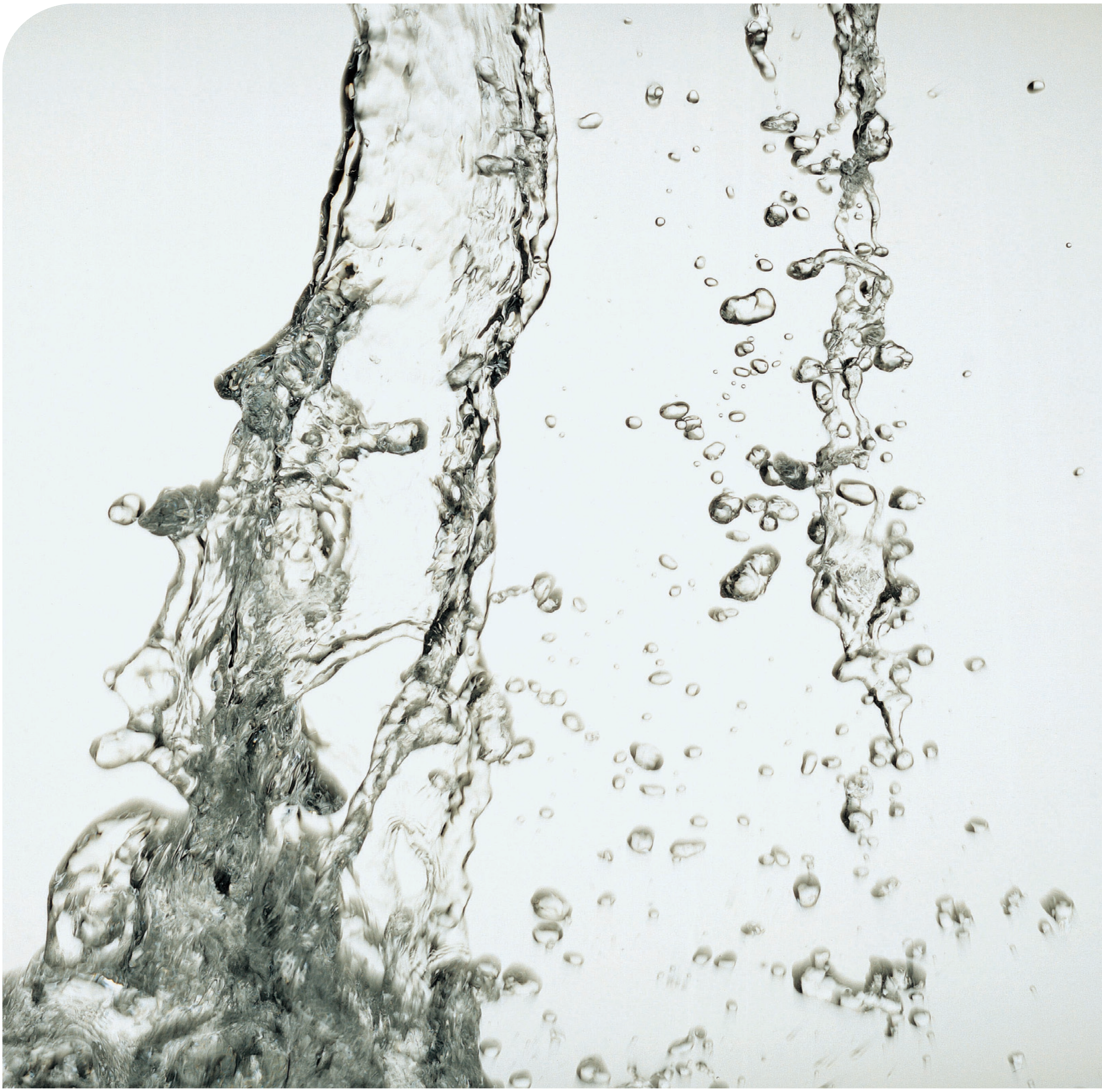
AECB Water Standards

Delivering buildings with excellent water and energy performance

VOLUME 2: THE WATER STANDARDS

TECHNICAL BACKGROUND REPORT



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Introduction

This document shows the rationale behind the AECB water standards, which complement the AECB energy standards. The approach of demand reduction, attention to detail and cost effectiveness is informed by these energy standards, which in turn are based on the German Passivhaus[1] methodology.

Whilst water efficiency is a crucial aspect of sustainable building design, the required reductions are far less than with energy or CO_2 where an 80-90% saving is a challenging but realistic target. This is because, unlike fossil or nuclear fuels, water is a limited but renewable resource. However at Passivhaus levels of insulation, the energy required to heat domestic hot water is greater than for space heating so reducing hot water demand is a clear priority.

Summary of recommendations

There are two specifications; Good Practice and Best Practice (table 1).

Good Practice: will result in normal or improved levels of performance and comfort. Extra effort will be required at the design and specification stage compared to a standard building, but the choice of fittings will be wide with minimal additional expense over ‘standard’ fittings.

Best Practice: performance and comfort maintained, may incur additional design effort and expense or a more limited choice of suitable fittings. Shower heads and tap outlets have a lower flow rate than under Good Practice, but Good Practice fittings must be provided for retrofitting should the low flow fittings be considered unacceptable by the end user. This is to encourage people to try lower flow fittings, whilst guarding against dissatisfied users over-reacting and retrofitting very high flow fittings.

Experimental technologies

Many people designing and building to AECB standards will be keen to innovate, and as with any other area of building design, a variety of experimental and innovative approaches to water use are possible. As is always the case with innovation, some of these technologies will turn out to be great successes (and may in the future become incorporated into Good and Best Practice standards), but others will fail at some point. Other innovations are likely to be very site-specific, or highly dependent on the clients attitude (e.g. waterless toilets), and as such will never be widely applicable. As such, it is difficult to incorporate innovative technologies into a standard.

Appliances meeting the Good and Best Practice standard are regarded as being suitable for the vast majority of users, with acceptable volumes and flow rates and normal levels of performance and comfort. There may be some people who are happy with lower volumes and flow rates, and we would encourage people to install lower water use fittings where they are happy to do so.

In the case of easily replaced items such as shower heads or tap outlets, innovative or experimental devices may still be fitted under the Good and Best Practice standards as long as a suitable replacement is provided as an option, should the innovation prove not to be successful. Installation of technologies that cannot easily be replaced by the householder (such as compost toilets, urine separating toilets, vacuum drainage, recirculating showers) represent more of a risk should the appliance not be suitable. Consequently, a building with such technologies cannot be described as meeting the AECB Good or Best Practice standard for water, and the water element of the property should be described as *Experimental*. This does not preclude compliance with the AECB energy standard, provided the maximum flow or volume requirements are not exceeded.

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[1] http://www.passiv.de/

The relative importance of energy savings and water savings should be remembered and is discussed further in Appendix II. It is not reasonable to install a water saving device that results in higher energy use. This argument still applies in properties where renewable energy is specified, since energy use should be minimized prior to consideration of lower carbon energy sources.

Table 1. Summary of performance requirements, further details in text.

Fitting	Good practice	Best practice
Showers	6 to 8 l/min	≤ 6 l/min (e.g. aerating)[2]
Basin and bidet taps (domestic)	4 to 6 l/min	≤ 4 l/min with lower default[3]
Urinals (non-domestic)	See text	See text
Basin taps (washroom)	≤ 1.7 l/min spray dead leg ≤ 0.5 litres	As Good Practice dead leg ≤ 0.25 litres
Kitchen sink taps	6 to 8 l/min	≤ 6 l/min with lower default[4]
White goods	See energy standard	As Good Practice
Toilets	≤ 6 l/ full flush	≤ 4.5 l/full flush
Baths (shower must also be installed)	≤ 180 litres to overflow	As Good Practice
Dead legs	≤ 1.5 litres	≤ 0.85 litres
Dead legs off secondary circulation[5]	≤ 0.5 litres	≤ 0.25 litres
Water softeners	Location specific, see relevant section	
Outdoor	Location specific, see relevant section	

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[2] A 6 to 8 l/min shower head must be provided for retrofit if required.

[3] e.g. water-brake or similar technology to encourage lower flows as default. A 6 l/min fitting must be provided for retrofit if required.

[4] A 8 l/min fitting must be provided for retrofit if required.

[5] Avoid secondary circulation where possible. When installed must be suitably controlled and insulated.

Commissioning

Flow rates of showers and taps must be checked to be compliant with the standard during commissioning, together with a record of mains water pressure at the time of the test. Evidence of WC flush volume and bath volume must also be provided. The internal volume of pipes which form dead legs must be calculated and the length, diameter and material stated. A checklist verifying these points should be included in the Home User Guide (see Appendix IV).

Provision of Home User Guide

A Home User Guide is required at all levels. This should include the following:

- Details of all water using appliances including manufacturer, product name, and website/phone number for spares or should further information be required.
- Description of each water using appliance, their water saving features and how to use them (for example water brakes in taps, dual flush toilet buttons or levers). Brief description of any maintenance requirements or checks.
- Carbon literate water efficiency advice emphasising the role of behaviour, tailored to the appliances at the property.
- Advice on leak detection and action to be taken.
- Commissioning checklist with measured flow rates and volumes for each appliance.

Differences between the AECB standard and Code for Sustainable Homes (CSH)

One of the initial decisions that has to be made when designing a strategy against which to measure water efficiency is whether to have a performance target for individual appliances or a whole house water use target based on calculation. The former approach has been used here, whereas CSH has opted for the latter. The differences between the two standards are summarised in table 2 and there is further discussion in Appendix I.

A calculated whole house performance standard is not appropriate for water, for the following reasons:

- A calculation such as that used by the Code will not provide a useful prediction of how much water is used in a house for a given suite of measures.

- Following the logic of the CSH water calculator results in unusable appliances that will be removed by the owner (e.g. specification of 1.7 l/min taps in a kitchen sink, or tiny baths as illustrated in figure 2). In this instance a negative experience with a low water use appliance may result in a rebound effect where a high water use appliance is then deliberately installed. It is therefore important to strike a balance between good levels of water efficiency, whilst maintaining good performance. More cynical (or aware) practitioners are currently specifying low-cost ultra low flow fittings such as tap sprays and showerheads that provide the maximum points for minimum cost in the knowledge that these will be replaced following certification.

- Reducing CO_2 emissions is more important than reducing water use *per se*. Achieving reductions in water use by (for example) rainwater harvesting or grey water recycling systems used for WC flushing will result in increased CO_2 emissions (Environment Agency, 2008). See Appendix II for a discussion of the environmental impacts of water supply in more detail.

- The CO_2 emissions resulting from heating water are far greater than those from the supply of water itself (figure 1). Consequently, trading off fittings against each other by using an overall household water use target (e.g. a low flush WC or recycled water allowing the installation of a high flow-rate shower) can easily result in a big increase in the CO_2 emissions associated with water.

Table 2. Summary of key differences between AECB standard and CSH.

AECB Water Standard (aims)	**CSH Water**
Appliance limits	Total household limits
Min and Max flow limits	No minimum flow limits
Emphasis on demand reduction	Can emphasise grey and rain
Carbon saving prioritised	Water can be saved at cost of carbon
Cost effectiveness considered	Cost effectiveness not considered
Location considered	Same measures for Thames or Cumbria
Peak demand considered (e.g. summer outdoors)	Average demand considered
Good initial plumbing design encouraged	No requirements for good plumbing design

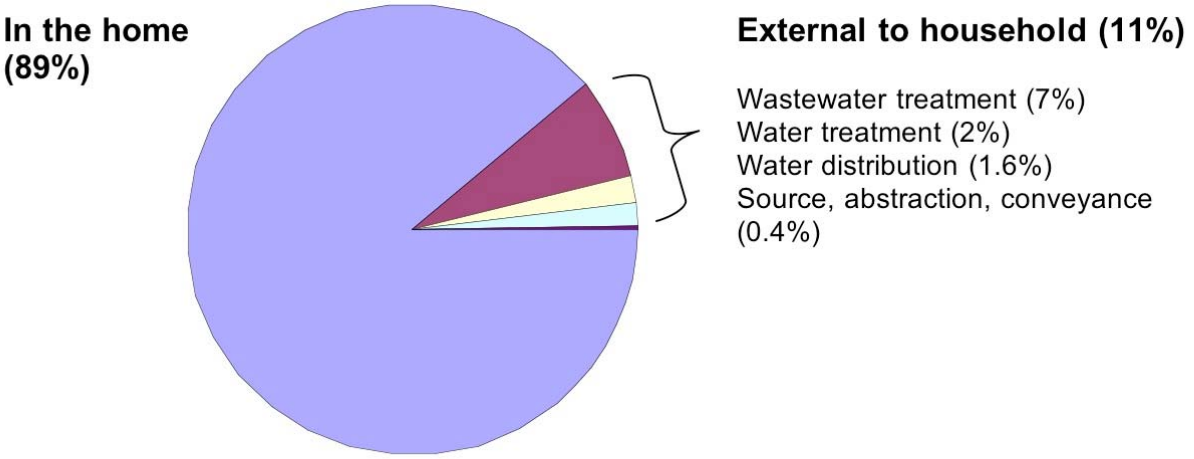

Figure 1. Greenhouse gas emissions due to domestic water use. From Environment Agency Briefing Note; greenhouse gas implications of future water resource options.

Figure 2. A 1300mm long, 110 litre bath installed for CSH compliance.

Relationship with other standards

As with the AECB and Passivhaus energy standards, the proposed AECB water standard is not equivalent to the April 2008 version of Code for Sustainable Homes. The authors have set out to develop guidance on what they believe to be genuine best practice. However, if the current CSH Water requirements are incorporated into the new Part G of the Building Regulations then a conflict will occur since even the AECB Best Practice specifications may then fail to meet the Building Regulations.

Conflict is not expected between the AECB water efficiency requirements and the Water Regulations and associated British and European standards and performance requirements which are an assumed pre-requisite for compliance with the AECB Good and Best Practice standards. It is possible that some designers will wish to implement more experimental solutions that go beyond or perhaps contravene current standards. It is considered important that such deviations are clearly identified as such, for example very low flow showers or tap sprays, which do not meet the minimum flow requirements of BS 6700 or the NHBC. It is possible that relaxation or justification will be required for Building Regulations and other approvals as is normal for such innovations that are outside of current standards.

Water in the Passivhaus and AECB Energy Standards

Passivhaus certification is only intended to address energy consumption. The Passivhaus Planning Package (PHPP 2007) does estimate hot water energy and losses from storage and distribution based on standard hot water consumption per person[6]. At Passivhaus levels of thermal efficiency, standard hot water consumption is equal to the annual space-heating requirement of 15kWh/(m^2.a) before accounting for losses or hot-fill for white goods. Whilst PHPP calculates hot water energy consumption based on a standard usage, there is no target other than the total primary energy limit of 120kWh/(m^2.a). Additionally Passivhaus certification does not set any limits on shower flow rates or bath sizes.

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[6] For dwellings this is 25 litres at 60°C per person per day although in effect this is 0.71 litres per m^2 as occupancy is calculated at 35m^2/person. Hot water consumption by white goods with hot-fill is additional to this and is also estimated.

PHPP estimates the energy loss due to hot water dead legs assuming that the total dead leg water volume and pipe material cools to room temperature 3 times per day per occupant. Whilst this is unlikely to provide an accurate estimate of actual water or energy wastage, the calculation does reward good design, i.e. short dead legs and minimum pipe sizes.

Whilst PHPP does not consider cold-water consumption it does make an allowance for space heating losses due to the warming of the cold water entering the building. This calculation assumes that 100 litres of cold water per person is warmed from 10°C to 16°C. However not all cold water entering the building will have sufficient time to reach this temperature. In addition some of this cold water is subsequently mixed with hot water and so the heat is transferred from space heating to water heating but is not lost. These issues have been raised with the Passivhaus Institute by the authors and are being considered. When the life cycle CO_2 emissions for WCs are calculated, this heat loss is the greatest contributor to total emissions[7], far more than emissions due to manufacture, transport or disposal (DEFRA 2008).

Regional differences

Regional differences in water scarcity should influence the extent to which designers focus on cold-water[8] efficiency measures. Although average annual outdoor water use is only around 6% of total domestic water use, on hot summer days when supplies are most stressed, over 70% of the water supply may be used for watering gardens.

The Environment Agency water stress classification (2007) ranks regions as suffering from low, moderate or severe water stress, based on factors related to water use, water availability and population forecasts. Dwellings in areas with moderate or severe water stress will be required to address the issue of outdoor water use and the standard requires non-edible planting schemes in these areas to be designed so as not to require the use of mains water once established. Even in areas classified as low water stress, water efficient gardening is to be encouraged.

Water stress categories according to water company region are given in Appendix III for ease of reference. Whilst the Environment Agency water stress categories are based on public water supply, they can be regarded as general indicators of regional water availability and the provision of a private water supply will not negate the need for compliance with the AECB standards.

International context

Domestic water use is already lower in the UK than in most other developed nations, and differences in water scarcity and culture complicate the relevance of overseas comparisons. A number of countries have labelling schemes for water efficient appliances (e.g. Australia, Singapore, USA), but there is very little evidence regarding how successful these are in reducing water use. They do however provide an indication of what volumes and flow rates other countries have found to be acceptable, and as such are referred to at relevant points below.

Gravity plumbing systems

The UK is unusual in having such a wide range of plumbing systems. Specifying flow regulated (rather than simply restricted) fittings for use with gravity systems is problematic and unnecessary, as the flows will tend to be low anyway. Gravity hot systems are uncommon for new build. However a low-energy dwelling might be designed to use a gravity hot water system if the supply pressure is low, for example from a long supply pipe or spring source. These situations will have to be considered as a special case and the designer will need to show that they have made efforts to meet the performance aims of the standard. The dead leg requirement will be a particular challenge due to the larger pipes needed and a relaxation of the requirement might make more environmental sense than installing secondary circulation. In these cases the designer should present their workings.

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[7] This heat loss has been claimed to represent about 96% of the environmental impact of a WC over its lifecycle.

[8] The environmental benefits of hot-water savings are independent of water availability.

Behaviour

The way in which appliances are used will have a major bearing on their water use. Indeed, variations in individual behaviour are a major reason why a whole house standard for water is not appropriate as a regulatory tool. There are a number of examples of people living in houses designed for water efficiency but which would achieve a zero CSH rating. Measured water use of less than 70 litres/person/day is easily achieved despite normal levels of comfort and hygiene. Many attempts to measure the water efficiency of appliances in the household have found that the differences attributable to behaviour are greater than the differences attributable to appliances. Furthermore, initial differences in water use between households with low water use appliances and households with normal appliances are not maintained in the long term. It is often not feasible to design out user behaviour such as brushing teeth or washing dishes with a running tap, or taking long and frequent showers. The interaction between a person and the appliance is therefore critical and this standard is designed to encourage water awareness. The provision of a Home User Guide is a vital part of this.

Flow regulation

Conventional taps and showerheads deliver water at a flow-rate that increases with pressure (see figure 4). Since hot and sometimes cold water was historically supplied from a header tank, fittings had to be designed with minimal restriction to flow.

With the now almost standard installation of direct mains fed hot water systems such as un-vented cylinders and combi-boilers, such fittings are capable of delivering very high flow rates. This can result in water and energy wastage but can also lead to problems with splashing when taps are turned on too quickly. The solution is flow regulation, which is applied at each fitting using a flow *regulator* of a specified flow rate. These devices typically contain an ‘O’ ring that deforms in response to variation in pressure so as to deliver a constant flow rate over a wide range of pressures, typically between about 1 and 5 bar. By comparison in a simple flow *restrictor* the flow will vary with pressure. Flow regulators have the additional advantage of balancing flows between different parts of the plumbing system thereby improving performance when several appliances are in use.

The flow rates for taps and showerheads within this standard are those that would be achieved at installation. Where mains pressure is above 1 Bar this is best achieved with flow regulators (figure 3) rather than restriction. Options include service valves with integral, removable regulator cartridges, taps with flow regulators inserted in the tail and outlet fittings such as aerators or sprays with built in regulators.

In gravity feed systems or where mains pressure is low, the use of flow regulators is likely to introduce unwanted resistance. In these situations the flow rate should be predicted from manufacturers performance graphs (e.g. figure 4).

Figure 3. Flow regulator built into a service valve. Courtesy Aquaflow Regulators.

Whilst it would be simpler to specify flow rates at a standard water pressure (e.g. CSH uses 3 Bar), a fitting will deliver higher flows where installed in a dwelling with higher water pressure but an inadequate flow in a dwelling with low mains water pressure. Figure 4 illustrates this point for an 8 litre/minute shower head. Consequently, flow rates are specified as that achieved at the fitting.

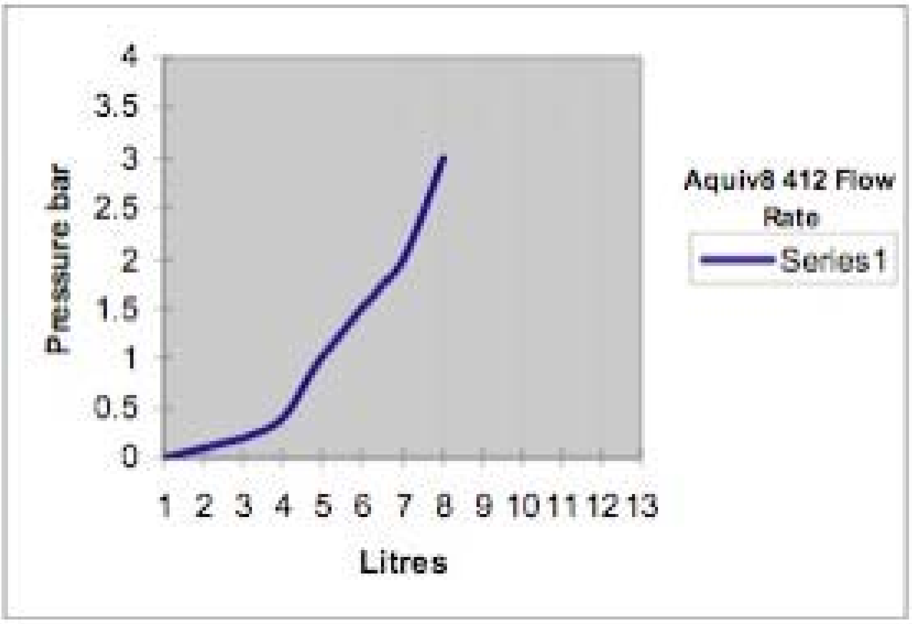

Figure 4. Water pressure against flow rate for an 8 litre/minute shower head, Challis Water Controls.

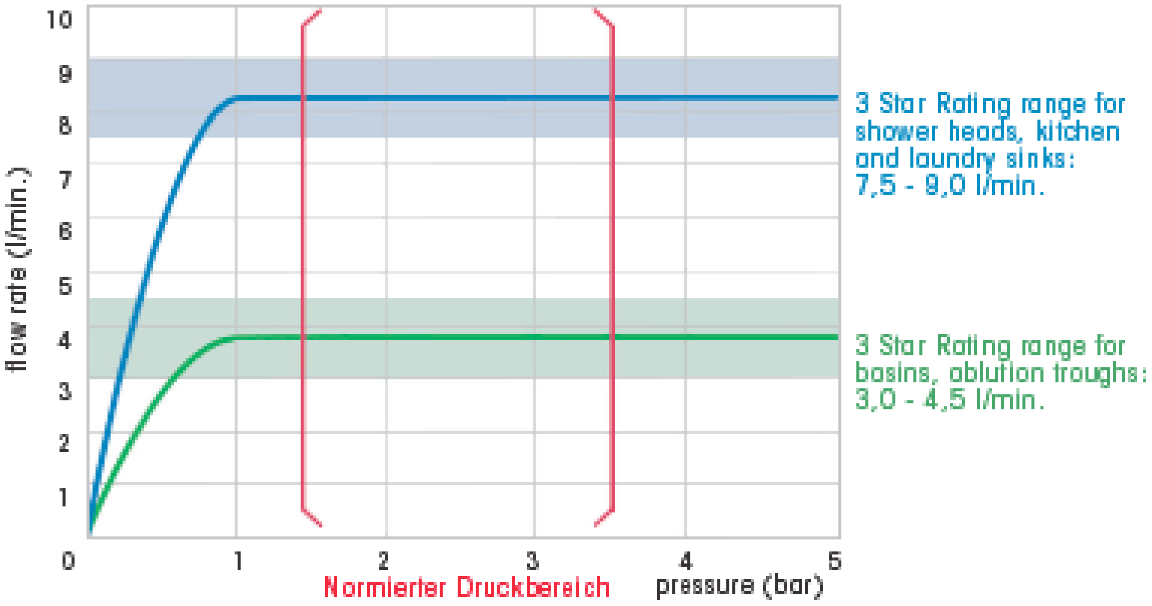

Figure 5. Flow against pressure for flow regulated fittings. Graph courtesy of Neoperl.

Fitting specific considerations

Combi boilers

Combi boilers can lead to water wastage due to the time needed for warm up. Some combi boilers are not suited to very low flow rates such as that to feed a spray tap (table 3, taken from Grant, 2007). Various solutions exist but the energy implications of these must be considered and consequently, the detail of combi boiler specification is not covered by the water standard.

Boiler	Minimum boiler output	Minimum flow for 27°C ∆T, litres/minute (15°C mains)	Minimum flow for 22°C ∆T, litres/minute[9] (20°C mains)	Notes
24kW, modulation down to 25%	6.0 kW	3.2	3.9	OK except for spray taps
24kW, modulation down to 30%	7.2 kW	3.8	4.7	OK except for spray taps
35kW, modulation down to 25%	8.8 kW	4.6	5.7	OK except for spray taps
35kW, modulation down to 30%	10.5 kW	5.6	6.8	Possible problem with lowest flow fittings in summer
(48kW, modulation down to 30%)	(15 kW)	(7.6)	(9.4)	Not compatible with low flow fittings - uncommon

Table 3. Minimum flow rates for commonly available boiler sizes including up to 20°C incoming mains water temperatures.

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[9] 20°C mains water is included in this table as the 15°C consensus may be an underestimate.

Showers

Recommended standard

Good: All mixers to have separate control of flow and temperature although this can be achieved with a single lever with 2 degrees of freedom (lift to increase flow, rotate to alter temperature). All mixers to a have clear indication of hot and cold. Showerheads to have a maximum flow rate of 8 l/min at installation.

Best: as Good plus maximum flow rate ≤ 6 l/min at installation.

Where a shower head has more than one setting or spray pattern, the standard refers to the setting with the highest flow rate[10].

Background information and research

WRc (referred to in MTP 2008a) found that showering is the single largest use of hot water in modern homes (comprising 23.1% of total water use), which makes it an important target for both energy and water savings. At the Passivhaus level of energy efficiency, the annual energy use for domestic hot water is greater than for space heating and most of this is for personal bathing.

An additional factor considered elsewhere is cold water that is run to waste whilst the water runs hot. For showers, warm water is also wasted whilst the temperature and flow are adjusted. No data were found for the extent of this wastage in the UK but in the worst installations the issue could be very significant and more research is needed.

Showers are a good example of an appliance whose water use is difficult to predict and where variables due to individual behavioural differences and preferences dominate. Focus groups on shower use preferences (MTP 2008b) have identified issues such as flow rate, force of spray, temperature stability, soap removal, spray pattern and area of body covered by water. Test methods for flow rate and spray pattern are defined in BS 6340-4, AS/NZS 3662, BS EN 13904 and BS EN 1112, but there is no common way of testing other parameters and therefore it remains difficult to have any universal definition of what constitutes a ‘good’ shower. From the perspective of CO_2 emissions, water use in showers is of prime importance, and these issues therefore require further work.

Minimum acceptable flow rates

The risk with specifying too low a flow rate is that the fitting will be replaced by users, possibly with a much higher flow rate fitting. Where the user does not have choice about the shower fitting (gravity hot water, hotel guests, teenagers etc) baths might be taken in preference to a poor shower thus increasing water use compared with a slightly higher flow shower that might be used in preference to a bath.

Research into “Showers Types Use and Habits” (Essex and Suffolk Water, 2006) found that 92% of people (sample size 104) were satisfied with their electric shower, despite the fact that electric shower flow rate is limited by the fixed heat input which typically limits the flow rate to 3-6 litres/minute[11].

In 2007 the average flow rate of installed showers was 6.8 litres/minute (MTP, 2008c) (consisting of 9.26 litres/minute for mixer showers and 4.31 litres/minute for electric showers).

Critchley and Phipps (2007) trialed aerated showerheads and found that 8 out of the 9 householders chose to keep the (7- 8.4 l/min) water saving head despite flow rate reductions (at full flow) averaging 27.5% (range 3-45% reduction). Interestingly the individual who chose not to keep the water saver shower had the highest flow shower (23.6 litres / minute) but gave it a satisfaction score of only 23 compared to the average score for the water saver showers of 33 (range 31-35).

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[10] The use of ‘average’ flow rate for showers in the CSH water calculator for showerheads with several flow settings is open to abuse by the installation of a shower with a low average flow but high maximum flow.

[11] Flow (l/min) = 14.3 x P (kW) /Temperature rise (C).e.g. 14.3 x 8.9kW/32°C = 4 l/min (5 l/min for a 25°C temperature rise, e.g. in summer).

A trial by Thames Water is currently looking at water savings and acceptability of 8 litre/minute aerated showerheads with a sample of over 1000 households (Chapman, 2008). Unfortunately results are not yet available.

In the USA the Federal Energy Policy Act of 1992 ANSI/ASME A112.18.1M-1996 requires shower heads to use no more than 2.5 US gpm at 80 psig (9.5 l/min at 5.5 bar). The Water Services Association of Australia (WSAA) National Water Conservation Labelling Scheme awards an AAA rating (High) for 9 litres/minute.

Achieving the standard

Limiting flow rate can be achieved directly at the showerhead, or via regulating the flow to the mixer valve. The easiest technical solution is to regulate the flow within the showerhead. Whether this regulation is achieved as part of the physics of the showerhead or by an additional in-line flow regulator will depend on the design. For example aerating and atomising heads tend to require sufficient pressure to function.

The alternative option is to fit in-line flow regulators to limit the hot and cold feeds to the mixer, for example using in line access valves with removable regulators.[12] Some energy and water consultants prefer to specify separate hot and cold regulators arguing that they can be built into the plumbing and so removal might be less likely. However this makes it difficult to know what the total flow will be as it will depend on water temperatures (hot, cold and shower).

Also limiting flow in this way will in effect reduce the pressure at the showerhead under dynamic conditions so that aerating and other water saver showerheads are unlikely to work unless designed for lower flow rates than the mixer valve is able to deliver.

For these reasons the simpler and cheaper option of regulating the flow at the showerhead or at the outlet from the mixer valve is recommended.

Other issues

The large range of permutations of shower and plumbing systems in the UK has been widely documented. Gravity hot water systems are becoming less common than mains pressure systems such as combi boilers, thermal stores or un-vented cylinders. Typically, gravity fed showers have a low flow rate due to lack of pressure. Available water saver regulated showerheads are designed for pressures above about 1 bar and are not suitable for gravity systems. Whilst electric showers are inherently flow-limited and therefore good from a water efficiency perspective, their use may be inconsistent with the water heating strategy in a house built to AECB energy standards.

Basin and sink taps

Recommended standard

All flow rates are those measured at the outlet. Flow regulation for mixer taps achieved at the outlet.
All taps and mixers to have a clear indication of hot and cold with hot tap or lever position to the left (standard installation).

Kitchen sinks

Good: 8 l/min.
Best: 6 l/min, with water brake, spray or some other means of ensuring that default flow is lower. Consider single lever taps that deliver cold water only when in central (default) position. An easily fitted 8 l/min regulator or regulated outlet should be provided as an option so that users can fit this if the lower flow rate is not sufficient. This is to discourage users simply removing the original regulator.

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[12] Aquaflow Regulators Access valve.

Basins
Good: 4 to 6 l/min (per pillar tap or per mixer outlet).
Best: 4 l/min or less (per pillar tap or per mixer outlet), with water brake, spray or some other means of ensuring that default flow is lower. Consider single lever taps that deliver cold water only when in central (default) position. An easily fitted 6 l/min regulator or regulated outlet should be provided as an option so that users can fit this if the lower flow rate is not sufficient. This is to discourage users simply removing the original regulator.

Basins (handwash only)
Good, Best: ≤ 1.7 l/min. Dead leg ≤ 0.5 (Good) ≤0.25 litres (Best).

Background information and research

The amount of water used by a tap is related to frequency of use, flow rate and duration. As stated in the introduction, reducing flow rate does not necessarily reduce water use, since some functions of taps are volume dependent (e.g. filling sinks, kettles) rather than duration dependent (rinsing, hand washing). Thus tap flow rates need to be high for filling but can be low for rinsing operations. Water brake taps, cartridges and innovations such as Tap Magic[13] attempt to address this issue. It is therefore essential to consider the likely functions of taps in different locations within a property. In downstairs cloakrooms, spray fittings might be completely appropriate, whereas bathroom and kitchen taps will be used in different ways.

The Identiflow® data[14] (Chambers et al., 2005) that has informed the CSH indicates that average tap flow rates in use are already low at around 3.4 litres/minute presumably either because the water pressure is low (gravity hot water systems) or because people choose not to turn the tap onto full flow. The CSH water calculator has dealt with this by using a figure of two-thirds the maximum flow rate, but this is a somewhat arbitrary ‘fudge factor’ that was introduced in response to an initial critique of the calculator. Additionally, histograms of flow rate from Identiflow® monitored properties had bi-modal distributions, one at around 0.8 litres/minute, and another at around 3.6 litres/minute. Tap events with lower flow rates actually had higher total water use than tap events with high flow rates. There are a number of possible explanations for this finding, but it serves to emphasise the lack of data robustness and reliable evidence regarding the relationship between flow rate and volume of water used.

In the US, flow rates to taps in public restrooms (i.e. in a scenario of hand washing only) are limited to 1.9 l/min, with all other taps limited to 8.3 l/min (all measured at 4.1 bar). Further reductions in this latter value are being considered (EPA, 2007). The Singapore WELS standard for basin taps considers 4 to 6 l/min as 'good', 2 to 4 l/min as 'very good' and < 2 l/min as 'excellent'. The Singapore standard for kitchen taps is 6 to 8 l/min 'good', 4-6 l/min 'very good' and < 4 l/min 'excellent' (WELS 2008).

Achieving the standard

As with showers there is a possibility of providing flow regulation within the tap or within the outlet fitting, typically within an aerator or spray fitting. The increasing popularity of taps with standard metric outlet threads allows sprays and aerators to be fitted to suit usage. As with showers, regulation can be achieved for the hot and cold feeds to a mixer tap but this raises the same issue that the flow rate can then be up to twice the regulated flow to each side. The fitting of sprays and aerators to dual flow taps could lead to backflow if the hot and cold water pressures are imbalanced. In this situation check valves should be fitted to comply with the Water Regulations but such an arrangement is not compatible with a cold mains and gravity hot water feed. Such are the complications of UK plumbing.

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[13] An outlet fitting for taps designed to provide a spray at low flow rates. As the flow rate is increased a valve opens allowing more flow for fillings basins.

[14] This is water use data derived for individual appliances and fittings using household level flow metering and specialist software.

White goods

Recommended standard
Good, best: This is covered by the energy standard.

Background information and research
Efficiency of these products is being driven by energy labelling and although it is accepted that these labelling schemes have their flaws[15], the performance standards required by them are increasing (DEFRA, 2008b). It is proposed that any white goods performance requirements are covered by the AECB energy standards. Briefly:

Washing machines: 80% of the energy used by a washing machine is used to heat the water required (MTP, 2008d), so water efficiency and energy use are closely linked. The best available energy class of machine is recommended (currently A, although manufacturers are using difficult-to-verify claims of AAA and A+). Ensure that the machine that allows both cold and 30°C washes. Further guidance is available (MTP, 2007). The issues surrounding the benefits or otherwise of hot fill are complex, and at present, machines allowing an intelligent hot fill only to the wash cycle (e.g. from Solar Hot Water) are not available.

Dishwashers: Whilst typically more water efficient than washing up by hand, they are less energy efficient (MTP, 2008e). Individual variations in dishwashing habits result in considerable data uncertainty and as such, the choice is left up to the individual. Where installed, they should be the best available energy class of machine.

Food waste disposal units: These are not covered by this standard. Further research is needed into the environmental impacts[16] of food waste disposal units as, in urban situations at least, there are arguments both for and against. Where possible, composting is assumed to be the environmentally preferred option.

WCs

Recommended standard
Good: ≤6 litre full flush volume when flushed with the water supply connected. For domestic properties dual flush is required. All valve flush (as opposed to siphon mechanism) WCs to be fitted with an easily accessible, quarter-turn isolating valve with a hand-operated lever. Where a valve flush WC is installed, the Home User Guide must include information on testing for leaks. There is no requirement for calculation of full:half flush ratios. Siphon flush WCs can be specified with dual flush siphons or fitted with a dual flush retrofit device that retains the leak-free siphon.

Best: As good Practice but ≤4.5 litre maximum flush with water supply connected. Flush mechanism to utilise a leak-free siphon or to be fitted with a suitable leak detection warning device. Full flush volumes less than 4 litres are considered to be experimental.

Background information and research
WCs have historically been responsible for the highest proportion of water use compared to any other appliance. As such, they have been the focus of considerable monitoring and research (reviewed by Waterwise, 2008).

Volume per flush
Under the Water Regulations, flush volume is measured with the water supply turned off (BS EN 997). Actual flush volumes are higher because the cistern refills during the flush cycle. The difference between measured and actual is therefore dependent upon the cistern refill rate, which in turn is dependent on supply pressure and the inlet valve design (figure 6).

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[15] For example an A rating on a washing machine is based only on its performance for a 60°C cotton wash and does not reflect the efficiency of any other programme.

[16] For example WRc project CP342 (ongoing), CIWEM (2003).

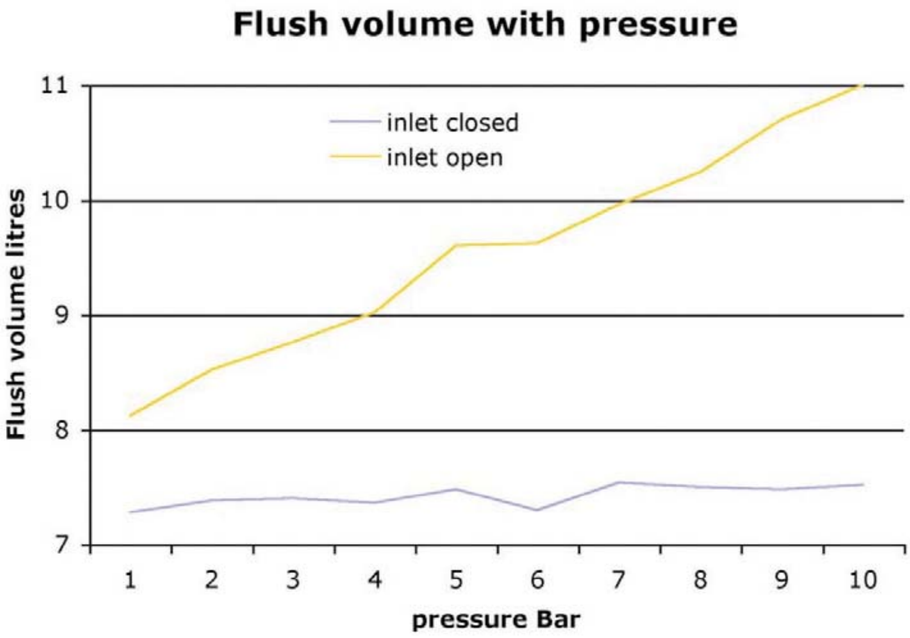

Figure 6. Variation in flush volume, for a nominal 7.5 litre WC, with pressure. Based on figures from WRc.

This difference between measured and actual flush volumes can be rectified using a delayed action inlet valve, and these are encouraged under this standard as a means of complying with the actual flush volume required. At least two manufacturers already incorporate a suitable mechanism whilst others can be retrofitted. Where no delayed action valve is fitted, 1 litre is to be added to the stated nominal flush volume. Thus a 6 litre WC becomes 7 litres which does not meet the minimum standard.

Leakage and its detection

Prior to January 1st 2001 both dual flush and valve flush WC's were illegal in the UK for reasons of water waste prevention. Both are now permitted but there is concern that valve flush WC's will leak and increase water wastage. As yet there has been little published evidence to support this in the UK other than a study of high consumption enquiries by Bournemouth and West Hampshire Water (reported in Environment Agency, 2007b and illustrated in figure 7). An Australian water calculator (NSW Government, 2006), incoporates a 10 litre/day leakage allowance into calculations, and the American Water Works Association report indoor water leakage (as opposed to supply main leakage) as 43 litres/person/day (AWWA, 1998). Mechanisms to warn of leakage are feasible but there is probably only one product currently on the market and this will only fit bottom fill cisterns[17]. Thus whilst ideally valve flush WC's would be required to be fitted with a device to detect leakage, this is currently not a reasonable demand. The standard requires all valve flush WCs to be fitted with an easily accessible, hand operated, quarter turn isolating valve to allow the water to be turned off between uses should a serious leak develop, e.g. due to a damaged mechanism. This will also allow the water to be turned off overnight to check for leaks. This requirement mirrors that of the Florida Water Star labelling scheme (2009).

In order to encourage innovation, the Best Practice standard requires cisterns to use either a leak free siphon mechanism or to incorporate an effective leak detection mechanism.

A related issue is that virtually all WC's in the UK market now have an internal overflow to the pan instead of an external overflow pipe. This makes inlet valve leaks more difficult to detect and easier to ignore. Specifiers should be aware of this fact and details of how to test for leaks should be included in the Home User Guide.

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[17] Fluidmaster Leak Sentry.

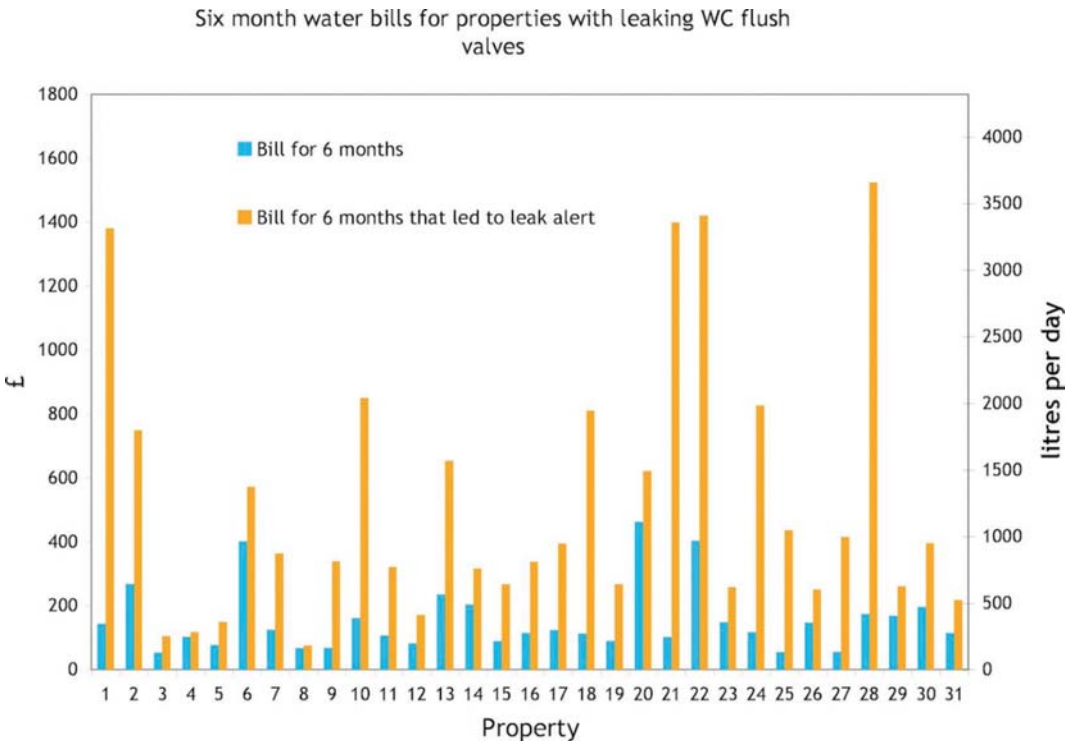
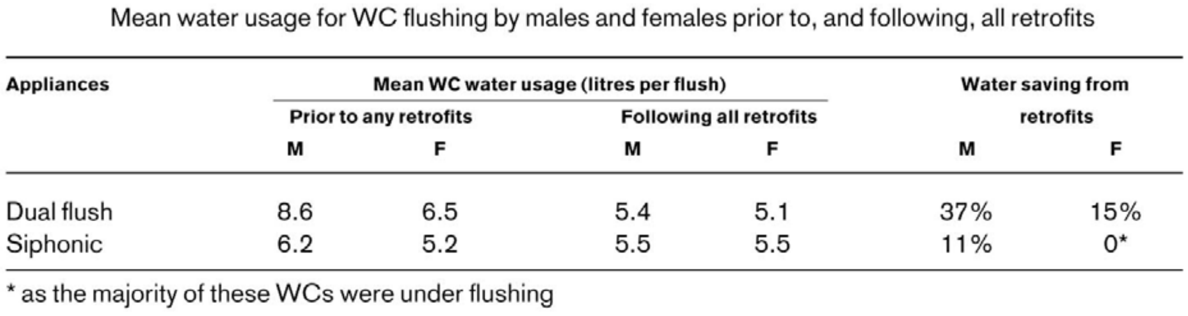


Figure 7. 6 month water bills showing increase due to leaking WC flush valves. Bournemouth and West Hampshire, (reported in Environment Agency 2007b).

Half: full ratios

Whilst dual flush WC's are purported to use less water than single flush WC's because of the use of the half flush button, the ratio of full:half varies sufficiently that calculating an average flush volume is unreliable. Ratios as high as 1:4 have been used although 1:1 has been reported in trials. 1:1 has been recommended (Environment Agency, 2006) and the CSH compromises at 1:2 whilst Ecohomes used 1:3. Most recent WRc data has revealed ratio's from 2:13 to 17:1 in 46 monitored households. Despite numerous studies (e.g. Hills *et al*. 2002, illustrated in table 4), there is little evidence that new dual flush WC's have lower water use in practice than single flush WC's and as such only the maximum flush volume is specified in this standard. It is accepted that in a well-maintained system, dual flush toilets have the potential to be more water efficient than single flush toilets. Interestingly in domestic trials where siphon flush WCs have been retrofitted with dual or interruptible flush devices savings of around 30% have been measured (e.g. Keating and Lawson 2002). Since the AECB water standard is not predicting total household water consumption, there is no requirement to calculate an average flush volume for a dual flush WC. However, clear identification of the mode of dual flush operation is required in order to avoid double flushing, as with many currently available WC's the full and half flush buttons are either difficult to distinguish or difficult to operate. Whilst instruction stickers are provided, these are often removed, so reference to the mode of operation should be in the Home User Guide. This is particularly important for dual flush siphon cisterns with levers, where the default flush for a brief lever press can be either full or half flush, depending upon the manufacturer.

Table 4. Water use per flush for 6 litre siphon and 6/3 valve flush WCs in the Millenium Dome. (Hills *et al*, 2002).



Mean water usage for WC flushing by males and females prior to, and following, all retrofits

Appliances	**Mean WC water usage (litres per flush)**				**Water saving from retrofits**	
	Prior to any retrofits		**Following all retrofits**			
	M	**F**	**M**	**F**	**M**	**F**
Dual flush	8.6	6.5	5.4	5.1	37%	15%
Siphonic	6.2	5.2	5.5	5.5	11%	0*

* as the majority of these WCs were under flushing

Drain carry with lower flush volumes
There is considerable concern within the industry regarding the impact of lower flush volume WC's on drain carry and the risk of sewer blockage. This subject has been recently reviewed (Environment Agency, 2008b). Major decreases in WC flush volume may require revisions of regulations on sewer pipe gradients and diameters, since WC flush water is the main factor influencing solid transport.

Hot tubs, spas and pools

Hot tubs and spas have not been considered in this water standard because whilst their water use is high, their energy use is of far more concern. It is assumed that a dwelling with a spa, pool or hot tub will not be able to meet the AECB energy standards in terms of primary energy use. Municipal and communal facilities shared between a large number of people may be a solution but are beyond the scope of this standard.

Baths

Recommended standard
All volumes measured to centreline of overflow.
Good: Bath volume to be ≤ 180 litres. A shower must also be provided although this can be over the bath provided the tiling and screen are suitable for stand-up showering.
Best: As Good practice or shower only.

Background information and research
Several poorly understood and inter-related issues affect water use in baths, and the CSH calculator is not expected to be a good predictor of bath water use.
Physical bath volume: Current BS EN standards do not specify a method for measuring volume; volume measured to the centre of the overflow is often used (MTP, 2008f), you should check with the manufacturer when specifying as some manufacturers quote a much lower figure that subtracts an amount for the water displaced by the body. Reductions in measured volume are being achieved for the purposes of CSH compliance by lowering the overflow, with no physical change in bath dimensions. Since people are likely to want baths that they can fully submerge themselves in, a market for retrofit measures such as variable overflows has developed.

Volume per use: this is not easy to predict, although it has been estimated to be 40% of volume to overflow (Chambers et al., 2005). There is no evidence that specifying small bath volumes results in lower water use per bath and it may be problematic for larger people, so it is not required at Good or Best Practice standard. Volume per use is likely to be highly variable given the different functions of a bath (e.g. washing, relaxation, bathing small children). Innovations such as soft, body contour following baths are a possibility for the future.
Use frequency: Use frequency data from the identiflow dataset is not normally distributed and has high variability and as such, a mean is not an adequate summary of the data for the purposes of the CSH water calculator. The relationship between shower use and bath use is another major variable and complicates establishing any hard and fast rules. This relationship may also have a seasonal variable (i.e. more showers but fewer baths in the summer), which could skew data and needs further research.

Bidets

Recommended standard
Good: 4 to 6 l/min tap flow rate if bidet installed.
Best: 4 l/min or less tap flow rate if bidet installed but using a reduced diameter outlet to maintain stream velocity. An easily fitted 6 l/min regulator or regulated outlet should be provided as an option so users can fit this if the lower flow rate is not sufficient. This is to discourage users simply removing the original regulator.

Background information and research
Bidets are assumed to increase water use in the CSH water calculations, although there is no data to support or refute this. The volume and use frequency figures in the CSH water calculation are taken from plumbing design guidelines rather than micro-component monitoring studies, and are therefore expected to be an over-estimate. Bidets could be used to reduce showering frequency and are particularly applicable where medical conditions might otherwise lead to high water use. In the absence of data, it is proposed that the AECB water standard will neither reward nor penalise the installation of bidets.

Dead-legs

Recommended standard

Dead leg volumes apply to sinks, basins, bidets and showers but not baths.

Whilst lower dead leg volumes are encouraged the specification of secondary circulation should be avoided if at all possible because of the significantly increased heat loss.

Good: Dead leg volume to be limited to a maximum of 1.5 litres (without a pumped secondary circulation loop) and 0.5 litres for dead legs coming off a pumped secondary loop. All hot and cold pipes greater than 12mm outside diameter must be insulated with continuous insulation with all joints glued. Cold water pipes shall be installed below hot water pipes to reduce heat transfer. Where secondary circulation is specified, the pipe must have continuous insulation with sealed joints and the pump must be controlled to minimise heat loss. This should be by time and temperature[18] or a flow switch and runback timer (time and temperature may be preferable in non-domestic buildings) . Heat loss from dead legs and secondary circulation must be calculated as part of the energy assessment (i.e. within PHPP or using the same calculation and assumptions).

Best: As Good practice plus 0.85 litres maximum dead leg volume, 0.25 litres for dead legs coming off a pumped secondary loop.

Background information and research

Cooled water in a pipe is run to waste when hot water is required (e.g. figure 8). This is also a waste of energy as the hot water left in the pipe (and the pipe material) then cools. This heat loss occurs even if the cooled water is not run to waste. Optimising the pipe size and length and adding insulation all help reduce this problem but there is no known research on the current water and energy wastage due to dead-legs in the UK. The German Passivhaus Planning Package (PHP 2007) calculates the energy loss[19] due to dead legs based on the total volume of hot water dead legs and an assumption of 3 uses per person, per day. This energy is lost to the building even if the cold water is not run to waste.

The Water Regulations Guide provides recommended maximum lengths for un-insulated hot water pipes (table 5) but there is no recommendation relating to insulated pipes.

Outside diameter mm	maximum length metres
12	20
over 12 up to 22	12
over 22 up to 28	8
over 28	3

Table 5. Water Regulations recommended maximum lengths for un-insulated hot water pipes still allow significant energy and water wastage.

Whilst 12m is not unreasonable for 15mm pipe (1.8 litre dead leg volume), a 22mm copper pipe 12m long will contain about 3.7 litres of water. If this water is at 60°C and is allowed to cool to say 20°C then the energy lost is 1.16 x (60-20) x 3.7 litres/1000 = 0.17 kWh. To put this in perspective in the context of low energy building, following the PHPP[20] assumptions this loss equates to over 5kWh/(m^2.year)[21] which compares with a useful hot water consumption at the tap of 15kWh/m^2, i.e. a potential 33% increase due to a single pipe run allowed to cool three times per occupant per day. This is a significant issue worthy of detailed consideration at the design stage of a building.

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[18] Secondary circulator pumps are available with built in a timer and temperature (flow rate) control.

[19] Some of this energy is not wasted as it might contribute to space heating in the heating season, thus PHPP calculates a utilisation factor and only increases the primary energy demand by the amount that is lost.

[20] PHPP is used in preference to SAP for this comparison. PHPP actually assumes the water cools to 20°C and includes a calculation for the pipe material heating and cooling which all leads to an even bigger heat loss.

[21] 35m^2/person.

Dead leg volume
The actual volume of water run to waste will depend on many factors such as the required temperature at the tap, the mass and material of the pipe, the level of insulation, pipe diameter and length and the time since the last draw off. A simplified definition of dead leg volume is used in these standards based simply on the internal volume of the pipe from the source to the final tap or shower. Table 5 includes values for this dead leg volume per metre run of pipe for a range of pipe sizes and materials.

Figure 8. Energy and water wastage due to dead legs is difficult to quantify but a daily experience.

The abandoned Energy Saving Trust Best Practice Specification recommends a maximum dead leg volume of 1.5 litres or 10m of 15mm copper pipe. Similar figures have been suggested in the USA (EPA, 2008). If a standard 1.7 litre/minute spray fitting and a maximum wait of 30 seconds is assumed this gives a maximum dead leg volume of 0.85 litres (table 6). This can be achieved with small-bore pipe at mains pressures with a reasonably compact plumbing layout.

Table 6. Target dead leg volumes and calculated[22] maximum pipe lengths. Note for small-bore pipe, max length is likely to be limited by pressure loss (flow restriction) rather than dead leg volume (figure 9).

Pipe diameter mm	**10**	**10**	**12**	**15**	**15**	**22**	**22**
Material	**PEX**	**Cu**	**Cu**	**PEX**	**Cu**	**PEX**	**Cu**
Wall thickness mm	1.7	0.6	0.6	1.7	0.7	2.2	0.9
Litres/m pipe length	0.03	0.06	0.09	0.11	0.15	0.24	0.32
Length for 1.5 litres (m)	43.9	24.7	16.4	14.2	10.3	6.2	4.7
Length for 0.85 litres	24.9	14.0	9.3	8.0	5.9	3.5	2.7
Length for 0.5 litres	14.6	8.2	5.5	4.7	3.4	2.1	1.6
Length for 0.25 litres	7.3	4.1	2.7	2.4	1.7	1.0	0.8

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[22] Whilst the reality is more complex, particularly for larger pipes, plug flow has been assumed and the pipe internal volume calculated.

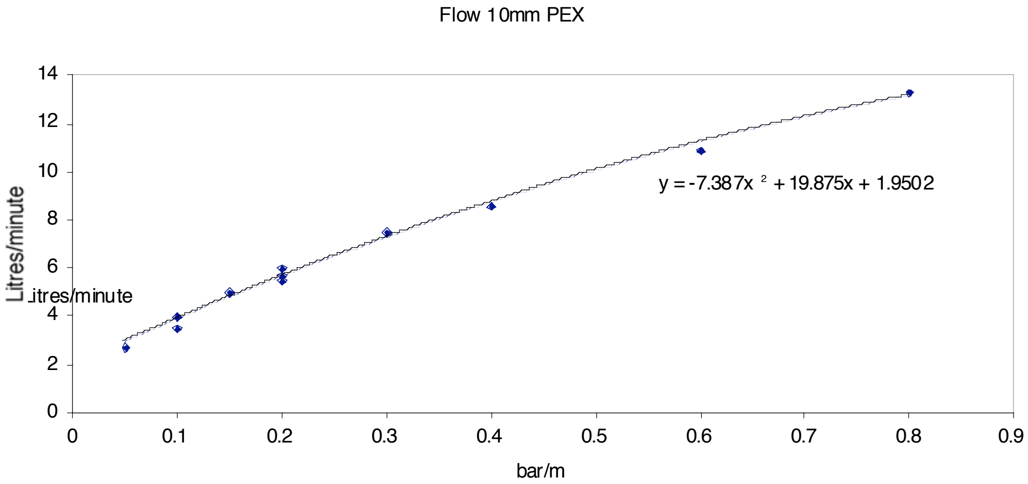

Figure 9. Flow rate against pressure drop for 10mm PEX micro-bore pipe. Experimental data for illustration not design.

Secondary circulation

Pumped secondary circulation can solve the issue of water wastage with dead legs, but introduces a significant energy loss. Larger dwellings and hotels will require secondary circulation. Where secondary circulation is specified, the pipe must have continuous insulation with sealed joints and the pump must be controlled to minimise heat loss. This should be by time and temperature[23] or, for domestic applications, a pump activation switch and runback timer or temperature sensor. In the USA the Structured Plumbing® concept has been developed in order to minimize dead legs and heat loss (Klein 2008). Dead legs and recirculation losses are calculated (although not displayed) in PHPP and contribute to the primary energy.

Urinals

Recommended standard

Good, Best: Designer shall justify that the choice of technology is the most appropriate for the given installation.

Background information and research

Urinal flushing can easily be the biggest user of water in non-domestic buildings. Under the Water Regulations, urinals should use no more than 7.5 litres per bowl per hour (10 litres for a single bowl) and should have a device fitted to prevent flushing when the building is not being used. In practice, flow rates are rarely measured and will drift with time, or are deliberately increased in a usually vain attempt to solve odour problems. Odour issues are often unrelated to the technology chosen, and are usually a result of poor detailing of surrounding areas and poor installation practices (Grant and Moodie, 2004).

The ideal environmental choice will vary between installations. Waterless urinals are clearly the most water efficient option, but the environmental and financial costs of the consumables required by some models may outweigh any advantages. Flush per use urinals may use less water than timed flush urinals where the number of users is low (figure 10). In the absence of a recognised standard that considers the life cycle impact of waterless urinals, it is up to the designer or specifier to demonstrate that the chosen technology will have a lower impact than conventional flushed urinals installed in accordance with the Water Regulations.

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[23] Secondary circulator pumps are available with built in a timer and temperature (flow rate) control.

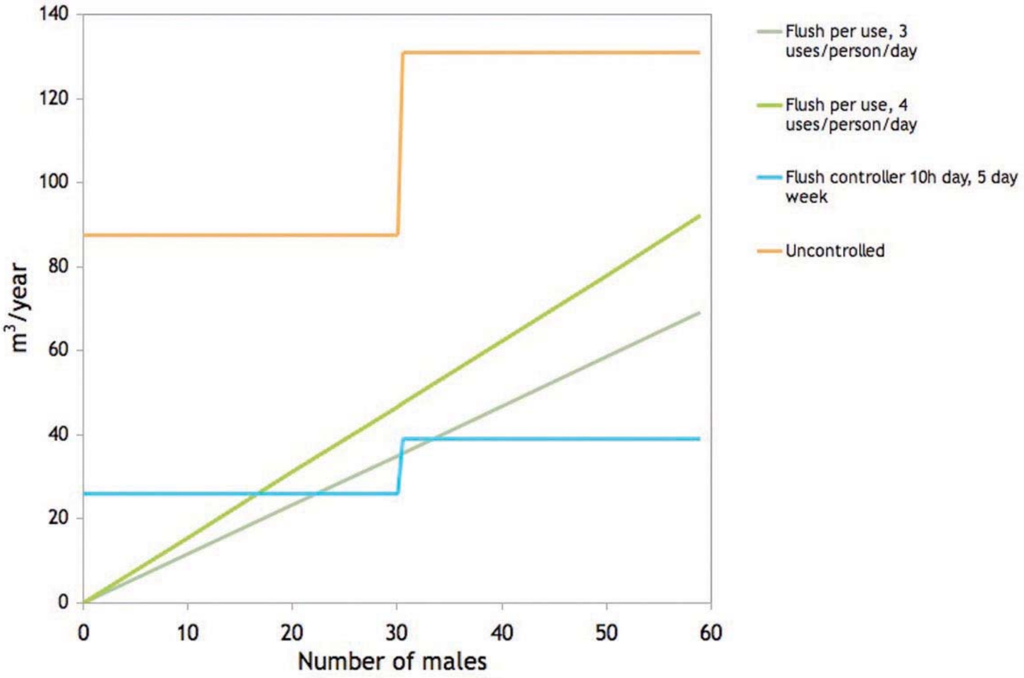

Figure 10. Comparison of flush per use and timed flush. From Environment Agency (2007c).

Water softeners

Recommended standard
Good, Best: Regeneration should be demand initiated (i.e. based on a volume of water rather than on a pre-programmed timer). The kitchen tap, outside tap and WCs should not be connected to the water softener. They should only be fitted in areas with water hardness over 200mg/l ($CaCO_3$).

Background information and research
Hard water is formed when rainwater dissolves calcium and magnesium salts as it percolates through limestone or similar rock. Heating this water causes these dissolved salts to become insoluble and form a solid carbonate limescale. This has energy efficiency implications if it builds up on heating elements (e.g. in washing machines, dishwashers and hot water cylinders) as well as affecting soap, washing up liquid and washing powder effectiveness. Water softeners consequently have the potential to save energy and could be recommended from this perspective, although further research is needed. Water softeners work by replacing calcium and magnesium ions with sodium ions from an ion exchange resin. However, regenerating the ion exchange resin with sodium uses water. The Water Regulations require that any fitting shall not waste or misuse water and that the water supplier is notified if a water softener is to be installed. Softeners manufactured to comply with BS EN 14743:2005 will satisfy the Water Regulations consumption requirements.

Pressure regulation, sub metering and leak detection

Recommended standard
Good practice: A water meter should be installed inside the house in a convenient to read location. Where an external tap is installed this should be fitted with a separate meter. Either leak detection or a simple to operate water supply isolating valve or switch should be installed where the cold water supply enters the property. Where static water pressure is greater than 3.5 Bar, consideration should be given to installing a pressure regulator. Where static water pressure is greater than 5 Bar a pressure regulator shall be fitted where the cold-water service pipe enters the building.
Best practice: A separate water meter to the hot water supply in addition to the above.

Background information and research
Water use on a household scale is extremely dependent on user behaviour, and encouraging awareness of water using behaviour may reduce demand. As discussed previously, hot water use has a high impact in terms of CO_2 emissions, so separate monitoring of hot water use is advantageous. Whilst sufficiently sensitive domestic leak detection units are not yet commercially available, there is widespread concern that the move towards valve flush WC's may cause difficult to detect leaks in the long term. If a valve flush WC is installed, particular attention should be paid to the potential for leakage. The risk of leakage should be made clear in the home users guide. At a household scale leaks can be detected by checking the meter for overnight water use (i.e. when no water using appliances are in operation).

As discussed in Appendix I, flow rates at the outlets are dependent upon water pressure, and this varies regionally and according to time of day. Studies of the impact of water efficiency measures have found the impact of differences in local water pressure can be greater than that due to water efficient appliances. The AECB standard therefore requires flow regulation at terminal fittings which also helps balance 'dynamic pressure' within the plumbing system. The US EPA Watersense specification for new homes has a max service pressure of 4 bar to be achieved with a pressure regulating valve (Environmental Protection Agency 2008).

Outdoor water use - location specific

This standard is location specific; dwellings in areas of moderate or severe water stress shall have landscape areas designed to be sufficiently drought tolerant that mains water is not required once established.

Good: Outdoor taps should be fitted with a water meter. Installation of an appropriate number of water butts made from reclaimed or recycled materials with overflows discharging to ground (e.g. soakaways) unless the ground is unsuitable. SuDS principles should be applied to encourage infiltration into the soil where possible, e.g. by slowing overland flow and by use of permeable surfaces. Planting should consider drought tolerance and moisture conservation.
Best practice: as Good Practice.

Background information and research
Outdoor water use only represents about 6% of average annual water use. However on hot summer days, when supplies are most stressed, over 70% of the water supply may be used for watering gardens.

Outside water use has been correlated with a number of variables including socio-economic class, time of day and recent weather (for example in Chambers et al., 2005, MTP 2008g), but the 'unknown unknowns' are also high. No correlation between outside water use and garden size is reported in the literature.

Rainwater butts: Received wisdom states that installing water butts for garden watering decreases the amount of mains water used in a garden, but evidence for this is sparse, indeed since keen gardeners are more likely to have water butts, the opposite may be true. The CO_2 emissions involved in manufacturing a rainwater butt could easily outweigh any CO_2 emissions that could be avoided by reducing mains water use in the garden, so the relative merits of energy versus water saving is relevant. Nevertheless installation of rainwater butts could be expected to reduce demand on the water network at key times, given that much of the summer peak in water use is due to outside use as is a significant portion of the diurnal peak (Chambers et al., 2005). Because of the CO_2 emissions resulting from production of water butts, recycled butts or reuse of other containers is encouraged. A fixed size for rainwater butts is not specified, as it will depend on location, garden and human variables.

Outside taps: Should have a separate water meter since water use with hoses, sprinklers and irrigation systems is very difficult to gauge and a meter provides useful feedback for the householder.

Garden design and irrigation: landscaping plans should be considered in relation to the local climate in order to reduce or avoid the need for summer watering.

Sustainable Urban Drainage Systems (SuDS): whilst this standard is concerned with fresh water supply rather than surface water, simple SuDS techniques are recommended as a means of dealing with rainwater. Any rainwater that is not collected in butts should be infiltrated to ground wherever soil conditions allow. Hard-standing areas should be permeable or drain to adjacent permeable areas where possible.

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Appendix I: Modelling water use, data robustness and the CSH

The amount of water used by an appliance depends on its **consumption per use** and its **frequency of use**. The reliability of information available about these two factors varies between water using appliances and broadly splits between water uses where the function is largely ‘fixed use’ (WC, washing machine, dishwasher) and water uses performing a wider range of functions (e.g. taps, showers, baths). In the longer term, the robustness of the appliance (e.g. propensity to leak) can also influence water use.

In general, the data on water use by ‘fixed use’ appliances is much more accurate than the data on other appliances. Consumption per use for washing machines and dishwashers is covered by efficiency labelling schemes and whilst these schemes have their limitations (see section on white goods for comments and references), they reflect real life use fairly well and values remain constant over time. WC water consumption per flush is tested by the manufacturer against BS EN 997 and does not accurately reflect consumption at end use (as it is measured with the water inlet to the cistern turned off and the ratio of part to full flush for dual flush WCs is highly variable) but nevertheless data is considered fairly robust. Average use frequency for dishwashers, washing machines and WC’s is also fairly predictable.

Data on both water consumption per use and use frequency for all other appliances are highly variable[24]. This is not surprising given the different functions that water-using appliances actually serve. For example kitchen taps may be used to fill kettles or washing up bowls (where a set volume is required), or for rinsing (where the volume required is not fixed and there is therefore scope for water efficiency by reducing flow rate). Consequently for these appliances reducing the flow rate will not automatically result in lower water use. The complete reliance of a calculator based on maximum flow rate in CSH is therefore regarded as flawed. Whilst it might be tempting to ‘refine’ the model by allowing a fixed volume for vessel filling plus a flow related consumption this approach is not suited to a design and regulatory method as there is no validation of such a model. As the number of variables involved in calculating the amount of water used by an appliance increases, the reliability of the output from a simple mathematical model will decrease. This is particularly the case for appliances, which have ‘human’ variables, or where the variables are not independent. The complexity of these factors is well illustrated by shower use. Shower duration and frequency vary considerably from person to person, and even from one event to another for an individual, flow rate can be set lower than the rated flow of the showerhead and flow rate can influence duration. Showers do not have a simple function and as such, trying to predict their water use is unlikely to lead to robust results.

The Water Calculator which forms the basis of the CSH water requirements attempts to predict savings by making simple assumptions on flow rate and duration and is based largely on data from the ongoing Identiflow project by WRc (Chambers et al., 2005). In this study measurements of total household water use are taken at one-second intervals and used to derive information about the water use of individual appliances. Whilst the dataset from these studies is large, there is enormous data uncertainty, particularly with those appliances that are not ‘fixed use’. There are a number of instances where mathematically dubious techniques are used to summarise data (for example the use of an arithmetic mean to summarise data where the distribution is clearly skewed or bi-modal) and the authors themselves acknowledge a lack of data confidence in some aspects, particularly with regard to taps and showers. A fairly comprehensive critique of some of the problems has been undertaken (Grant, 2008) and it is suggested that the CSH approach is abandoned.

It might be possible to develop a model that can help predict water savings for a given range of fittings and user behavior (for example known showering frequency and bath/shower preference), but the inputs to the model should be based on actual data collected at the level of the appliance rather than predicted from whole house meter readings[25]. Even if such a model is developed, its implementation and use must be designed to ‘reward’ measures that lead to genuine savings without driving down performance or hygiene to the point that fittings are replaced with less efficient ones.

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[24] Use frequency and volume histograms from the Identiflow data in Chambers et al. (2005) are a good example of this.

[25] In mathematical terms, the use of water meter data to predict micro-component water use is an example of trying to solve the “inverse problem”. Given the human behavioural variables involved in water use, this approach is never likely to yield sufficiently robust results for regulatory purposes, and a model based on micro-component water use itself would be more appropriate, albeit more difficult to achieve.

Given the numerous behavioural variables involved in water use and the fact that these variables can interact with each other in complex ways, such a model is not a suitable basis for regulation because of its poor confidence level in accurately predicting savings due to adopted measures.

Appendix II: Environmental impacts of water supply

Calculating the environmental impacts of a product or system including its manufacture, use and disposal is fraught with difficulty, and there are many potential techniques (reviewed by Baumman and Cowell, 1999). Whilst methodologies and exact results may differ according to what boundaries are placed on the analysis, two over-arching themes emerge:

- Using less of a resource usually has lower impacts than securing additional supply; conservation is more important than reuse.
- The complete 'cradle to grave' life cycle must be considered in order to ascertain which aspects contribute most to overall impacts and are therefore the best targets for efficiency measures.

Conservation versus reuse
Table 7 below illustrates the carbon costs associated with reducing water use by a number of measures (from Environment Agency, 2008). Numerous other studies have illustrated that rainwater harvesting systems result in higher CO_2 emissions than supply of the equivalent volume of mains water[26]. The same is likely to be true of grey water recycling systems given their reliance on impact intensive technologies such as pumps and disinfection (Brewer et al., 2001). Design improvements to grey water recycling systems that would lessen their environmental impact have been made in recent years[27], but there are no independent studies calculating their impacts.

Table 7. Carbon costs associated with reducing water use with various demand management options. Data from the Environment Agency Science Report Greenhouse gas emissions of water supply and demand management options.

Demand management option	**Carbon cost (p/m^3)**
conventional metering	26
efficient showers	26
spray taps	26
low flush toilets	28
current water 'supply-use-disposal' carbon cost	28
rainwater harvesting (retrofit)	38
grey water reuse (retrofit)	44

Whilst the CSH does not require rainwater harvesting or grey water reuse, in practice higher levels of the Code can only be achieved by incorporating these measures and this will increase carbon emissions[28]. Arguments about the exact energy requirements of rainwater and grey water recycling notwithstanding, water reuse has become a common way in which to allow greater hot water use for a given code level, thereby increasing carbon emissions (Hassell, 2008).

Because of these issues, the proposed AECB water standard does not reward rain or grey water reuse within the household, although it is recognised that use of these sources may be worthy of consideration in the garden if the collection and distribution systems are sufficiently low-tech that their life cycle impacts are low.

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[26] For example Crettaz et al. 1999, Hallman et al. 2003, Thornton 2008.

[27] For example the Ecoplay, which does not include disinfection and stores the water in a tank in the wall cavity close to the WC cistern, thereby minimising energy required for pumping.

[28] Modelling a combination of water efficiency and rainwater harvesting in order to meet code level 5/6 was found to increase carbon emissions compared to achieving code level 3/4 (water efficiency without rainwater harvesting measures), Environment Agency (2008).

It is important to note that in dryer climates water use for garden irrigation can be very high and occurs when resources are most stressed. In that situation simple greywater reuse systems could be very valuable.

Cradle to grave life cycle of water

The CO_2 emissions due to heating water in the home far outweigh the CO_2 emissions due to the water supply itself (figure 1). If a standard was focussed on CO_2 emissions, logic would dictate a large bias towards hot water savings over cold water savings. However, moderate hot water use for domestic purposes is a social norm so whilst demand reduction for hot water should be emphasised above that for cold water, both are considered necessary and desirable. It is important to avoid the situation where measures are encouraged that lead to increased carbon emissions as is the case for the CSH Water Calculator. It is also likely that many properties attempting to comply with the AECB energy standards will be using solar hot water heating or biomass and so the balance of CO_2 emissions attributable to heating water as opposed to water supply will vary on a case-by-case basis.

Appendix III: Areas of Water Stress in England

Taken from Environment Agency (2007) Areas of Water Stress: Final Classification. GEHO1207BNOC-E-E

Table 8. Water Stress Classification for England. From EA 2007.

Water company area	Classification
Essex and Suffolk Water	Serious
Folkestone and Dover Water	Serious
Southern Water	Serious
Thames Water	Serious
Three Valleys Water	Serious
Portsmouth Water	Serious
Sutton and East Surrey Water	Serious
Cambridge Water	Serious
South East Water	Serious
Mid Kent Water	Serious
Bournemouth and West Hampshire Water	Serious
Anglian Water	Serious
South Staffordshire Water	Moderate
South West Water	Moderate
Tendring Hundred Water	Moderate
Severn Trent Water	Moderate
United Utilities	Low
Bristol Water	Low
Northumbrian Water	Low
Yorkshire Water	Low
Cholderton and District Water	Low
Wessex Water	Low
Anglian Water (formerly Hartlepool Water)	Low

The EA classifications are based on calculations related to a number of factors that may change over time. Consequently, regions may have their classifications changed periodically. These classifications were not originally designed to be used in a water efficiency standard, but the AECB regards them as indicative of the current situation. Scotland and Wales are currently regarded as being areas of low water stress for the purposes of this standard.

Appendix IV: Design and commissioning checklist

The following items need to be included in a design and commissioning checklist, in a format appropriate to the dwelling. This checklist accompanies the Home User Guide.

General information
Property name and address
Water stress category of area
Water Company
Date commissioned
Mains water pressure at time of test
Good or Best Practice specification
Name and contact details of person carrying out the commissioning.

Appliance specific details
In all instances sufficient detail should be provided to verify that the appliance has been tested and delivers the correct flow rate or volume at installation. The Home User Guide should also give the householder sufficient information to allow replacement/maintenance (including manufacturer, product name, website/phone number for spares and further information). Where more than one appliance of a type is fitted, clear identification of each is needed, and test results for each.

Water meters fitted (indoor, hot meter, outdoor tap)
Pressure regulator (if fitted)
Leak detection devices fitted, how to test for leaks for specific appliances.
Isolation valve on incoming main
Showers
Basin taps (domestic, washroom)
Sink taps
WCs
Baths
Bidets
Flow regulators (locations within the plumbing system must be clearly stated)
Water softener if fitted (including regeneration volume)
Details of garden landscape water efficiency measures
Dead legs (length, diameter, material, insulation λ, volume) for each dead leg in the property. Heat loss calculations (within PHPP, or using same calculation and assumptions).
Secondary circulation if fitted; pipe length, diameter, insulation, pump and control details
If experimental technologies are fitted sufficient details of these must be given to alert the householder to potential issues that may arise and how the item can be replaced.