Appliances Guide
Get super efficient appliances

bigEE

What users can save with energy and water efficient washing machines

Authors
Dr. Claus Barthel
Thomas Götz

Published 03/2013

Index

1 Introduction

A significant part of the typical energy and water consumption of today's washing machines could be saved with the most efficient appliances currently available, and even higher savings will be possible with next generation technologies.

Washing laundry is one of the most widespread forms of housework in the world. In the past, it was generally hard and used to be a time-intensive mechanical kind of work, and for many households in the world, it still is. The common purpose of washing machines is to provide hygienically clean laundry and to preserve its value as well as to reduce the required time and effort (Pakula / Stamminger 2010). As this is one of the basic needs, saturation of washing machines is generally high in industrialized countries. Within these countries, most households own a washing machine, while at the same time a high growth rate can be observed in developing and especially in newly industrializing countries. In many industrialized countries, washing machines are among the highest energy-using appliances in the average home, after refrigerators (ACEEE 2011).

With focus on the user perspective, this bigEE text presents the potential energy, water and cost savings, which can be achieved by the most efficient appliances currently available (Best Available Technology, BAT) and from designs that are technically feasible with what we know today, but which are not yet commercialised (BNAT: Best Not (yet) Available Technology) for common types of washing machines (See chapter 2). Prior to that, we present some basic facts about washing machine functions and their technology.

1.1 What are washing machines?

The main task of all types of washing machines, also known as ‘clothes washers’, is to provide hygienically clean laundry and to preserve its value. Washing machines use energy to heat the washing water, to run the motor and the (electronic) control system (Pakula / Stamminger 2010). Washing machines can be defined by two product performance parameters. The first parameter is the capacity (kg) or the volume (expressed in litres or cubic-feet) of the appliance. The second parameter defines the product’s cleaning performance or the service provided by the appliance. In principle, the same water and detergent based technology is used worldwide although there are some significant differences regarding categories and types of domestic washing machines as well as energy efficiency standards.

1.2 Main types of ‘washing’ technologies, technical background

Horizontal axis washing machines are more efficient than vertical axis appliances

All contemporary automatic domestic washing machines work on the same principle. In an automatic washing machine, the load is fully treated by the machine without the need for user intervention at any point during the programme prior to its completion (Faberi et al. 2007). They use water, electricity, chemical substances (detergents) and process time as resources and provide mechanical work to clean laundry. After the cleaning process, all automatic washing machines remove most of the remaining water from the clothes by spinning and then pumping the water out of the machine.

Energy- and water-efficient washing machines incorporate numerous saving technologies and features. The most recent vertical axis machines use advanced electronic controls to adjust the water level automatically (depending on the load size) as well as higher spin speeds. Nevertheless, **horizontal axis front- and top-loading washers** are generally more efficient than top loading vertical axis models. Horizontal-axis machines don’t completely submerge clothes, so they use on average 30 to 50 % less water than vertical-axis models. The less water a washing machine uses, the less energy is needed to heat it up for the washing process or to remove the water after rinsing and during spinning (toptenusa.org 2011).

In contrast, most traditional and less efficient top-loading vertical axis models fill the tub to fully submerge the clothes. **Agitator washing machines** use an agitator to swirl the water and clothes around. There are also other top-loading vertical-axis models that use a moving plate **(Impeller washing machine)** in the bottom of the tub, in place of an agitator, to bounce clothes through the water (toptenusa.org 2011).

Figure 1: Sinner Circle, parameters of cleaning performance (In washing machines the mechanical action is provided by the drum, agitator or impeller movement).

Source: based on glasswashing.biz 2012

Apart from the electricity and water consumption of washing machines, the effectiveness of the washing process is determined by additional relevant factors. Thereby, good cleaning performance needs *a minimum amount of energy input*, which includes *mechanical work, thermal energy, chemicals and time.* These parameters for the cleaning performance can be described as segments of the "Sinner Circle" (Figure 1). Presuming a constant cleaning performance (circular area) this means: In order to reduce one of these four components, the segment areas of the others have to be increased. This can be achieved either by enlarging the amount or by raising the efficiency of the respective parameter of cleaning performance.

Especially in countries where cold wash programs are mostly used in combination with vertical axis top-loading machines (e.g. in China, Japan), good cleaning performance is often achieved by more frequent wash cycles and/or an additional input of chemical and mechanical energy outside the washing machine. Although the electricity consumption per wash cycle of these washing machines is low (if cold water is used), the environmental impact of the entire washing process may be much higher. Pre- and post-treatment processes, which are mostly done manually, increase the consumption of energy (when done with warm water), water, detergents as well as time spent on laundry washing (Pakula / Stamminger 2010).

Due to the drawbacks of vertical-axis washing machines, worldwide development tends towards high-efficient horizontal axis washing machines with the capability of compensating for the reduced energy consumption (especially due to lower washing temperatures) by more efficient mechanical work and more extensive wash cycles in combination with high efficient detergents. Hence, the design options to further reduce the environmental impacts of washing machines usually refer to this type of machines.

A more detailed description of the technical background of washing machines and which technical options are available to reduce energy and water consumption as well as the climate change impact, is provided in the bigEE text ***'Technical background and design options to raise energy efficiency and reduce the environmental impact of domestic washing machines'***.

2 Energy and cost saving potential

Three types of automatic washing machines dominate the market and offer large energy and water savings

The three major types of 'domestic washing machines' can be assigned in two **categories**:

1. **Horizontal axis machines:**

In horizontal axis machines (see Figure 2**)**, only the bottom of the washtub is filled with water. Compared to vertical axis machines, significantly less water per wash cycle is used. Horizontal axis machines are commonly equipped with an internal electric water heating system. Hence, the energy consumption heavily depends on the chosen washing temperature.

Modern washing machines with horizontal axis technology have an automatic load sensing function in order to reduce water and electricity consumption in response to consumer loads that are smaller than the rated capacity. Horizontal axis machines are gaining market shares in almost all markets worldwide (Pakula / Stamminger 2010).

Figure 2: Horizontal axis washing machine, Front load configuration,

Source: iStockphoto 2013

2. Vertical axis machines:

Traditionally, the tub is entirely filled with water, but most modern vertical axis machines (see Figure 3) also have automatic water level settings or the user can set the water level manually. Nevertheless, even present-day vertical axis machines often consume about twice as much water per wash cycle as horizontal axis machines. Although vertical axis machines are usually not equipped with an integrated water heating system, warm washes can be done by using hot water from external sources. The additional energy needed to heat up water from the tap is hard to estimate, because it can be done by electricity or other energy sources like gas, coal, oil or solar power (Pakula / Stamminger 2010). Vertical axis machines are still most widespread in America, Australia and Asia.

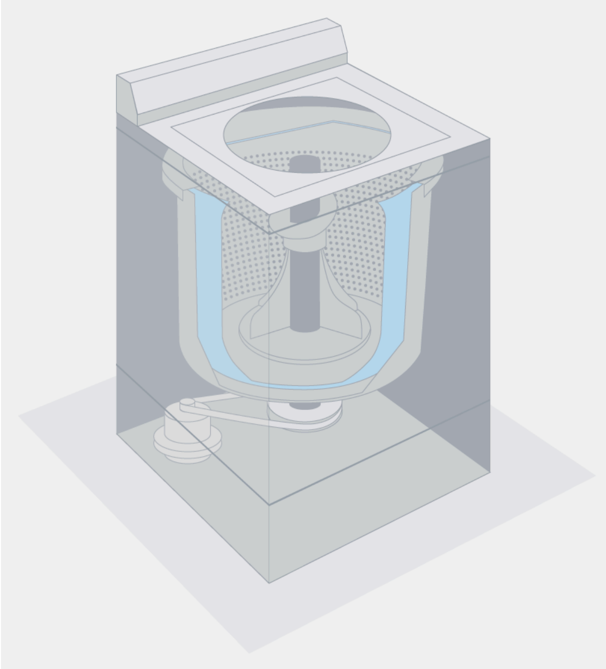

Figure 3: Vertical axis washing machine (Agitator type)

Source: Wuppertal Institute 2013

In addition to these 'automatic domestic washing machines', in some regions of the world laundry is still done manually or with semi-automatic washing machines.

Manual laundry

The energy and water consumption for manual clothes washing and pre- and post-treatments of laundry has not been taken into consideration in this context because reliable data is not commonly available. However, according to Pakula / Stamminger (2010), resource consumption for manual laundry washing is considered as an important and interesting future research area with respect to the global resource consumption for laundry washing.

Although no reliable information on the exact share is available, manual laundry washing may contribute significantly to the domestic hot water consumption in many households. Therefore, the reader is referred to energy-saving options for domestic hot water production and use on the bigEE.net platform.

Semi-automatic washing machines

A ‘semi-automatic’ washing machine requires user intervention at one or more points during the programme to enable the machine to proceed to its next operation. Examples of user intervention could include manual filling (water and detergents), non-automatic water levelling, transfer of the load between a washing drum and a spin extractor drum or manual draining at single and twin-tub semi-automatic washing machines (Faberi et al. 2007). Twin tub machines are typically side-by-side two tub units where one tub provides the washing service and the second tub spins the load. The user is required to transfer the load between tubs. Although the energy consumption per wash cycle is low (if cold water is used), these units are considered to be significantly less efficient than automatic washing machines as their overall resource consumption (energy, water, detergents) is highly dependent on the individual operator (IEA 4E 2009). Consequently, exact and reliable data is commonly not available, but high levels of washing treatments with relevant amounts of water, chemicals and energy outside the washing machine indicate a low level of washing performance by these machines (Pakula / Stamminger 2010). Semi-automatic washing machines account for only a small and falling proportion of the market for washing machines in industrialized countries (IEA 4E 2009). Nevertheless, in some regions of the world (especially in Africa, Latin-America and Asia), this type is still very common as an entry-level washing machine. Because semi-automatic machines are also commonly referred to as “vertical axis (VA)” washing machines, the available stock data for some countries may include both types of VA washing machines (automatic and semi-automatic).

Appliances vary greatly in their configurations and the range of options. The most common types of automatic washing machines worldwide are:

- **Horizontal axis, front- or top loading washing machine**
- **Vertical axis, top loading agitator washing machine**
- **Vertical axis, top loading impeller washing machine**

Table 1: Comparison of washing machine categories and types

Category	**Horizontal axis**	**Vertical axis**		
Type	**Drum-type front or top loading (fully automatic)**	**Semi automatic (single- or twin tub)**	**Top loading agitator (fully automatic)**	**Top loading impeller (fully automatic)**
Capacity	4 to 9 kg	4 to 8 kg	5.5 to 6 kg	5.5 to 10 kg
Wash Quality	Excellent	Low to Average	Good	Good
Energy consumption	Electricity: Low to High (Depends on chosen washing temperature)	Electricity: Low, but overall consumption (including external sources) is highly user dependent	Electricity: Low to Average, but overall consumption (including external energy sources): Average to High	Electricity: Low to Average, but overall consumption (including external energy sources): Average to High
Water consumption	Average to Low	(Very) High (User dependent)	(Very) High	(Very) High
Standard Wash Cycle Duration	Average to Slow (typically 60 - 90 minutes or more)	Fastest (< 30 min, Highly user dependent)	Fast (typically 30 to 45 minutes)	Fast (typically 30 to 45 minutes)
Internal heat generator (Hot Wash option)	All (Some: Cold wash option and/or Hot water inlet)	No (Manual fill only)	Some (Usually external heat sources)	Some (Usually external heat sources)
Delicate Clothes Treatment	Excellent	Average	Rough	Good
Water Connection	Required with pressure	Not required	Required	Required
Acquisition costs	Average to High	Low	Average	Average

Source: Further developed illustration, based on http://indiahometips.com and www.energywise.govt.nz 2011

2.1 Agitator washing machine (Vertical axis)

Vertical axis, top loading agitator washing machines show large energy- and water savings compared to inefficient models on the market, especially in North- and Latin America as well as in Australia, as such washing machines are popular in these regions. However, vertical axis machines often consume about twice as much water per wash cycle as horizontal axis machines.

2.1.1 Overview and description of the appliance

In an agitator washing machine the textiles are substantially immersed in the washing water. The mechanical action is produced by an agitator (see Figure 4) moving about or along its vertical axis with a reciprocating motion. This device usually extends above the maximum water level (EN 60456:2005/AEA 2009). Traditionally, agitator-type washing machines are designed as top-loading devices with a tub accessible from one single door on the top.

Figure 4: Vertical axis washing machine, Agitator

Source: iStockphoto 2013

If cold water is used, the energy consumption per wash cycle is low. But although the majority of washing machines in North America are vertical axis machines without internal heating system, the average washing temperature is reported to be at about 30°C, which causes an electricity consumption of about 0.43 kWh per wash cycle (Harrel 2003). This might include warm water from the tap and thus energy from external resources, which are hard to quantify (Pakula / Stamminger 2010). The higher usage of bleach and other detergents, as well as washing treatments with relevant amounts of water and energy outside the washing machine indicate only a mediocre level of washing performance provided by these machines.

2.1.2 Used mainly in the following world regions:

Vertical axis agitator washing machines are most widespread in North- and Latin America as well as in Australia.

2.1.3 Good practice examples, average consumption, BAT and BNAT

Alternatives are ‘high efficiency’ (HE) vertical-axis top-loading washers and especially horizontal axis washers in combination with low-temperature washing programmes. Top loading Vertical Axis HE washers are usually equipped with an advanced automatic water levelling system and use special mechanical agitators, described by different manufacturers as “wobblers,” “nutating” plates, or most frequently as “impellers” (see chapter 2.2) to create agitation that is gentler in comparison with centre-post agitators. Nevertheless, the more energy and water-efficient horizontal-axis front-loaders dominate the HE market worldwide. In the US, for example, horizontal axis machines comprise about 90 % of the HE machines market (AATCC 2011).

2.2 Impeller washing machine (Vertical axis)

Vertical axis, top loading impeller washing machines show large energy- and water savings compared to inefficient models on the market, especially in Asia (China, South Korea, Japan) and Australia as such washing machines are popular in these regions. However, vertical axis machines often consume about twice as much water per wash cycle as horizontal axis machines.

2.2.1 Overview and description of the appliance

Figure 5: Vertical axis 'high-efficiency' washing machine, Impeller

Source: iStockphoto (2013)

In impeller washing machines the textiles are substantially immersed in the washing water. The mechanical swirl-action is produced by a device, which is variously named by different manufacturers as impeller or 'pulsator', rotating about its axis continuously or which reverses after a number of revolutions (see Figure 5). During operation, the uppermost point of this device is substantially below the minimum water level (EN 60456:2005 / Faberi et al. 2007). This type of washing machine is traditionally designed as a top-loading device (accessible from one single door on the top). If cold water is used, the energy consumption per wash cycle is low. However, although vertical axis impeller machines are usually not equipped with an internal water heating system, the usage of preheated water from external sources through a separate hot water inlet is commonly possible and is often reported (Pakula / Stamminger 2010).

Occasionally, impeller-type washing machines are also referred to as 'high efficient washers' (especially in North America) due to an improved washing process and a reduced water usage compared to inefficient agitator-type models. Nevertheless, a higher usage of bleach and other detergents, as well as washing treatments with relevant amounts of water and energy outside the washing machine may indicate only a mediocre level of washing performance provided also by these machines. Moreover, the water consumption is still significantly higher compared to the more recent horizontal-axis machines.

2.2.2 Used mainly in the following world regions:

Vertical axis impeller washing machines are most widespread in Asia (China, India, South Korea, Japan) and Australia.

2.2.3 Comparing inefficient models and BAT on the worldwide market

Table 2: Energy consumption, impeller washing machines with cold water use

Washing capacity		Energy (kWh/cycle with cold water) in accordance with Chinese Standard GB/T 4288 2008 GB 12021.4-2004	Energy class	Energy saving potential compared to ineffi-cient mod-el	Energy cost savings versus inef-ficient mod-el (EUR in 15 years, 3300 cycles at 12 EUR-Cent/kWh)
Small - Medium ≤ 6 kg	Inefficient model	0.18	Chinese Na-tional energy efficiency grade 3		
	BAT level	0.06	Chinese Na-tional energy efficiency grade 1	66 %	47
Large > 6 kg	Inefficient model	0.15	Chinese Na-tional energy efficiency grade 4		
	BAT level	0.07	Chinese Na-tional energy efficiency grade 1	53 %	32

Source: top10.cn 2012 for energy consumption (kWh/year) of typical inefficient model and example of BAT model, energy saving potential and energy cost savings

Please note: The reported energy consumption of horizontal axis drum type washers (see 2.3) is almost ten times higher compared to the impeller-type machines. The **difference in the reported energy use** is largely due to the **difference in test procedures**: Impeller models are only tested with an inlet water temperature of 20°C, while HA drum models are tested with input water of 15°C which is internally heated to 60°C (Biermayer / Lin 2004).

Table 3: Water consumption, impeller washing machines with cold water use

Washing capacity		**Water consumption (L/cycle)**	**Energy class**	**Water saving potential versus inefficient model**	**Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles) at 2.64 €/m^3)**
Small < **6kg**	Inefficient model	145	Chinese National energy efficiency grade 3		
	BAT level	106	Chinese National energy efficiency grade 1	27 %	340
Large > **6kg**	Inefficient model	235	Chinese National energy efficiency grade 4		
	BAT level	111	Chinese National energy efficiency grade 1	53 %	1078

Source: EuP-study lot 25, Task 2 for water costs (€/litre); top10.cn 2012 for water consumption (L/cycle) of typical inefficient model and example of BAT model, water saving potential and water cost savings.

Table 4: Combined energy and water lifetime cost savings, impeller washing machines with cold water use

Washing capacity		**Energy class**	**Energy and water cost savings versus inefficient model (EUR in 15 years, 3300 cycles)**
Small to Medium ≤ 6 kg	Inefficient model	Chinese National energy efficiency grade 3	
	BAT level	Chinese National energy efficiency grade 1	388
Large > 6 kg	Inefficient model	Chinese National energy efficiency grade 1	
	BAT level	Chinese National energy efficiency grade 1	1,109

Source: Calculated, based on Table 2 and Table 3

The prices of efficient models have been steadily coming down. While they cost more than those with out-dated designs that use large amounts of energy and water, consumers should also consider their hot water heating costs, their water bills and their local need for water efficiency as they compare prices (toptenusa.org 2011).

2.3 Horizontal axis front- and top loading washing machines

Horizontal axis washing machines (also known as 'front-loader' or 'drum type' machines) show both large energy and water savings compared to inefficient models on the market, especially in Europe as such washing machines are most popular in this region. Additionally, the share of horizontal axis machines is also steadily rising in most other markets worldwide. Switching from vertical axis to horizontal axis machines offers another important water and energy saving potential, because horizontal axis machines usually consume about half as much water per wash cycle as vertical axis machines (or even less).

2.3.1 Overview and description of the appliance

In a horizontal axis drum washing machine, the textiles are placed in a horizontal or inclined drum and are partially immersed in the washing water. The mechanical action is produced by the rotation of the drum about its axis, whereby the movement can be either continuous or periodically reversed (EN 60456:2005 / Faberi et al. 2007). The drum is accessible from one single door on the front (front-loader configuration) or from several adjacent doors on the top of the machine and the drum (top-loader configuration). Many traditional horizontal axis machines have a minimum programme temperature of 30°C, which means that these machines use electricity to heat up water even in the coldest programme selectable (Pakula / Stamminger 2010). Since the introduction of high efficient low-temperature detergents, many contemporary washing machines have been equipped with 20°C, 15°C and 'cold wash' programmes to reduce the energy consumption significantly.

Figure 6: Horizontal axis machines

Source: iStockphoto 2013

2.3.2 Used mainly in the following world regions

Horizontal axis drum type washing machines are used mainly in Western Europe, Eastern Europe, Turkey and increasingly in most other markets. The market share of horizontal axis machines in other markets world-wide is rising steadily and in many countries traditionally dominated by vertical axis machines, a system change to horizontal axis technology can be observed. For example, 22 % of the households in Australia used a horizontal axis machine in in 2007, compared to only 13 % in 2005. In some areas of the country, horizontal axis machines already amount to 50 % of the new sales of washing machines (Australian Bureau of Statistics 2008, Pakula / Stamminger 2010).

2.3.3 Comparing inefficient models and BAT on the worldwide market with future BNAT potential

Table 5: Horizontal axis washing machines, energy consumption for 60 °C hot wash cycle

Washing capacity		Energy consumption (kWh/cycle at 60°C wash cycle)	Energy class	Energy saving potential versus inefficient model	Energy cost savings versus inefficient model (EUR in 15 years, 3300 cycles at 12 EUR-Cent/kWh)
Small < 6 kg	Inefficient model	1.24	Chinese National energy efficiency grade 2		
	BAT level	0.94	Chinese National energy efficiency grade 1	24 %	117
	BNAT (wash temperatures between 20 and 40°C max.)	0.34		73 %	355

Medium 6 kg	Inefficient model	1.32	Chinese National energy efficiency grade 2		
	BAT level	0.90	Chinese National energy efficiency grade 1	32 %	166
	BNAT (wash temperatures between 20 and 40°C max.)	0.43		67 %	352
Large > 6 kg	Inefficient model	1.80	Chinese National energy efficiency grade 1		
	BAT level	0.98	Chinese National energy efficiency grade 1	46 %	325
	BNAT (wash temperatures between 20 and 40°C max.)	0.49		73 %	517

Source: top10.cn 2012 for energy consumption (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, energy saving potential and topten.eu 2012 for energy cost savings.

Please note: The reported energy consumption of horizontal axis drum type washers is almost ten times higher compared to the impeller-type machines (see 2.2). The **difference in the reported energy use** is largely due to the **difference in test procedures**: Impeller models are only tested with an inlet water temperature of 20°C, while HA drum models are tested with input water of 15°C which is internally heated to 60°C (Biermayer / Lin 2004).

Table 6: Horizontal axis washing machines, water consumption for 60 °C hot wash cycle

Washing capacity		Water consumption (L/cycle)	Energy class	Water saving potential versus inefficient model	Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles) at 2.64 €/m³)
Small < 6 kg	Inefficient model	64	Chinese National energy efficiency grade 2		
	BAT level	55	Chinese National energy efficiency grade 1	14 %	78
	BNAT	44		31 %	172
Medium 6 kg	Inefficient model	75	Chinese National energy efficiency grade 2		
	BAT level	59	Chinese National energy efficiency grade 1	22 %	141
	BNAT	44		41 %	270
Large > 6 kg	Inefficient model	96	Chinese National energy efficiency grade 1		
	BAT level	69	Chinese National energy efficiency grade 1	28 %	233
	BNAT	49		49 %	409

Source: EuP-study lot 25, Task 2 for water costs (€/litre); top10.cn 2012 for water consumption (L/cycle) of typical inefficient model and example of BAT model, own calculations of BNAT level, water saving potential and water cost savings.

Table 7: Horizontal axis washing machines, combined energy and water lifetime cost savings for 60 °C hot wash cycle

Washing capacity		**Energy class**	**Energy and Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles)**
Small **< 6 kg**	Inefficient model	Chinese National energy efficiency grade 2	
	BAT level	Chinese National energy efficiency grade 1	195
	BNAT		528
Medium **6 kg**	Inefficient model	Chinese National energy efficiency grade 1	
	BAT level	Chinese National energy efficiency grade 1	307
	BNAT		623
Large **> 6 kg**	Inefficient model	Chinese National energy efficiency grade 1	
	BAT level	Chinese National energy efficiency grade 1	557
	BNAT		926

Source: top10.cn 2012 for energy and water consumption of typical inefficient model and example of BAT model, own calculations of BNAT level cost savings

The prices of energy- and water-efficient models have been steadily coming down. While they cost more than those with out-dated designs that use large amounts of energy and water, consumers should also consider their hot water heating costs, their water bills and their local need for water efficiency as they compare prices (toptenusa.org 2011).

3 References

AATCC (2011): American Association of Textile Chemists and Colorists: High Efficiency Washers in North America http://www.aatcc.org/testing/resources/docs/204-HiEfWash.pdf

ACEEE (2011): American Council for an Energy-Efficient Economy, Washington, D.C http://www.aceee.org/topics/laundry, (Accessed: 09/2011)

AEA (2009): Discussion Report: EU Ecolabel for Washing Machines, September 2009, AEA consulting group, http://www.endseurope.com/docs/90922a.pdf

Australian Bureau of Statistics (2008): Environmental issues: Energy use and conservation. Canberra: Australian Bureau of Statistics.

Berkholz, P., Stamminger, R., Kruschwitz, A., & Brückner, A. (2006): Definition und Ermittlung verhaltensabhängiger Energiesparpotentiale beim Betrieb elektrischer Haushaltswaschmaschinen. Bonn.

Biermayer, P. J. / Lin, J. (2004): Clothes Washer Standards in China – the Problem of Water and Energy Trade-offs in Establishing Efficiency Standards, Lawrence Berkeley National Laboratory (LBNL), Conference Paper, 2004 ACEEE Summer Study, August 22 - August 27, 2004 2004-05-19, LBNL-55115, http://efficiency.lbl.gov/drupal.files/ees/Clothes%20Washer%20Standards%20in%20China_the%20Problem%20of%20Water%20and%20Energy%20Trade%20offs%20in%20Establishing%20Efficiency%20Standards_LBNL-55115.pdf

European Commission (1995): Commission Directive 95/12/EC of 23 May 1995 implementing Council Directive 92/75/EEC with regard to energy labelling of household washing machines.

European Commission (2005): EuP Studies for Eco-Design Requirements of EuP's (Tender TREN/D1/40-2005). Retrieved from http://www.ecowet-domestic.org/.

European Commission (2010A): Commission Regulation (EU) No 1015/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for household washing machines. In: Official Journal of the European Union, 11. 11. 2010.

Faberi, S. / Presutto, M. / Stamminger, R. / Scialdoni, R. / Mebane, W. / Esposito, R. (2007): Preparatory Studies for Eco-design Requirements of EuPs (Tender REN/D1/40-2005), LOT 14: Domestic Washing Machines and Dishwashers Final Report, Draft Version, Tasks 1 -2, www.ecowet-domestic.org

glasswashing.biz (2012): Relation of temperature, chemistry, time and mechanics, Optimum washing result - the Sinner's circle, http://www.glasswashing.biz/fileadmin/redakteur/en/images/content/gl-content-0303-washing-philosophy-sinners-circle-r.jpg, Accessed 03/2012

Harrel, C. W. (2003): The US Laundry Market. IEC SC 59D WG Meeting, Gaithersburg, Oct 13, Procter & Gamble communication to IEC SC59D working groups (private communication). IBM. (2002). AISE code of good environmental practice: Final report to the European Commission 1996–2001. Brussels: IBM.

IEA 4E (2009): 4E - Efficient Electrical End-Use Equipment, Mapping and Benchmarking Annex, Product Definition: Domestic Laundry (Washing) Appliances Final Issue: 2nd December 2009, http://mappingandbenchmarking.iea-4e.org/shared_files/34/download

IEA-4E (2011A): Efficient Electrical End-Use Equipment, Documents related to the mapping and benchmarking of Domestic Washing Machines, http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3 (Accessed: 09/2011)

Pakula, C. / Stamminger, R. (2010): Electricity and water consumption for laundry washing by washing machine worldwide, Energy Efficiency (2010) 3:365–382 DOI 10.1007/s12053-009-9072-8, http://www.springerlink.com/content/f6197608u2761084/fulltext.pdf

Your guide to energy efficiency in buildings.

bigee.net

bigEE is an international initiative of research institutes for technical and policy advice and public agencies in the field of energy and climate, co-ordinated by the Wuppertal Institute (Germany). Its aim is to develop the international web-based knowledge platform bigee.net for energy efficiency in buildings, building-related technologies, and appliances in the world's main climatic zones.

The bigee.net platform informs users about energy efficiency options and savings potentials, net benefits and how policy can support achieving those savings. Targeted information is paired with recommendations and examples of good practice.

Co-ordinated by

Wuppertal Institute for Climate, Environment and Energy

Partners to date

中城深科 CSUSIBR

sonedi

cscp

Financial support

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Dr. Stefan Thomas • bigee@wupperinst.org

Wuppertal Institute for Climate, Environment and Energy • Doeppersberg 19 • 42103 Wuppertal • Germany • Phone: +49 (0)202 2492-129