Cold wash – the cool and modern way to launder

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Abstract

Heating-up cold tap water to 30 °C, 40 °C, 60 °C or even 90 °C/95 °C uses the lion's share of washing machines' electricity consumption. "Cold wash" – washing at 15 °C/20 °C – saves around 60 % electricity compared to a cycle at 40 °C. Thus, cold wash holds a tremendous energy saving potential, not matched by any other measure in the whole washing process. In EU-27 cold wash can save up to 11 TWh per year, 2,200 million Euros per year or the annual production of the nuclear power plant Emsland.

The EU Ecodesign Regulation 1015/2010 requires washing machines to offer a washing cycle at 20 °C. A variety of detergent designed for a temperature range from 15 °C/20 °C up to 60 °/90 °C are available in Europe. Despite all of this, prejudices, traditions and habits prevent most consumers from cold-washing. Discussions on cold wash – especially on the washing performance – are often controversial and emotional.

To contribute to the debate with impartial and scientific facts, Topten (www.topten.eu) arranged 24 test situations and carried out 18 tests in collaboration with the VDE Testing and Certification Institute and the consumer organisation Stiftung Warentest in December 2014. The tests measure the washing performance and energy consumption of washing cycles under several combinations of factors: temperature (20 °C and at 40 °C); detergent (three different products), washing machines (three models), loading (half- and full-load) and pre-treatment (or not) of stains.

The paper presents and analyses test results. It concludes with recommendations for various stakeholders such as EU policy makers, retailers, producers, NGOs and academia.

Introduction

The washing of clothes and textiles is part of our everyday routine. But by using energy and water it puts a strain on our environment.

Heating-up cold tap water to 30 °C, 40 °C, 60 °C or even 90 °C/95 °C uses the lion's share of washing machines' electricity consumption. Cold wash – washing at 15 °C/20 °C – saves around 60 % electricity compared to a cycle at 40 °C. Thus, cold wash holds a tremendous energy and CO_2 saving potential, not matched by any other measure in the whole washing process.

At the EEDAL-conference 2013 Topten International Services TIS in collaboration with Mibelle Group and the Federation of Migros Cooperatives presented the paper "Cold Wash – Do Prejudices Impede High Energy Savings?" (Josephy et al. 2013). The paper was mainly based on the knowledge of experts on cold wash. It showed that washing machines with a 15 °C/20 °C cycle – as required by the EU Ecodesign Regulation since end 2013 (Commission Regulation (EU) No 1015/2010) – and appropriate detergent for low washing temperatures both are available on the European market. In the case a consumer perceives the washing result as insufficient, it is not necessarily the fault of the cold wash, but may have a number of other causes such as laundry sorting, pre-treatment of stains, loading of the washing machine etc. It is mainly prejudices, but also tradition and custom, that hinder consumers from taking the step towards cold wash in their everyday life.

The discussions on cold wash – especially on its washing performance – run mostly controversial and emotional. To contribute to this debate with impartial and scientific facts, Topten (Best products of Europe, www.topten.eu) arranged 24 test situations and carried out 18 tests in collaboration with the VDE Testing and Certification Institute and the consumer organisation Stiftung Warentest in December 2014.

To our knowledge, the test arrangement is a novel approach: the tests compared the washing performance at 40 °C and at 20 °C. Thereby factors influencing the washing performance were systematically investigated at each temperature such as detergent (3 products), pre-treatment of stains (yes and no), washing machines (3 models) and loading (half and full). The measurements followed EN 60456 (for details see below). During the wash cycles electricity consumption and programme duration were recorded.

Hygiene was not part of the tests. A research of the University of Bonn and Hochschule Rhein-Waal showed that, due to their long programme duration, energy saving washing programmes remove many germs from the laundry even at low temperatures. Bleach helps to remove them. Those bacteria and fungi, which survive at low temperatures even with bleach, are most likely not a danger for healthy people (test 11/2014a).

Also biofilm – a film of bacteria and fungi multiplying in the humid environment of the washing machine and settling especially on plastic parts, hard to reach areas and on the washing machine's drum – was not part of the tests. Biofilm can be avoided with simple measures such as leaving the door of the washing machine and detergent compartment open so that the residual moisture can evaporate and running a load of laundry at 60 °C with heavy-duty detergent occasionally (test 11/2014a, Washing at 20 °C is Cool, 2014).

This paper first describes the methods and test conditions. Then it presents and discusses the results and concludes with recommendations for various stakeholders such as EU policy makers, retailers, producers, NGOs and academia.

How it was tested

Methods and test conditions are described in detail in the test report (Prüfbericht, 2015).

The measurements followed EN 60456: 2011 with test laundry, standardised soiling and under normative test conditions.

For the determination of the washing performance, standard test strips "Swissatest No. 108" were sewed on the laundry in accordance with EN 60456 (Figure 1a). Each test strip was soiled with the five standard soiling sebum/pigment, mineral oil/carbon black, blood, chocolate/milk and red wine.

Test programmes were:

- standard 40 °C cotton programme (energy saving programme) as also tested and used for the EU Energy label for washing machines (Commission Delegated Regulation (EU) No 1061/2010)
- 20 °C cotton programme as required by the EU Ecodesign Regulation 1015/2010 for washing machines (Commission Regulation (EU) No 1015/2010).

24 situations were arranged to investigate the influence on the washing performance (each 12 situations at 20 °C and at 40 °C, see Table 1) by varying detergent (good, medium, sufficient), pre-treatment of stains (yes, no), washing machine (good, medium, sufficient) and loading (half-load, full-load). Some situations occurred multiple times (S1 & S5; S2, S8 & S11). Therefore in total 18 tests were carried out (each 9 tests at 20 °C and at 40 °C).

With exception of the tests regarding the influence of loading it always was tested at half-load[1]. Half-load is the load, which is tested at 40 °C for the EU Energy label. Therefore and to get comparable values with 20 °C it was tested this way. Furthermore half-load better reflects real consumer behaviour: the average washing load in European households is assumed to be between 3 kg and 4 kg (Josephy et al. 2013). The respective number of laundry pieces (cotton towels, pillows, bed sheets) for the loadings "half" and "full" was in accordance with EN 60456.

Washing machines, detergent and the product to pre-treat stains were selected as follows:

- The three washing machines were selected with regard to their washing performance (good, medium and sufficient) according to the latest test results published by the consumer organisation Stiftung Warentest in test 11/2014a. They are of different brands, but are all rated in the best Energy efficiency class according the EU Energy label (A+++) and have the same rated capacity.
- The detergent were selected with regard to their washing performance (good, medium and sufficient). The "good" and the "sufficient" were selected on basis of the latest test results published by the consumer organisation Stiftung Warentest in test 11/2014b. The "medium" detergent corresponds to the standard-detergent (IEC A*) which is in accordance with EN 60456 and thus also is used when testing for the EU Energy label. All three detergents were heavy duty powders with bleach. IEC A* was dosed according to standard, the other ones according to manufacturer's instructions.
- The product to pre-treat the stains was selected on an expert's recommendation. It is assumed to be wide spread product on the European market. It was sprayed on each soiling at four points by one stroke from the spray bottle into a cylinder of 40 mm in diameter (Figure 1b). Exposure time was about 5 minutes.[2]

During the wash cycle electricity consumption and programme duration were recorded. Also recorded but not focused and discussed in this paper were water consumption, amount of alkalinity remaining in the textiles, temperature, maximum spin speed and residual moisture.

After being washed, the laundry was dried in accordance with EN 60456 (Figure 1e). Then reflectance of each of the

1. Corresponds to "partial load" according to the Commission Delegated Regulation (EU) No 1061/2010 and Commission Regulation (EU) No 1015/2010.

2. During the test procedure it was found that the product to pre-treat stains was not suitable for blood (the pre-treated areas turned darker instead of more brightened). According to the manufacturer's information the product is designed for human blood and not for blood of pigs as used on the test strips. It is assumed that in daily practice there is no degradation for blood when applying the product. For blood therefore the same reflectance values were taken when testing with the product as when testing without it.

Table 1. Overview on the test arrangement.

Situation	Test Nr.		Temperature	Varying parameters	Fix parameters
Influence of detergent					
S1	Test 2a	T2	20°C	good detergent	no soil remover good machine half-load
	Test 2b		40°C		
S2	Test 3a	T3	20°C	medium detergent	
	Test 3b		40°C		
S3	Test 5a	T5	20°C	sufficient detergent	
	Test 5b		40°C		
Influence of pre-treatment of stains					
S4	Test 1a	T1	20°C	plus soil remover	good detergent good machine half-load
	Test 1b		40°C		
S5	Test 2a	T2	20°C	no soil remover	
	Test 2b		40°C		
S6	Test 8a	T8	20°C	plus soil remover	sufficient detergent sufficient machine half-load
	Test 8b		40°C		
S7	Test 9a	T9	20°C	no soil remover	
	Test 9b		40°C		
Influence of washing machine					
S8	Test 3a	T3	20°C	good machine	medium detergent half-load
	Test 3b		40°C		
S9	Test 6a	T6	20°C	medium machine	
	Test 6b		40°C		
S10	Test 7a	T7	20°C	sufficient machine	
	Test 7b		40°C		
Influence of loading					
S11	Test 3a	T3	20°C	half-load	good machine medium detergent no soil remover
	Test 3b		40°C		
S12	Test 4a	T4	20°C	full-load	
	Test 4b		40°C		

five soiling was measured (Figure 1f) and the average was derived after the completion of a test cycle. These five average-values then were summed up to the test strip's total reflectance (in %).[3]

Washing Efficiency Index

The reflectance values by themselves as measured after washing do not have an explanatory power on the washing performance. Relevant for conclusions is the so called Washing Efficiency Index. It is the ratio between the reflectance value of the test (C_{test}) and the reflectance value from a reference machine (C_{ref}). According to Commission Regulation (EU) 1015/2010 temperature of the reference machine is 60 °C.[4]

The Washing Efficiency Index (I_W) according to Commission Regulation (EU) 1015/2010 is based on the three Washing Efficiency Index of the three standard cotton programmes 60 °C full-load ($I_{W,60}$, 3 ×), 60 °C half-load ($I_{W,601/2}$, 2 ×) and 40 °C half-load ($I_{W,401/2}$, 2 ×).

The Washing Efficiency Index (I_W) is calculated and rounded to three decimal places in accordance with Annex II of Commission Regulation (EU) 1015/2010.

For washing machines with a rated capacity higher than 3 kg the Commission Regulation (EU) 1015/2010 requires a Washing Efficiency Index (I_W) of >1.03.

3. Example (Test 2b, 40 °C): average reflectance of sebum/pigment: 74.55; mineral oil/carbon black: 47.89; blood: 86.04; chocolate/milk: 75.15; and red wine: 82.60. Reflectance sum: 366.23.

4. Example (Test 2b, 40 °C): reflectance sum of test (C_{test}): 366.23, reflectance sum of reference machine ($C_{ref, 60°C}$): 330.37, Washing Efficiency Index ($C_{test}/C_{ref, 60°C}$) = 1.109.

Figure 1. a) Test strips are sewed on the test laundry (top left), b) pre-treatment of stains (top middle), c) the washing machine is loaded in accordance with EN 60456 (top right), d) undloading of the washing machine (down left), e) drying of the laundry (down middle) and f) measuring of reflectance of each soiling (down right).

To allow comparisons of our test results with the EU Ecodesign requirements, the Washing Efficiency Index (reference 60 °C) in addition was calculated for all tests at 20 °C (half-load ($I_{W,201/2}$) and full-load (I_{W20}) as well as for the test at 40 °C full-load ($I_{W,40}$).

Results and Discussion

60 % LESS ELECTRICITY CONSUMPTION AT 20 °C THAN AT 40 °C

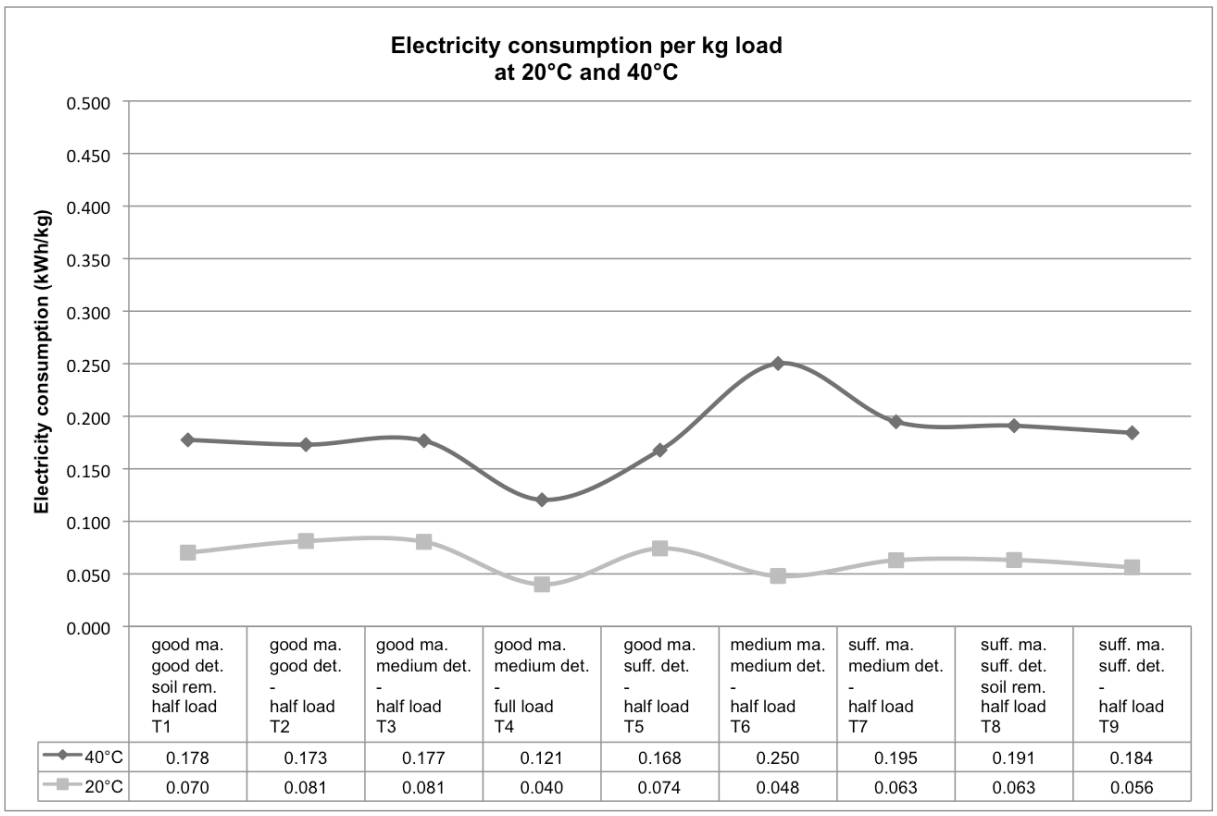
A key finding of this study is: washing at 20 °C consumed between 53 % and 80 % less electricity per kg load than washing at 40 °C. In average washing at 20 °C consumed 64 % less electrical energy than at 40 °C (Figure 2).

GOOD WASHING RESULTS AT 20 °C ARE POSSIBLE

- The washing performance at 20 °C lays in average around 10 % below the one at 40 °C (Figure 3, minimum: 7.2 %; maximum: 12.6 %). This partly can be explained by the shorter programme times of the 20 °C-programmes compared to the 40 °C-programmes (details see below).
- But – and this is the most important result of this study – washing at 20 °C provides good washing results when using a good machine with a good detergent (with or without additional soil remover). Reference for "good" is the Washing Efficiency Index (I_W) >1.03 as required by the EU Ecodesign (Commission Regulation 1015/2010). T1 at 20 °C (with soil remover) reaches 1.032, T2 (without soil remover) reaches 0.994 and fulfils the requirement of >1.03 too, when taking the allowed tolerance into account[5]. Both results are remarkable, especially given the fact that 40 °C-programmes at half-load as tested for the EU Energy label[6] usually deliver a Washing Efficiency Index ($I_{W,401/2}$) around 1.03 (experienced by VDE).
- Another interesting finding is that washing at 20 °C reaches even better or approximately the same results than washing at 40 °C.
  - T1 at 20 °C reaches in six cases better washing results than T4 to T9 at 40 °C.
  - T2 at 20 °C washed better or approximately as well as T7 to T9 at 40 °C.

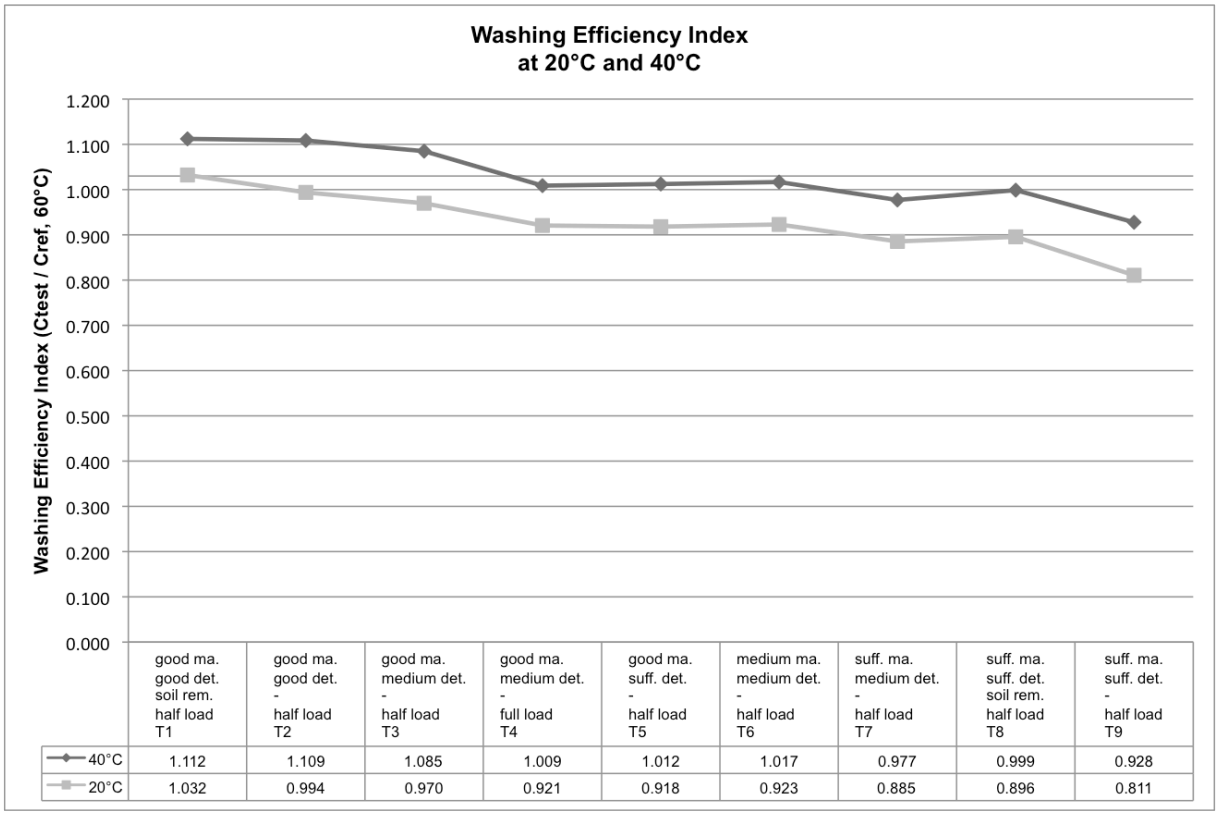
5. Annex III of Commission Regulation 1015/2010: The measured value shall not be less than the rated value of the Washing Efficiency Index (I_W) by more than 4 %.

6. For EU Energy labelling is tested with the IEC A* detergent, which in this study corresponds to the medium detergent.



	good ma. good det. soil rem. half load T1	good ma. good det. - half load T2	good ma. medium det. - half load T3	good ma. medium det. - full load T4	good ma. suff. det. - half load T5	medium ma. medium det. - half load T6	suff. ma. medium det. - half load T7	suff. ma. suff. det. soil rem. half load T8	suff. ma. suff. det. - half load T9
40°C	0.178	0.173	0.177	0.121	0.168	0.250	0.195	0.191	0.184
20°C	0.070	0.081	0.081	0.040	0.074	0.048	0.063	0.063	0.056

Figure 2. Washing at 20 °C uses around 60 % less electricity per kg load than at 40 °C.



	good ma. good det. soil rem. half load T1	good ma. good det. - half load T2	good ma. medium det. - half load T3	good ma. medium det. - full load T4	good ma. suff. det. - half load T5	medium ma. medium det. - half load T6	suff. ma. medium det. - half load T7	suff. ma. suff. det. soil rem. half load T8	suff. ma. suff. det. - half load T9
40°C	1.112	1.109	1.085	1.009	1.012	1.017	0.977	0.999	0.928
20°C	1.032	0.994	0.970	0.921	0.918	0.923	0.885	0.896	0.811

Figure 3. Washing at 20 °C provides good washing results when using a good machine with a good detergent.

Table 2. Overview on the influence on the washing performance by detergent, pre-treatment of stains, washing machine and loading.

Variation of the washing performance due to changes in …	at 40 °C	at 20 °C
Detergent: from the good to the sufficient one	-8.7 %	-7.6 %
Pre-treatment of stains		
Good detergent & good machine: from additionally soil remover to no additionally soil remover	-0.3 %	-3.7 %
Sufficient detergent & sufficient machine: from additionally soil remover to no additionally soil remover	-7.1 %	-9.5 %
Washing machine: from the good to the sufficient one	-9.9 %	-8.7 %
Loading: from half-load to full-load	-7.0 %	-5.1 %
All parameters: from best (T1) to worst scenario (T9)	-21.5 %	-16.6 %

WASHING PERFORMANCE IS INFLUENCED BY DETERGENT, PRE-TREATMENT OF STAINS, MACHINE AND LOADING

Overall impact by detergent, pre-treatment of stains, machine and loading is higher than by temperature

The tests showed that detergent, pre-treatment of stains, washing machine and loading have an impact on the washing performance at 20 °C and at 40 °C. Details see below. Table 2 summarizes:

Best scenario at 40 °C and at 20 °C is the combination of the good machine with the good detergent plus soil remover (T1) whereas the worst scenario at 40 °C and 20 °C is the sufficient machine combined with the sufficient detergent and no additionally soil remover (T9). The comparison of worst versus best scenario shows:

- 40 °C: the washing performance of the worst scenario was 21.5 % lower than of the best one.
- 20 °C: the washing performance of the worst scenario was 16.6 % lower than of the best one.

These differences in the washing performance between best and worst scenario at 40 °C (-21.5 %) and at 20 °C (-16.6 %) lead to the conclusion that the impact by detergent, pre-treatment of stains, washing machine and loading is more relevant than temperature, which shows a difference in the washing performance of around 10 % between 40 °C and 20 °C.

Influence of detergent

The influence of the detergent was tested at 40 °C and at 20 °C by washing with the good, medium and sufficient detergent using always the same washing machine (T2, T3, T5, see Table 1).

- The good detergent achieved at 40 °C as well as at 20 °C better washing performances than the medium detergent and the medium one better washing performances than the sufficient one (Figure 4a).
- The sufficient detergent's washing performance was at 40 °C 8.7 % lower and at 20 °C 7.6 % lower than the washing performance of the good detergent.

Influence of pre-treatment of stains

The influence of the pre-treatment of stains was tested at 40 °C and 20 °C by using a) the good machine with the good detergent and b) the sufficient machine with the sufficient detergent, each with and without additional soil remover (a) T1, T2, b) T8, T9, see Table 1).

- The application of additionally soil remover had a particularly positive influence when using the sufficient detergent in the sufficient machine. Without soil remover the washing result was at 40 °C lowered by 7.1 % and at 20 °C by 9.5 % (Figure 4b).
- The influence of the soil remover in combination with the good detergent/good machine was comparatively weak (-0.3 % at 40 °C and -3.7 % at 20 °C).

Influence of washing machine

The influence of the washing machine was tested at 40 °C and 20 °C by washing with the good, medium and sufficient washing machines using always the same detergent (T3, T6, T7, see Table 1).

- The good machine achieved at 40 °C and at 20 °C better washing results than the medium machine, the medium machine better washing results than the sufficient one (Figure 4c).
- The washing performance of the sufficient machine was at 40 °C 9.9 % lower and at 20 °C 8.7 % lower than the washing performance of the good machine.

Influence of loading

The influence of loading was tested at 40 °C and 20 °C by washing at half-load and at full-load in the same machine and with the same detergent (T3, T4, see Table 1).

- The washing performance was at 40 °C and 20 °C better at half-load than at full-load (Figure 4d).

The washing performance at full-load was at 40 °C 7.0 % worse and at 20 °C 5.1 % worse than the washing performance at half-load. This result can mainly be explained by a higher mechanical influence at half-load because the laundry can move better in the drum, which positively affects the washing result according to the Sinner circle.[7]

7. According to the Sinner circle – the mechanism of action, with which the cleaning processes are organized and accomplished – a good washing result always depends on the interaction of the four factors mechanics (i.e. the agitation of the laundry in the drum), temperature, time and chemistry. Mechanics, wash temperature and wash time are controlled by the washing machine and by the selected washing cycle, respectively. The chemistry is given by the chosen detergent. All four factors are interdependent, but inter-changeable in size. If one of the factors is changed, it must be compensated with one or more other factors in order to achieve the same satisfactory washing result.

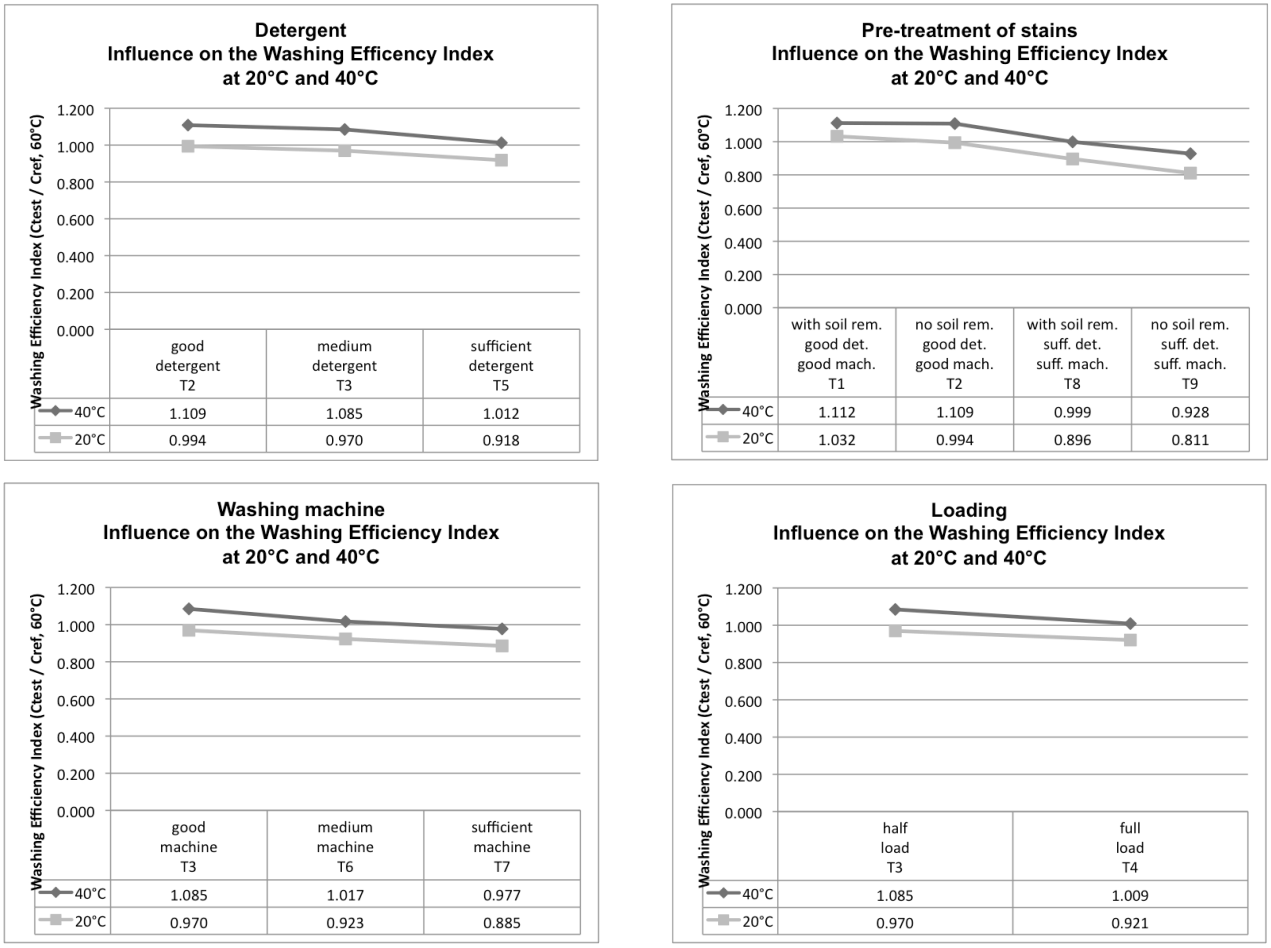


Figure 4. Influence on the washing performance by a) detergent (top left), b) pre-treatment of stains (top right), c) washing machine (down left) and d) loading (down right).

PROGRAMME DURATION ALSO AFFECTS THE WASHING EFFICIENCY INDEX

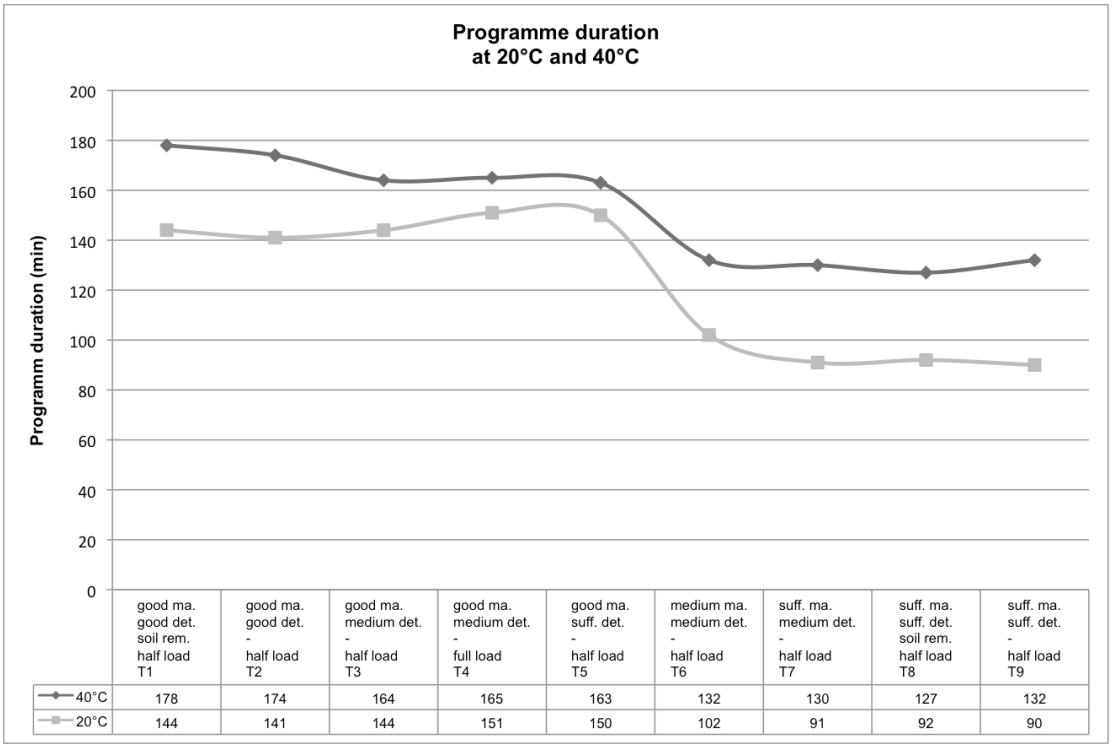
- Programme duration differs between the two tested temperature levels 40 °C and 20 °C (Figure 5): The 20 °C-programmes were all shorter than the 40 °C-programmes (as used for the EU Energy label). They only last between 1.5 and 2.5 hours while the 40 °C-programmes run between 2 and 3 hours. The time savings at 20 °C were between 14 and 42 minutes, in average half an hour. According to the Sinner circle time is one of the four parameters for achieving a good washing result (see Footnote 7). The 40 °C standard programmes usually are optimised also in duration with regard for a good energy efficiency classification on the EU Energy label.
- Programme duration also differs between the three tested washing machines: the good machine (T1 to T5) had a considerably longer wash time than the sufficient one (T7 to T9). The programme duration of the good machine was at 40 °C around 30 minutes longer, at 20 °C up to 1 hour longer than programme duration of the sufficient machine.
- The good machine not only had the longest programme duration (at 40 °C and 20 °C) but also reached the best washing performances (at 40 °C and 20 °C, see Figure 3). Vice versa: the sufficient machine had the shortest programme duration and the worst washing performance. Once again this demonstrates well the correlation between programme duration and washing performance (see also Footnote 7 on the Sinner circle).
- The around 10 % worse washing results at 20 °C compared to 40 °C might partly be explained by the shorter programme durations of the 20 °C-programmes.

Conclusions

- Across the washing arrangements tested, washing at 20 °C saved on average around 60 % electrical energy compared to the 40 °C-programme. Thus, cold wash holds a tremendous electricity and CO_2 savings potential, which cannot be reached as easily by any other measure in the whole washing process. It may be worthwhile to rethink the everyday routine.

  The EU-27-stock of washing machines was estimated to be around 180 million units in 2013 with a total electricity consumption of 19 TWh per year[8] ("Omnibus" Review Study 2014).

8. Assumptions according to the "Omnibus" Review Study 2014: 185 cycles per unit per year and 0.57 kWh per cycle based on average 40 °C part load programme plus 12 % for slightly higher load (+10 %) and 1 °C higher wash temperature. Note: Electricity consumption would be higher if based on the EU Energy label: 220 cycles and inclusion of the 60 °C-programme.



	good ma. good det. soil rem. - half load T1	good ma. good det. - half load T2	good ma. medium det. - half load T3	good ma. medium det. - full load T4	good ma. suff. det. - half load T5	medium ma. medium det. - half load T6	suff. ma. medium det. - half load T7	suff. ma. suff. det. soil rem. half load T8	suff. ma. suff. det. - half load T9
40°C	178	174	164	165	163	132	130	127	132
20°C	144	141	144	151	150	102	91	92	90

Figure 5. Programme duration influences the washing result.

Lowering the washing temperature from 40 °C to 20 °C leads to electricity savings of 60 % (see our tests), which equals savings of 11 TWh per year, of 2,200 million Euros per year[9] or of the annual production of the nuclear power plant Emsland (Germany, 11.5 TWh 2013, Wikipedia).

- Washing results depend on a variety of factors: unsurprisingly, washing performance decreases with the quality of detergent and of the washing machine. Pre-treating stains increases washing performance, just as washing half-load (as opposed to full-load). The washing performance is also affected by the duration of the programme.
- Washing at higher temperatures (40 °C) generally results in better washing performance (around 10 %). Good washing performance – in compliance with the EU Ecodesign Regulation 1015/2010 requirements (>1.03) – is reached at 20 °C when using good machines and good detergent (with or without additional soil remover).
- Though not part of the test, one can assume that the potential of cold wash – washing at 15 °C/20 °C – is not yet reached and that the threshold of 1.03 even can be exceeded at 20 °C, e.g. with washing machines with an even better washing performance than the tested one (e.g. as also presented in test 11/2014a), better detergent and/or with longer programme duration at 20 °C.
- Furthermore it has to be kept in mind, that the tests were carried out with standard test laundry, which is heavily soiled. However, our everyday clothing only worn for a few hours or one day usually are free of stains and are only slightly and normally soiled. For this type of laundry cold wash absolutely is appropriate.

Recommendations

We recommend promoting cold wash across Europe. The tremendous but still dormant electricity savings potential is unmatched in the whole washing process, and represent an opportunity not to be missed. To promote cold wash, we suggest:

- EU policies: the revision of EU Ecodesign Regulation 1015/2010 to include requirements on washing efficiency at 20 °C.
- Washing machine manufacturers, detergent manufacturers and retailers: active and continued advertisement of cold wash for slightly and normally soiled laundry; ongoing optimization of the 15 °C/20 °C-cycles and of detergent appropriate for these temperatures.
- Environmental organizations, consumer organizations, energy agencies: active and continued consumer information and education campaigns on cold wash (e.g. with flyers such as "Washing at 20°C is Cool", 2014).
- Academia, research institutes, testing laboratories: Publication of studies (consumer and technical), continuing tests on cold wash not only on heavily soiled but also on slightly and normally soiled laundry.

9. Assumption electricity tariff: €0.20/kWh. However, there can be large differences depending on country or electric utility.

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