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Saving Potential of Miele Washing Machines with the PowerWash 2.0 Technology

Comparison of the Energy Consumption and Global Warming Potential of Washing Machines with PowerWash 2.0 with Appliances of Competitors with Conventional Technology

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Summary

Background and goal

For several years now, we see the emergence of a trend towards an increasing loading capacity in washing machines. At the same time, there is a steady decline in the average size of households, an increasing differentiation in the programme design of washing machines towards more specific programmes, and the correspondent supply of appropriate special washing agents on the market. Against this background, private consumers will encounter increasing difficulties relating to the use of the appliance at full load, although this remains a reasonable and effective way of reducing electricity and water consumption for doing laundry.

Against this background, Miele has developed the PowerWash 2.0 technology, the use of which enables a very good adaptation of the energy consumption values to be achieved at reduced load. As the advantages of this technology (low consumption values in most programmes while at the same time good washing performance and short programme duration) are not adequately represented on the energy efficiency labelling the goal of this study is to quantify the energy saving potential of the new technology as compared to appliances from competitors with traditional technology. Also the water consumption, washing efficiency and programme duration shall be compared.

Methodology

After a detailed analysis of the new technology is was decided that a narrow methodological approach is appropriate for the study at hand:

- The calculations focus solely on the use phase of the washing machines.
- The study solely focuses on the electricity consumption and the connected global warming potential (GWP).

The study results and especially the comparative assertion are intended to be disclosed to the public. Therefore the data, calculations and the study results were reviewed internally, taking into account the main principles of a critical review under LCA (life cycle assessment) methodology.

The goal of this study is to quantify the energy saving potential of the PowerWash 2.0 technology as compared to appliances from competitors with traditional technology. To this end a Miele washing machine equipped with this technology is compared to equivalent, high efficient new appliances of competitors. The geographical scope of the study is Germany.

Target audiences of this study are decision makers in industry and commerce, as well as consumers that are interested in the background calculations of the marketing claims of a manufacturer. As functional unit the annual number of washing cycles of an average 2-person household is defined. Both an uncertainty and two sensitivity analyses are conducted.

The PowerWash 2.0 technology

The PowerWash 2.0 technology aims at reducing the electricity consumption when the washing machine is only partially loaded. It is based on three main characteristics that lead to a substantial reduction of the electricity consumption under these circumstances: very exact estimation of the real load, very low remaining moisture content of the laundry and heating up by steam.

Data and assumptions

As the Miele-appliance with PowerWash 2.0 is a very efficient premium model with a rated capacity of 8 kg (front loader), three alternative appliances were selected in accordance with these specifications, i.e. very efficient 8 kg-front loaders of competitors.

The washing behaviour is derived from several consumer surveys conducted during the past years. A slightly simplified typical washing behaviour was assumed. As the results might depend on this assumption two sensitivity analyses were conducted (larger household and higher share of the use of standard programmes).

For the programmes that were assumed to be mostly used by consumers the electricity consumption, the washing efficiency, the programme duration and the water consumption of the selected appliances is defined based on direct measurements or self-declarations of the manufacturers.

Results

The Miele washing machine with PowerWash 2.0 has the lowest annual energy consumption (76 kWh p.a.) of the compared appliances under the assumed usage conditions. This contrasts the energy labelling declaration, where the Miele appliance has the highest annual energy consumption. Under the assumed real-life conditions the Miele appliance with PowerWash 2.0 saves between 14% and 27% of the annual electricity consumption compared to the selected appliances of other manufacturers. The absolute saving potential is between 12 and 28 kWh per year, which represents 0.4 to 0.9% of the overall electricity consumption of a typical 2-person household.

As in case of the electricity consumption, the Miele washing machine with PowerWash 2.0 technology has the lowest annual global warming potential with 48 kg CO_2-eq per year. The savings compared to the other alternatives are 8 to 18 kg CO_2-eq per year. The relative saving is the same as in case of the electricity consumption.

The uncertainty analysis shows that the savings can be considered to be significant. The sensitivity analyses show that in case of larger households the absolute saving potential increases whereas the relative saving potential stays the same. For households that often use the very energy efficient standard programmes the additional saving through the PowerWash 2.0 technology is smaller than if mainly other programmes are used.

The PowerWash 2.0 technology does not lead to higher water consumption, lower washing efficiency and longer programme duration. In contrast, the Miele appliances shows the lowest average water consumption, the best average washing efficiency and the shortest average programme duration of the compared appliances. Especially the standard programmes are substantially shorter than the equivalent programmes of the appliances of the other manufacturers.

Zusammenfassung

Hintergrund und Zielsetzung

Seit einigen Jahren ist eine zunehmende Beladungskapazität bei Waschmaschinen zu beobachten. Gleichzeitig nimmt die durchschnittliche Haushaltsgröße stetig ab, die Programmgestaltung von Waschmaschinen wird zunehmend ausdifferenziert hin zu mehr Spezialprogrammen bei gleichzeitigem Angebot von entsprechenden Spezialwaschmitteln im Handel. Vor dem Hintergrund dieser Entwicklungen ist es für private Konsumenten zunehmend schwierig, die Geräte immer nur mit voller bzw. empfohlener Beladung zu nutzen, auch wenn dies weiterhin ein sinnvoller und effektiver Weg ist, den Energie- und Wasserverbrauch durch das Wäschewaschen zu senken.

Vor diesem Hintergrund hat Miele die PowerWash 2.0-Technologie entwickelt, die insbesondere bei Minderbeladung eine sehr gute Anpassung der Verbrauchswerte erreicht. Da die Vorteile dieser Technologie (niedrige Verbrauchswerte in den meisten Programmen bei gleichzeitig guter Waschleistung und kurzer Programmdauer) durch das Energielabel nicht adäquat wiedergegeben werden, ist das Ziel der vorliegenden Studie, das Einsparpotenzial der neuen Technologie hinsichtlich des Stromverbrauchs im Vergleich zu Geräten von Wettbewerbern mit herkömmlicher Technologie zu quantifizieren. Außerdem sollen der Wasserverbrauch, die Waschleistung und die Programmdauer verglichen werden.

Methode

Nach einer detaillierten Analyse der neuen Technologie wurde entschieden, dass ein enger methodischer Ansatz für die vorliegende Studie angemessen ist:

- Die Berechnungen berücksichtigen ausschließlich die Nutzungsphase der Waschmaschinen.
- Die Studie betrachtet nur den Stromverbrauch und das damit zusammenhängende Treibhauspotenzial.

Da die Ergebnisse der Studie und insbesondere die vergleichenden Aussagen zur Veröffentlichung bestimmt sind, werden die Daten, Berechnungen und Ergebnisse der Studie intern begutachtet, wobei die Grundprinzipien eines Kritischen Gutachtens gemäß der Ökobilanzierung berücksichtigt wurden.

Ziel der Studie ist es, das Energieeinsparpotenzial der PowerWash 2.0-Technologie im Vergleich zu Geräten von Wettbewerbern mit herkömmlicher Technologie zu quantifizieren. Hierfür wird eine Miele Waschmaschine mit dieser Technologie mit äquivalenten, hocheffizienten neuen Geräten von Wettbewerbern verglichen. Der geographische Bezugsraum ist Deutschland.

Zielgruppe der Studie sind Entscheider in Industrie und Handel, sowie Konsumenten, die an den Hintergrundberechnungen von Marketingaussagen eines Herstellers interessiert sind. Als funktionelle Einheit wird die jährliche Anzahl von Waschzyklen eines durchschnittlichen 2-Personen-Haushalts festgelegt. Sowohl eine Analyse zur Bewertung der Signifikanz der Ergebnisse als auch zwei Sensitivitätsanalysen werden durchgeführt.

Die PowerWash 2.0-Technologie

Die PowerWash 2.0-Technologie reduziert den Stromverbrauch wenn die Waschmaschine nur zum Teil beladen ist. Sie basiert auf drei Haupteigenschaften die zu einer deutlichen Stromein-

sparung unter diesen Umständen führen: sehr genaue Abschätzung der tatsächlichen Beladung, sehr niedriger Restfeuchtegehalt der Wäsche, sowie Aufheizen durch Dampf.

Daten und Annahmen

Da das Miele-Gerät mit PowerWash 2.0-Technologie ein sehr effizientes Premiummodell mit einer Nennkapazität von 8 kg ist (Frontlader), wurden drei alternative Geräte in Übereinstimmung mit diesen Eigenschaften ausgewählt, d.h. sehr effiziente 8 kg-Frontlader von Wettbewerbern.

Das Waschverhalten wurde mit Hilfe von mehreren Verbraucherstudien abgeleitet, die in den letzten Jahren durchgeführt wurden. Ein leicht vereinfachtes typisches Waschverhalten wurde angenommen. Da die Ergebnisse von diesen Annahmen abhängen können, wurden zwei Sensitivitätsanalysen durchgeführt (zum einen für einen größeren Haushalt, zum anderen bei höherem Anteil der Nutzung von Standardprogrammen).

Für die Waschprogramme, die am häufigsten durch die Konsumenten genutzt werden, wurden, basierend auf direkten Messungen oder auf Selbstdeklaration der Hersteller, der Stromverbrauch, die Waschleistung, die Programmdauer und der Wasserverbrauch der ausgewählten Geräte definiert.

Ergebnisse

Die Miele-Waschmaschine mit PowerWasch 2.0 hat unter den angenommenen Nutzungsbedingungen den niedrigsten jährlichen Energieverbrauch der verglichenen Geräte (76 kWh pro Jahr). Dies steht im Widerspruch zur Energieeffizienzkennzeichnung, bei der das Miele-Gerät den höchsten jährlichen Verbrauch hat. Unter den angenommenen realen Bedingungen spart das Miele-Gerät mit PowerWash 2.0 im Vergleich zu den ausgewählten Geräten der Wettbewerber 14 bis 27% des jährlichen Stromverbrauchs ein. Das absolute Einsparpotenzial liegt zwischen 12 und 28 kWh pro Jahr, was 0.4 bis 0.9% des Gesamtstromverbrauchs eines typischen 2-Personen-Haushalts entspricht.

Entsprechend dem Stromverbrauch hat die Miele Waschmaschine mit PowerWash 2.0 mit 48 kg CO_2-eq das niedrigste Treibhauspotential. Die Einsparung im Vergleich zu den alternativen Geräten beträgt 8 bis 18 kg CO_2-eq pro Jahr. Die relative Einsparung ist mit der des Stromverbrauchs identisch.

Die Analyse zur Bewertung der Signifikanz der Ergebnisse zeigt, dass die Einsparungen als signifikant angesehen werden können. Die Sensitivitätsanalysen zeigen, dass im Fall von größeren Haushalten das absolute Einsparpotential ansteigt, während das relative Einsparpotential gleich bleibt. Für Haushalte, die häufig die sehr effizienten Standardprogramme nutzen, ist das zusätzliche Einsparpotenzial durch die PowerWash 2.0-Technologie kleiner als wenn hauptsächlich andere Programme genutzt werden.

Die PowerWash 2.0-Technologie führt nicht zu einem höheren Wasserverbrauch, niedrigerer Waschleistung und längeren Programmdauern. Im Gegenteil, das Miele-Gerät hat den niedrigsten durchschnittlichen Wasserverbrauch, die beste durchschnittliche Waschleistung und die kürzeste durchschnittliche Programmdauer der verglichenen Geräte. Vor allem die Standardprogramme sind deutlich kürzer als die äquivalenten Programme bei Geräten anderer Hersteller.

1. Background and goal of the study

For several years now, we have seen the emergence of a trend towards an increasing loading capacity in washing machines. The average capacity, i.e. load size of the appliance models offered for sale, for example, increased from 4.9 kg in 2000 to 7.04 kg in the year 2013 (JRC IPTS 2015). The range, too, has grown considerably: While, in 1997, primarily appliances smaller than 6 kg were on offer, most of the appliances today have a capacity between 5 and 9 kg, even appliances with up to 15 kg are available (JRC IPTS 2015).

At the same time, there was a steady decline in the average size of households (Statistisches Bundesamt 2011), as a result of which the volume of laundry per household tends to be smaller. Another trend is the increasing differentiation in the programme design of washing machines towards more specific programmes (see, e.g. Hauswirtschaft.info (2016)), and the correspondent supply of appropriate special washing agents on the market.

Against the background of these developments, private consumers will experience increasing difficulties relating to the use of the appliance only at full load (or the load recommended depending on the specific programme chosen), although this remains a reasonable and effective way of reducing electricity and water consumption for doing laundry, since, as a rule, full load involves the most efficient washing by use of a washing machine.

Almost all washing machines commercially available on the market today are equipped with a so-called automatic load detection for detecting reduced load and adjusting water and power consumption accordingly. However, this adjustment only takes place incompletely. Having measured a total of 50 different washing machine models, Stamminger & Schmitz (2016), for example, revealed that power consumption in the standard programme “cotton 60°C” at half load was only reduced by an average of 17% as compared to the full load consumption (ranging between 0% and 40%). The average reduction in water consumption reached 21%. It can be assumed that the reduction potential at reduced load is rather lower in other programmes, as energy consumption levels at half load are not taken into account in the calculation for the energy efficiency labelling in these programmes. It can be inferred from this that the specific water and power consumption related to the quantity of laundry at reduced load of the washing machine is higher than if the same volume of laundry had been washed at full or recommended load.

Against this background, Miele has developed the PowerWash 2.0 technology, the use of which, in particular at reduced load, enables a very good adaptation of the energy consumption values to be achieved. The specific energy consumption values at reduced load (i.e. per kg of washed laundry) are almost equal to those at full load.

Although the information on the energy label is based on the measurement of power consumption at half load, whereby savings through the PowerWash 2.0 technology also positively affect the energy efficiency labelling, the reduction of electricity use can also be achieved by simpler means, such as by a certain reduction of the quantity of water used while at the same time reducing the washing temperature and extending the duration of the programme. This, however, is associated with considerable disadvantages; the nominal temperature, for example, is not reached, the wash programmes take a very long time, and the savings, as a rule, are only achieved in the so-called standard programmes, i.e. the programmes, the energy consumption of which is measured with regard to the labelling on the energy label. Modern washing machines, in addition to the standard programmes, however, provide alternative 40°C and 60°C cotton programmes washing significantly faster, but electricity consumption in these washing cycles is much higher. Hence, the

standard energy consumption indicated on the energy label is contrasted by a significant upward deviation of energy consumption under real use conditions.

It is exactly at this point where the beneficial effects of the new technology developed by Miele can be enjoyed, because not only the reduction of energy consumption at reduced load will be significantly greater than with traditional automatic load detection, but also because it is not limited to the standard programmes but applies to most programmes. At the same time, the specified washing temperature is neither reduced nor the duration of washing increased.

To adequately highlight the advantages of appliances equipped with the PowerWash 2.0 technology in terms of energy consumption in the advertising and marketing of appliances with this technology, the goal of this study is to quantify the energy saving potential of the new technology as compared to appliances from competitors with traditional technology.

2. Methodology

2.1. General approach

When making comparisons between different products, in principle, all relevant phases of the life cycle must be taken into account. This means that the impact of a technology on material production, manufacture, distribution, use and disposal must be investigated to avoid that savings at a certain stage of the life cycle (e.g. the use phase) will be (over)compensated by additional expenditures in other phases (e.g. additional expenditure for material in the manufacturing phase).

In the preparation phase of the study at hand the appropriate methodological approach has been discussed intensively with Miele as commissioner. In a first attempt Oeko-Institut assumed that the implementation of the PowerWash 2.0 technology would require a completely new designed washing machine, including specific sensors and actors like electromagnetic valves etc. Therefore it was expected that there are significant differences not only in relation to energy and water consumption in the use phase of the machines, but in regard to the bill of materials (BOM) of a conventional washing machine on the one hand and the PowerWash 2.0 machine on the other hand, too. Under this condition it would have been necessary to conduct the comparison based on the method of Life Cycle Assessment (LCA). With the help of this holistic method the full range of environmental impacts assignable to products and services throughout the whole life cycle, including raw-material production, manufacture, distribution, use and disposal are taken into account. The procedure how to conduct an LCA is described in detail in DIN EN ISO 14040:2006 and 14044:2006. Furthermore to determine whether an LCA complies with the requirements in terms of methodology, data, analysis, and reporting, a critical review has to be conducted. In those cases where the LCA results shall be used for comparative assertion intended to be disclosed to the public, the critical review by a panel of interested parties would be compulsory.

However when discussing the characteristics of the PowerWash 2.0 technology in detail it turned out that no new components are required, the technology is based on the same BOM (bill of materials) as conventional Miele-machines on the market (i.e. Miele washing machines without PowerWash 2.0 technology). Obviously there are differences in the BOMs between different manufacturers, especially as Miele follows the approach of high durability and long lifetime of its products. However these differences cannot be attributed to the technology which is in focus of the study at hand and are therefore not considered here. The differences to a conventional washing process are completely realised with the help of software based adaptations and described more

detailed in section 3 of this study. Against this background it was decided to narrow the methodological approach as follows:

- Instead of an LCA which takes into account the whole life cycle of the systems under consideration, the calculations focus solely on the use phase of the washing machines.
- Instead of calculating a whole range of environmental impacts, the adapted approach solely focuses on the electricity consumption and the connected global warming potential (GWP).

The study results and especially the comparative assertion are still intended to be disclosed to the public. However, as the methodological approach does not claim to comply with the scope of an LCA, a formal critical review by a panel of interested parties was no longer necessary. However, the data, calculations and the study results were reviewed internally, taking into account the main principles of a critical review under LCA methodology.

2.2. Scope

The goal of this study is to quantify the energy saving potential of the PowerWash 2.0 technology as compared to appliances from competitors with traditional technology. To this end a Miele washing machine equipped with this technology is compared to equivalent, high efficient new appliances of competitors. All appliances have a rated capacity of 8 kg and are currently available on the market.

In order to be able to make a statement in as concrete terms as possible, the calculations will be carried out in a baseline scenario on the basis of a typical 2-person household. To ensure that this statement will equally apply to larger households, a sensitivity analysis for a typical 4-person household will be drawn up.

The study shall display the purchase situation when consumers are looking for a new washing machine and have to decide which appliance they should buy. Therefore only appliances currently (April/May 2016) for sale are compared with each other. Also, as the Miele-appliance is a very efficient premium model, the alternative appliances were selected in accordance with these specifications (see also section 4.1).

The geographical scope of the study is Germany.

2.3. Target audiences, intended and not intended applications of the study

Target audiences of this study are decision makers in industry and commerce, as well as consumers that are interested in the background calculations of the marketing claims of a manufacturer. Hence, the results can be used to derive the respective marketing claim of Miele with regard to the saving potential of the PowerWash 2.0 technology compared to similar washing machines of competitors.

It is important to note that the results of this study are only valid for Miele washing machines with PowerWash 2.0 technology, i.e. the calculated saving potential does not apply to all Miele washing machines or washing machines with only “PowerWash” technology (the preceding technology).

The study compares new washing machines, thus representing the purchase situation of a consumer when taking a decision between different new washing machines. It does not give information on possible saving compared to appliances in stock.

2.4. Functional unit

As functional unit the annual number of washing cycles of an average 2-person household is defined. For the sensitivity analysis of an average 4-person household the washing behaviour is adapted correspondingly. The concrete washing behaviour of the households is defined in section 4.2.

Additionally, to ensure the delivery of the same function (clean laundry) by all regarded alternatives (e.g. that there are no negative side effects on other parameters of the washing process), the following parameters are compared (the comparison takes place per wash cycle, not per functional unit):

- Water consumption,
- Washing efficiency (washing performance), and
- Programme duration.

The respective results can be found in section 6.

2.5. Indicators and impact categories

The regarded alternatives are compared with regard to the

- Electricity consumption and the
- Global warming potential (GWP).

The electricity consumption considers the annual electricity consumption of the defined households through the use of the different washing machines. It is the main aspect that is directly influenced by the PowerWash 2.0 technology.

The global warming potential describes the contribution of anthropogenic emissions at the heat absorption in the atmosphere and thus is an indicator to measure the so called greenhouse effect. Emissions to air that contribute to the greenhouse effect (e.g. CO_2, methane, nitrous oxide) are accounted for and are characterized in accordance to their specific global warming potential to the overall global warming potential. The specific global warming potential describes the greenhouse effect of chemical substances in relation to carbon dioxide (CO_2) with the help of CO_2-equivalents (CO_2-eq).

The GWP resulting from the electricity consumption is calculated with the following data set:

Table 2-1: Data set for calculation of the global warming potential of electricity generation

Data set of the Ecoinvent v3.2 database (2015)	GWP (according to IPCC (2007))
Market for electricity, low voltage [DE]	0.6374 CO_2-eq/kWh

The results of the electricity consumption and the respective global warming potential per functional unit can be found in section 5.

2.6. Uncertainty and sensitivity analyses

The measurement of the consumption and performance values of the selected washing machines obviously shows a certain degree of variation, resulting from intra- and inter-laboratory variability. Therefore the measurement results (wfk 2016) are analysed and the impact of the variation on the results is assessed (see section 5.3).

The uncertainties with regard to the consumer behaviour are covered by the sensitivity analyses. The following sensitivity analyses have been carried out:

- Larger household (4-person household instead of 2-person household, see also section 2.2)
- Increased use of the standard programmes (the programmes that are used for measuring the annual energy consumption for the EU energy label, i.e. cotton 60°C “eco” full and half load, cotton 40°C “eco” half load).

The assumptions of the respective consumer behaviour are described in section 4.2, the results of the sensitivity analyses can be found in section 5.4.

2.7. Evaluation of the significance of the differences found

The significance of the differences between the compared alternatives is evaluated in section 7.

2.8. Internal critical review

The data, calculations and the study results were reviewed internally, taking into account the main principles of a critical review under LCA methodology. In this regard the following requirements have been considered und ensured that

- the methods used to carry out the study are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal and intended applications of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

3. Explanation of the PowerWash 2.0 technology

The PowerWash 2.0 technology aims at reducing the electricity consumption when the washing machine is only partially loaded. It is based on three main characteristics that lead to a substantial reduction of the electricity consumption under these circumstances (Miele 2014b):

- First the automatic load detection is based on a measurement procedure that provides a very exact estimation of the real load. The mass is measured with the help of the mass inertia by short spinning of the dry laundry in the beginning of the wash cycle. If the washing machine is only partly loaded the PowerWash 2.0 process is utilized. If the load is higher than a certain threshold value the conventional wash process takes place.
- If the PowerWash 2.0 process takes place, the laundry is wetted by the “spin&spray” process in the main wash phase. This means that the drum speed is increased and the laundry forms a tunnel in the centre of the drum. At the same time the wash liquid is sprayed over the laundry. A second circulation pump recirculates the wash liquid until the laundry is completely wetted. The remaining moisture content of the laundry stays low during the whole wetting process 1) as the laundry is not drenched in the wash liquid and 2) through the spinning. Thus, compared to conventional technologies, much less water is bound to the laundry which reduces the amount of energy needed to heat the wet laundry up to the set temperature.
- Finally the wetted laundry is heated up to the set temperature by steam: As soon as the laundry is fully wetted a small amount of water in the suds container is heated to generate steam that heats the laundry.

In 2013, Miele introduced the PowerWash technology (Miele 2014a) a predecessor of the PowerWash 2.0 technology. This former technology is supposed to lead to a better and faster wetting of the laundry and a better utilisation of the detergent. It mainly consists of a second circulation pump to circulate the wash liquid and spray it directly on the laundry. The detergent, that usually tends to collect at the bottom of the suds container, is recirculated and led back into the inner drum. PowerWash thus leads to better cleaning results and faster wash cycles compared to appliances without the recirculation of the wash liquid.

In contrast to the PowerWash technology only PowerWash 2.0 leads to substantial lower electricity consumption in case of partial loading. The circulation pump is the prerequisite for PowerWash 2.0 but it has been introduced before and similar systems are also included in washing machines of other manufacturers (AEG 2015; Samsung 2010; Spray Project 2016). Thus PowerWash 2.0 is mainly a change in the process management. Additional components like sensors or pumps are not necessary compared to similar modern washing machines.

4. Data and assumptions

4.1. Selection of the alternative washing machines

As already outlined in section 2.2 the study aims at displaying the purchase situation when consumers are looking for a new washing machine and have to decide which appliance they should buy. Therefore appliances currently (April/May 2016) for sale of different manufacturers are compared with each other.

As the Miele-appliance is a very efficient premium model with a rated capacity of 8 kg (front loader), the alternative appliances were selected in accordance with these specifications, i.e. very efficient 8 kg-front loaders of competitors have been selected. To this end the website of the consumer information campaign "EcoTopTen" (EcoTopTen 2015) and the individual manufacturers' websites have been searched for the most efficient appliances currently on the market. If other, less efficient appliances would have been selected, the potential savings through the PowerWash 2.0 technology would be larger. The chosen approach thus represents a conservative approach.

The calculations of the study are based on the consumption and performance values of existing models of competitors; however in this report the model names are anonymized. The concrete models are listed in a separate annex that can be requested from Miele.

The following table shows the specifications of the washing machines that have been selected for the comparison.

Table 4-1: Selected washing machines

	Energy efficiency class	Annual energy consumption according to energy label
Miele WKF 131 WPS ("Miele")	A+++ -30%	137 kWh
Alternative 1	A+++ -50%	89 kWh
Alternative 2	A+++ -50%	97 kWh
Alternative 3	A+++ -40%	116 kWh

sources: Data from the websites and product fiches of the selected washing machines.

When comparing the selected washing machines with regard to the declarations on the EU energy label, it can be seen that the Miele appliances appears to be the least efficient model. To better understand the difference between these declarations and the results of the study at hand, it is shortly described how the declared energy consumption is calculated.

The declared weighted annual energy consumption is calculated taking into account the energy consumption of the standard programmes, i.e. the programmes "cotton 60°C, full load", "cotton 60°C, partial load" and "cotton 40°C, partial load" (weighted in the ratio 3:2:2), and the energy consumption in the left-on and the off-mode. All other programmes that are offered by the

appliances and often used by consumers (see the following section 4.2) are not considered in the label calculations. By comparing the annual energy consumption with a so called “standard annual energy consumption”, which is a benchmark energy consumption only depending on the rated capacity of the washing machine, the Energy Efficiency Index (EEI) is calculated. The EEI serves for the classification into a certain energy efficiency class. (European Commission 2010a)

As for the standard programmes the energy consumption is the most important characteristic (as this is shown on the label and serves for classification in an energy efficiency class), these programmes are optimised in a way to have the lowest possible energy consumption (with a given washing efficiency). Possible drawbacks of this design are that the stated temperature of the programmes is often not reached anymore and that the programmes have a very long duration. For example, the German consumer test institute “Stiftung Warentest” reports in its latest test on washing machines (Stiftung Warentest 2015) temperatures in the cotton 60°C eco programme of as low as 27°C and durations of 3.5 hours and more. Also JRC IPTS (2015) gives several examples of long programme duration in the standard programmes of up to 4 hours – and partly even more. This way of optimisation is within the legal framework of the energy label and ecodesign directives (European Commission 2010a, 2010b). As very long programme durations are not always attractive to consumers, a few years ago manufacturers started to offer alternative cotton 60°C/40°C programmes, which are usually much faster however also have considerably higher energy consumption than the standard programmes: Depending on the manufacturer and model the “normal” cotton 60°C (full load) programme can have an energy consumption which is twice or three times as high as that of the “eco” cotton 60°C (full load) (see e.g. AEG (n.d.); Siemens (n.d., 2016)).

In this study, the standard programmes are marked with the suffix “eco”, to explicitly distinguish them from the alternative cotton 60°C and cotton 40°C programmes, even though this is not an official indication.

4.2. Consumer Behaviour

4.2.1. Number of wash cycles, average loading and amount of laundry

The currently most recent consumer survey on washing behaviour has been conducted by the University of Bonn (Alborzi et al. 2015). Alborzi et al. (2015) assessed the washing behaviour in 11 European Countries by means of an online survey in April and May 2015. For the study at hand, the results for Germany have been taken, as this represents the geographical scope. The results of that consumer survey have been compared to other surveys of previous years (Berkholz et al. 2007; Kruschwitz et al. 2014), see the following table.

Table 4-2: Consumer surveys on washing behaviour – meta data and general results

	Berkholz et al. (2007)	Kruschwitz et al. (2014)	Alborzi et al. (2015)
Meta data			
Geographical Scope	Germany	Germany	EU/Germany*
Year of observation	2006	2009	2015
No. of observed households	100	236	580
Methodology of data collection	In-home study with 1-month wash diary	In-home study with 4-week wash diary	Online questionnaire
Capacity of washing machines in observed households	Not specified	94.5%: 5 kg	Average: 6.4 kg
Results			
No. of wash cycles			
· per average household and week	3.0	4.0	4.4**
· per 2-person household and week	3.4	3.4	3.3**
· per 4-person household and week	6.4	5.3	5.9**
Amount of laundry per household and week			
· 2-person household	7.8 kg	9.8 kg	n.a.
· 4-person household	16.4 kg	18.8 kg	n.a.
Average loading per cycle			
· 2-person household	2.6 kg	3.0 kg	n.a.
· 4-person household	3.1 kg	3.6 kg	n.a.

* European study in eleven countries. Results are partly differentiated per country. Where not specified differently the data refers to the German situation.

**European average data, no specific data for German households available.

Regarding number of wash cycles per week the studies show only minor differences: average 2-person households wash between 3.3 and 3.4 times per week, average 4-person households wash between 5.3 and 6.4 times per week. The amount of laundry per week does not show significant differences when calculated on a per person basis: approximately 4 to 5 kg laundry per week and person are washed, irrespective of the household size. This coincides with the result that the average loading per cycle is slightly higher in 4-person households than in 2-person households (3.1 to 3.6 kg vs. 2.6 to 3.0 kg). Unfortunately the amount of laundry and the loading per cycle were not investigated in Alborzi et al. (2015).

From these results it can be derived that

- the number of wash cycles per person and week is higher the smaller the household is,
- the amount of laundry per person and week does not depend on the household size,
- the average loading per cycle is lower the smaller the household is,
- the average loading of washing machines with a capacity of 5 kg is about 50 to 70% of the rated capacity. Today, washing machines with a rated capacity of 5 kg are hardly found on the market (according to JRC IPTS (2015) already in 2013 only some 8% of the models were 5 kg machines).

4.2.2. Usage of washing programmes

The following table compares the same studies with regard to the use of different washing programmes (not differentiated according to household size). (Kruschwitz et al. (2014) does not give such data.)

Table 4-3: Usage of different washing programmes

Washing programmes	Berkholz et al. (2007)	Alborzi et al. (2015)
cotton 90°C	4,0%	5%
cotton 60°C	25,7%	14%
cotton 60°C eco	-	7%
cotton 40°C	21,7%	17%
cotton 40°C eco	-	9%
cotton 30°C	10,1%	11%
cotton 20°C	0,4%	2%
easy care 60°C	2,5%	-
easy care 40°C Synthetic/easy care 30/40°C	8,1%	11%
easy care 30°C	5,9%	-
quick wash short	-	11%
delicates (30°C+40°C)	8,1%	-
wool + silk + synthetic	3,8%	-
mix	6,3%	8%
others	3,4%	4%

In 2006 washing machines had only one programme for cotton 60°C and one programme for cotton 40°C. Today, as result of the EU ecodesign and energy labelling regulations, most washing machines have two programmes for cotton 60°C and two programmes for 40°C, as one of each is the programme which is used for the declaration on the energy label (here marked with the suffix “eco”, see also section 4.1). The more recent consumer survey of Alborzi et al. (2015) takes this development into account and differentiates between these two types of programmes.

The results of both studies are quite similar, considering the partly differing programme definitions. The more recent study of Alborzi et al. (2015) shows a lower share of usage of “cotton 60°C” (both

normal and eco) of 21% in comparison to 26% in Berkholz et al. (2007). In contrast the usage of “cotton 40°C” is higher in Alborzi et al. (2015) (26% compared to 22% in Berkholz et al. (2007)). Also the use of the cotton 20°C programme is slightly higher (2% vs. 0.4%). These differences can be explained by the fact that there are several consumer information campaigns fostering the use of lower wash temperatures. People therefore indeed rather use the washing programmes with lower temperatures or at least know they should and overestimate the number of washes in such programmes (the results in Alborzi et al. (2015) are based on an online survey, not on in-home observation as in Berkholz et al. (2007)). Also the cotton 20°C programme has only been introduced in washing machines a few years ago.

As Alborzi et al. (2015) is the most recent survey, the number of observed households is larger compared to the other surveys, and the average size of the washing machine is bigger, the data gathered in that study is more appropriate for usage in this study.

The definition of the consumer behaviour is very important for the results of the study at hand, therefore a sensitivity analysis has been conducted with a higher share of the use of the standard (“eco”) programmes (for results see section 5.4.2).

4.2.3. Loading of washing programmes

As the PowerWash 2.0-technology has its main advantages in case of partial loading of the washing machines, the average loading of the different programmes is considerably relevant. As shown in Table 4-2 average loading over all programmes was already rather low (50 to 70%) in 5 kg machines (2.6 to 3.6 kg per cycle). Both Berkholz et al. (2007) and Kruschwitz et al. (2014) give some insight in the loading of different washing programmes, see the following table.

Table 4-4: Load per washing programme

Washing programme	Recommended loading (in 5 kg machine)	Loading	Arithmetic average amount of load with standard deviation
source	**Kruschwitz et al. (2014)**	**Berkholz et al. (2007)**	**Kruschwitz et al. (2014)**
		in kg per wash cycle	
Cotton	5 (100%)	3.18	3.4 +/- 1.2
Mix	3.5 (70%)	2.64	3.7 +/- 1.4
Synthetics	3 (60%)	-	3.0 +/- 1.0
Easy care	3 (60%)	2.28	2.8 +/- 1.0
Wool	2 (40%)	2.46	2.1 +/- 1.1
Delicates	3 (60%)	2.36	2.3 +/- 1.2

Whereas for the programmes “Mix”, “Synthetics”, “Easy care” and “Wool” people tend to load as recommended (recommended loading of 2 to 3.5 kg), especially for the cotton programmes the real loading is much lower than recommended (3.2 to 3.4 kg, i.e. 64 to 68% of rated capacity).

As in the study at hand washing machines with substantial higher rated capacities (8 kg) are regarded, the question is how people load those bigger machines. In principle there are two possibilities:

- People either load them by the same percentage as their old, presumably smaller washing machine (i.e. for cotton they would put around 65% (5.2 kg) of laundry in their 8 kg appliance), which would result in less numbers of washing cycles per year (assuming a constant amount of laundry).
- People stick to their wash habits, i.e. they wash as often as before and put the same absolute amount of laundry in their machine, which would result in much smaller relative loading (e.g. loading 3.4 kg into an 8 kg appliance means a load factor of only 43%).

Research indeed shows that the frequency of washing (slightly) decreased over the past years (JRC IPTS 2015). For example, according to Schmitz & Stamminger (2014) the number of wash cycles per week and household decreased in Germany from 3.8 times in 2006 to 3.7 times in 2011. However at least partly this trend can be attributed to demographic factors like the decrease of household sizes: the average number of wash cycles per week and person hardly shows any difference with 1.5 times both in 2006 and 2011.

Therefore it can be assumed that the real, absolute loading of most wash cycles does not differ significantly from the loading when using a smaller machine. As simplification, “half load”, i.e. an absolute loading of 4 kg is assumed for all washing cycles, except for the “60°C cotton eco” programme. For this programme it is assumed that it is used up to full in a certain number of cases (for details see below). For all programmes this signifies that by using a washing machine with a rated capacity of 8 kg the absolute loading slightly increases compared to the loading of a 5 kg machine. In the sense of the study, this is a conservative assumption as the main advantage of the PowerWash 2.0 technology occurs in case of partial loading of the washing machine.

4.2.4. Summary of assumed washing behaviour

Table 4-5 gives an overview of the assumptions regarding the washing behaviour. As it was not possible due to time and financial restrictions to measure 10 or 11 different programmes for 4 washing machines, some simplifications were made to reduce the number of different programmes to be measured and still cover a high percentage of washes with the calculations in the study at hand:

- The programmes “quick wash short” and partly “mix” can be considered as very similar to the programme “easy care 40°C”. Therefore all washes of “easy care 40°C”, “quick wash short” and half of the washes of “mix” are summed up.
- The consumption values and performance parameters of the “cotton 60 C eco” (full and half load) and the “cotton 40 C eco” programme were not measured but taken from manufacturers’ publications (like user manual, product fiche or information on the product website), see also the following section 4.3. These data are self-declared, however measured under standard conditions.
- The loading of all programmes is assumed to be 4 kg, except for “cotton 60°C eco”. Both for 2-person and for 4-person households a certain number of cycles are assumed to be fully loaded.

The overall number of wash cycles per household is assumed to be 175 (2-person household) and 300 (4-person household). The values correspond with the number of wash cycles per week observed in Berkholz et al. (2007) and Kruschwitz et al. (2014) (see Table 4-2) multiplied by 52 weeks.

For the sensitivity analysis “higher share of eco-programmes” (2-person household) it is assumed that

- 10% less wash cycles are washed in the programme “cotton 60°C” (half load)
- Half of these washes (5%) are washed in the “cotton 60°C eco” (full load) and half in the “cotton 60°C eco” (half load). This means that in total a share of approximately 8% of the washes is fully loaded.
- 10% less wash cycles are washed in the programme “cotton 40°C” (half load)
- Instead these washes are washed in the programme “cotton 40°C eco” (half load)

In order to keep the amount of washed laundry constant, the number of wash cycles per year is slightly reduced (to 165 from 175). The assumptions are summarised in Table 4-5.

Table 4-5: Assumed washing behaviour

	Usage of programmes*	Assumption for further calculations						
			2-person household		4-person household		Sensitivity: higher share of eco-programmes** (2-person household)	
Washing programmes		Loading	Share	Number	Share	Number	Share	Number
· Cotton 90°C	5%	--	--	--	--	--	--	--
· Cotton 60°C	14%	4 kg	14%	24.5	14%	42.0	4%	6.6
· Cotton 60°C eco fully loaded	7%	8 kg	3%	5.3	4%	12.0	8%	13.2
· half loaded		4 kg	4%	7.0	3%	9.0	9%	14.9
· Cotton 40°C	17%	4 kg	17%	29.8	17%	51.0	7%	11.6
· Cotton 40°C eco	9%	4 kg	9%	15.8	9%	27.0	19%	31.4
· Cotton 30°C	11%	4 kg	11%	19.3	11%	33.0	11%	18.2
· Cotton 20°C	2%	--	--	--	--	--		
· Synthetic/easy care 30/40°C Easy care 40°C	11%	4 kg	26%	42.9	26%	73.5	26%	42.9
· Quick wash short	11%	--	--	--	--	--	--	--
· Mix	8%	--	--	--	--	--	--	--
· Others	4%	--	--	--	--	--	--	--
SUM/covered share of programmes	*99%*		*84%*	*147 (of 175)*	*84%*	*252 (of 300)*	*84%*	*139 (of 165)*

* Alborzi et al. (2015)

** the overall number of cycles is slightly reduced (170 instead of 175) in order to result in the same amount of laundry washed per year (609 kg).

It can be seen that with the described simplifications in this study a share of 84% of all wash cycles in a typical 2- respectively 4-person household is covered.

With respect to the remaining share (16%) it is considered that there are no differences between the performance and consumption characteristics of the considered washing machines.

4.3. Consumption and performance data of the selected appliances

The following table shows the data sources of the electricity consumption, the washing efficiency, the programme duration and the water consumption of the selected appliances, differentiated per washing programme.

Table 4-6: Data sources of the consumption and performance data of the washing machines under consideration

	Electricity consumption	Water consumption	Washing efficiency	Programme duration
Washing programmes				
cotton 60, half	Measured*	Measured*	Measured*	Measured*
cotton 60 eco, full	Self-declaration**	n.a.	n.a.	Self-declaration**
cotton 60 eco, half	Self-declaration**	n.a.	n.a.	Self-declaration**
cotton 40, half	Measured*	Measured*	Measured*	Measured*
cotton 40 eco, half	Self-declaration**	n.a.	n.a.	Self-declaration**
cotton 30, half	Measured*	Measured*	Measured*	Measured*
easy care 40, half	Measured*	Measured*	Measured*	Measured*

* wfk 2016

** self-declared values from product fiches and user manuals of the selected washing machines.

The concrete values of the electricity consumption (in kWh per cycle) are given in Table 4-7 and depicted in Figure 4-1. The water consumption, washing efficiency and programme duration of the selected washing machines can be found in section 6.

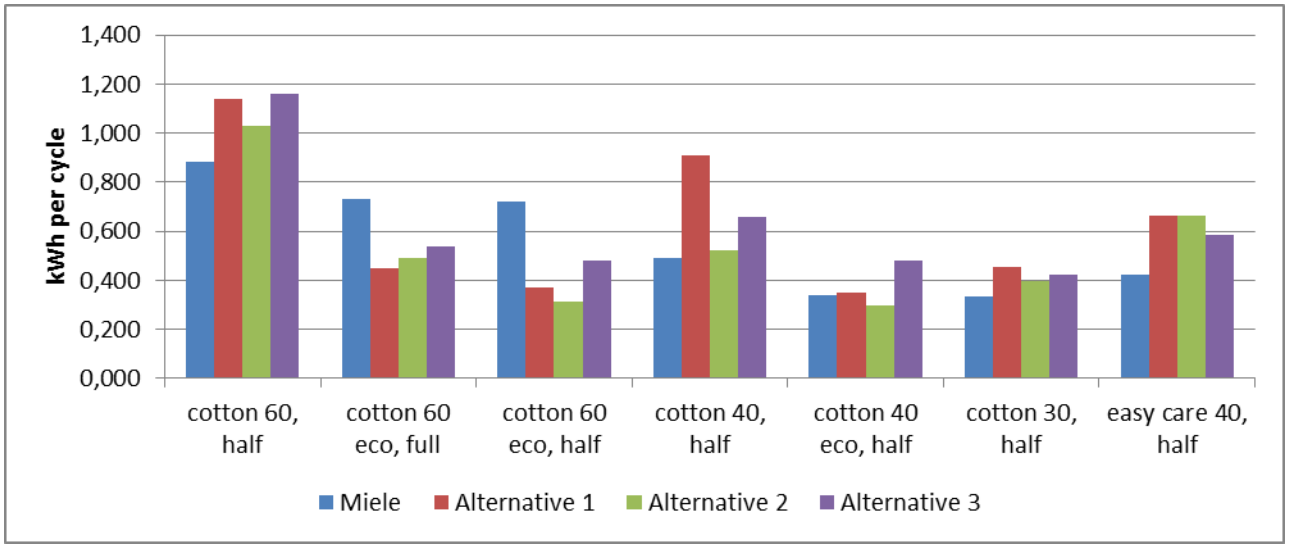
Table 4-7: Electricity consumption of the washing machines under consideration

	Miele	Alternative 1	Alternative 2	Alternative 3
	in kWh per cycle			
cotton 60, half	0,883	1,139*	1,032	1,160
cotton 60 eco, full	0,730	0,450	0,493	0,540
cotton 60 eco, half	0,720	0,370	0,314	0,480
cotton 40, half	0,490	0,909	0,520	0,657
cotton 40 eco, half	0,340	0,350	0,299	0,480
cotton 30, half	0,335	0,456	0,395	0,421
easy care 40, half	0,421	0,666	0,665	0,584

* In case of the 'alternative 1' one result of the three conducted measurements in the cotton 60°C programme showed an abnormal high water intake (84,4 litres instead of 67,3 litres) and correspondingly the electricity consumption and programme duration were increased. For the calculations in the study at hand, the average value of the other two measurements was used. This is a conservative assumption in the sense of this study as the water and electricity consumption and the programme duration is lower than the average of all three measurements.

source: wfk (2016) and self-declared values from product fiches and user manuals of the selected washing machines.

Figure 4-1: Electricity consumption of the washing machines under consideration



sources: own graph with data from wfk (2016) and self-declared values from product fiches and user manuals of the selected washing machines.

5. Results

5.1. Annual electricity consumption (2-person household)

Table 5-1 shows the calculation of the annual electricity consumption of the considered alternatives under the previously described assumptions. It additionally shows the relative annual electricity consumption of the alternative appliances compared to the Miele washing machine.

Table 5-1: Annual electricity consumption through the use of the washing machines under consideration

	Share of programme	Annual number of wash cycles	Miele	Alternative 1	Alternative 2	Alternative 3
				in kWh per year		
cotton 60, half	14%	24,5	22	28	25	28
cotton 60 eco, full	3%	5,3	4	2	3	3
cotton 60 eco, half	4%	7,0	5	3	2	3
cotton 40, half	17%	29,8	15	27	15	20
cotton 40 eco, half	9%	15,8	5	6	5	8
cotton 30, half	11%	19,3	6	9	8	8
easy care 40, half	26%	45,5	19	30	30	27
SUM	**84%**	**147,0**				
Annual electricity consumption*			**76**	**104**	**88**	**96**
Relative to Miele appliance			***100%***	***137%***	***116%***	***127%***
Absolute saving of Miele compared to…				***-28***	***-12***	***-20***
Relative saving of Miele compared to…				***-27%***	***-14%***	***-21%***

source: own calculation

* The annual electricity consumption only covers the consumption of the regarded washing programmes. The annual electricity consumption of the remaining programmes (cotton 90°C, cotton 20°C, half of the mix programmes and „other“ programmes), representing 16% of the wash cycles, accounts for approximately 25 to 30 kWh (assumptions for full load with specific consumption data of Gensch & Blepp (2015) and own estimations).

It can be seen that the Miele washing machine with PowerWash 2.0 has the lowest annual energy consumption (76 kWh p.a.) under the assumed usage conditions. This contrasts the energy labelling declaration, where the Miele appliance has the highest annual energy consumption (cf. Table 4-1).

Under the assumed real-life conditions the Miele appliance with PowerWash 2.0 saves between 14% and 27% of the annual electricity consumption compared to the selected appliances of other manufacturers. The absolute saving potential is between 12 and 28 kWh per year.

5.2. Global Warming Potential (2-person household)

Table 5-2 shows the annual global warming potential of the regarded alternative appliances and the relative annual global warming potential of the alternative appliances compared to the Miele washing machine.

Table 5-2: Annual Global Warming Potential (GWP) through the use of the washing machines under consideration

	Miele	Alternative 1	Alternative 2	Alternative 3
Annual electricity consumption (in kWh p.a.)	76	104	88	96
Specific GWP per kWh*	0,6374 kg CO_2-eq / kWh			
Annual GWP (in kg CO_2-eq per year)	48	67	56	61
Absolute saving of Miele compared to…		*-18*	*-8*	*-13*
Relative saving of Miele compared to…		*-27%*	*-14%*	*-21%*

according to IPCC (2007)

As in case of the electricity consumption, the Miele washing machine with PowerWash 2.0 technology has the lowest annual global warming potential with 48 kg CO_2-eq per year. The savings compared to the other alternatives are 8 to 18 kg CO_2-eq per year. The relative saving is the same as in case of the electricity consumption (14% and 27%).

5.3. Uncertainty analysis

As already outlined in section 2.6 the measurement of the consumption and performance values of the selected washing machines shows a certain degree of variation.

In wfk (2016) the relative standard deviation of the measurements of the electricity consumption is in all but two cases between 1 and 3%. In one case it is 5%, in another case 9%. The average relative standard deviation is 2.4%. Compared to the savings of the Miele appliance with PowerWash 2.0 technology (14 to 27%) this is a rather small value and the savings can be considered to be significant.

However the results are only valid under the assumed average usage conditions.

5.4. Sensitivity analyses

5.4.1. 4-person households

Table 5-3 shows the annual electricity consumption and the respective global warming potential of the use of the selected washing machine though a 4-person household.

Table 5-3: Annual electricity consumption and GWP through the use of the washing machines under consideration (4-person household)

		Miele	Alternative 1	Alternative 2	Alternative 3
Annual electricity consumption	kWh per year	130	179	152	165
Absolute saving of Miele compared to…	*kWh per year*		*-49*	*-21*	*-35*
Relative saving of Miele compared to…			*-27%*	*-14%*	*-21%*
Annual GWP	kg CO_2-eq per year	83	114	97	105
Absolute saving of Miele compared to…	*kg CO_2-eq per year*		*-31*	*-14*	*-22*
Relative saving of Miele compared to…			*-27%*	*-14%*	*-21%*

source: own calculation

As in case of the 2-person household the Miele washing machine with PowerWash 2.0 has the lowest annual energy consumption (130 kWh p.a.) under the assumed usage conditions. Due to the higher number of wash cycles per year (300 instead of 175 cycles) the absolute consumption is higher than in case of the 2-person household.

The absolute saving potential of the Miele appliance with PowerWash 2.0 is between 21 and 49 kWh per year and thus also higher than in case of the 2-person household. The relative saving potential is the same as in case of the 2-person household (14% to 27%).

Also the annual GWP is higher than that of the 2-person household. The GWP of the Miele appliance with PowerWash 2.0 is lower than that of the selected alternative appliances. The absolute saving potential is between 14 and 31 kg CO_2-eq per year. The relative saving potential equals that of the electricity consumption (14 to 27%).

5.4.2. Higher share of standard programmes

Table 5-4 shows the annual electricity consumption and the respective global warming potential of the use of the selected washing machine though a 2-person household with a higher share of use of the standard programmes.

Table 5-4: Annual electricity consumption and GWP through the use of the washing machines under consideration (higher share of standard programmes)

		Miele	Alternative 1	Alternative 2	Alternative 3
Annual electricity consumption	kWh per year	67	77	69	77
Absolute saving of Miele compared to…	kWh per year		-11	-2	-11
Relative saving of Miele compared to…			-14%	-4%	-14%
Annual GWP	kg CO_2-eq per year	42	49	44	49
Absolute saving of Miele compared to…	kg CO_2-eq per year		-7	-2	-7
Relative saving of Miele compared to…			-14%	-4%	-14%

source: own calculation

For all appliances the absolute annual electricity consumption is reduced by a higher share of standard programmes (including higher share of fully loaded washes). The reduction is higher for the alternative appliances than for the Miele appliance with PowerWash 2.0. Thus both the absolute and the relative saving through the use of such an appliance compared to alternative appliances is smaller than in the base case. The absolute energy saving potential is 2 to 11 kWh per year. The relative savings are 4 to 14%.

Regarding the global warming potential the situation is very similar. The absolute saving potential is between 2 and 7 kg CO_2-eq per year, the relative saving potential is equivalent to that of the electricity consumption.

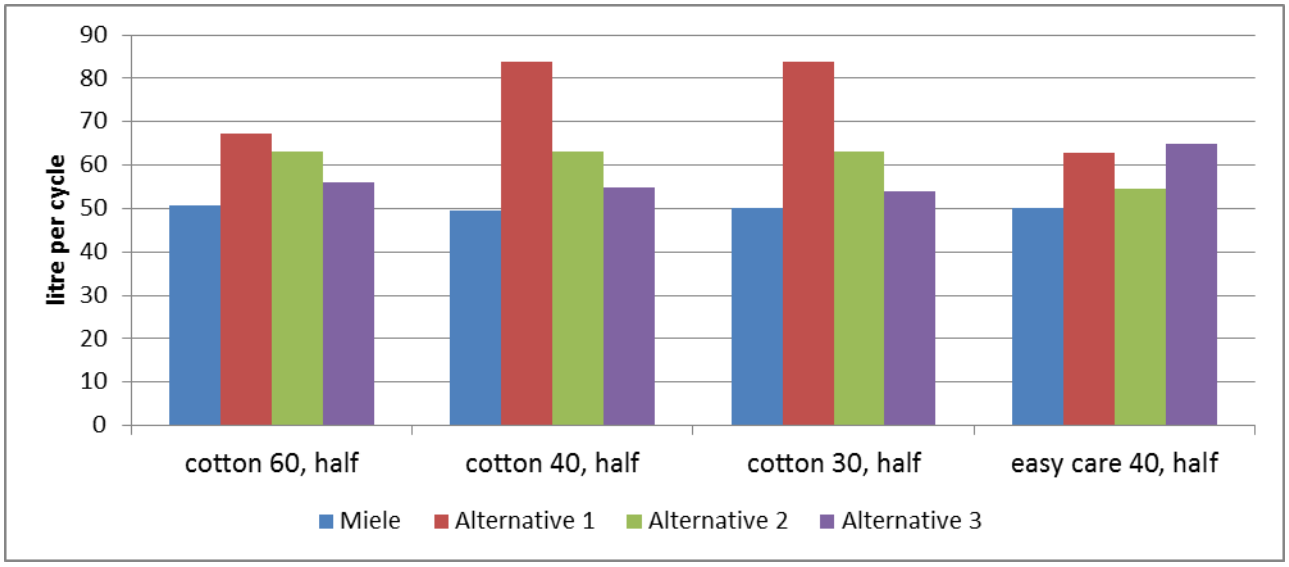
6. Washing efficiency, programme duration and water consumption

The washing efficiency, the programme duration and the water consumption have not been calculated for the functional unit but on a per programme basis. The main goal of the study was to quantify the saving potential through the PowerWash 2.0 technology. The comparison of the following parameters is important however to ensure that the reported energy savings are not connected with lower washing efficiency or much increased programme duration or water consumption.

6.1. Water consumption

Figure 6-1 shows the water consumption of the measured washing programmes of the four selected washing machines. Table 6-1 shows the respective data and additionally the weighted average water consumption.

Figure 6-1: Water consumption of the washing machines under consideration



source: own graph with data from (wfk 2016)

Table 6-1: Water consumption of the washing machines under consideration

		Miele	Alternative 1	Alternative 2	Alternative 3
Washing programmes	**Share**	**Water consumption in litre per cycle**			
cotton 60, half	14%	51	67*	63	56
cotton 40, half	17%	49	84	63	55
cotton 30, half	11%	50	84	63	54
easy care 40, half	26%	50	63	55	65
Weighted average		**50**	**74**	**60**	**59**

* In case of the 'Alternative 1' one result of the three conducted measurements in the cotton 60°C programme showed an abnormal high water intake (84,4 litres instead of 67,3 litres) and correspondingly the electricity consumption and programme duration were increased. For the calculations in the study at hand, the average value of the other two measurements was used. This is a conservative assumption in the sense of this study as the water and electricity consumption and the programme duration is lower than the average of all three measurements.

source: wfk 2016

It can be seen that

- the water consumption of the Miele appliance is in all measured washing programmes lower than that of the other washing machines
- the Miele appliances has the lowest average water consumption of all selected appliances (weighted average of the four measured).

It can be concluded that the PowerWash 2.0 technology does not lead to a higher water consumption.

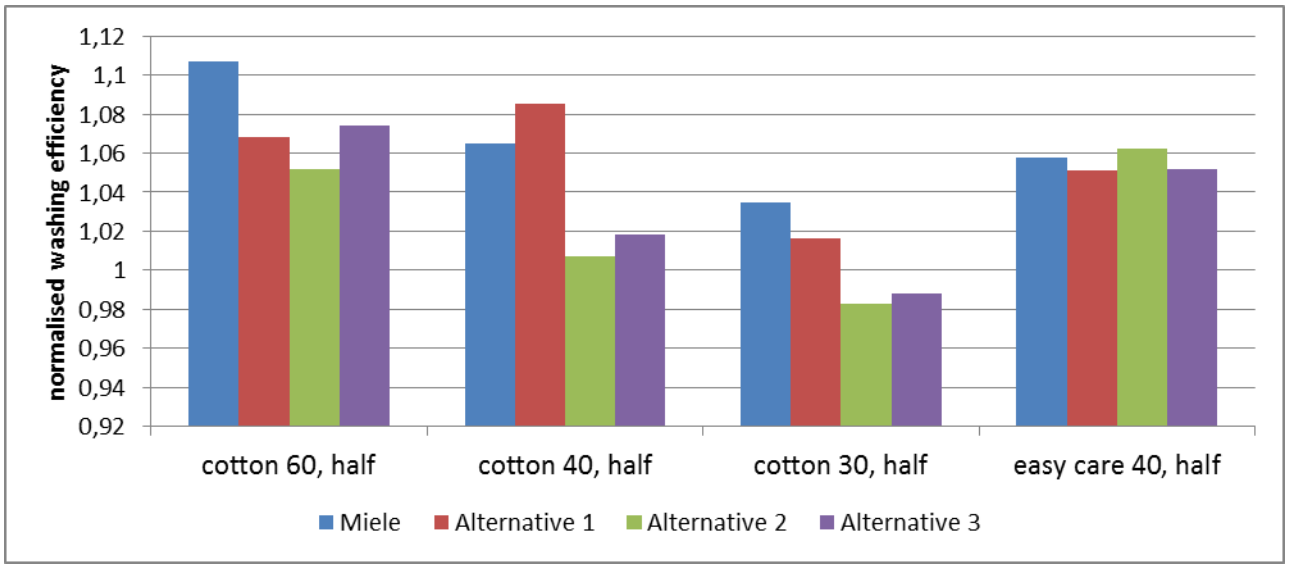
6.2. Washing efficiency

Figure 6-2 shows the washing efficiency of the four measured washing programmes of the four selected washing machines[1]. Table 6-2 shows the respective data and additionally the weighted average normalised washing efficiency.

A value of "1" means that the washing efficiency equals that of the reference washing machine. A value higher than "1" means that the washing efficiency of the respective appliance is better than that of the reference machine.

[1] The results are normalised against the washing efficiency of the reference programme of the reference washing machine (Electrolux Wascator FOM 71 CLS).

Figure 6-2: Washing efficiency of the washing machines under consideration



source: own graph with data from wfk (2016)

Table 6-2: Washing efficiency of the washing machines under consideration

		Miele	Alternative 1	Alternative 2	Alternative 3
Washing programmes	**Share**	**Normalised washing efficiency**			
Cotton 60 (4kg load)	14%	1,107	1,068	1,052	1,074
Cotton 40 (4kg load)	17%	1,065	1,085	1,007	1,018
Cotton 30 (4kg load)	11%	1,035	1,016	0,983	0,988
Easy care 40 (4kg load)	26%	1,058	1,051	1,062	1,052
Weighted average		**1,066**	**1,057**	**1,033**	**1,038**

source: wfk 2016

It can be seen that

- The Miele washing machine always has a normalised washing efficiency larger 1, i.e. better than that of the reference appliance.
- The washing efficiency of the Miele appliance is as high as or even higher than that of the other measured washing machines. Only in the programme “cotton, 40°C” Alternative 1 has a better washing efficiency. The differences in the easy care programme are not considered as significant.
- The Miele appliance shows the best weighted average washing efficiency of the selected appliances.

The washing efficiency of the standard programmes (the programmes that are used for measuring the annual energy consumption for the EU energy label have not been measured by wfk (2016).

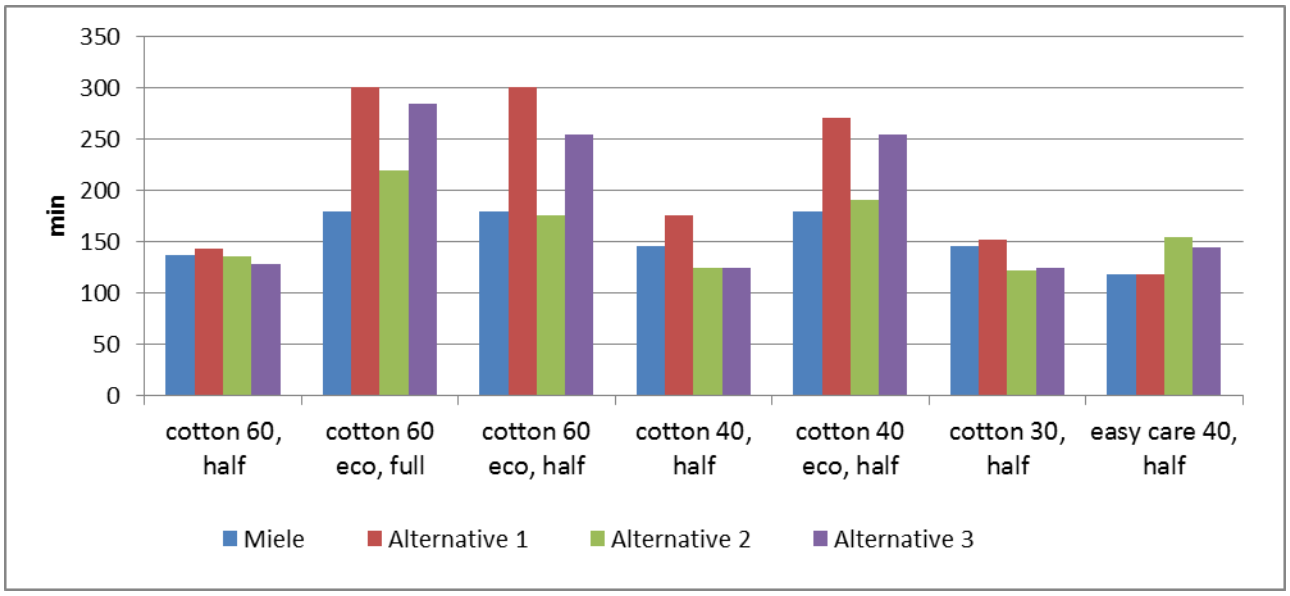
However, as the EU Ecodesign directive (European Commission 2010b) sets a high washing efficiency as minimum requirement, it can be assumed that the washing efficiency of all appliances in these programmes is good and in a comparable range.

It can be concluded that the PowerWash 2.0 technology does not lead to a worse washing efficiency.

6.3. Programme duration

Figure 6-3 shows the programme duration of all regarded washing programmes of the four selected washing machines. Table 6-3 shows the respective data and additionally the weighted average programme duration.

Figure 6-3: Programme duration of the washing machines under consideration



source: own graph with data from wfk (2016) and self-declared values from product fiches and user manuals of the selected washing machines.

Table 6-3: Programme duration of the washing machines under consideration

		Miele	Alternative 1	Alternative 2	Alternative 3
Washing programmes	**Share**	**Duration in min per cycle**			
cotton 60, half	14%	136	143*	136	128
cotton 60 eco, full	3%	179	300	219	284
cotton 60 eco, half	4%	179	300	176	254
cotton 40, half	17%	145	176	124	124
cotton 40 eco, half	9%	179	270	191	254
cotton 30, half	11%	145	152	121	124
easy care 40, half	26%	118	119	154	144
Weighted average		**142**	**170**	**148**	**157**

* In case of 'Alternative 1' one result of the three conducted measurements in the cotton 60°C programme showed an abnormal high water intake (84,4 litres instead of 67,3 litres) and correspondingly the electricity consumption and programme duration were increased. For the calculations in the study at hand, the average value of the other two measurements was used. This is a conservative assumption in the sense of this study as the water and electricity consumption and the programme duration is lower than the average of all three measurements.

sources: wfk (2016) and self-declared values from product fiches and user manuals of the selected washing machines.

It can be seen that

- the programme duration of the Miele washing machine is in the same range or, especially in the standard programmes, substantially shorter than the equivalent programmes of the appliances of the other manufacturers. Especially Alternative 1 and 3 require quite long programme duration in the standard programmes with up to five hours.
- The Miele appliance has the lowest average programme duration (weighted average) of 142 min per cycle.

It can be concluded that the PowerWash 2.0 technology does not lead to prolonged programme duration.

7. Summary and Conclusions

The calculations of the study at hand show that washing machines with PowerWash 2.0 technology indeed show a certain saving potential compared to similar appliances of competitors without this technology. Table 7-1 summarises both the declarations on the energy label and the results of this study.

Table 7-1: Summary: Label declarations and annual consumption and average performance values of the washing machines under consideration

		Miele	Alternative 1	Alternative 2	Alternative 3
Label declarations					
Energy efficiency class		A+++-30%	A+++-50%	A+++-50%	A+++-40%
Annual electricity consumption	kWh p.a.	137	89	97	116
Results of the study at hand					
Annual electricity consumption	kWh p.a.	76	104	88	96
Annual GWP	kg CO_2-eq p.a.	48	67	56	61
Water consumption **	litre per cycle	50	74	60	59
Washing efficiency **	per cycle	1.066	1.057	1.033	1.038
Programme duration **	min per cycle	142	170	148	157

* own calculations

**weighted average

The summary shows that appliances with the PowerWash 2.0 technology lead to savings in the electricity consumption and in the connected global warming potential without negative side effects on water consumption, washing efficiency and programme duration.

The washing machine with PowerWash 2.0 technology shows the lowest electricity consumption under the assumed real-life usage conditions. This contrasts the annual energy consumption values declared on the energy label.

The savings (electricity and GWP) compared to the use of alternative appliances are in the range of 14 to 27% which equals a saving in the electricity consumption of 12 to 28 kWh per year (for a 2-person household). Compared to the overall electricity consumption of a typical 2-person household of 3000 kWh per year (household without electric warm water generation, according to BDEW (2016)) the saving is rather small however (0.4 to 0.9%).

The relative standard deviation of the measured electricity consumption is quite low, the savings are therefore considered to be significant.

For 4-person households the situation is quite similar: the relative saving equals that of a 2-person household, the absolute savings are higher (21 to 49 kWh per year). Compared to the overall electricity consumption of a typical 4-person household of 4200 kWh per year (household without electric warm water generation, according to BDEW (2016)) the saving amounts to 0.5 to 1.2%).

If a higher share of the standard programmes is used the saving is reduced as these programmes have a very low electricity consumption in all washing machines. This means that for consumers that often use the very energy efficient standard programmes the additional saving through the PowerWash 2.0 technology is smaller than if mainly other programmes are used. However, as the comparison of the programme duration shows (section 6.3) the standard programmes can last up to 5 hours.

It can be concluded that under the assumptions of this study the PowerWash 2.0 technology leads to savings in electricity consumption and the connected global warming potential without compromising this achievement through higher water consumption, lower warming performance or longer programme duration.

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