regulation of the EU energy label for washing machines recently has been updated. The new regulation entered into force in December 2010 and the new EU energy label must be shown on appliances from December 2011 [2]. During this transition period of one year, the old and the new EU energy labels can coexist. As shown in Table 1, the new EU energy label presents a number of differences compared to the old version:

Table 1. Differences between old and new EU energy label for washing machines

	Old EU Energy Label	New EU Energy Label
Rated capacity	kg at full load 60°C	kg at full load 60°C or 40°C, whichever is the lower
Cycles for the calculation of the Energy Efficiency Index, electricity and water consumption, remaining moisture content	60°C full load (cotton)	60°C full load (cotton) 60°C half load[1] (cotton) 40°C half load (cotton)
Energy consumption	kWh per cycle	kWh per year[2]
Water consumption	Litres per cycle	Litres per year[3]
Washing performance classes	A to G	Not indicated any more[4]
Energy efficiency classes	A to G: A ≤ 0.19 kWh/kg[5] B ≤ 0.23 kWh/kg C ≤ 0.27 kWh/kg D ≤ 0.31 kWh/kg Etc. Etc.	A+++ to D: A+++ EEI[6] < 46 A++ $46 \leq EEI < 52$ A+ $52 \leq EEI < 59$ A $59 \leq EEI < 68$ Etc. Etc.
Spin-drying efficiency class	A to G[7]	A to G[8]
Label		

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[1] Half load is measured in order to better reflect the use of washing machines in homes.

[2] Weighted annual energy consumption for washing (60°C full load (3x), 60°C half load (2x), 40°C half load (2x)) for 220 standard washing cycles, inclusively consumption for the left-on mode and off mode. Calculation details see Annex VII of [2].

[3] Based on 220 standard washing cycles, calculated in accordance with Annex VII of [2].

[4] For washing machines with a capacity > 3 kg minimum performance A is required (B for machines ≤ 3 kg), see below.

[5] 60°C full load cotton.

[6] The Energy Efficiency Index (EEI) shall be determined in accordance with Annex VII of [2].

[7] 60°C full load cotton.

[8] Weighted remaining moisture content in percentage (60°C full load (3x), 60°C half load (2x), 40°C half load (2x)) in accordance with Annex VII of [2].

Introduction of Eco-design Requirements

The preparatory study lot 14 for domestic washing machines and dishwashers was carried out to analyse the technical, environmental and economic aspects of washing machines (and dishwashers) [3]. Based on that, an Eco-design regulation for washing machines has been worked out, which entered into force in December 2010 [1], [4]. It sets minimum performance and information requirements on washing machines to be sold on the European market. An overview on requirements and the date, from when the requirements shall be applied, is given in Table 2.

Table 2. Overview on the Eco-design requirements for washing machines

	December 2011	June 2012	December 2012	December 2013
Energy Efficiency Index	EEI < 68 (all machines)			EEI < 59 (≥ 4 kg)
Washing Efficiency Index	> 1.03 (> 3 kg) > 1.00 (≤ 3 kg)			
Water consumption per cycle	≤ 5 x c + 35[9] (5 kg: 60 litres 6 kg: 65 litres 7 kg: 70 litres 8 kg: 75 litres 9 kg: 80 litres 10 kg: 85 litres)			≤ 5 x c/2 + 35[10] (5 kg: 47.5 litres 6 kg: 50 litres 7 kg: 52.5 litres 8 kg: 55 litres 9 kg: 57.5 litres 10 kg: 60 litres)
Generic requirements		Instruction manuals shall provide information on 60°C and 40°C cotton programmes, power consumption off/ left-on, programme time, remaining moisture content, energy and water consumption, recommendation on detergents.	For the calculation of the energy consumption and other parameters for washing machines, the cycles which clean normally soiled cotton laundry at 40°C and 60°C shall be used and shall be clearly identifiable.	Availability of a cold wash programme (max. 20°C)

The Eco-design requirements can be summarized as follows:

• By the end of 2011 all washing machines must be at least of energy class A. This requirement will be strengthened to A+ for washing machines ≥ 4 kg by the end of 2013. In other words: washing machines below (new) energy class A will be banned from the market by the end of 2011.

• Minimum washing performance for washing machines > 3 kg corresponds to class A according to the old EU energy label.

• Limits are set for the water consumption and will be slightly strengthened by the end of 2013.

• All washing machines have to offer a cold wash programme (max. 20°C) by the end of 2013[11].

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[9] Where c is the rated capacity for 60°C or for 40°C at full load, whichever is the lower.

[10] Where c1⁄2 is the rated capacity for 60°C or for 40°C at partial load, whichever is the lower.

Requirements by The Blue Angel, the EU Ecolabel and Topten

Besides the Eco-design requirements outlined above, The Blue Angel and the EU Ecolabel (both environmental endorsement labels) as well as Topten set voluntary minimum criteria for washing machines.

The Blue Angel

Particularly energy-efficient and climate-friendly products are awarded by the well-known German Eco-label The Blue Angel[12]. The award criteria for washing machines are described in RAL-UZ 137 [5] and can be summarized as follows:

- Energy Efficiency Index: < 52
  (which corresponds to A++ and better according to the new EU energy label)

- Left-on mode: max. 3.0 Watt; Off mode: max. 0.5 Watt

- Water Consumption: max. 9 litres/kg

- Washing Efficiency Index: > 1.03
  (which corresponds to A according to the Eco-design requirements)

- Spin-drying efficiency: B or better

- Further requirements are made on the availability of a 20°C-programme, noise, the availability of (most important) spare parts, materials, water safety and instruction manuals.

EU Ecolabel

The European Ecolabel is a voluntary scheme that today covers a wide range of services and products[13]. The Ecolabel for washing machines is currently under revision[14]. Criteria will be set for:

- Energy Efficiency Index

- Water Consumption

- Washing Efficiency Index

- Spin-drying efficiency

- Further requirements are made on noise, flame retardants and heavy metals, prevention of excess use of detergents, appliance design, design for disassembly, user instructions, life time extension, information appearing on the Ecolabel and biocides.

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[11] However it is not specified whether this programme should be for cotton and easy-care or just for wool or silk.

[12] For more information see http://www.blauer-engel.de/en/index.php

[13] For more information see http://ec.europa.eu/environment/ecolabel/

[14] At the closing date of this paper the revised EU Ecolabel for washing machines was not yet published.

Topten

Topten is an international online search tool which presents the most energy efficient products such as household appliances, office equipment, consumer electronics, building components, lamps and cars.

Topten-criteria are primary based on the EU energy label. Depending on the product group additional criteria are required. The Topten-criteria for highly efficient washing machines are listed in section "Best Performing Washing Machines of Europe". For more information on Topten see [6], [7].

Key Parameters of Washing Machines[15]

The most significant environmental aspects of washing machines are energy and water consumption in the use phase [1].

One measure to reduce the energy consumption is an effective load sensor. Further measures considerably reducing the energy consumption are the availability of a cold wash programme and hot water supply. Best spinning performance (with few remaining moisture content) is of high importance for the drier's energy consumption.

An effective load sensor reduces not only the energy consumption but also the water consumption. However, rinsing should be sufficient[16].

The common practice of users to over-dose detergents can be prevented by automatic dosage systems. Correct dosage of detergents raises the rinsing quality and reduces the amount of chemicals released to the environment.

The use of rainwater in washing machines can be an expedient and cost effective option. Depending on local water and sewage water tariffs and/or the water consumption of the washing machines, the water costs for washing machines may be as much as 50 to100% of the respective electricity costs.

Noise during washing and spinning can be disturbing, but this impact strongly depends on where the washing machine is installed and is more relevant in flats than in the cellar.

The following sections discuss energy efficiency, effective load sensor, spin-drying efficiency, availability of a cold wash programme and supply for hot water in more detail.

Energy Efficiency

Energy efficiency according to the new EU energy label is positively influenced by an effective load sensor which reduces energy consumption at partial load as well as by an optimised 40°C programme. The influence of the power consumption in left-on mode and off mode is secondary. The increase of energy efficiency is often connected to longer programme duration.

Although the energy efficiency of washing machines still can be optimised, the development is relatively limited in the near future compared to other white goods such as refrigerators and freezers. Additional, but high energy saving potentials lay in a high spin-drying efficiency, the availability of a cold wash programme and the supply for hot fill.

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[15] See also [8].

[16] An EU standard allowing the measurement of the rinsing performance is in development.

Effective Load Sensor

Due to the trend towards larger washing machines (6 to10 kg) as well as the related problem of filling washing machines only partially, it is important that the washing machine has a sensor capable of estimating the weight of the laundry load and able to automatically adjust programme duration, energy and water consumption. Half load theoretically would lead to a reduction of 50% of electricity and water consumption compared to full load. In reality the reduction with load sensors might be about 20%. An effective load sensor positively influences the energy efficiency and in particular is meaningful for larger-sized washing machines (> 6kg), which are rarely fully loaded. Load control features should be accompanied by an eye-catching indication in case of failure, to prevent full-load setting as default for long periods.

Spin-drying Efficiency

As shown in Figure 1, moving from a washing machine with a spin-drying class B to one with a spin-drying class A saves three times more energy (in case that a tumble drier is used for drying) than moving from a washing machine with energy class A to one with (unofficial "old") energy class A+[17]. Thus the spin-drying efficiency is of high importance to the overall efficiency of the total laundering process.
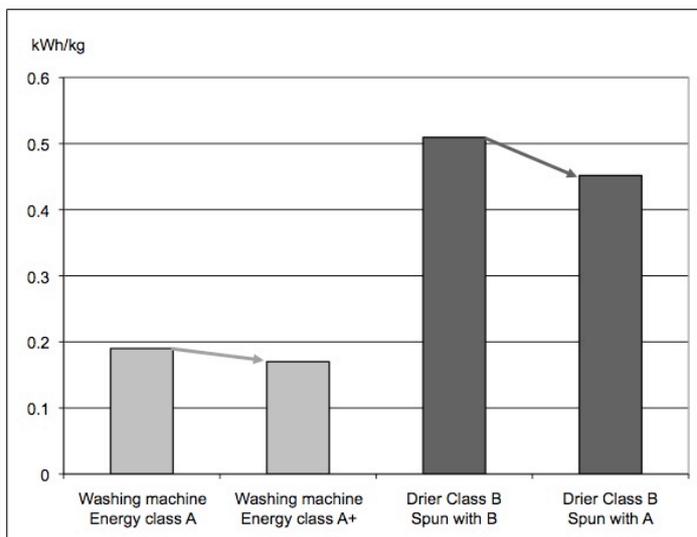

Figure 1. Energy consumption and energy savings per kg of laundry according to higher efficiency classes for washing and spinning (with drier class B), related to the old EU energy label, calculated by Topten[18].

Availability of a Cold Wash Programme

The lion's share of washing machine electricity consumption is for heating water from the pipe temperature up to 30°C, 40°C, 60°C or even 90°C. Washing at lower water temperatures (max. 20°C) requires up to 70% less electric energy compared to 60°C.

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[17] Classes according to the old EU energy label. The unofficial energy class A+ (< 0.17 kWh/kg) is a voluntary agreement between CECED manufacturers and the European Commission.

[18] 0.02 kWh/kg are saved by increasing the energy efficiency from 0.19 kWh/kg (A) to 0.17 kWh/kg (unofficial A+). 0.06 kWh/kg are saved by increasing the spin-drying efficiency from B to A (Washing machine with spin-drying efficiency class B = 52% initial moisture content, A = 44% initial moisture content; a drier with class B (a type that is still widespread in European households [9]) consumes 0.51 kWh/kg if the washing machines' spin-drying efficiency is B and 0.45 kWh/kg if the washing machines' spin-drying efficiency is A).

In 2009, the Swiss retailer Migros was one of the first to develop and sell environmentally friendly detergents designed for low water temperatures. Environmentally friendly cold wash detergents then became a standard for producers within a very short time and are recognised as an innovation by the whole laundry industry sector[19].

Hot Water Supply

Hot water supply ("hot fill") for washing machines can be both economically and ecologically reasonable provided that the hot water is heated efficiently (e.g. by renewable energy sources, heat-pump-heating or district heating (e.g. from renewable energy sources or waste heat)) and that it is possible to appropriately install a warm water pipe [10], [11]. The higher the washing temperature, the higher the potential savings from hot water supply (up to 70% less electricity consumption by the washing machine). If the "hot fill" hot water is heated to 100% by an electric water heater, this (of course) does not bring any energetic benefits compared to direct warming in the machine. The technology is available on the European market, however, its practical use strongly differs within the European countries.

Market Development of Washing Machines

In 2005, 167 millions washing machines were installed in the EU-25 [3]. The market is mature and of substitution (not first equipment).

The current standard size of washing machines is 5 kg. There is a clear trend towards washing machines larger than 6 kg (up to 10 kg).

The old EU energy label for washing machines contains various performance values: energy and water consumption, washing performance and spin-drying performance (see above).

Since 2004, almost all new washing machines sold in Europe reach energy class A according to the old EU energy label (< 0.19 kWh/kg)[20] [9][21]. Many washing machines have an energy consumption of 0.17 kWh/kg and even less, claiming the old (unofficial) energy class A+.

In 2008, the spin-drying performance of the washing machines sold in Europe was mostly B and C [9]. This is insofar of high relevance as weakly spun laundry strongly increases the driers' energy consumption (see above).

The percentage of sold A-machines as well as the percentage of the spin-drying efficiency classes strongly differ within European countries [9].

Best Performing Washing Machines of Europe according to the New EU Energy Label

Topten – "Best Products of Europe"

Topten presents on www.topten.eu the most efficient household appliances, office equipment, consumer electronics, building components, lamps and cars available on the European market ("Best Products of Europe") and thus is an important tool for policy design processes. For more information on Topten see [6], [7].

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[19] For further information on detergents see e.g. wfk detergency conference and articles in Chemical & Engineering News covering enzymes, phosphates, and other aspects.

[20] 60°C cotton.

[21] GfK-sales data for 8 representative EU-countries: Denmark, France, Germany, Italy, Netherlands, Poland, Portugal, United Kingdom and data from Swiss Association of the Domestic Electrical Appliances Industry FEA for Switzerland.

Topten-Inquiry with European Washing Machine Manufacturers

According to the old EU energy label for washing machines the declarations are based on a 60°C standard cotton programme with full load. With the new EU energy label also programmes with lower temperatures and partial load become relevant. Therefore the classification of the new EU energy label cannot directly be compared to the classification of the old label and will provide a new picture of the market of washing machines.

To map this new picture early in time, Topten conducted an inquiry with European washing machine manufacturers (12 brands). The objective was to present a list on www.topten.eu with the best performing washing machines available on the European market according to the new EU energy label.

As only aggregated values are declared on the new EU energy label and the declaration of the underlying values for the calculations is not required (e.g. energy consumption at 60°C full load, 60°C half load and 40°C half load, programme times etc., see [2]), manufacturers were asked to provide Topten also these values. Furthermore, they were asked to provide maximum spin speed and the availability of other features such as cold wash programme, hot/rainwater supply and automatic dosage system.

Topten Selection Criteria for Washing Machines

Topten designed stringent criteria to help finding the most efficient washing machines available on the European market.

In order to qualify for www.topten.eu washing machines must meet the following criteria:

- Energy efficiency class: A+++ according to the (new) EU energy label

- Spin-drying efficiency class: A according to the (new) EU energy label

- Washing efficiency class: A (is not declared on the new EU energy label because it is a requirement for all washing machines with a capacity of more than 3 kg, see above)

- Water consumption: maximum 12 litres per kg laundry, calculated as follows: annual water consumption according to the declaration on the EU energy label in litres divided by the annual amount of washed laundry in kg (220 cycles).

- Available in at least one European country.

Additionally suppliers have to provide Topten with the following data:

- Energy Efficiency Index

- Energy consumption per cycle in kWh for 60°C full load, 60°C half load and 40°C half load

- Programme duration for 60°C full load, 60°C half load and 40°C half load

- Power consumption of left-on mode and off mode

- Availability of a 20°C-programme for cotton

- Maximum spin speed

- Availability of a water protection system (Aqua Stop, waterproof, water control system etc.)

The selection criteria will regularly be updated according to market development.

Best Performing Washing Machines of Europe

Figure 2 shows the best performing washing machines of Europe according to the Topten-criteria.

Brand	Miele	Miele	Miele	Miele	Miele	Miele	Miele	Miele
Model	W SPECIAL S3	W 19-79	W 58-25	W 59-05	W 58-41	W 67-69	W Supertronic	W 59-69
Costs for electricity and water (€/15 years)	787	787	787	787	787	787	880	880
Capacity (kg)	7	7	7	7	7	7	8	8
Energy efficiency class	A+++	A+++	A+++	A+++	A+++	A+++	A+++	A+++
Energy Efficiency Index	41.9	41.9	41.9	41.9	41.9	41.9	42.5	42.5
Spin-drying class	A	A	A	A	A	A	A	A
Energy (kWh/year)	160	160	160	160	160	160	182	182
Energy (kWh/cycle) $60 / 60_{1/2} / 40_{1/2}$	0.8 / 0.66 / 0.58	0.8 / 0.66 / 0.58	0.8 / 0.66 / 0.58	0.8 / 0.66 / 0.58	0.8 / 0.66 / 0.58	0.8 / 0.66 / 0.58	0.91 / 0.76 / 0.66	0.91 / 0.76 / 0.66
Water (litres/year)	10780	10780	10780	10780	10780	10780	11880	11880
Programme time (min) $60 / 60_{1/2} / 40_{1/2}$	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119	179 / 149 / 119
Left-on/off (W)	0.75 / 0.2	0.75 / 0.35	1.0 / 0.35	1.0 / 0.35	1.0 / 0.35	1.5 / 0.15	1.5 / 0.2	2.25 / 0.15
Max. spin speed (rpm)	1600	1600	1600	1600	1600	1600	1600	1600
20° C for cotton	yes	yes	yes	no	yes	yes	yes	yes
Hot/Rain water supply	no / no	no / no	no / no	no / no	yes / yes	no / no	no / no	no / no
Countries available	on demand	on demand	on demand	on demand	on demand	on demand	on demand	on demand

Figure 2. Best performing washing machines of Europe presented on www.topten.eu (7kg and 8 kg, Screenshot, 6th May 2011)

At the closing time of this paper already first washing machines (Miele) comply with the stringent Topten-criteria. The list on www.topten.eu will be amended as soon as complying products are available on the European market.

The Energy Efficiency Index of the listed washing machines is 41.9 (for 7 kg-machines) and 42.5 (for 8 kg-machines) respectively. This exceeds the threshold for the A+++-class (EEI < 46) by 9%.

Miele has developed its 7-kg models further (they still have the same model names) and has reduced their energy consumption for 60°C full load by 24% from 1.05 kWh/cycle to 0.8 kWh/cycle.

The listed washing machines consume at 60°C half load about 17% less energy than for washing at 60°C full load[22].

All of the listed machines reach best spin-drying efficiency class (A)[23]. Maximum spin speed is 1600 revolutions per minute.

Seven of the eight listed models offer already a cold wash programme for cotton.

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[22] The energy consumption values for the different loads and temperatures are measured values according to the drafted revised EN 60456.

[23] The thresholds for the spin-drying efficiency classes are identical between the old and the new EU energy label, but the calculation has changed (old label: remaining moisture content (in %) at 60°C full load; new label: weighted remaining moisture content (in %) at 60°C full load (3 x), 60°C half load (2 x), 40°C half load (2 x), in accordance with Annex VII of [2]).

One of the listed washing machines offers a hot water supply and thus allows to benefit of renewable energies (e.g. solar water heaters).

It is worth underlining that Miele already publishes detailed data in its catalogues (e g. energy consumption at different loads and temperatures, power consumption in left-on and off-mode, programme times etc.).

Discussion

A high energy saving potential of washing machines lies in a further reduction of the energy consumption at half load (theoretically 50%; in practice about 20%, which in fact leads to an increase of the energy consumption per kg laundry). An effective load control positively influences the energy efficiency and in particular is meaningful for larger-sized washing machines (> 6kg), which are seldom fully loaded.

It is feasible to reach the best Energy Efficiency class as well as the best spin-drying efficiency class. It seems that to manufacturers with an interest to produce highly efficient washing machines both aspects – energy efficiency and spin-drying efficiency – are important.

The Eco-design regulation accounts for the high energy saving potential of cold wash and requires a 20°C-programme after December 2013. However it is not specified for which type of laundry this programme should be designed. Best-performing washing machines are already equipped with this feature for cotton (and not just for wool or silk for which such "gentle care" programmes are anyway often available).

Conclusions: Policy Discussion

Revision of the New EU Energy Label

The introduction of new energy classes (A+ to A+++) obviously encouraged industry to improve their machines. This shows that revising label classes strongly stimulates industry to develop and bring onto the market more efficient products and demonstrates further the key impact of updated labels.

However, a good part of the efficiency potential seems not to be used by the new labeling scheme for washing machines. As some washing machines already exceed the threshold of the best class by 9% there seems to be no incentive for further developments. The new energy efficiency classes are too weak, it is necessary to revise the EU energy label as soon as possible to facilitate further improvements. The top classes then should be held empty for future technical developments.

Revision of the Eco-design Requirements for Washing Machines

It is recommended to revise the Eco-design Requirements for Washing Machines as soon as possible, in particular to strengthen the requirements on the Energy Efficiency Index. Additionally it is key that Minimum Energy Performance Standards (MEPS) shall also be set for the spin-drying efficiency (A is recommended). Drying laundry by tumble driers consumes far more energy than the washing itself and spinning is much more efficient than tumble drying.

Revision of The Blue Angel RAL-UZ 137 and the EU Ecolabel

The Blue Angel designed its criteria for RAL-UZ 137 at a date where no data was available according to the new EU energy label. The revised EU Ecolabel is not published so far. Both labels should focus on best products and therefore should – based on the results outlined above – revise/design their requirements as soon as possible, in particular regarding the Energy Efficiency Index and the spin-drying efficiency (A is recommended).

Acknowledgements

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