FABER MAUNSELL | AECOM

Project Number: BD2735

Title: Research to review the Code for Sustainable Homes Water Calculator

Final Report

June 2009

Acknowledgements

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Disclaimer

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Executive Summary

Faber Maunsell was commissioned by Communities and Local Government to undertake a review of the Code for Sustainable Homes internal water use calculator. The brief was to consider whether the calculator delivers the right results in terms of calculated water use, water efficient design, and acceptability to householders; to take into account the most relevant evidence base of research and experience available in the UK and internationally; and to make recommendations on improvement to the calculator, comment on the appropriateness of Code target water levels, and identify any further research needed.

The review involved testing of the water calculator; a review of international approaches to water saving in new homes; a review of microcomponent data as the basis for modelling water use; and stakeholder engagement. The main findings and recommendations are summarised below.

Rationale of the Code water section

The documentation supporting the water calculator should include a clear statement of underpinning principles and the specific objectives that guide the design of the water calculator. The following objectives guided this review:

- To drive design that, in combination with water-saving householder behaviour, would reduce water use while maintaining the functionality and usability of sanitaryware, associated plumbing, drainage, and other connected systems[*].
- To incentivise measures in proportion to their potential to deliver water savings.
- To allow design flexibility, which implies there should be a range of feasible options to reach established Code level targets, particularly mandatory target levels.
- To encourage innovation in the design of sanitaryware, plumbing and other connected systems.
- To achieve a reasonable statistical correlation between calculator results and measured water use.

The introduction of a water hierarchy would encourage implementation of the most effective water efficiency measures, from those that save the most water at least cost and risk, to those that only need to be adopted where targets cannot be achieved otherwise.

Reviewing the Code water calculator

A microcomponent calculator approach is reasonable in principle and research data, used with care, makes it feasible in practice. The principle that there should be a reasonable statistical relationship between calculator results and measured water use provides a starting point for considering the effectiveness and consistency of the current calculator.

Comparisons suggest that calculator results for ‘code default’ or ‘typical’ sanitaryware specifications are too high, do not correspond with average daily water use reported for the UK as a whole, or with daily water use measured in either microcomponent studies or longer term monitoring studies.

Overall, the review found that the current calculator does not observe a number of the proposed calculator objectives and it is recommended that it is revised.

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[*] E.g. boilers

Revising calculator algorithms

The high ‘typical’ calculator result is largely attributable to inadequate allowance for average flow intensity, based on evidence that components such as taps and showers are used at much below their maximum flow rate. Another contributory factor is the overestimation of frequency of use factors resulting from adoption of figures from microcomponent studies that remove data corresponding to householder absences. The review team also supports the view of the majority of expert stakeholders that bidets should not be considered to give rise to a fixed quantity of additional water use.

The review identified potential ‘game playing’ related to averaging of multiple tap, shower and bath fittings. Weighted averaging is recommended. There is evidence suggesting a large proportion of water use at kitchen taps and some of the water use at other internal taps is a relatively fixed volume (events such as filling a vessel or basin) and not dependent on flow rate. There was stakeholder support for introducing a fixed volume element to the calculator algorithms for taps, which we recommend.

Revisions to algorithms for whole-house systems

The current algorithm for water softeners ignores mains water use for regeneration if it makes up less than 4% of home water use. Stakeholders generally supported including the full water use of plumbed-in water softeners. This is recommended along with the addition of waste disposal units, in line with proposals for Part G of Building Regulations.

Rainwater and greywater

Systems that harvest rainwater, or recycle greywater from baths and showers for use in WCs and washing machines are explicitly encouraged in the Code. This implies that they are more sustainable than using mains water. Some research challenges this. It was widely agreed by stakeholders that water efficiency should be encouraged before considering water re-use systems, as reflected in the ‘water hierarchy’ above.

Developers suggested it had been difficult to reach Code levels 3 and 4 without rain or greywater systems and the review found that it virtually impossible to achieve the highest Code levels 5/6 without them. The literature review identified research that raised question about the net environmental benefits of the application of rain and grey water systems.

Wider Code water methodology and scope

The review also identifies other practical problems with the status quo.

User acceptability and standards. British Standards establish minimum flow rate limits relating to fittings including taps and showers, based on maintaining user acceptability. These standards and implications for sanitaryware design are not discussed in the Code technical guidance. The absence of limits to calculator inputs allows designers to push sanitaryware specifications beyond limits of user acceptability, which is widely considered a real issue that affects the longevity of water efficiency measures and related savings. We recommend that limits are introduced to protect usability and acceptability to users.

Pressure. Delivered pressure to homes varies considerably across the UK and this affects the impact of water efficiency measures considerably. Moving to calculator inputs based design maximum flow rates at site/system water pressure would appear to be a solution. At the high pressure end this would provide a strong incentive for pressure regulation on the incoming main in direct plumbing systems.

Occupancy. There are arguments for and against applying occupancy factors. While the occupancy relationship cannot be included in the microcomponent part of the calculator, it could be allowed for by applying an occupancy factor to the total calculated water demand.

Scope – additional microcomponents and efficiency options. The review considered areas where the scope of the water calculator could be expanded, primarily with a view to harmonising it with other standards, to improve comparability of results with measured water use; and to incentivise a wider range of efficiency measures.

Assessor and specifier guidance. Detailed consideration of Code technical guidance is outside the scope of this review but a desire for expanded this was a strong theme in feedback from the assessors and specifiers. The review identified a number of areas where Code technical guidance could be expanded or enhanced.

Keeping the calculator up to date. The calculator and related guidance would benefit from the introduction of a reactive technical review mechanism, and regular reviews involving stakeholders.

Areas for further research

The following areas of research would contribute to future calculator improvements:

- Improve the microcomponent evidence basis of the calculator by: undertaking larger and more representative studies; agreeing full access to data for past studies; developing a standardised brief for future monitoring.
- Improve understanding of relationship between microcomponent water savings and hot water use and savings. Hot water is an increasingly significant issue within the industry due to the dual benefits of energy and water savings.
- Monitoring of Code assessed homes using the standardised monitoring brief.

A way forward

A revised set of algorithms has been developed and illustrated based on an updated evidence base and experience from other countries. Large changes in key constants mean the results produced by the revised calculator for a ‘typical’ specification are significantly lower than previously. The scope for savings from water efficient fittings is correspondingly much reduced.

A criticism of the current water calculator is that it tends to drive some fitting specifications below the level of user acceptability. Introducing minimum limits to the calculator as proposed, radically cuts the scope for water saving and for reaching Code levels 1 and 2. With the same limits, the revised algorithm offers a reasonable range of options for reaching Code levels 1 and 2, and hence also the proposed Part G target. It remains difficult to reach middle levels of the Code and very difficult to reach higher levels without rain or greywater systems.

While many performance scales have narrowing bands at the top end, recognising that as performance improves it gets harder to make further progress, mandatory water targets in the Code become increasingly harder.

In terms of water use targets currently set in the Code, there are good reasons to review the mid to top levels 3 to 6. The requirement for or contribution of rain and greywater systems to meeting targets should receive particular consideration.

This review makes 14 recommendations covering changes to the water calculator and development of the calculator and its related methodology, guidance and evidence base.

Recommendations

This review makes 14 recommendations covering changes to the water calculator and development of the calculator and its related methodology, guidance and evidence base. The recommendations are listed below. Context and discussion can be found in Section 5, Conclusions and recommendations of the review report.

Recommendation 1. Establish Code water principles, calculator objectives, and a water hierarchy to guide ongoing development of the Code approach to water efficiency.

Recommendation 2. Modify the calculator so the result for 'typical' sanitaryware is 135 – 150 litres / person / day.

- **a. Update frequency and duration of use factors used in Code water calculator algorithms based on WRc CP337.**
- **b. Revise Code water calculator algorithms to include average flow intensity for showers and reduce the average flow intensities for taps from the current 2/3 'use factor'.**
- **c. Revise Code water calculator algorithms to include non-linear average flow intensity for showers.**
- **d. Remove bidets from the Code water calculator.**

Recommendation 3. Ensure current and future Code water calculator revisions account for microcomponent study methodology when adopting or deriving factors for use in calculator algorithms.

Recommendation 4. Modify calculator algorithms to reduce water savings scope.

- **a. Where fittings have varying specifications, use weighted averages in water calculator algorithms for: design flow rate for multiple basin taps; design flow rate for multiple kitchen/utility room taps; design flow rate for multiple showers; and fill volume to overflow for multiple baths.**
- **b. Revise Code water calculator algorithms for basin taps and kitchen sink taps to include a fixed proportion of water use.**

Recommendation 5. Revise the Code water calculator algorithm for water softeners to include all water uses supplied by the softener and to derive regeneration frequency based on daily demand for softened water.

Recommendation 6. Review the role of rain and greywater systems in meeting Code water levels.

Recommendation 7. Revise the Code water calculator algorithm for rain and greywater systems based on the prospective British Standards.

Recommendation 8. Introduce limits to design flexibility to maintain functionality and user acceptability.

Recommendation 9. Move to calculator inputs based on measurement or best estimate of site / system water pressure.

Recommendation 10. Consider applying an occupancy factor to the Code water calculator figure for household water demand.

Recommendation 11. Expand or consider expanding the scope of the water calculator as follows:

a. **Add waste disposal units, in line with revised Part G.**

b. **Consider adding external water use to align Code water calculator results with results for the Part G calculator.**

c. **Add an allowance for leakage to the Code water calculator and consider including an equivalent saving for specification of leak detection and avoidance measures.**

d. **Undertake a scoping study to determine the relative impacts of microcomponents of water use and saving measures not currently included in the calculator or addressed in the Code methodology. Use this as the basis for planning for the expansion of the calculator scope in future revisions.**

Recommendation 12. Expand and improve Code water technical guidance:

a. **Improve guidance on treatment of mixer taps and separate hot and cold taps with different flow rates at the same basin and multi-setting shower heads;**

b. **Improve guidance on interpretation of manufacturers' product specifications and translation into calculator inputs; and related to this**

c. **Limit all calculator inputs and outputs to values rounded to the nearest 0.5 litres. (This does not apply to internal calculator calculations as this would risk rounding errors.)**

Recommendation 13. Establish appropriate review procedures for Code water section issues.

a. **Establish a reactive Code water technical review mechanism;**

b. **Involve stakeholders in regular reviews of the water calculator.**

Recommendation 14. Review higher target levels of the Code and relative spacings of the targets along with the range of water efficiency options currently available to meet each target level.

Table of Contents

1 Introduction

1.1 Background

1.1.1 Project scope

Faber Maunsell was commissioned by the Department of Communities and Local Government (CLG) to undertake a review of the Code for Sustainable Homes (the Code) internal water use calculator (the calculator).

The aims and objectives of the review, as defined in CLG's project brief, were:

Aim:

To provide support to CLG in developing the Code such that it results in new developments using water sustainably.

Objectives:

- *To determine whether the Water Calculator is predicting correct water usage based on comparison with observed water consumption in existing properties.*
- *To review the most relevant information on water use volumes and frequencies with a view to improve the Water Calculator.*
- *To make clear recommendations for improvements to the Water Calculator or improvements to the water use element of the Code.*
- *To identify any further research needed, where appropriate and in close cooperation with a range of Code users and experts.*

Questions to be addressed were:

- *Does the Code Water Calculator deliver the appropriate outcome in terms of water efficiency of fittings but also acceptability to users?*
- *Does it use correct assumptions?*
- *If not, how can this be improved?*
- *In the light of all other aspects of the review, are the levels that are currently set within the Code appropriate?*

1.1.2 Final project report

This final report sets out the work undertaken within the review, and the project findings, conclusions and recommendations. It is organised as follows:

Section 1 – Introduction to the project, background information and context.

Section 2 – Summary of the review methodology.

Section 3 – Findings of the review.

Section 4 – Conclusions and recommendations.

Section 5 – Illustration of revised calculator algorithms.

Summary reports for each of the main project tasks undertaken as part of the review are annexed to the main report.

1.1.3 Contact details

The report has been prepared by Charlotte Parkes, Rachel Waggett, Abena Poku-Awuah and Zac Grant in Faber Maunsell's Sustainable Development Group, in collaboration with a project team consisting of Nick Grant and Judith Thornton of Elemental Solutions and Sarah Bell of UCL. The main authors can be contacted as follows:

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1.2 Introduction to the Code and the water calculator

1.2.1 The Code for Sustainable Homes

The Code for Sustainable Homes is the main mechanism for encouraging both public and private housebuilders to build more sustainable and water efficient new homes. The Code has six Levels and a nil rating, which is for homes that: do not meet six mandatory requirements (including water efficiency); do not perform well enough overall; or are not assessed. Since 1 May 2008 all buyers of new homes must be provided with a Home Information Pack including a Code certificate; nil-rated certificates must be included where relevant.

The mandatory water efficiency requirement at Code Level 1 is a maximum calculated internal water use of 120 litres / person / day. Mandatory maximum limits also apply at Code Levels 3 and 5 (see Table 1).

Water consumption (litres/person/day)	Credits	Mandatory
≤ 120	1	Levels 1 and 2
≤ 110	2	
≤ 105	3	Levels 3 and 4
≤ 90	4	
≤ 80	5	Levels 5 and 6

Table 1: Code water consumption targets (October 2008)

Achieving certain Code levels is compulsory for public housing receiving grant funding. The requirement in the 2008 to 2011 programme is Level 3, i.e. calculated water use of 105 litres / person / day. The Code is currently voluntary for private housebuilders, but it has been used by local authorities as the basis of sustainable construction targets[2].

1.2.2 The Code water calculator

The water calculator is the method prescribed in the Code to calculate the water use of a given sanitaryware specification. The calculator result is translated into a number of credits achieved and mandatory limits met as shown in Table 1.

[2] The Code replaced EcoHomes in April 2007. It is assumed that most local planning authorities whose existing policies refer to an EcoHomes target rating now expect developers to deliver an equivalent Code Level.

The calculator methodology was adapted from a previous water calculator developed by BRE Global Ltd for EcoHomes. Daily water use of sanitaryware is assumed to depend on either: flow rate and duration and frequency of use (‘flow-based’); or on volume per use and frequency of use (‘event-based’) (see Table 2). Bidets and water softeners are exceptions, but are rarely specified. In the calculator algorithms, average durations and frequencies of use for each sanitaryware item (or microcomponent) are constants. Flow rates and volumes per use are supplied as user inputs, based on the sanitaryware specification. The total water use is the sum of uses for individual microcomponents. The basis of this calculation approach is described as a microcomponent model of household water use.

Sanitaryware	Algorithm type	Basic algorithm
Fittings: kitchen & basin taps, showers	Flow-based	flow rate x duration of use x uses per day
Fittings: WCs, baths Equipment: washing machines, dishwashers	Event-based	volume per use x uses per day
Fittings: bidets Equipment: water softeners	Other	custom

Table 2. Basic water use calculation algorithms for sanitaryware fittings and equipment.

The Code Technical Guidance (October 2008) explains the use of the calculator for Code assessments and provides outline guidance for assessors. The BRE provides assessors with a Microsoft Excel spreadsheet that implements the calculator for use in assessments.

1.3 The calculator in the wider context

1.3.1 National policy context

This review was undertaken with an awareness of the proposed introduction of water demand reduction measures through Part G of the Building Regulations and the review of the Water Supply (Water Fittings) Regulations (1999). They aim to deliver ‘market transformation’ that will both reduce the stress on the water supply system and reduce CO_2 emissions associated with water supply and treatment, and heating of domestic hot water.

Future Water (DEFRA, 2008) describes the Government’s water strategy for England looking ahead to 2030. It considers the water cycle as a whole, from rainfall and drainage through to discharge and treatment.

DEFRA’s strategic vision for 2030 includes:

- *Reduced per capita consumption of water through cost effective measures, to an average of 130 litres per person per day by 2030, or possibly even 120 litres per person per day depending on new technological developments and innovation;*

and

- *Water efficiency playing a prominent role in achieving a sustainable supply demand balance, with high standards of water efficiency in new homes, and water-efficient products and technologies in existing buildings.*

Future Water makes reference to the proposed water efficiency requirement for new homes in the Building Regulations (Part G, 1992) and the Code for Sustainable Homes as mechanisms for achieving its vision.

1.3.2 Building Regulations

Part G – Water Efficiency

In 2006 CLG and DEFRA published a joint consultation on Water Efficiency in New Buildings (CLG / Defra, 2006). This included a proposal for a whole-building performance standard for water efficiency in new homes. The subsequent joint CLG / DEFRA policy statement (CLG / Defra, 2007), proposed that new homes should have a calculated water use of less than 125 litres / person / day. This was reiterated in consultation proposals for amending Part G of the Building Regulations (CLG, 2008). There are currently no proposals for “a progressive tightening of standards” in Building Regulations.

The proposed Part G standard of 125 litres /person / day includes 5 litres / person / day for external water use. As the Code calculator excludes external water use, this means the proposed Part G standard is aligned with the Code Level 1 target of 120 litres / person / day (internal) + 5 litres / person / day (external).

The Part G consultation proposed a calculation that “is a simplified version of the one used for the Code for Sustainable Homes”. Its example calculator included an algorithm for food waste disposal units while omitting one for water softeners, which are included in the current calculator. Reference was made to the use of the Code methodology for rainwater and greywater calculations. Otherwise, except for presentation, the example Part G calculator is identical to the current Code calculator.

Communities and Local Government plans to publish a final revised version of Part G (hygiene) and Approved Document G later in 2009 (CLG, 2008b).

Part L – Energy Efficiency

Regulations are driving improvements in the thermal performance of the building envelope and the efficiency of space heating systems in new homes. As a result, producing hot water accounts for an increasing proportion of energy use and associated CO_2 emissions. Consequently there is keen interest in the relationship between sanitaryware specification and hot water demand and the contribution that water efficiency could make to energy and CO_2 savings; this is discussed further in section 3.3.

1.3.3 Planning

The Planning Policy Statement (PPS) on climate change (CLG, 2007) encourages Local Authorities to support sustainable development through the planning process. It enables local authorities, where appropriate, to ask for higher levels of building sustainability than those set nationally through the Building Regulations. The PPS states that Regional Planning Bodies must “consider and take account of the availability of water resources” within their Regional Spatial Strategies.

DEFRA’s Future Water (DEFRA 2008) states that:

> *Local planning authorities are expected to demonstrate clearly the local circumstances that warrant and allow such local requirements. These could include, for example, where planned areas of development are located in areas of serious water stress and the envisaged development would be unacceptable without a higher standard of water efficiency. Any local requirements should be specified in terms of the achievement of nationally described sustainable buildings standards. In the case of housing, this could be done by expecting proposals to be delivered at a specific level of the Code for Sustainable Homes.*

In response to the PPS, local Planning Authorities are adopting overall Code targets, which is equivalent to adopting the mandatory water targets corresponding to the target Code Level (see Table 1).

1.3.4 Standards

There are numerous standards relating to water fittings, and to system design and function. The three main British Standards identified as relevant to the review are:

- BS 6700 – Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages (BSI, 2006);
- BS EN 12056 – Gravity drainage systems inside buildings (BSI, 2000); and
- BS EN 1111 – The hydraulic performance of thermostatic mixing valves (BSI, 1998).

The implications of standards for the calculator are discussed in section 3.2.2.

1.3.5 Water industry regulation

Section 93A of the Water Industry Act (1991) requires water companies to promote the efficient use of water by consumers. OFWAT announced in PN 36/08 (OFWAT 2008) that water companies must increase water efficiency savings by 40 percent from 2010. Companies must deliver savings by providing households and business with information on how to use water wisely.

The targets must be delivered by behavioural change and promoting water saving devices and excludes savings from supply pipe replacement and repairs. The target were to be introduced on a trial basis in April 2009, coming into full effect in 2010.

2 Project review methodology

The review was originally organised into four tasks:

1. Quantitative and qualitative testing of the Code water calculator;
2. A review of international approaches to water saving in new dwellings;
3. A review of microcomponent data as the basis for modelling water use in dwellings;
4. Stakeholder engagement around the project activities.

The literature review and data gathering elements of tasks 2 and 3 were undertaken together. The influence of the available microcomponent evidence on calculator design was a logical extension of the quantitative calculator testing. This reorganisation of tasks is reflected in the methodologies described below and in the annexed task summaries.

2.1 Task 1: Testing the calculator

2.1.1 Qualitative review

The qualitative review served as a scoping exercise for the other parts of the review, in particular the quantitative testing of the calculator. It involved a wide ranging critique of the current calculator based on the expert views of the project team and others in the field. It took account of views and anecdotal reports about the calculator that were circulating in the industry prior to the commencement of the review.

After summarising drivers, context and history, the review considered:

- Inherent problems with a microcomponent calculator approach and specific issues with the current algorithms, e.g. compared to those used previously in EcoHomes and in approaches elsewhere (Basix, LEED).
- The ways in which the calculator could inadvertently drive poor design, whether as part of an ignorant or calculated effort by designers to reach Code targets.
- The potential for perverse outcomes, e.g. where householders react to dissatisfaction by replacing fittings with much less water efficient alternatives.
- Anomalies and potential loopholes in the calculator;
- Additional opportunities to incentivise water efficient fittings or design, e.g. reduced draw-offs (‘dead legs’), reduced WC leakage using delayed inlet valves, etc.

A summary of the initial qualitative review is included as an annex to this document.

2.1.2 Quantitative review

The quantitative review set out to check the evidence base of the calculator and the validity of its algorithms and results as follows:

1. Verification of BRE spreadsheet calculator against published algorithms.
2. Implementation of a spreadsheet calculator for use in the review validated against the BRE spreadsheet calculator[3].
3. Parametric analysis of the calculator (excluding rain and greywater) as follows:

[3] This identified an anomaly in the algorithm for water softeners. Clarification was sought and obtained from BRE and the algorithm was corrected in rev.9 of the assessor spreadsheet.

a. Identification of the range of calculator input values corresponding to the range of possible sanitaryware specifications (see Annex).
b. Selection of ‘code default’, ‘typical new’, ‘good’ and ‘best’ sanitaryware specifications. The ‘best’ specification takes account of minimum flow rate or flow / use thresholds for sanitaryware item based on assumptions about user acceptability.
c. Calculation of microcomponent and total water use for representative sanitaryware specifications in the range and for the ‘code default’, ‘typical new’, etc. combinations (see Figure 1) and ‘maximum’ and ‘minimum’ calculator results.

4. Comparison of calculated and measured water use for dwellings with ‘known’ sanitaryware specifications using sample sets of homes which have both metered data and fittings data from original design information and/or from plumbing surveys. Results of the comparison are summarised in section 3.2.1.
5. Identification and collation of an evidence base for revised calculator algorithms and selection of factors for a revised calculator illustration (see Task 3).
6. Illustration and testing of revised calculator algorithms.

The findings of the quantitative review are discussed in section 3 and the illustration of the revised calculator algorithm is presented and discussed in section 4. A summary of the quantitative review is included as an annex to this report.

2.2 Task 2: Data and literature review and gap analysis

2.2.1 Review of alternative methods for reduction in water usage

The review looked at selected international approaches and methods for driving water efficiency in new homes. It gauged local user and expert attitudes to these methods, with the aim of determining applicability and lessons in the UK context.

A summary of the international review is included as an annex to this report.

2.3 Task 3: Review of microcomponent and other research data

The review identified research reports and datasets on water use in dwellings in the UK. Copies of publicly available reports were obtained and reviewed for applicability to the study. Approaches were made to copyright holders (WRc[4], water companies, local councils, and other potential sources) for access to unpublished reports and monitored microcomponent and other water use data.

The constraints and difficulties in obtaining and applying microcomponent and other water use data as part of the review were recognised from an early stage in the study. Despite not gaining access to some of the datasets identified and some difficulties in handling large and unfamiliar datasets, it was possible to partially realise the desired outcomes regarding microcomponent data set out in the project brief:

1. Identification of updated factors for use in water calculator algorithms.
2. Assessment of the quality of the evidence base and its suitability as the basis for a microcomponent water use calculator.
3. Testing of revised algorithms accounting for stakeholder feedback on issues with the current calculator.
4. Identification of knowledge gaps where further research is needed.

The microcomponent evidence base for the calculator is discussed in section 3.1.3.

[4] WRc is a specialist water industry consultancy

2.4 Task 4: Stakeholder engagement

2.4.1 Communications plan

A stakeholder engagement programme was undertaken to canvass opinion, and to draw on the experience and expertise in the sector. The programme included a series of events held for different groups as shown in Table 3.

Stakeholder Group	Target audience	Engagement activities
Assessors	Code Assessors	Online Assessor Questionnaire
		Code Assessor Day Presentation
Specifiers	Developers, RSLs, Quantity Surveyors, Architects, Public Health Engineers, House Builders, Consultants	Online Specifier Questionnaire
		Specifier Stakeholder Workshop
Experts	Environment Agency, Waterwise, Defra Water Saving Group, Universities, Water Companies, WRc, Associations, Product Manufacturers	Online Expert Questionnaire
		Expert Stakeholder Workshop

Table 3. Stakeholder groups and engagement activities

The stakeholders events were undertaken early in the review and attendees were not invited to comment on the findings, conclusions and recommendations set out in this report, which were developed subsequently.

2.4.2 Code assessor engagement

A web-based questionnaire for Code assessors was prepared using Survey Monkey software (www.surveymonkey.com). An online hyperlink to the questionnaire was circulated to all registered Code assessors in England and Wales.

Faber Maunsell attended the BRE Code Assessor Day on 5 November 2008 and gave a short presentation to increase awareness of the stakeholder engagement programme and particularly the online questionnaire.

A total of 130 assessors filled in the questionnaire providing useful feedback from the perspective of those involved in assessing the water efficiency of sanitaryware specifications for new homes using the Code calculator.

2.4.3 Specifier engagement

A web-based questionnaire aimed at specifiers was developed using Survey Monkey. The link to the questionnaire was circulated to a list of individuals and members of professional bodies involved in specifying sanitaryware in new homes. The specifiers were contacted directly by email or indirectly through member organisations' email lists, electronic newsletters and specialist internet forums. A total of 98 specifiers filled in the questionnaire.

A specifier forum was organised and nine organisations attended the event at Faber Maunsell's London offices on 5 December 2008.

2.4.4 Expert engagement

A separate, more detailed online questionnaire was prepared to elicit feedback on the calculator methodology from technical experts and professionals in the water industry. A total of 76 experts filled in the questionnaire.

Two expert workshops were organised. The first was an all-day event at Faber Maunsell's London offices on 15 December 2008, the second a half-day event at CLG's offices on 18 December 2008. The workshop attendees represented a wide range of industry experts.

2.4.5 Attendance at water sector events

In addition to the events organised as part of the project, members of the project team attended several scheduled industry events. These provided opportunities to explain the project and gain feedback from other attendees. The events were:

- National Water Conservation Group meeting, London, 5/11/08;
- Construction Products Association Code for Sustainable Homes Pre-Consultation meeting, London, 18/11/08;
- Code for Sustainable Homes Technical Advisory Group meeting, London, 24/11/08;
- CLG meeting regarding implications of water efficiency and Part G on SAP and Part L, London, 24/11/08.

Information was also fed into the presentation for the Review of the Code for Sustainable Homes Pre-Consultation meeting with Next Generation on 27 November 2008.

2.4.6 Summary of stakeholder feedback

The key feedback from the stakeholder groups has been incorporated in the main review findings in section 3.

A report of the stakeholder feedback is included as an annex to this report. Its appendices include survey questions, full database of responses, event agendas, minutes and summary notes.

3 Findings of the review

Based on the four review tasks, this section sets out the findings of the review with supporting discussion building towards the conclusions and recommendations presented in section 5. The discussion proceeds as follows:

- Fundamentals – the concept and application of a whole-building calculation method to drive water efficiency in new homes.
- The current calculator – findings of the review; implications for revisions, focusing on modifications within the current scope of the calculator.
- Wider considerations – issues identified in the review that suggest modifications beyond the scope of the current calculator.
- Learning from experience – a summary of themes from the stakeholder feedback and of approaches adopted internationally; consideration of how these could influence thinking on the development of the calculator.

3.1 Promoting water efficiency in new homes

3.1.1 Objectives and alternative approaches

In terms of water, the Code is intended to encourage more sustainable use of water in new developments and particularly to reduce mains water consumption in new homes.

For water, as for energy, there are two broad approaches to influencing design with a view to improving efficiency:

- Design standards – for water these are: plumbing design standards and product standards for sanitaryware;
- Whole building performance standards with a related calculation procedure.

Design standards approaches

There are widely recognised bodies for developing technical standards (BSI, ISO), however they have not yet necessarily been focused on water efficiency. Plumbing and product standards are developed with a view to broad applicability and therefore tend to be technically robust in terms of ensuring primary functionality but correspondingly conservative in terms of other objectives such as water efficiency.

The international review suggests that most countries use fittings-based water efficiency requirements for new dwellings as part of building control or similar regulation. Regulatory standards for individual fittings are by their nature minimum standards, i.e. they establish the least good performance that is acceptable. Aggregating fittings standards for water efficiency results in an overall minimum water efficiency standard.

A collection of minimum sanitaryware standards does not realise the full potential for improving water efficiency. It is often possible to specify better fittings than those meeting minimum standards without compromising functionality and user satisfaction. One water efficiency standard, WELS[*], deals with this by setting multiple sets of standards each corresponding with a level in the labelling system. The drawback is that overall aspiration is likely to be limited to the level of the worst performing fitting. A solution to that might be to

[*] See the annexes for more on WELS AUS/NZ and WELS Singapore.

allow improvements on standards for some fittings to offset shortfalls on others. This implies some rules about the trade-offs allowed, which would sensibly be related to water use or savings. This comes close to being a whole building performance standard based on calculated water use or savings.

Whole building performance approaches

Many voluntary sustainability standards opt for whole building performance standards for water use. For example, BREEAM, EcoHomes and LEED, which are all voluntary building environmental assessment methods for, use either percentage improvements on a baseline (LEED) or absolute targets (EcoHomes, BREEAM Offices, and also the Code). All such methods rely on a calculation of whole building performance. This is conceptually the same approach adopted in Building Regulations Part L for energy.

The benefit of the whole building performance approach, by contrast to design and product standards, is that it can incentivise efficient design while allowing flexibility to deal with specific constraints and opportunities. Another argument is that the approach provides a more consistent incentive for improvements and innovation in product design. For example, the current calculator rewards any improvement in the water efficiency specification of a product (e.g. tap flow rate, WC flush volume, etc.) achieved through product design.

There are potential weaknesses of the whole building performance approach:

- Realising the potential of the whole building performance approach relies on a calculation that reasonably reflects the savings from efficiency measures, relative to each other and relative to baseline performance;
- A focus on specifying efficient products may come at the expense of equally important design aspects such as functionality and user acceptability;
- The strong incentive for ‘efficient’ products may result in development and marketing of products that do not meet relevant and widely used product standards – it may not be immediately clear if the products or the standards are deficient; and
- Calculation algorithms may not work well with innovative new products, resulting in over- or underestimations of their savings contribution.

Therefore important aspects of a successful whole building performance approach include:

- An effective and credible calculation with a mechanism to make reactive changes;
- Supporting product standards to ensure technical functionality and user satisfaction;
- Product testing standards to validate manufacturers’ claims and to provide confidence in the performance of innovative products;
- A regular cycle of calculator reviews, covering the supporting standards and testing, that matches the pace of change in the subject sector in terms of supporting research and product innovation.

To summarise, different ways of standard setting include:

- A single set of minimum standards for a range of fittings and equipment;
- A performance label with higher levels of the label corresponding to a better set of minimum standards;
- A flexible set of minimum standards that allows some trading off between standards for different types of fitting and equipment but not based on water use;
- A performance standard based on a calculation of total water use or of water savings against a baseline.

In responding to the project brief, this review focuses on the current calculator, but necessarily considers the other aspects above and the implicit question about whether the available evidence base is good enough to support an approach to water efficiency based on a whole building performance standard.

3.1.2 The scope for water savings in homes

Water efficiency measures can be broadly categorised into those relating to physical changes (plumbing design and sanitaryware specification) and those relating to behavioural changes by householders. There is some cross-over between the two where behaviour can be influenced by product design. For example, the design of pushbuttons on a dual flush WC is likely to influence whether householders flush appropriately.

Therefore the water use of an average home can be seen as made up of:

- A quantity of water use 'essential' for day-to-day household activities (a notional minimum quantity for personal bathing, cooking & drinking, etc.), and
- A further quantity of water use which, by definition could be saved – the scope for water savings.

This scope for water savings is made up of the following parts:

- Savings achievable primarily through technology, which can be end use efficiency (e.g. reduced WC flush volume reduces water use for a given frequency of use[*]) or supply side measures (e.g. rain- and greywater systems, leak prevention);
- Savings influenced by technology but primarily resulting from behaviour change enabled by the technology (e.g. better design of dual flush WC pushbuttons);
- Savings attributable primarily to behaviour change, which can reduce both the quantity of non-essential water use for 'necessary' end uses (e.g. shorter average shower durations, reuse of rinse water for watering plants and similar ad hoc reuse) and waste ('unnecessary' water use e.g. running basin taps while brushing teeth).

Product specification affects the savings that result from many changes in behaviour. The quantity of water used for a shorter shower is still related to the shower flow rate, for example.[†]

A challenge in designing the calculator is to recognise and target the scope for water savings related to the design of new homes. This equates broadly to savings achievable primarily through technology and product design. The remaining scope for saving through behaviour change may be amenable to other forms of influence but is unlikely to be realised solely through sanitaryware specification in new homes.

The scope for technology savings relative to behavioural savings has not been well studied but has big implications for setting water use targets and understanding how to meet them. The lower a target the more likely that achieving it will depend on behavioural change as well as technology.

3.1.3 Microcomponent basis of the calculator

There is an understandable expectation that microcomponent models are based on a sound evidence base. The available evidence in the UK is in the form of microcomponent studies, most of which are commissioned by water companies. The majority of the studies to date have been undertaken by WRc, a private specialist water sector research company. The current calculator algorithms use factors drawn from WRc microcomponent data.

The current calculator is based on a microcomponent model of household water use. Its calculation algorithm could be represented as follows:

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[*] Although see discussion of 'rebound effect' in section 3.2.2.

[†] Although see discussion of non-linearity of average flow intensity in section 3.2.2.

$$Total\ water\ use\ per\ person\ per\ day = \sum_{\mu_{flow}} flow\ rate \times period\ per\ use \times uses\ per\ person\ per\ day + \sum_{\mu_{event}} flow\ per\ event \times events\ per\ person\ per\ day$$

where

μ_{flow} = microcomponents where water use is assumed to depend on the flow rate of a fitting or item of equipment (e.g. tap, shower use is ‘flow-based’)

μ_{event} = microcomponents where water use is taken to be constant per use of a fitting or item of equipment (e.g. WC, washing machine use is ‘event-based’)

The implicit assumption in the brief for this review is that the results from available microcomponent research should inform any refinement of the calculator. Before refining an existing microcomponent-based approach it is worth stepping back and considering underlying fundamental assumptions (axioms) and reviewing the nature and extent of the supporting evidence base.

Axioms of this approach

The current calculator approach includes the following inherent assumptions:

- Microcomponents of water use are dependent *either* on the flow rate *or* on the water use per event of a fitting or item of equipment.
- There is a fixed relationship between maximum design flow rate and the average flow rate in use. (This report adopts the term ‘average flow intensity’ to describe the relationship between maximum design flow rate and the average user-selected flow rate for a fitting.)
- There is a linear relationship between occupancy and total water use.

These axioms can be challenged as follows:

- For some fittings currently using a flow-based calculation, survey data shows that a proportion of uses are event-based; i.e. to deliver a fixed quantity of water for a given purpose, such as ‘filling’ a kettle, saucepan, sink, or basin (vessel-filling). This supports individual experience and common sense, and is reflected in the literature on microcomponents of water use (Waterwise, 2008).
- The evidence base recognises the likelihood of a non-linear relationship between maximum design flow rate and the average user-selected flow rate. For example, while spray taps and showers with a low maximum flow rate are likely to be used at or near their maximum flow rate (i.e. have a high average flow intensity), higher flow fittings are likely to be used at a lower average flow intensity.
- The non-linearity of per capita water use with household size is well documented (e.g. Essex & Suffolk, undated).

Hence, a microcomponent model for household water use could be expected to consider:

- Combinations of flow- and event-based calculations for relevant microcomponents;
- Non-linear average flow intensity for fittings where this is considered significant;
- Separate occupancy factors or variation in use factors to account for occupancy.

Inherent difficulties in using a microcomponent approach

Practical and cost limitations mean that most microcomponent studies measure water use in a small number of homes at a time (20-40 is typical of the studies reviewed). Sim et al (2006) note that “microcomponents are best applied to fairly large and demographically representative groupings". In addition to non-linearity of water use with occupancy, they list several limitations on the use of microcomponents for demand forecasting:

- Small samples drawn from single regions are subject to local bias and are more likely to deviate from demographic norms;
- Lack of socio-economic context prevents comparisons between areas; and
- The neat averaging of microcomponents of water use obscures other aspects of demand and the "scale or nature of 'natural' variability in household demand".

They suggest in passing that significant difference in consumption between regions is a barrier to the use of a general microcomponent model for demand forecasting.

Problems specific to the evidence base of available studies

This review looked at a selection of available microcomponent studies. This identified additional difficulties with using results from these particular studies as the basis of a general microcomponent model for household water use.

Studies are generally commissioned with highly specific aims, often focused on a particular difference between households in two selected groups or the same / similar households in different circumstances. For example, studies have looked at the differences in microcomponents of demand:

- In households with direct (mains pressure) and indirect (gravity-fed tanks) water supplies; and
- In peak and non-peak periods in otherwise nominally similar households.

Because study aims are so specific, incomplete household datasets (e.g. indicating that households have gone away for weekends / holidays) are routinely discarded as this is considered to hinder or potentially skew the desired comparison. This practice has serious implication for the use of the same results to inform any general microcomponent model of household water use. With the exception of data missing due to logging equipment failure, the discarded 'missing' data corresponding to householder absence is a critical part of understanding long term water use. Ignoring days of zero / low water use during and around absences results in a systematic overestimation of frequencies of use and average household water use for each microcomponent.

Another common issue with the reported data on microcomponent studies is that results are presented on a per household basis without corresponding occupancy figures to allow water use in litres/person/day to be calculated.

The issues of 'missing' data and lack of corresponding occupancy data could be remedied by obtaining access to the raw monitoring data underlying past reports and by increasing the priority assigned to these aspects of data gathering and analysis in future studies.

3.1.4 Other microcomponent data

Whilst the calculator is currently based on WRc data, some other research is available or will become available in the future.

Anglian Golden 100

A sample of data from the Golden 100 surveys was provided by Anglian. The Golden 100 monitoring project was set up in 1992 consisting of 100 properties (just under 60 properties are still being monitored) (WRC, 2008). Monitoring involves remote reading of individual meters on the main microcomponents in the dwellings. The data are in the form of hot and cold water use over 15 minute periods.

Other studies in progress

BRE is currently working with Essex and Suffolk and NHBC to collect microcomponent data for a sample of homes built to different Code levels. Data for 1 minute periods is again read remotely and is accessible via a specialised website. The project is in its early stages.

A benefit of both these studies is that they differentiate hot and cold water use and the water use at different taps (kitchen, bathroom, etc.), unlike the WRc Identiflow data. However the intervals between readings (1 and 15 minutes) are too long to enable frequencies and durations of use to be derived and checked against those from WRc studies. WRc Identiflow data remain the only source of the frequency and duration of use factors that are central to a microcomponent calculator.

3.1.5 Updating the calculator evidence base

BRE provided information on the evidence base for the current calculator. This lists the following sources (quoted as provided) as the basis of factors used in calculator algorithms:

- WRc CP187;
- EA UC7231;
- BRE 200456;
- JS Air and Water Centre and Harvey Softeners.

WRc CP187 is the main source for frequency and duration of use and volume per use factors for microcomponents in the current calculator. WRc has since conducted a study of water use in new dwellings, WRc CP337. While details of this study are not in the public domain, it forms the basis of a published Market Transformation Programme Briefing Note (MTP BNWAT28). Table 4 shows how the factors in the current calculator compare with updated factors based on WRc CP337.

Sanitaryware item	Current calculator		Revised calculator illustration	
	Use Factor	No of uses/ person/day	Average duration or ratio of use	WRc/MTP uses/ person/ day*
WC (fixed flush)	1.0	4.8	1.0	4.42
WC (dual flush)	0.33	4.8	0.33	4.42
	0.67	4.8	0.67	4.42
Bidet	1.0	2.0		
Basin taps	0.67	7.9	**0.43**	**10.46**
Showers	5.0	0.6	**5.6**	**0.78**
Baths	0.4	0.4	**1.0**	**0.49**
Kitchen sink taps	0.67	7.9	**0.43**	**10.46**
Washing machine	1.0	0.34	1.0	0.35
Dishwasher	1.0	0.3	1.0	0.3
Significant changes in bold *assuming average occupancy of 2.4; not modified to account for householder absence				

Table 4. Comparison of factors in the current calculator with those derived from CP337.

Among the main differences between CP187 and CP337 are the figures for duration of use for taps, with the more recent figures being lower.

This new microcomponent data have been used in this review to derive updated factors for the illustration of revised calculator algorithms. However, the factors proposed in the illustration are modified to account for findings and conclusions discussed later in this report. A comparison of the factors in the current calculator and those in the illustration of a revised calculator is included in section 4

3.2 The current water calculator

The Code water objectives discussed in section 3.1.1 imply that the calculator should be judged on its general effectiveness in driving more water efficient design rather than its accuracy in modelling water use. At the same time, the greater the gap between calculator results and measured water use, the more the validity of the calculator may be questioned and the less effectively it may contribute to its objectives. More could be done in the guidance to explain the objectives of the calculator, its limitations, and the balance it aims to strike between influencing design while remaining a reasonable predictor (in a statistical sense) of water use in new homes. To that end, the idea of a set of calculator 'principles' is discussed in section 5.1.

Given the aims of this review, the sections below focus on how and why the calculator, given information on sanitaryware specification, may fail to correctly model water use in an 'average' new home. They look at the fit between calculator results and measured data, and explore the conceptual and practical issues arising from the current calculator and Code approach to water efficiency.

3.2.1 Quantitative comparisons

Analysis using selected representative specifications

The review compared current calculator results for 'code default' and 'typical new' sanitaryware specifications against average UK household water use. There are some inherent difficulties in making this comparison, including:

- The 'average' sanitaryware specification in the housing stock is unknown and the 'code default' and 'typical new' specifications may not be similar;
- Average UK water use includes external and 'atypical' water uses not included in the calculator (e.g. Part G proposes 5 litres / person / day for external water use);
- Preferable comparisons would be against just metered and / or just 'new' homes.

Average per capita water use for the complete stock of UK households, reported by OFWAT based on water company data, is ~150 litres / person / day (the figure for metered households is ~135 litres / person / day). This broadly corresponds with the results of individual microcomponent studies and longer term monitoring studies.

Calculator results for a range of selected sanitaryware specifications are shown in Figure 1. Results for 'code default' and 'typical new' specifications are 212.0 and 195.5 litres / person / day respectively. This suggests that calculator results are broadly ~45 – 60 litres / person / day (~30% – 40%) higher than the reported average for all UK households.

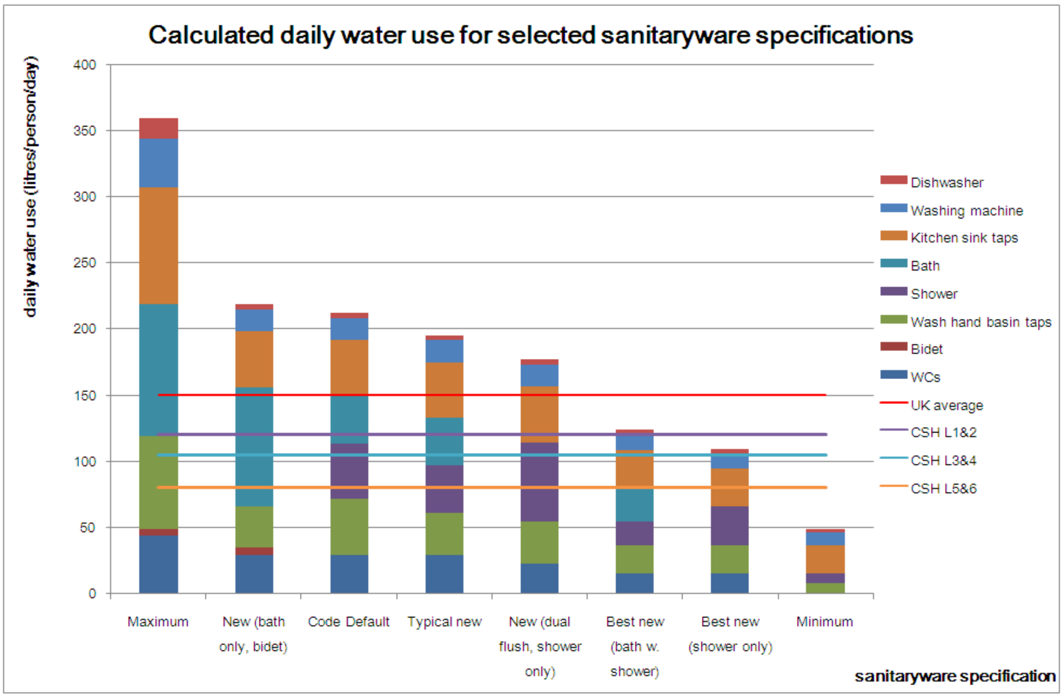


Figure 1. Current calculator results for selected sanitaryware specifications

Neither the current calculator spreadsheet nor associated guidance limit the input values for flow rates or volume per use of sanitaryware. For the purposes of the review, a 'best' sanitaryware specification (without rain- or greywater) was established taking account of standards and householder acceptability issues as discussed in section 3.2.2.

The review considered other representative sanitaryware specifications. The calculator result for a 'best new (bath & shower)' specification is 123.4 litres / person / day, 3.5 litres above the Code Level 1 threshold. The result for a 'best new (shower only)' specification is 109.0 litres / person / day, 4 litres above the Code Level 3 threshold.

Allowing that opinions may differ on the 'best' specification, the analysis suggests that, without the use of rain- or greywater:

- For dwellings with baths, specifiers of sanitaryware are likely to be pushing the boundaries of user acceptability to achieve any Code water credits;
- For dwellings with showers only, specifiers are likely to be pushing the boundaries of user acceptability to achieve more than 2 Code water credits.

Overall, the analysis suggests that the current combination of Code Level targets and the results generated by the Code water calculator are leading specifiers of sanitaryware to push the boundaries of user acceptability.

Comparison of calculated results and measured data

Stakeholders are interested in the extent to which the calculator results correspond to measured water use. Over 40% of the experts surveyed as part of this review "agreed" or "strongly agreed" that the calculator "should...be a statistical predictor of the water consumption of new homes", while less than 30% disagreed. This suggests that a systematically large difference between calculated and measured water use will tend to challenge the credibility of the approach.

The review looked at datasets where measured water use could be associated with sanitaryware specifications of existing homes. In terms of analysis, no criteria were set regarding the age or other typological aspects of dwellings, but the data generally relies on the presence of a water meter, which are more commonly present in newer homes. The datasets analysed are summarised in Table 5.

Data Source	Reference	Dataset size
BioRegional (BedZED)	BR	65
Elemental Solutions	ES	6
Essex & Suffolk	E&S	17
Thames Water	TW	286
South East Water (Mid Kent Water)	SE	22

Table 5 Measured datasets used for comparison with calculator results

Figure 2 illustrates the relationship between calculated and measured water use for these analysed. The comparison is displayed with homes arranged in order of their calculated water use, which is shown as a solid bold red line. Corresponding measured water use for each home is plotted as a blue dot. Three further lines are shown. The bold black line (short horizontal sections) shows the average measured water use for the BR, E&S 1 and E&S 2 datasets; homes *within* each of these groups have identical specifications. The dotted horizontal black line shows the average measured water use for the TW and ES (small and not labelled) datasets; homes in these groups have a variety of specifications. Where a group of homes have identical specifications their measured water uses are plotted in order (the most obvious example is the group of BR dwellings). The dashed grey line is the moving average (across 21 dwellings) of measured water use.

It is apparent from Figure 2 that:

- The calculated water use for a given specification (bold red line) is greater than the average measured water use (bold black line);
- All the averages of measured water use (the bold black, dotted black and dashed grey lines) are lower than the calculated water use;
- The difference between calculated and measured water use grows with increasing calculated water use;
- There is great variation in water use independent of sanitaryware specification; evidence of the importance of other factors (behaviour, leakage);
- Average measured water use at BedZED is notably low. Savings of 15 litres / person / day reported for the rainwater system explain part of this. The remainder could be due to householder awareness of sustainability resulting in water efficient behaviours. (The atypical nature of this dataset is allowed for in later analysis.)
- There are many examples of households with a measured water use of less than 80 litres/person/day – 50 of the 308 dwellings without rainwater systems have water use below this level;
- A small number of dwellings have very high water use. Median measured water use is 106 litres / person / day (114 litres / person / day excluding BedZED); the average is 121 litres / person / day (132 litres / person / day excluding BedZED).

The general conclusions from this analysis are that there is a definite gap between calculator results and measured water use in homes. Calculator results are consistently and significantly higher than average measured water use.

NB. The current calculator does not include external water use, the first 4% of water used to regenerate ion exchange water softeners, and other 'atypical' end uses such as ponds, swimming pools, etc. These water uses may be included in the measured data analysed. It is difficult to identify and quantify these components of water use in the measured data and no effort has been made to do so or to make corresponding modifications to measured or calculated water use. Were such modifications possible they would tend to increase calculated, or decrease measured water use, increasing the identified gap. (End uses not covered and implications for the calculator are discussed in section 3.3.1).

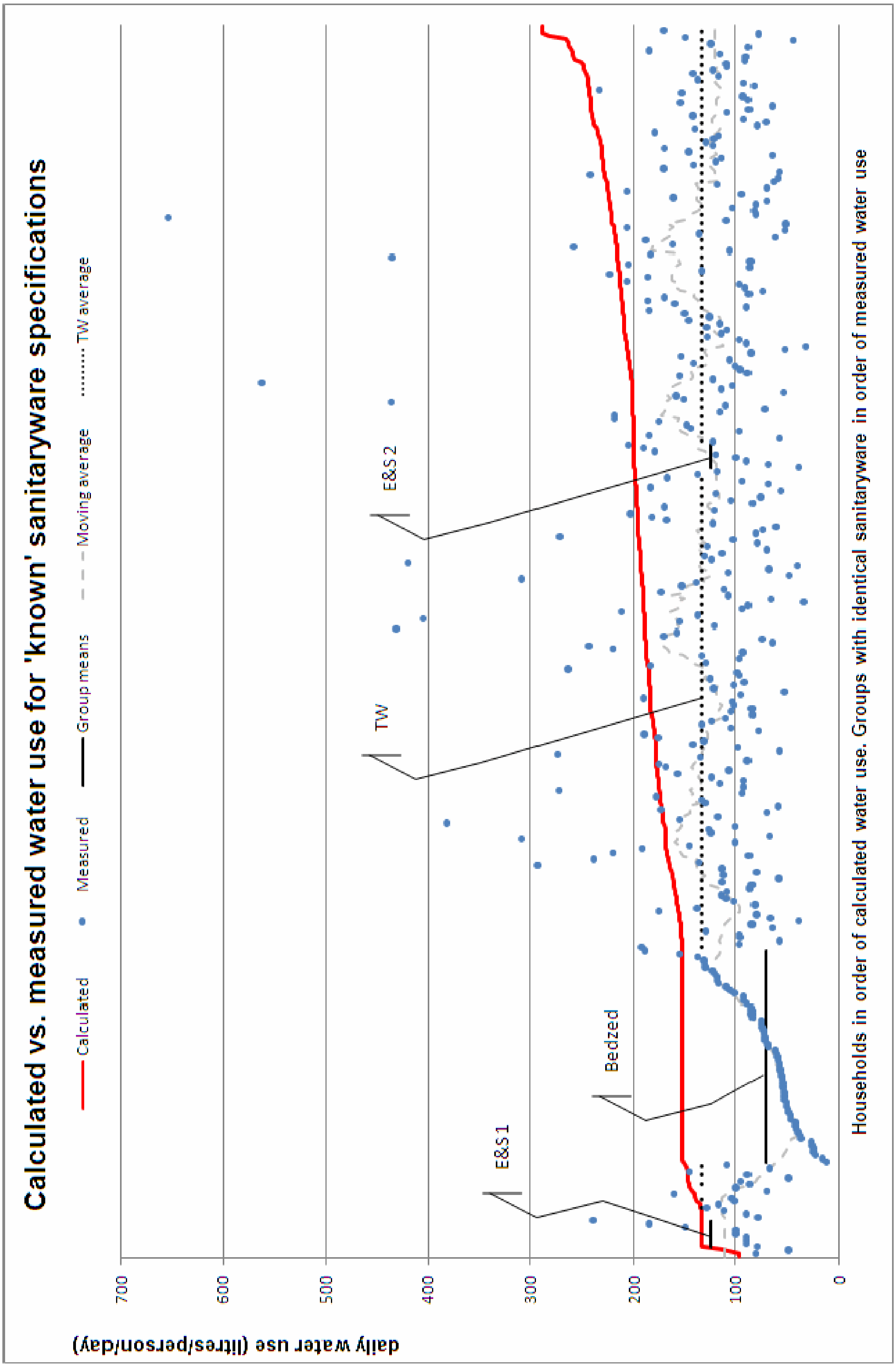


Figure 2. Calculated vs. measured water use for dwellings with known sanitaryware specifications.

Explaining the gap between calculator results and measurements

The review of the microcomponent basis for the current calculator suggests that the following contribute to calculated results being higher than measured water use:

- Handling of 'average flow intensity' – this is likely to be the biggest contributor to the gap between calculated results and measurements.
- Overestimation of duration of use of taps (based on lower reported duration of use in the recent CP337 compared to CP187 on which the current calculator is based);
- The systematic overestimation of frequency of use figures associated with their adoption from microcomponent studies.

The effects of addressing these points can be seen in the comparison between the current calculator and the illustration of revised calculator algorithms in section 4.

3.2.2 Qualitative calculator design considerations – current scope

The following narrative discussion about issues influencing calculator design is based on the qualitative review and feedback from stakeholder engagement.

Flow rates and intensities – taps

The tap calculation in original version of the Code calculator was based on the maximum tap flow rate at 3 bar pressure. This was subsequently changed to include a 2/3 flow rate modifier, acknowledging that people rarely use taps at their maximum design flow rate. This reduced the calculated water use for average taps, which was otherwise very high.

The calculator allows any tap flow rate to be entered. Products are available with flow rates ranging from more than the 12 litres / minute Code default figure, down to ~1.7 litres / minute; calculated water use for taps varies by a factor of seven across this range. By comparison, EcoHomes assumed a 50% saving for all tap water efficiency measures. While the EcoHomes saving is likely to be generous in some cases it is smaller than the savings at tap flow rates below 6 litres/ minute in the current calculator, so the transition to the Code appears to have resulted in a large change in water saving potential from taps. In another context, a manufacturer claim of a seven fold saving in water use from a new 'eco tap' would generate considerable scepticism.

A 2/3 flow rate modifier (to give 'average flow intensity') seems reasonable when applied to a 'typical' or 'default' flow rate, reflecting that these taps are unlikely to be used at their maximum design flow rate. However, it does not seem reasonable to apply the same factor to very low flow spray taps, for example, which are much more likely to be used at or close to maximum flow. I.e. the relationship between design tap flow rate and average flow intensity is likely to be non linear.

The feedback from stakeholders showed relatively high dissatisfaction with the treatment of taps in the calculator. The general opinion appears to be that water use from taps has a disproportionate effect on the calculation that is not representative of reality and is driving tap flow rates well beyond the limit of user acceptability. The point that kitchen taps and wash basin taps have different functions and their water use should be calculated accordingly was also made repeatedly.

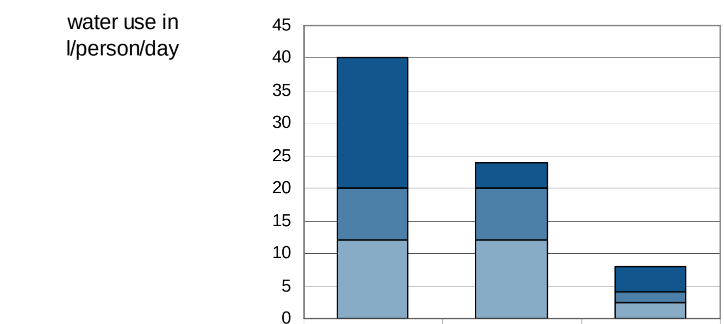
Vessel filling

A low flow tap takes longer to deliver a fixed quantity of water, as when filling a vessel e.g. a kettle, sink / basin, cup, etc.; considerably longer for very low flow rates. The clear potential effect on user satisfaction has been a clear concern of some international approaches. WELS Singapore and WaterSense (USA) both include minimum flow rates for taps to address this issue (see section 3.4.2).

Technical solutions include dual mode taps with a low flow mode for hand washing and occasional rinsing and a higher flow filling mode. The argument for such sophistication and innovative design needs to be balanced against the case, made by some stakeholders, for traditional rotary taps with their progressive flow increase and ease of control. This is one example of a general rule that caution must be applied when attempting to anticipate the effect of a technical change, without supporting evidence.

The current calculator treats all tap water use as ‘flow-based’ and all reductions in flow rate result in linearly proportional water savings. The UK literature and international approaches acknowledge that a proportion of basin use and some if not all kitchen sink use is function-dependent, ‘event-based’ use (to fill vessels, the sink /basin, etc. for a particular use). 32% of stakeholders surveyed had concerns about the calculator approach to kitchen taps. Of these, 21% cited “vessel filling” and 9% “user acceptability” as the reason for their concern.

The BASIX water calculator developed by New South Wales in Australia uses an alternative approach incorporating a proportion of fixed water use. It splits sink tap water use into a fixed volume for cooking, drinking and washing up (if a dishwasher is not present) and a variable quantity dependent on flow rate. A similar approach, with a proportion of fixed use, was also a feature of the BSRIA water calculator (Parker, 2006). Figure 3 compares the water use and relative savings calculated using the BASIX and current Code calculator algorithms as a result of an 80% reduction in the maximum design flow rate of the sink tap from a base case of 14 litres / minute to 2.8 litres / minute. Using the BASIX approach, the fixed volumes for cooking and drinking (20%), and for washing up (30% if dishwasher not present) are unchanged with only the remaining 50% affected by the reduced tap flow rate. The result is a 40% overall reduction in water use at the sink tap. By comparison the Code calculator applies the 80% reduction equally to all constituents of water use giving an 80% overall saving.



	Base Case	Basix 80% Reduction	CSH 80% Reduction
Litres/day Flow Dependant	20	4	4
Litres/day Cooking	8	8	1.6
Litres/day Dishwashing	12	12	2.4

Figure 3: Comparison of Basix and CSH calculated water saving at the kitchen sink tap as a result of an 80% reduction in tap flow rate.

Data from microcomponent studies provide limited information to inform the inclusion of a fixed use component in the algorithm for kitchen tap water use. WRc Identiflow data cannot currently distinguish use of the kitchen tap from other tap use and related studies only report an aggregate figure for internal tap water use. However, Future Water (Defra, 2008) reports that “around 7% of the water used in our homes is used for drinking and cooking” and this could provide an initial basis for a fixed use approach in the Code calculator.

The inclusion of a fixed volume element is more significant for kitchen than basin taps as basin water use (e.g. hand washing, tooth brushing) is more likely to be flow dependent.

Flow rates and intensities – showers

The logic related to tap user flow intensity can also be applied to showers. It is likely that a 4 litre / minute shower would be used at or near its maximum flow rate, whereas a 20 litre / minute shower may be used at much less than the design maximum flow rate. Anecdotal evidence suggests that people spend more time in showers with a low flow rate, and BASIX accounts for this relationship in its shower calculation. Table 6 sets out one estimate of the relationship between maximum design flow rate, user-selected flow rate (‘average flow intensity’) and shower duration, suggesting a non-linear relationship.

Rated flow	% of flow in use	Actual litres/min	Minutes/day	litres/use	CSH litres/use
20	70%	14	5	70	100
9	90%	8.1	5.5	45	45
6	100%	6	6	36	30

Table 6. An approach to estimate the relationship between maximum flow rate, the flow rate set by the user (user flow intensity) and duration of showering (Wilkenfield, 2003).

34% of the stakeholders surveyed had technical concerns about showers with low flow rates. Of these, over 40% were related to user acceptability.

User acceptability and rebound effects

The current calculator inputs are design maximum flow rates or volume per use, as appropriate for each microcomponent. Any value can be entered and all reductions in flow rates and volumes are rewarded (i.e. result in lower calculated water use). There is a concern that flow rates and volumes are being driven down to and beyond the limits of user acceptability and product functionality to meet Code targets. By contrast, EcoHomes grouped fittings into a number of bands with the same water use, meaning that the savings achievable by moving between specification bands were fixed.

Stakeholders responses to questions about acceptable minimum flow rates for kitchen sink taps and basin taps and for showers are shown in Figure 4 to Figure 6.

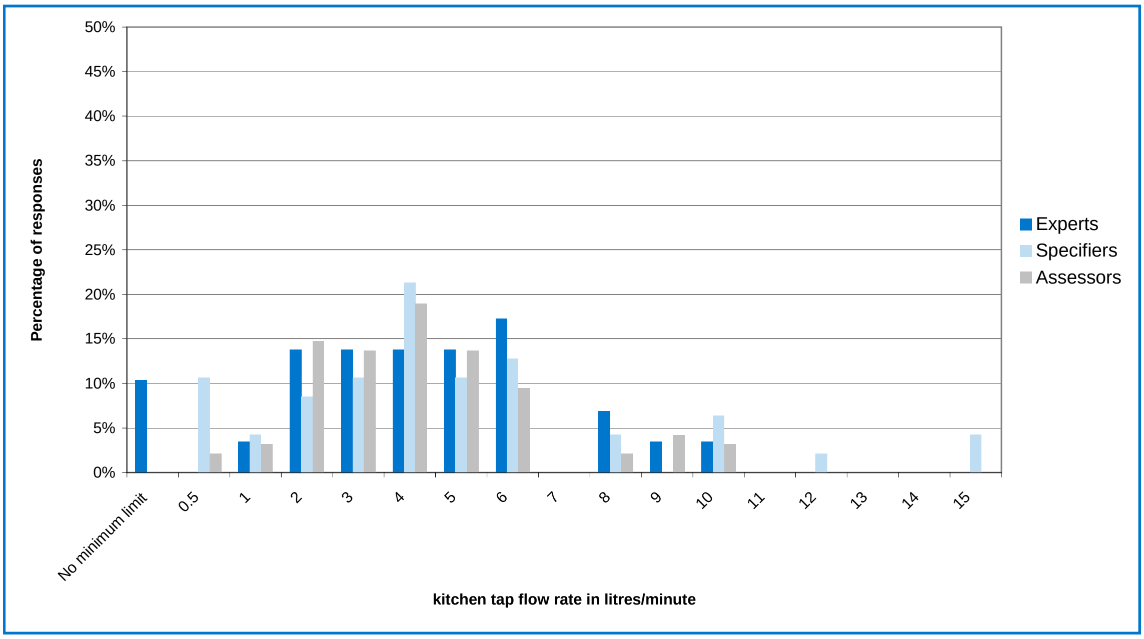


Figure 4. Responses from all stakeholders on minimum acceptable flow rate for kitchen taps

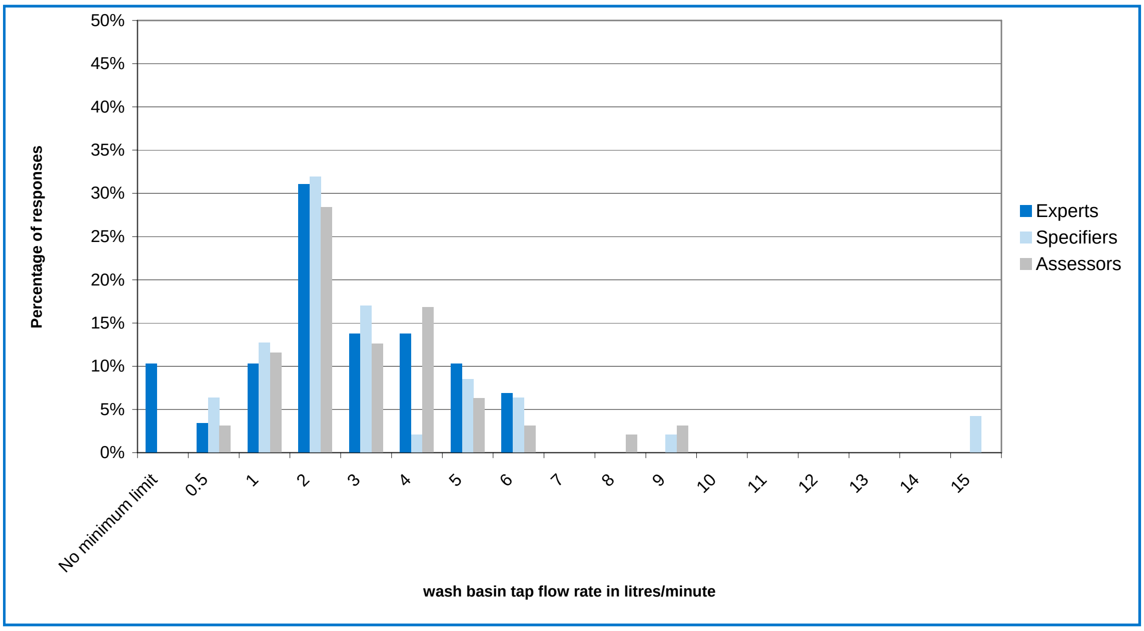


Figure 5. Responses from all stakeholders on minimum acceptable flow rate for basin taps

The vast majority of stakeholders responded to the questions on tap and shower limits in a way suggesting they support minimum acceptability limits. There is a range of opinion on the minimum acceptable flow rate for kitchen taps with many suggesting between 2 and 6 litres / minute, but around 15% suggesting limits above 8 litres / minute. There was greater agreement on a minimum limit for basin taps of between 1 and 4 litres / minute with around 30% across all stakeholder groups suggesting 2 litres / minute. 15% (most of the remaining respondents) suggested slightly higher limits of 4 to 6 litres / minute.

Opinions on the minimum acceptable flow rate for showers were mainly between 4 and 9 litres / minute with a large proportion of each stakeholder group (~30-35%) suggesting a minimum limit of 6 litres / minute.

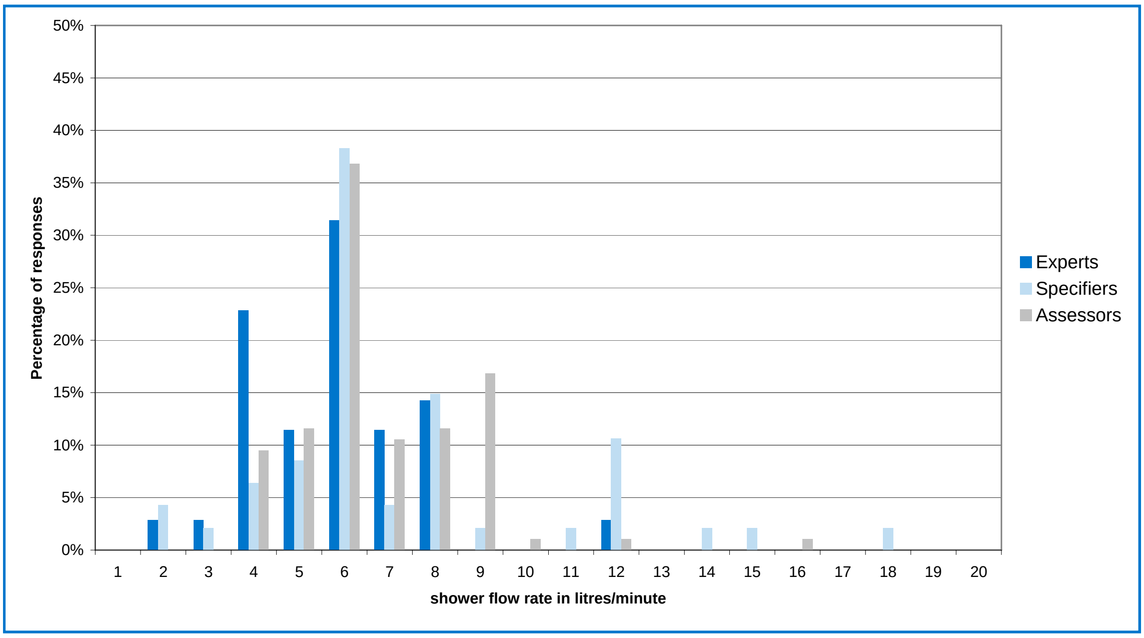


Figure 6. Responses from all stakeholders on minimum acceptable shower flow rate

The overall feedback from stakeholder surveys and workshops was that while minimising water use should be championed as an objective, it is very difficult to meet current Code targets with products that are functional and acceptable to the majority of householders.

It is conceivable that products rewarded for low water use in the calculator but that are unacceptable to many users will be specified regardless, to meet target Code levels, particularly if they are easily replaced. An anecdotal example is the specification of spray taps with the lowest available flow rate in kitchen sinks. An example of a more intrusive change to address user acceptability comes from a report on long term monitoring of properties for Essex and Suffolk Water (Essex & Suffolk Water, 2007). It recorded specification changes between successive monitoring periods and the reasons for the changes and found that small bathtubs were replaced with standard sized baths in two out of twelve homes with “water-efficient” specifications. Anecdotal and documented reports of specification changes to address user acceptability are examples of the ‘rebound effect’.

The rebound effect is a widely recognised phenomenon in economics and energy use (e.g. Binswanger, 2001). It describes the case where a behavioural reaction to the introduction of an efficiency measure reduces, cancels out, or at worst reverses the supposed efficiency savings (Waterwise, 2008). Such behaviour changes could relate to one or more of duration, frequency and/or intensity of use, or equipment replacement as discussed above. In terms of water use, rebound could include:

- Replacement of low water use products with alternatives with higher water use, following negative householder experience;
- Retention of fittings with user behaviour changes to compensate for differences in performance (e.g. use of extra rinse cycle for clothes washing).

Such rebound effects are difficult to measure, but to the extent that they relate to non-linearity in use factors (e.g. duration / frequency / intensity of use) or can be prevented through limits to design flexibility (e.g. minimum flow rate standards) other approaches have attempted to address rebound to varying degrees.

Maintaining user acceptability and function can be achieved for some fittings (e.g. WCs) through improved standards and product testing. Setting minimum flow rates within the Code calculator could also play a role.

Fitting averaging

Where more than one fitting of a given type is installed, the current calculator uses average values, essentially assuming equal use of all fittings of that type. It is conceivable that this opens up an opportunity for game playing. For example, in large dwellings with a large bath in the main bathroom and a number of en-suite bathrooms, a better score can be achieved by installing undersized baths with the showers in the additional bathrooms rather than just showers. The smaller baths would bring down the average bath volume even though they may result in more baths being taken (compared to only showers being specified) or baths only being taken in the bigger main bath.

A related potential loophole is the averaging of flow rates for multifunction shower heads. A product could have a number of very low-flow eco-settings (with unusably low flow rates) and one high flow setting (that is most likely to be used). No products were found exploiting this loophole but this is a conceivable response to current calculator design.

Previous calculators have used the performance of the ‘worst’ fitting rather than an average of all the fittings (e.g. Parker, BSRIA 2006) to avoid these issues.

Rain and grey water systems

Systems that collect rainwater, or recycle greywater from baths and showers, for use in WCs and washing machines are encouraged in the Code. The technical guidance specifically mentions that the aim of the methodology is “to reduce the consumption of potable water in the home from all sources…through the use of water recycling systems”. This implies that these systems are a more sustainable solution than the use of mains water. Some research challenges this.

Future Water (DEFRA, 2008) refers to the Housing Corporation and English Partnerships requirement to achieve Code Level 3, "*a performance standard of 105 l/person/day, representing current best practice in water efficiency* ***without*** *requiring water reuse or rainwater harvesting".* This suggests that DEFRA does not expect the specification of rain- and greywater at mid levels of the Code. The strategy also highlights some of the potential issues with rain and greywater systems stating, for example:

> *Recycling water from showers, baths and sinks within households to use for such things as toilet flushing is made somewhat more difficult by the relatively large upfront and maintenance costs...*
>
> *As greywater recycling systems – and some rainwater harvesting systems – require energy for treatment and pumping we do not think it appropriate to mandate these types of systems within all buildings. However, greywater technology continues to be developed. ...*[We] *will work with others to develop standards for non-potable water use.*

In terms of the 'need' to install rain or greywater systems to reach Code levels, a common criticism of the current methodology from stakeholders during the review was that it is impossible to achieve the highest Code levels 5/6 without them. (This is supported by the parametric analysis in this study which found that a rain- or greywater system or a shower-only specification is needed to reach Code levels 5/6, assuming limits to design flexibility)[*].

Feedback from a number of developers through survey responses or stakeholder events was that it had been difficult to reach the mid Code levels 3 and 4 without rain or greywater systems (suggesting they are being considered alongside water efficient fittings to achieve mid Code levels). Combined with local authorities pushing for homes to be built to higher Code levels, there was concern that rain- and greywater systems would effectively become essential for new homes with little meaningful design flexibility; built forms with small roof areas per person would have no choice but to apply greywater recycling.

In terms of handling in the calculator, stakeholders considered the current algorithm for rainwater collection to be overly simplistic, with a tendency to over-estimation of useful rainwater collection and water savings.

The initial qualitative review raised a number of issues about the ability of the calculator and the Code water section to drive appropriate application of rain- and greywater systems. Stakeholders agreed that the freedom to 'trade off' relatively high water use fittings (e.g. power showers) against water savings from collected water is problematic. This is compounded where the trade-off favours cold water savings over hot water savings,. Stakeholders questioned whether the calculator is sophisticated enough to account for the complex set of issues that should influence whether and how rainwater systems are specified (water stress of the location, dynamics of supply-demand related to collection area, tank sizing, occupant density, end uses for collected water, etc.).

Stakeholders were asked about the role of rain- and greywater systems in water efficiency of new dwellings; opinions were divided. On the positive side, some felt that rain- and greywater systems brought flexibility to design and could contribute to relieving pressure on the mains supply during water-stressed periods. On the negative side, others were wary based on experiences ("customers lost patience with the technology fairly soon after installation"; "all existing systems that I am aware of have been switched off or decommissioned") or had concerns about the maturity of the technology and the market citing:

---

[*] If baths are not specified higher levels may be reached without the need for rain or greywater systems.

- Maintenance and management – requirement at odds with industry trend towards lower maintenance housing; doubts about costs-benefits (related to lifecycle issue) and hence likelihood of ineffective maintenance and management;
- Related uncertainty about the longevity of water savings compared to efficient fittings and equipment;
- Real or perceived health risks;
- Doubts about public acceptability (linked to all the above).

There was general agreement that recycled greywater in particular has higher embodied carbon emissions than mains water, but there was no consensus within or across groups as to the overall positive or negative environment impacts of rain- and greywater systems.

It was widely agreed by stakeholders that water efficiency should be encouraged before considering water re-use systems, i.e. water saving options should be prioritised along similar lines to the waste hierarchy, “reduce, reuse, recycle”. A notable contribution on this point came in a written submission from the UK Rainwater Harvesting Association (UKRHA) who confirmed that they were:

“broadly happy with the 150/120/105/80 benchmarks currently set-out in the CSH, provided that these are aligned practically along the lines:

- *150-ltrs/person/day ≈ the notional consumption in the absence of ameliorating measures*
- *120-ltrs/person/day ≈ the notional assumed consumption when water economising measures (small cisterns, dual-flush, aerated taps & shower-heads, and water-efficient appliances) to a defined British Standard are installed*
- *105-ltrs/person/day ≈ the notional assumed consumption when water recycling technologies, such as rainwater harvesting and/or greywater recycling, are used that can demonstrate mains water savings of at least 15-ltrs/person/day; alternatively a smaller bath to a defined standard that achieves the same savings may be used*
- *80-ltrs/person/day ≈ the notional assumed consumption when water recycling technologies are used that can demonstrate mains water savings of at least 25-litres/person/day, or can demonstrate this saving in conjunction with a smaller bath”*

The review team’s interpretation of this submission is that the UKRHA supports the principle that lower levels of the Code (e.g. Levels 1 & 2) should be achievable with water efficiency measures alone. By extension this implies support for the concept of a water hierarchy (see section 5.1.2). Reference to “demonstrating” defined (and differing) contributions from rain and greywater systems at Code levels 3 and 5/6 implies support for the principle that these systems should be fitted where they are appropriate, e.g. can make a significant contribution to water savings. The UKRHA’s assumption that rain- and greywater should be considered to reach Code level 3 is at odds with Defra’s reporting of English Partnerships / Housing Corporation expectations on requirements to meet Code Level 3 and the preferences of some stakeholders as summarised above.

WC flush volumes

WCs are performance tested in accordance with BS EN 997 (BSI, 1997) to determine their flush volumes. Measurements of WC flush volumes in real-world trials has shown that actual volumes in use are generally higher than in standard product tests (see Figure 7). There is particular uncertainty about the average effective flush volume for dual flush WCs, with studies reporting a range of full flush : part flush ratios.

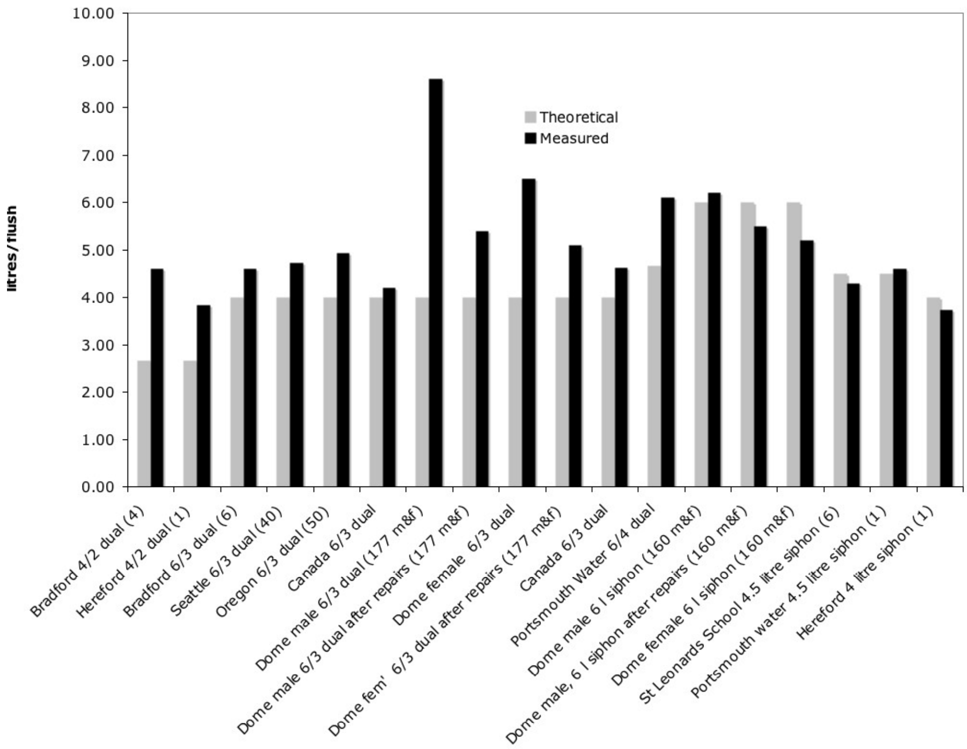


Figure 7:
Measured WC flush volumes in trials compared with theoretical flush volume based on a ratio of 1 full flush to 2 part flushes

The current WC algorithm was broadly supported by stakeholders across all groups, with acceptance that actual flush volumes can vary significantly from those quoted by manufacturers. There was less agreement on the assumptions made for the number of WC uses per day and the ratio of full flushes to part flushes for dual flush WCs. Of the respondents who supported their comments with references to published research, the majority disagreed with the assumptions used in the calculator but inconsistent alternatives were proposed, with some suggesting better ratios, and others worse ones.

Bidets

The current methodology assumes that if present, bidets use a fixed quantity of 5.28 litres / person / day. Few of the stakeholders consulted had detailed knowledge about bidets. Their direct water use and any indirect impacts on water use of other sanitaryware was perceived differently by different groups. Specifiers and assessors generally believed bidets resulted in increased water use or had no effect. Conversely, the majority of experts believed bidets had no effect or resulted in savings on shower / bath / basin use. All stakeholder shared the concern that the Code in its current form could “kill the bidet”. On balance this was regarded as negative in terms of consumer choice and water efficiency.

Many respondents suggested that bidets should be treated as “low-level wash basins” and included in the calculation for taps, or removed from the calculator altogether.

Washing machines

There is anecdotal evidence of poor rinse performance of washing machines when using their most water efficient programme cycles.

Feedback from stakeholders regarding white goods focused on the difficulty of finding accurate product information on water use.

Water softeners

Some designs of water softener need to be periodically regenerated by rinsing them through with a brine solution. This uses a quantity of mains water and explains why plumbed in softeners are included in the current calculator.

A weakness of the current calculator water softener algorithm is that it assumes a fixed frequency of regeneration cycles. Water softeners regenerate after supplying a given quantity of water so regeneration frequency could be derived as part of the calculator algorithm.

The current calculator algorithm ignores the mains water used for regeneration if it makes up less than 4% of the water used in the dwelling. (This would be ~5 litres / person / day in a home just meeting the Code Level 1 water target of 120 litres / person /day.) Only water use for regeneration in excess of 4% is calculated and added to the daily water use per person. While other water uses are also not covered by the Code or not included in the calculator (see section 3.3.1), the treatment of water softeners – counting some but not all water use – is unique. Notes from BRE record reference sources for the water softener algorithm but do not provide a rationale.

The anomalous treatment of water softeners has practical implications for the comparison of calculator results with large monitored datasets. (The TW dataset in the comparison of calculator results and measured water use includes some properties with water softeners; see discussion in section 3.2.1).

There was comparatively little feedback from stakeholders on the use of water softeners; this is likely to be due to lack of experience and specialist knowledge in this area. The few comments suggested that although softeners use water in their regeneration cycles, they could potentially have efficiency benefits through reduced cleaning and leakage. They may also extend product lives by preventing scaling. Stakeholders generally supported including the full water use of plumbed in water softeners in the calculator results.

Conflicting technologies – electric showers vs. solar water heating

Two Code-assessed projects (Griggs, 2008 & Siddall, 2008) were found to have solar hot water heating installed (to achieve renewables credits) in conjunction with electric showers (to achieve water credits as suggested in Assessing the Cost of Compliance with meeting the Code for Sustainable Homes (WRc, 2006)). The reduction in mains hot water as a result of an electrically heated shower may not have been taken into consideration in the sizing, specification and benefit assumed for the solar water heating (SAP 2005 does not distinguish between electric and boiler-fed mixer showers). If reduced hot water demand *was* taken into account the example still highlights that, in the absence of design-related constraints, the water calculator may incentivise questionable design in pursuit of credits.

Trigger flow rates to start combination boilers

Combination boilers start heating water when they detect a hot water flow rate above a trigger level. There is a risk that low flow fittings such as taps and mixer showers will fail to trigger a combination boiler, particularly when used at lower intensities (see Table 7). For taps that mix a hot and cold stream together, the flow rate of the hot stream may be half the total flow, so a mixer tap that seems to have a reasonable total flow rate may still not trigger a combination boiler.

Fitting	Flow litres/minute	Boiler output (kW)*	Notes
Spray tap	1.8	3.2 kW	Instantaneous combi not suitable
Very low flow shower	4.0	7.5 kW	Possible with smaller modulating combis up to about 25kW
Lowest flow tap aerator*	5.0	9.4 kW	OK with most modulating combis
Tap aerator/efficient shower	6.0	11.3 kW	OK with most modulating combis
Aerating shower	8.0	15.1 kW	OK with all modulating combis surveyed
Highest flow, saver shower	9.5	17.9 kW	OK with all modulating combis
for 15°C mains, 42°C delivered water temperature			

Table 7: Low flow limitations of combi-boilers (Grant, 2007). (NB Since the report was published 4 litre/minute aerators have become available.)

The compatibility of low flow taps and showers with combination boilers was the most common technical concern associated with the move to more efficient fittings and was highlighted repeatedly across all of the stakeholder groups.

Conflicts with standards

The review identified three British Standards relating to product and system design and function as being particularly relevant to the Code calculator.

BS 6700 (BSI, 2006) defines minimum delivered flow rates for a range of sanitaryware fittings and appliances to maintain user satisfaction. Relevant minimum design flow rates are summarised in Table 8.

Outlet fitting or appliance	Flow rate		
	Design	Minimum rate	
	litres/second		litres/minute
WC cistern (to fill in two minutes)	0.13	0.05	3
Washbasin	0.15	0.1	6
Handbasin (pillar taps)	0.1	0.07	4.2
Handbasin (spray or spray mixer taps)	0.05	0.03	1.8
Bidet	0.2	0.1	6
Bath (G ¾)	0.3	0.2	12
Bath (G 1)	0.6	0.4	24
Shower head (see Note 2)	0.2	0.1	6
Kitchen sink (G ½) (see note3)	0.2	0.1	6
Kitchen sink (G ¾)	0.3	0.2	12
Kitchen sink (G 1)	0.6	0.4	24
Washing machine	0.2	0.15	9
Dish-washing machine (see Note 1)	0.15	0.1	6
Pressure flushing valves for WCs or urinals	1.5 max.	1.2 min.	
NOTE 1 The manufacturer should be consulted for required flow rates to washing and dish-washing machines for other than single dwellings. NOTE 2 The rate of flow required to shower heads will depend on the type fitted and the advice of the shower manufacturer should be sought. NOTE 3 G refers to the tap thread type			

Table 8: BS 6700:006 Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages – (Taken from Table 3 Design flow rates).

As previously discussed, the Code sets no limits on design flexibility in terms of minimum or maximum flow rates for individual fittings or items of equipment. This study suggests that under the current calculator, a high proportion of solutions for Code level 1 and above are likely to rely on tap flow rates below the minimums listed in the British Standard.

* Neoperl 5 l/min PCA aerator. 3 l/min was available but is discontinued.

Some stakeholders deemed the design flow rates listed in BS 6700 to be out of date. Nevertheless, the conflict between the standard and likely sanitaryware specifications to meet Code levels is a substantive concern. NHBC uses extracts from British Standards in its House Building Standards, which then form the basis of NHBC warranty schemes. The House Building Standards currently include Table 3 Design flow rates from BS 6700 (see extract above). NHBC's Head of Standards suggested it is likely that a householder claim against a house builder on the basis that fittings failed to meet BS 6700 minimum flow rate standards would be decided in the householder's favour.

BS EN 1111 (BSI, 1999) is a standard for the hydraulic performance of thermostatic mixing valves. It requires that the flow for thermostatic mixing valves at 3 bar should not be less that 12 litres / minute for washbasins, bidets, sinks and showers. The standard relates to the flow through the mixing valve rather than the delivered flow from the tap or showerhead and therefore has an indirect impact in the context of the Code and the water calculator.

BS EN 12056 (BSI, 2000) sets design criteria for gravity drainage systems in the UK. It indicates that 4 litre WC cisterns are not permitted within a "System type III" installation. Other system designs listed within the standard do not exclude 4 litre WC cisterns. The wording in the standard creates a conflict with specifiers' typical designs. However, as other European design standards listed in the BS can be used and do not differ greatly from typical system design* this is not considered to be a significant issue.

Expert stakeholders were confident that if attention is paid to plumbing design and user education, water efficient WCs should perform as effectively as conventional models. However, they also advised that building and upstream drainage, and falls for low water use homes need to be considered as part of plumbing design, especially for single or small groups of homes or where rain- or greywater systems are used (BRE, 2008).

In summary, the concern is that sanitaryware specified to meet Code targets runs the risk of contravening the identified standards. Code technical guidance does not currently identify such conflicts or indicate how developers and designers might resolve them.

3.3 Wider Code water section and calculator considerations

The review also considered issues that relate to water use and water efficiency but are not currently included in the calculator or addressed in the related guidance.

3.3.1 Additional water end uses

A number of water uses are either not covered in the Code or not included in the calculator. This raises two broad issues:

- Impact of calculator inclusion/treatment on design and technology take-up – Are technologies like water softeners and waste disposal penalised if related water use is included in a calculator? Could inclusion in a calculator prevent the technology from being applied where it is really needed? Who decides when and where a technology is really necessary?
- Calculator credibility, wider applicability and comparisons – It is more difficult to validate the calculator results against measured data if some end uses, particularly common ones such as external water use, are excluded. It is also unhelpful and could be confusing if closely related calculator methods (e.g. the Code and Building Regulations) cover different end uses.

Examples and related issues are discussed below (and the anomalous treatment of water softeners was discussed in section 3.2.2).

* Indicated in both Specifier and Expert workshops

Waste disposal systems

Waste disposal systems are not included in the current calculator. The proposals to amend Building Regulations Part G include waste disposal systems. This seems to establish the principle that ‘atypical’ end uses with calculable water use should be included in a whole-building calculator – although the exclusion of water softeners (which are included in the current Code calculator) from the Part G proposal then needs to be explained.

A Part G consultation response from the Association of Manufactures of Domestic Appliances requested a revision to the proposed Part G figure of 8 litres / person / day where a waste disposals unit is specified. The association suggested the use of the MTP average of 3 operations / household / day and either the manufacturer’s declared average water use per operation or the average 2.46 litres / use reported by MTP.

Stakeholder feedback in this review supported the inclusion of waste disposal units in the Code calculator.

Condensing washer-dryers

A large proportion of stakeholders felt that condensing washer-dryers should be included in the calculator, since they are growing in popularity and can have very high water use. However, no existing method of calculating the water used by a washer dryer in its drying cycle was identified during this study.

External water use

The proposed Part G standard includes 5 litres / person / day for external water use. As the Code calculator excludes external water use, this means the proposed Part G standard of 125 litres / person / day is aligned with the CSH Level 1 target of 120 litres / person / day (+ 5 litres / person / day).

It seems sensible to keep the scope of the Code water calculator and the Part G calculator the same so that results are immediately comparable. Apart from harmonising the scope of the two approaches, adding a constant quantity of external water use to both calculator results and target Code levels makes no substantive difference.

3.3.2 Additional water efficiency opportunities

There are a number of physical demand reduction measures that are not included in the current calculator, some of which are included in water efficiency schemes in other countries. Assuming their water use or savings can be quantified, some or all of the following measures could be included in a calculator:

- Delayed action inlet valves,
- Reduction of water draw-offs (dead legs),
- Reduction of combination boiler warm up losses, and
- Leakage detection and prevention.

Savings from other measures such as product ergonomics, smart metering and water efficient product innovations are more difficult to quantify and may be better encouraged through other approaches.

Figure 8 shows the positive responses from the assessor and specifier stakeholder groups for the inclusion of additional water saving features in the calculator.

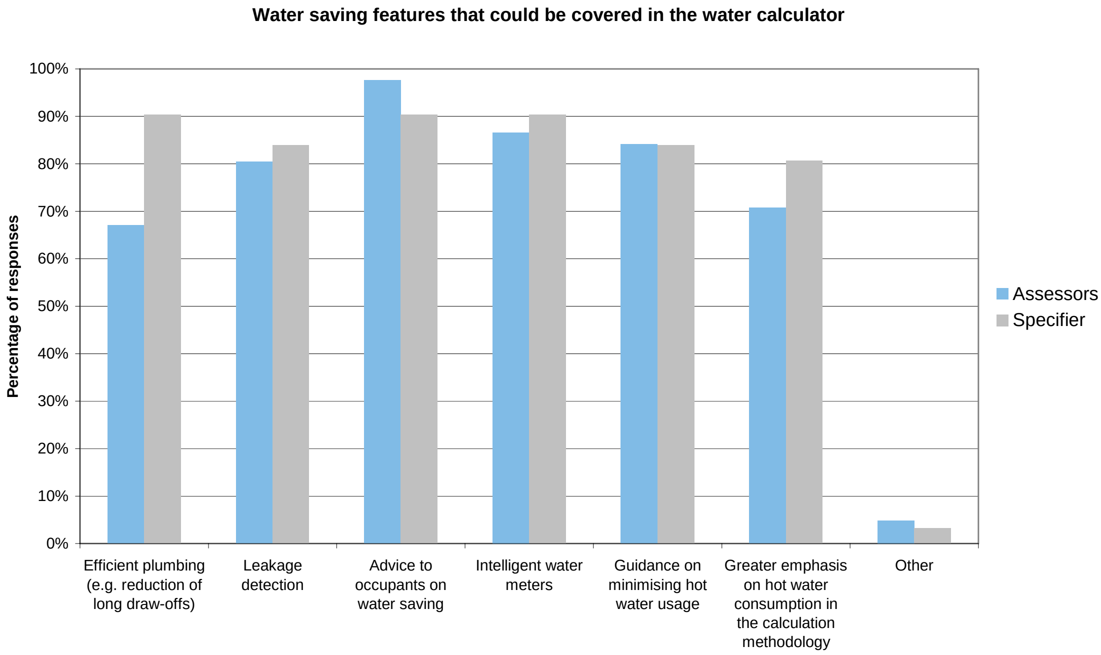


Figure 8: Assessor and Specifier group feedback on water saving features that could be included in the water calculator

The other water efficiency measures that could be added to the calculator are discussed below.

Reduced combination boiler start-up flow losses

Water is wasted as a combination boiler performs its purge and firing cycle and then warms the heat exchanger. Solutions currently on the market include the provision of a small thermal store or a 'keep warm' system where occasional firing of the boiler or electric heating keep the heat exchanger warm.

An EST report on hot water use in homes looked at the destination and volume of hot water run-offs for a small sample dataset. It found that the volume of water used by standard and combination boilers for bathroom basin, bath and washing machine was similar. However, the volume of water used at the kitchen sink in homes with combination boilers was significantly higher. The hypothetical explanation was that it takes longer for a combination boiler to achieve the higher temperatures demanded at the kitchen sink, therefore more water is run off (Martin, 2008).

It follows that boiler design and specification can have an impact on water use and reduction of start-up flow losses could be covered in the water calculator. 'Keep warm' systems are included as an option in SAP so the energy implications are addressed. This highlights a potentially complex relationship between measures to reduce water use and impacts on energy demand (see section 3.3.5).

Durability and leak avoidance

In the longer term, the robustness of an appliance (e.g. propensity to leak) will influence water use. It is questionable whether this can be included in a calculation method although the Australian BASIX system assumes 10 litres toilet valve* leakage per person per day. A

* Inlet and flush valve.

fittings based standard such as the Water Fittings Regulations could require leak detection* for non fail-safe flushing cisterns. In the absence of such a fittings based standard, inclusion of a leakage allowance in the water calculator could improve its statistical predictive accuracy.

Delayed action inlet valves

Delayed action inlet valves for WCs are mentioned in the Code Technical Guidance but there is currently no reward for fitting them nor penalty for omitting them. Whilst it could be argued that this is a matter for Water Fittings regulations, uptake of these devices could be encouraged by their inclusion in a water calculator. This would require an additional water usage to be associated with valve flushes unless a delayed inlet valve was specified. An alternative approach (which would have a similar effect) would be to require actual flush volumes to be used in the water calculator rather than nominal flush volumes. For this to be a robust solution, the testing standard for WCs such as the British Standard (BSI, 1991) or independent testing schemes such as the BRE Certification and listings of low flow WC suites (www.greenbooklive.com) would need to be modified to allow for the inclusion of additional flush volume attributable to premature filling of the cistern.

Concerns were raised by the Bathroom Manufactures' Association regarding the durability of delayed action valves. This concern was not investigated further as part of the review.

Long water draw-offs ('dead legs')

Reduced draw-offs potentially have three-fold benefits:

- Reduced energy use due to less hot water being wasted during draw-offs to reach desired temperature and to reduced heat losses from hot water pipework;
- Reduced water use due to less of both hot and cold water being drawn offs to reach desired hot and cold water temperatures;
- Improved user satisfaction due to shorter waits for desired water temperature. Especially important where low flow rate fittings such as spray taps are specified.

Long draw-offs and inefficient plumbing design are difficult to address post-construction. It is therefore important that they are included in any design stage approach if they can make a cost effective contribution to water savings. Addressing draw-offs in Building Regulations, seems particularly relevant given the dual energy and water efficiency benefits. Some of the issues with long draw-offs can be addressed through optimising pipe sizing and through the insulation of both hot and cold water pipes.

The now superseded Energy Saving Trust Advance Practice Specification (EST, 2003) recommended a maximum draw-off volume of 1.5 litres, or 10m of 15mm copper pipe. Similar figures have been suggested in the USA (EPA, 2008).

Pressure reduction on the incoming main

Delivered pressure to homes varies considerably across the UK from 1 bar to (anecdotally) 14 bar in some areas. There is an added variation in plumbing pressure within homes due to the difference between direct (mains pressure) and indirect (gravity fed) systems. Indirect system can have an internal water pressure below 1 bar. The impact of water efficiency measures is considerably affected by differences in local water pressure.

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* A number of simple technical solutions are possible but the lack of regulatory requirements means that commercial products that are suitable for the use in the UK are not currently available. Leak free siphon cisterns are however still available from most manufacturers although the trend is towards valves.

The calculator guidance currently requires the assessor to look up and enter maximum design tap and shower flow rates at 3 bar. Where actual plumbing pressure is lower, this combined with the specification of fittings with lower maximum flow rates could contribute to unacceptably low flow rates in the completed dwelling. Eventual water use may or may not be lower, depending on the strength of ‘rebound’ effects. Where higher site pressure is combined with direct plumbing, water use is likely to be higher, though not in proportion to increased pressure due to non-linearity in user-selected average flow intensity.

There is an asymmetry to the issues and possible solutions. At the high pressure end, the calculator guidance could require pressure regulation on plumbing systems and fittings fed directly from the mains (note that this on its own would do nothing to tackle the issue with low pressure sites and plumbing systems). There is no obvious solution at the low pressure end, apart from using estimated site / plumbing system pressures both for design and as the basis for looking up calculator inputs based on manufacturers’ product data (which *would* deal with both high and low pressure situations).

The WaterSense specification for new US homes sets a maximum service pressure of 4 bar to be achieved with a pressure regulating valve (EPA, 2008).

Many stakeholders, including members of the review steering group, highlighted water pressure as an important issue for the calculator.

Ergonomic product design

It is likely that good ergonomic design of fittings could help users save water. Related issues were raised by all of the stakeholder groups. For example, measures could include:

- Well designed and self explanatory dual flush WC buttons,
- Stable and clearly marked temperature settings on showers (thermostatic),
- Pause buttons on showers,
- Fast temperature response of shower mixers, and
- Taps that provide a good spray pattern at low flows but change mode for vessel or basin filling.

The savings from such measures would be difficult to quantify and so would be hard to reward within a revised calculator. Product related measure (such as dual flush button and shower mixer design) could be covered by mechanisms other than the Code such as British Standards or Water Fittings Regulations.

Expert stakeholders emphasised that shower performance is closely linked to showerhead design, particularly at lower flow rates. They noted that simply fitting flow restrictors to standard models is likely to impair performance and user satisfaction, whereas it should be possible for well-designed, low flow showers to perform as well as higher flow models.

3.3.3 Householder behaviour

The impact of behaviour on water use is widely recognised. Data analysis in the review shows great variation in water use across homes with identical sanitaryware specifications. This underlines the importance of any mechanisms that can be found to realise more water-efficient behaviours.

There is a range of technological options that may incentivise or encourage water saving behaviour. Measures such as audible leak detection, smart metering, monitoring and householder information could be rewarded in the calculator or elsewhere in the Code. It may be more appropriate to address some behavioural change incentives through mechanisms outside the Code (e.g. variable tariffs, savings information on bills).

The assessor and specifier stakeholder groups felt that more emphasis should be placed on helping occupants to understand the water saving features in their homes. Specifiers were concerned that people do not relate to "litres / person / day" with some suggesting more familiar alternative units (e.g. buckets). Stakeholders also suggested that information on water saving could be provided to occupants in a similar way as for energy efficiency, perhaps through a certificate in Home Information Packs at the time of purchase.

3.3.4 Hot water

With the continuing improvement in the thermal performance of homes the energy demand for hot water is an increasingly significant element of home energy use. The potential for energy saving by reducing household hot water use is large compared to the energy used in treatment and supply of water (Environment Agency, 2008). As such, efficient use of hot water is an important issue with dual energy and water saving benefits.

Consideration should be given to any trade-off in the calculator between hot and cold water savings for the same overall water efficiency target. Splitting the water calculator into hot and cold uses could eventually play a role in clarifying such trade-offs and incentivising hot water savings more strongly. However, the existing calculator evidence base does not contain the data to inform this split. Anglian Golden 100 data includes the percentage of centrally heated water use by microcomponent which could contribute to the design of separate algorithms for hot and cold water. However it does not identify where electric showers are fitted nor does it consider other issues such as plumbing design.

Further research is needed to establish the end use split of hot water demand in homes. It should consider whether unrestrained trade-offs as allowed in the current Code are appropriate given the relative importance of incentivising hot and cold water savings.

3.3.5 Conflicting environmental objectives – water vs. energy / carbon saving

Hot water is the main example of a wider potential conflict between energy and water saving objectives. The Environment Agency Science Report, Measurement of Domestic Hot Water Consumption in Dwellings (Environment Agency, 2008) considered the water and carbon savings from various water efficiency measures (see Figure 9). The analysis takes into consideration the hot water use of fittings and illustrates the high carbon cost of localised supply systems compared to mains water supply. The study considered a limited range of rain- and greywater systems, and calls for further research to investigate the environmental costs and benefits of these systems.

Water efficiency option	**Water Savings** Ml per year	**Carbon costs** £ '000	**Carbon savings** £ '000	**Net carbon emitted** tCO_2e '000
Water efficiency measures - model results for 1000 households over 60 years				
Metering	13 to 16	2 to 4	250 to 320	-5 to -6
Low flush toilet	9 to 12	<1 to 5	10 to 20	-0.2 to -0.3
Bath/shower/tap	3 to 15	4 to 15	50 to 200	-0.8 to -4
White goods	1	80	30	1.8
Rainwater harvesting	40	160 to 280	50	2.4 to 4.8
Greywater recycling	25	180 to 295	35	3.0 to 5.4
Variable tariffs	7	0	125	-1.5
Water audits	4	0	125	-2.5
Leakage Control - model results based on available data				
Repair leaks detected	365 to 1500	250 to 1200	300 to 1300	-1 to 2
Repair leaks reported	5730	3500	4900	-21
Water mains renewal	365	345 to 800	310	3 to 16
Service pipes renewal	365	120	310	-3
Control pressure	6200	no data	5300	-110

Figure 9 Carbon cost model results for water efficiency measures (reproduced from Environment Agency, 2008).

Carbon intensive options potentially rewarded by the current calculator method include:

- Rainwater collection,
- Greywater recycling,
- Cold water savings at the expense of hot water savings, and
- White goods selected based on water use rather than energy efficiency.

Measures not covered by the current calculator but that may raise similar conflicts include:

- Keepwarm facilities on Combi boilers, and
- Secondary circulation to eliminate hot water dead legs.

Potential conflicts between water and energy savings should be considered in a joined up way in the development of Building Regulations Part G and in the Code.

3.3.6 Occupancy

There is evidence that larger households use less water per person (e.g. Essex & Suffolk Water, undated). Many microcomponent studies do not include occupancy information and average occupancy is assumed to derive factors such as frequency of use on a per person basis from the reported per household figures. It follows that current calculator results correspond to an average household size, i.e. 2.4 people.

Many of the stakeholders consulted felt that the effects of occupancy should be taken into account as this should improve the correspondence between calculator results and measured data making the calculator more credible and more widely applicable. There was also discussion about the role that demographic information, regional location, building type, day- and night-time use, age profiles, etc. could play in a more ‘realistic’ calculator.

Others noted that the relationship between occupancy (and other factors) and household water use is complex and that including occupancy in the calculator could make it more complicated. There were also concerns that smaller homes would face tougher targets.

3.3.7 Code water section – administrative and technical issues

Design guidance for Code assessors

A common concern amongst the stakeholder groups was that the knowledge base and common practices among plumbers and designers have not kept pace with the drive for water efficiency and the technologies on the market. Potential issues identified during this review include:

- Inappropriate specification and/or installation of low-flush WC systems, ignoring site characteristics, plumbing design, and manufacturers’ technical guidance;
- Taps and showers with very low water use at the 3 bar testing pressure specified for homes with lower delivered water pressure;
- The specification of conflicting technologies such as electric showers and solar water heating, and combination boilers and very low flow rate fittings;
- The specification of products that do not meeting current British Standards;
- Confusion around interpretation of manufacturers’ technical product data. E.g. bath volumes (which may be quoted with or without displacement).

Responses to the Code assessor survey suggest that many assessors feel the Code technical guidance could include more information and tools to help them to provide good advice on water efficiency measures. Stakeholders wanted information on good design practice, emphasis on the importance of efficient and well designed plumbing systems, and encouragement for creative water saving solutions such as intelligent leak detection.

Innovation in water efficient products

In response to the adoption of the Code, sanitaryware manufacturers are developing products to help meet Code targets, increasing the number of products marketed as 'environmentally friendly' and specifically 'water efficient' or 'low water'.

Feedback from stakeholders was that they would like the Code to include a mechanism to recognise innovative products that save water.

3.4 Building on experience

3.4.1 Previous and existing UK approaches

Historical water calculators

Various water calculator based tools have been developed over the years with an aim to encourage low water use sanitaryware design in buildings. These have included the EcoHomes, BSRIA and Aquaspec calculators. The majority of historical calculators have used a microcomponent approach with differences in the end uses included, basic algorithms, and their use of fixed and variable components of water use. All came with strong disclaimers regarding data quality and assumptions.

BREEAM

BREEAM is the environmental assessment method for non-domestic and multi-residential buildings in the UK. A water calculator is included in the water efficiency section of the majority of the BREEAM schemes, with credits awarded on the basis of calculated water use per occupant per day. Occupancy is generally standardised and based on floor area, therefore in fact the benchmark is a function of water use per unit of net floor area. The calculator is based on nominal flow rates of fittings and an assumed number of uses per day. A 'standard' sanitaryware specification does not achieve any credits under the system; achieving all three credits requires installation of rain- or greywater systems.

BREEAM multi-residential differs in that the water section is based on a standards approach with minimum backstops.

Bathroom Manufacturers Association

The Bathroom Manufacturers Association (BMA) water efficient product labelling scheme identifies products that meet a set of water efficiency criteria, summarised in Table 9.

Fitting	Specification	Notes
Single flush WC	Not exceeding 4.5 litres per flush	Must comply with Class 2 of EN997
Dual flush WC	Effective flush not exceeding 4.5 litres per flush.	As above, also note that effective flush is taken to be 1 full flush and 3 reduced flushes.
Internal taps	6 litres per minute	At pressures up to 5 bar
Showers	13 litres per minute	At maximum operating pressure, or 5 bar if not known.
Baths	80 litres (at 40% of the volume to overflow)	

Table 9: BMA water efficient product labelling scheme criteria (source BMA, undated).

Waterwise Marque

The Waterwise Marque is a label "awarded annually to products which reduce water wastage or raise the awareness of water efficiency". Products must be submitted annually to maintain their status. 27 labels were awarded in 2008. To be eligible for a Marque, bathroom products must obtain the relevant BMA Water Efficiency Label.

3.4.2 International approaches

There are few microcomponent based water calculators in use globally for new build regulation. Of the countries reviewed, most use fittings-based water efficiency standards as part of building control or similar regimes for new dwellings. Information received indicates that calculation methods are not planned or necessarily seen as required in these places.

By contrast, calculation methods are often used in building environmental assessment methods. This is generally attributed to the desire to push standards and reward buildings that go beyond the current minima. We have also been advised *(in anecdotal information from LEED, BREEAM and BASIX assessors and not necessarily representing the views of the standard-setting organisation themselves)* that this allows more flexible design options to be applied to a range of buildings, where a single target may not be appropriate.

Two prominent examples of water calculators for new homes are the system proposed for larger buildings in the LEED Neighborhood Development scheme and BASIX in Australia.

LEED (USA)

LEED for Neighborhood Development (currently being piloted and expected to be available in 2009, and not to be confused with LEED Homes) proposes that buildings of over three storeys are assessed by calculating water savings against a 'typical' water use baseline for the building set based on the US Federal Energy and Regulatory Commission, Energy Policy Act (EPA)(1992) fittings performance requirements.

LEED for Neighborhood Development assessment for large buildings	
Baseline	'typical' water use baseline for the building using the US Federal Energy and Regulatory Commission, Energy Policy Act 1992 fixture performance requirements
1 point awarded	20% below the baseline
2 points awarded	30% below the baseline
3 points	30% below the baseline + land irrigation using rainwater, recycled wastewater, recycled grey water or non-potable municipal water, or alternatively use no irrigation after establishment (one year after planting).

Table 10: Proposed LEED for Neighborhood Development water use assessment.

LEED for New Construction (LEED-NC) was primarily designed as an assessment method for new office and commercial buildings, however it has also been used for residential buildings of over 4 storeys. Although not directly comparable in terms of the type of building to which it applies, this system is of interest to this study because it does use a water calculator. Similarly to LEED for Neighborhood Development, a baseline is calculated, based on US EPA minimum fittings standards. Credits are achieved for the design based on percentage improvements over the base case.

A significant feature of the LEED-NC calculator is that user behaviour constants within the microcomponent algorithms (duration and uses per day) can be modified by the assessor. These modifications need to be justified and approved by LEED. Such modification of 'use factors' may be more appropriate in commercial contexts (where factors such as flow duration of a push-button tap can be reasonably estimated) than in homes.

BASIX (Australia)

In Australia, regulation of the performance of new homes is state-driven. The New South Wales Government introduced, the Building Sustainability Index (BASIX), a certification system that sets targets for water efficiency and greenhouse gas emissions depending on location and building type. BASIX is implemented as an online software program that assesses a design against a series of energy and water targets. Modifications can then be made to the design to meet the required targets before a certificate is printed, showing the design specifications.

The main premise behind BASIX is that it is flexible, allowing multiple options to achieve the targets, and maintaining an element of design flexibility and personal choice. BASIX operators confirm that this was one of the major reasons for the selection of a calculator approach and acceptance of the concept when it was launched (Ridgewell, 2008), and that the flexibility of the calculation methodology means that no particular fitting is compulsory.

Basix targets are set relative to current New South Wales average values of residential potable water use per person, taken from census and statistical data. The benchmark for water is equivalent to **90,340 litres of potable water per person per year (247.51 litres per person per day**). The targets to be achieved vary depending on location and climatic factors, but the maximum target is a 40% reduction – equivalent to a **target water consumption of 148.51 litres per person per day**.

A percentage target has been used so that targets can be altered relatively simply in line with policy or technology changes. Targets can be changed without altering the calculator mechanism or the enabling legislation (Ridgewell, 2008). This is not the case with legislation that limits the maximum water use of fittings, as in the US EPA, for example.

The BASIX internal water use calculation is broken down into eight microcomponents:

- shower
- bath
- bathroom basin
- toilet
- washing machine
- laundry trough
- kitchen sink and
- dishwasher

Of these eight, it is assumed that water use in the bath and laundry trough is constant, irrespective of sanitaryware (and bath volume is not considered) (Schlunke, undated). Water use for the other six microcomponents can be reduced through efficiency measures.

The BASIX system relies heavily on an 'external' water efficiency rating and labelling system called WELS (see Annexes). This system allows the user to construct a model using regulated products with defined flow or flush volumes.

Since implementation, a monitoring program of 100 BASIX compliant designs has been undertaken. All information entered into the online program is also recorded for statistical analysis. In terms of water efficiency, all 100 monitored homes have efficient shower heads and taps and rainwater tanks, the majority of which provide water for WC flushing, clothes washing and garden watering (New South Wales Government Department of Planning, undated). Other efficiency measures vary.

Anecdotal information from BASIX developers suggests they believe its success relies heavily on the WELS system as a robust method for rating product water efficiency and performance. The person contacted for this study suggested that without WELS, there would be no way of ensuring that the specification applied in BASIX related to practical and available products (Ridgewell, 2008). The dependence of BASIX on WELS was noted by others consulted in the study (Thornton, 2008).

A great deal of information is collected on BASIX as a result of the online inputs, and the intention is to continue to use this to analyse and report on the system in the future. The availability of data on calculated water savings is seen as one of the major strengths of BASIX. Monitoring studies can compare measured with predicted water use and apply this to refining the calculation model in future.

3.4.3 Key themes from stakeholder engagement

The main themes arising from the stakeholder engagement are summarised below.

Householder acceptability

Most stakeholders agreed that any product fitted with the aim of improving water efficiency in homes should be "fit for purpose" i.e. the performance of the product should meet customer expectation.

Achievable targets

The overwhelming feedback from all of the surveys and workshops was that while saving water is an objective that should be championed, it is very difficult to meet current targets with products that are acceptable to householders. In its current form, the methodology encourages the specification of fittings that are unpopular and likely to be replaced.

Fitting and appliance labelling

A number of stakeholders felt that an appliance rating or labelling system may be a better approach than a calculator due to the uncertainties surrounding behaviour and the ability to influence both the new and retrofit markets.

Credit for innovation

A common criticism was that the current methodology is inflexible and does not encourage or reward novel or innovative solutions.

Revising the calculator

It is clear that the majority of stakeholders believe that the current methodology needs major revision.

Transparency of the calculator methodology

Stakeholders wanted greater transparency about the sources of data underpinning the ‘use factors’ in the calculator. The expert group highlighted that:

- A major issue with a microcomponent method is lack of validated data,
- Good quality research into water use in homes is required and it would be beneficial if extensive, post occupancy monitoring was carried out, with results published.

The Code was seen as a route for generating data by awarding credit(s) to incentivise monitoring, the results of which could inform future reviews and Code updates.

Stakeholder involvement in the calculator review

The feedback from all sessions was that the opportunity to be involved in the calculator review was greatly appreciated. Continuing involvement, perhaps as part of future revision cycles, would build trust and enhance the calculator’s credibility amongst stakeholders.

4 Illustration of a revised calculator

This section illustrates a set of revised water calculator algorithms designed to tackle the actual and conceivable problems with the current calculator discussed previously.

4.1 Calculator algorithms

Revised calculator algorithms are set out below. Bold blue text indicates inputs to the calculator.

WCs – revised algorithm

Daily water use per person = **Average flush volume** x uses per person per day
Average flush volume = Proportion of full flush x full flush volume + proportion of part flush x part flush volume

Bidets – no separate calculation

Daily water use per person = Zero additional water use

Basin taps – revised algorithm

Daily water use per person = fixed daily water use per person + variable daily water use per person
Fixed daily water use = Some proportion of default tap water use (to be determined through future research - illustration uses 10%) Variable daily water use per person = **Weighted average*** design tap flow rate*** x uses per person per day x average duration per use x average flow intensity**
*Design tap flow rate = maximum tap flow rate at system water pressure (based on manufacturer's information and best available information on system water pressure). This is the flow rate of a mixer tap, or the flow rate of individual hot and cold taps (assuming identical flow rate characteristics - where the flow rates form the taps are different the worst flow rate should be used). **Average flow intensity is the percentage of design tap flow rate that users select in average use. ***Weighted average of multiple design tap flow rates calculated as follows:

Basin specification information		Weightings				Results
	Tap design flow rates (in descending order)	Number of basins				
		1	2	3	more	
Basin 1		100%	60%	50%	40%	
Basin 2			40%	30%	30%	
Basin 3				20%	20%	
More basins					10%	
					Weighted average	

Table 11. Weighted average design tap flow rate - lookup table.

Showers – revised algorithm

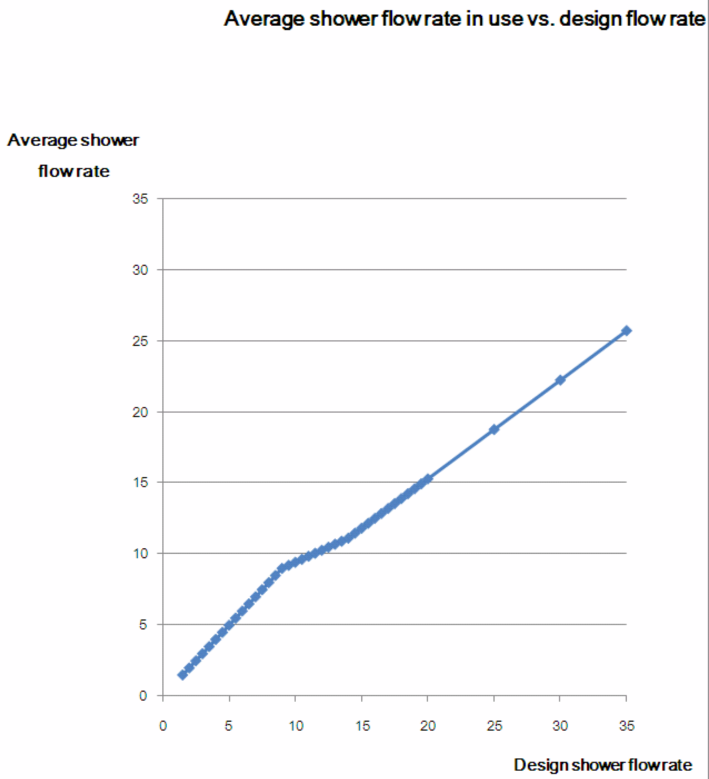
Daily water use per person = **Weighted average*** design shower flow rate*** x uses per person per day x average duration per use x (non-linear) average flow intensity**
*Design shower flow rate = maximum shower flow rate at system water pressure (based on manufacturer's information and best available information on system water pressure). This is the flow rate at point of use. **(non-linear) average flow intensity = average flow intensity for the specified design shower flow rate (see look-up table below)

Shower specification information		Weightings			Results
Shower design flow rates (in descending order?)		Number of showers			
		1	2	3	
Shower 1		100%	60%	50%	
Shower 2			40%	30%	
Shower 3				20%	
				Weighted average	

Table 12. Weighted average design shower flow rate - lookup table.

Non-linear average flow intensity for shower

	Design shower flow rate	Average shower flow rate	Assumed flow intensity
Electric showers	1.5	1.5	100%
	2.0	2.0	100%
	2.5	2.5	100%
	3.0	3.0	100%
	3.5	3.5	100%
	4.0	4.0	100%
	4.5	4.5	100%
	5.0	5.0	100%
	5.5	5.5	100%
	6.0	6.0	100%
	6.5	6.5	100%
	7.0	7.0	100%
	7.5	7.5	100%
	8.0	8.0	100%
	8.5	8.5	100%
	9.0	**9.0**	**100%**
Mixer showers	9.5	9.2	97.0%
	10.0	9.4	94.3%
	10.5	9.6	91.8%
	11.0	**9.9**	**89.5%**
	11.5	10.1	87.5%
	12.0	10.3	85.6%
	12.5	10.5	83.9%
	13.0	10.7	82.3%
	13.5	10.9	80.8%
	14.0	**11.1**	**79.5%**
Power showers	14.5	11.5	79.1%
	15.0	**11.8**	**78.8%**
	15.5	12.2	78.5%
	16.0	12.5	78.2%
	16.5	12.9	78.0%
	17.0	13.2	77.7%
	17.5	13.6	77.5%
	18.0	13.9	77.3%
	18.5	14.3	77.0%
	19.0	14.6	76.8%
	19.5	14.9	76.7%
	20.0	15.3	76.5%
	25.0	18.8	75.1%
	30.0	22.2	74.2%
	35.0	25.7	73.5%



The slopes of the first line sections (0 - 9) is 1 suggesting low-flow electric showers are used at their labelled flow rate. The subsequent line sections take account of evidence that average mixer shower flow rates are 9.85 litres/minute, and pump assisted shower average flow rates are 11.8 litres/minute. However, as no corresponding average design flow rate is reported for these shower types, there is considerable scope to design the curve to drive desired specification choices. As such, the slopes of the mixer and power shower line sections (9 -14, 14 - 20+) were selected to reflect non-linearity in flow intensity while intending to retain a strong disincentive for fitting power showers.

Bold red values are taken from MTP as the average flow rates for mixer and pump assisted (power) showers. Selection of design shower flow rate corresponding to average shower flow rate is a designer judgement.

Figure 10. Non-linear average flow intensity for showers.

Kitchen (& utility) taps – revised algorithm

Daily water use per person = fixed water use per person per day + variable water use per person
Fixed water use = constant (see note) Variable water use per person = **Weighted average** design tap flow rate*** x uses per person per day x average duration per use x average flow intensity***
*Design tap flow rate = maximum tap flow rate at system water pressure (based on manufacturer's information and best available information on system water pressure). This is the flow rate of a mixer tap, or the flow rate of individual hot and cold taps (assuming identical flow rate characteristics). **Weighted average of multiple design tap flow rates calculated as for basin taps. ***Average flow intensity is the percentage of design tap flow rate that users select in average use.

Baths – revised algorithm

Daily water use per person = **Weighted average bath volume to overflow*** x uses per person per day x average fill proportion
*Weighted average bath volume to overflow = total volume of the bath to overflow when empty

Bath specification information		Weightings				Results
	Bath design volume (in descending order)	**Number of baths**				
		1	**2**	**3**	**more**	
First bath (largest volume bath)		100%	60%	50%	40%	
Bath 2			40%	30%	30%	
Bath 3				20%	20%	
More baths					10%	
					Weighted average	

Table 13. Weighted average bath fill volume to overflow - lookup table.

Washing machine

Daily water use per person = **Water use per cycle on standard setting** x uses per person per day

Dishwasher

Daily water use per person = **Water use per cycle on standard setting** x uses per person per day

Water softeners – revised algorithm

Daily water use per person (if present) = **S** x total mains water demand
S = % of capacity per regeneration Total mains water demand = demand for all fitting and water using equipment including the allowance for external water use – water supplied by rain or grey water systems

Waste disposal units – added to calculator

Daily water use per person (if present) = average water volume* x uses per person per day**
* Fixed volume of water with average use (MTP suggests 2.46 litres/use) ** uses per person per day (MTP suggests 1.25 uses per person per day (taking their reported 3 uses per household per day and assuming average occupancy of 2.4)).

Rainwater and Greywater – revised algorithm

Calculator algorithm should be in line with the BS design calculations.

4.2 Results for the revised calculator illustration

4.2.1 Calculator inputs and factors

The majority of factors used in the revised calculator illustration are shown in Table 14.

	Current calculator		Revised calculator illustration				
Installation type	Use Factor	No of uses/ person/day	Flow rate modifier	Average duration or ratio of use	WRc/MTP use per day*	Average flow/use intensity	fixed use (litres)
WC (fixed flush)	1.0	4.8	1	1.0	4.20	1	
WC (dual flush)	0.33	4.8	1	0.33	4.20	1	
	0.67	4.8	1	0.67	4.20	1	
Bidet	1.0	2.0	1		0.00		
Basin taps	0.67	7.9	0.67	0.43	8.95	0.39	1.49
Showers	5.0	0.6	1	5.6	0.74	Lookup	
Baths	0.4	0.4	1	1.0	0.26	0.50	
Kitchen sink taps	0.67	7.9	0.67	0.43	3.03	0.29	10.36
Washing machine	1.0	0.34	1	1.0	0.34	1	
Dishwasher	1.0	0.3	1	1.0	0.29	1	
* based on occupancy of 2.4 and 5% reduction to account for householder absence							

Table 14. Comparison of factors in the current calculator vs. those in the revised illustration.

<u>**Equipment specifications examples selected from parametric analysis**</u>

The equipment specifications used for the comparison of the current/original and revised calculator are shown in Figure 11.

Representative specifications	WCs	Bidet	Wash hand basin taps	Shower	Bath	Kitchen sink taps	Washing machine	Dishwasher
Maximum	9.0		20.0	0.0	250.0	25.0	110.0	50.0
Code Default	6.0		12.0	14.0	225.0	12.0	49.0	13.0
New (bath only, bidet)	6.0	2.64	9.0	0.0	225.0	12.0	49.0	13.0
Typical new	6.0		9.0	12.0	225.0	12.0	49.0	13.0
New (dual flush, shower only)	6/4.5		9.0	12.0	0.0	12.0	49.0	13.0
Best new (bath w. shower)	4.5/2.5		6.0	6.0	165.0	8.0	40.0	10.0
Best new (shower only)	4.5/2.5		6.0	6.0	0.0	8.0	40.0	10.0
Minimum	0.0		2.0	1.5	0.0	6.0	30.0	7.0

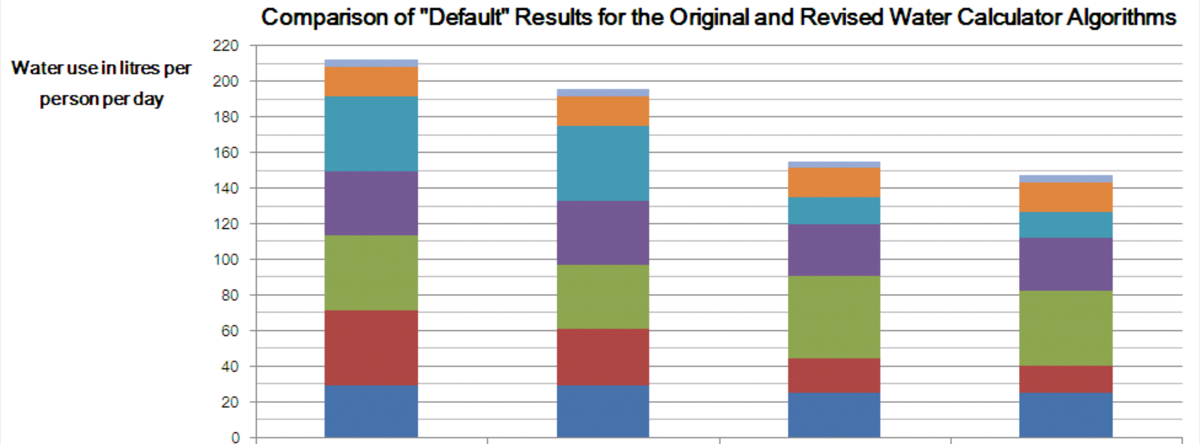
Figure 11. Equipment specifications for selected specifications.

Using the factors set out in Table 14 and applying the new algorithms to the same set of default and ‘typical’ specifications as before resulted in the changes in results set out in Table 15 and illustrated in Figure 12 toFigure 15.

‘Default’	‘Typical’	Revised ‘default’	Revised typical
212.0	195.5	155.2	147.2

Table 15. Comparison of typical results from the current calculator with those from the revised calculator illustration.

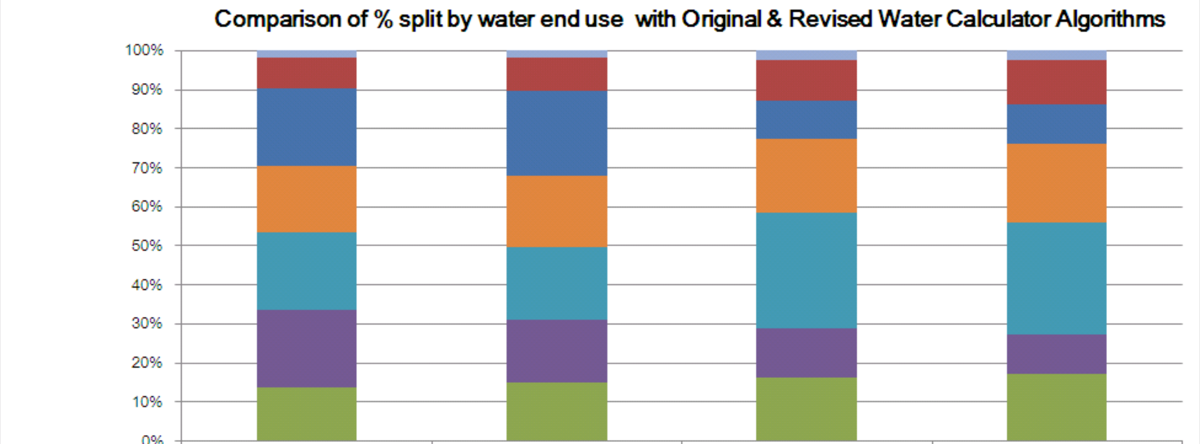
Results from the revised calculator algorithm illustration for typical sanitaryware are lower than the original algorith and closer to the UK average figure.



	Original Algorithm & Defaults	Original Algorithm Revised Defaults	Revised Algorithm Original Defaults	Revised Algorithm & Code Defaults
Dishwasher	3.9	3.9	3.7	3.7
Washing machine	16.66	16.66	16.49	16.49
Kitchen sink taps	42.34	42.34	14.91	14.91
Baths	36.00	36.00	29.67	29.67
Showers	42.00	36.00	45.87	42.36
Basin taps	42.34	31.76	19.39	14.91
WCs (all)	28.80	28.80	25.08	25.08

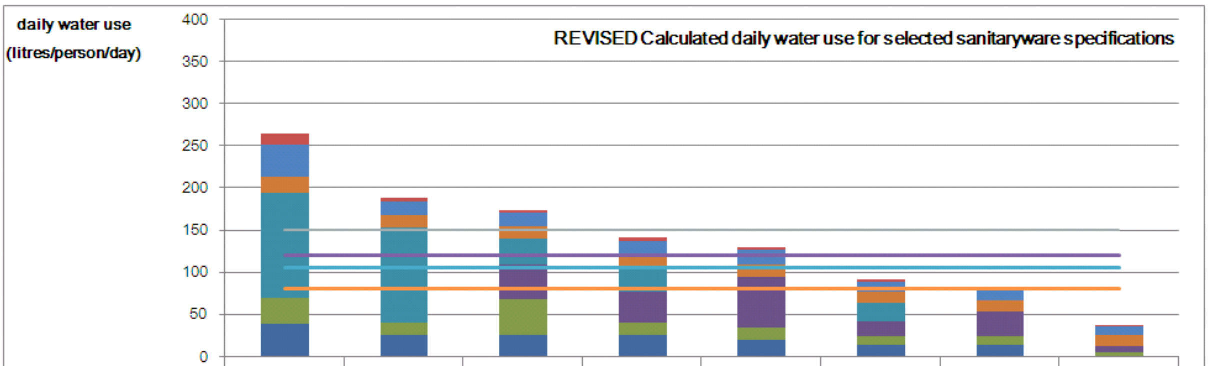
Figure 12. 'Typical' results for the current (original) calculator and revised calculator illustrations

Figure 12 and Figure 13 illustrate that the main differences in water use relate to kitchen sink and bathroom tap use and showers.



	Original Algorithm & Defaults	Original Algorithm Revised Defaults	Revised Algorithm Original Defaults	Revised Algorithm & Code Defaults
Dishwasher	2%	2%	2%	3%
Washing machine	8%	9%	11%	11%
Kitchen sink taps	20%	22%	10%	10%
Baths	17%	18%	19%	20%
Showers	20%	18%	30%	29%
Basin taps	20%	16%	12%	10%
WCs (all)	14%	15%	16%	17%

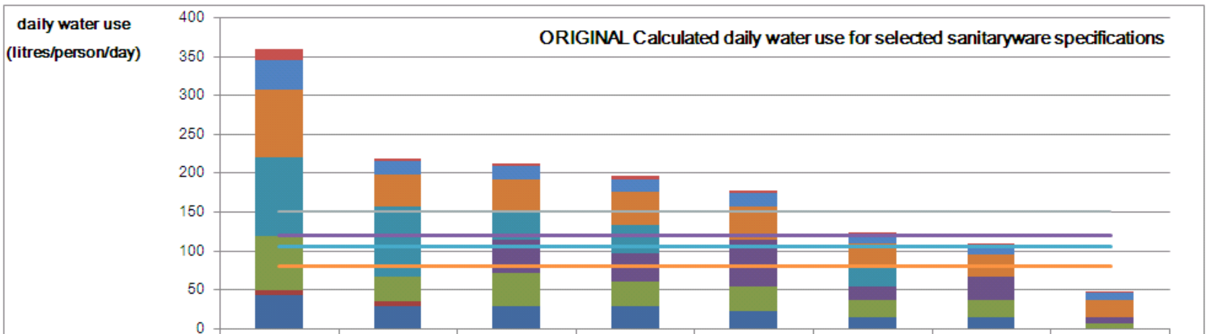
Figure 13. 'Typical' end use split for the current (original) calculator and revised calculator illustrations



sanitaryware specification	Maximum	New (bath only, bidet)	Code Default	Typical new	New (dual flush, shower only)	Best new (bath w. shower)	Best new (shower only)	Minimum
Dishwasher	14.3	3.7	3.7	3.7	3.7	2.9	2.9	2.0
Washing machine	37.0	16.5	16.5	16.5	16.5	11.8	11.8	10.1
Kitchen sink taps	19.8	14.9	14.9	14.9	14.9	13.4	13.4	12.6
Bath	125.0	112.5	29.7	29.7	0.0	21.8	0.0	0.0
Shower	0.0	0.0	42.0	36.0	60.0	18.0	30.0	7.5
Basin taps	31.3	14.9	42.3	14.9	14.9	10.4	10.4	4.5
WCs	37.6	25.1	25.1	25.08	19.5	12.8	12.8	0.0
UK average	150	150	150	150	150	150	150	150
CSH L1&2	120	120	120	120	120	120	120	120
CSH L3&4	105	105	105	105	105	105	105	105
CSH L5&6	80	80	80	80	80	80	80	80

Figure 14. Revised calculator results for selected sanitaryware specifications

Figure 14 shows that under the revised algorithm illustrated with these factors, the best new bath + shower specification can reach Code levels 1-3 with the proposed user acceptability limits.



sanitaryware specification	Maximum	New (bath only, bidet)	Code Default	Typical new	New (dual flush, shower only)	Best new (bath w. shower)	Best new (shower only)	Minimum
Dishwasher	15.0	3.9	3.9	3.9	3.9	3.0	3.0	2.1
Washing machine	37.4	16.7	16.7	16.7	16.7	11.9	11.9	10.2
Kitchen sink taps	88.2	42.3	42.3	42.3	42.3	28.2	28.2	21.2
Bath	100.0	90.0	36.0	36.0	0.0	26.4	0.0	0.0
Shower	0.0	0.0	42.0	36.0	60.0	18.0	30.0	7.5
Wash hand basin taps	70.6	31.8	42.3	31.8	31.8	21.2	21.2	7.1
Bidet	5.28	5.28						
WCs	43.2	28.8	28.8	28.8	22.4	14.7	14.7	0.0
UK average	150	150	150	150	150	150	150	150
CSH L1&2	120	120	120	120	120	120	120	120
CSH L3&4	105	105	105	105	105	105	105	105
CSH L5&6	80	80	80	80	80	80	80	80

Figure 15. Current calculator results for selected sanitaryware specifications

5 Conclusions and recommendations

The conclusions of the review and related recommendations are set out below.

5.1 Rationale of the Code water section

5.1.1 Code water principles

In our view it would be helpful if the Code included a clear rationale or statement of the principles that underpin the water section and the specific objectives that guide the design of the water calculator. This would establish the relative priority assigned to competing objectives and constraints. As well as guiding design and modification of the calculator, the principles and objectives would be a basis for explaining the focus and limitations of the calculator and for managing stakeholders expectations.

The following calculator objectives have guided the design of the revised calculator illustration and the drawing up of conclusions and recommendations in this review:

- To drive design that, in combination with water-saving householder behaviour, would reduce water use while maintaining the functionality and usability of sanitaryware, associated plumbing, drainage, and other connected systems*.
- To incentivise measures in proportion to their potential to deliver water savings.
- To allow design flexibility, which implies there should be a range of feasible options to reach established Code level targets, particularly mandatory target levels.
- To encourage innovation in the design of sanitaryware, plumbing and other connected systems.
- To achieve a reasonable statistical correlation between calculator results and measured water use.

5.1.2 Water efficiency hierarchy

The aim of a water hierarchy would be to encourage implementation of the most effective water efficiency measures. A possible water hierarchy is illustrated in Table 16.

Type	Description	Examples
Demand reduction	Reduce water use by eliminating unnecessary demand generators	e.g. jacuzzis;
	Reduce unnecessary water use	e.g. running basin taps while brushing teeth, delayed action inlet valves;
	Reduce non-essential water use for necessary uses	e.g. shorter showers, dual flush WCs;
Water supply	Water supply displacing mains water	e.g. rain and grey water.

Table 16. An illustrative water hierarchy

A feature would be that the high priority measures at the top of the hierarchy are the best – the ones that save the most water at least cost and risk. It follows that measures lower in the hierarchy provide less cost effective savings; this is not intended to imply that implementing them is a demonstration of greater commitment. On the contrary, as with the waste hierarchy, the aim is to achieve related targets as far as possible using the best solutions, and to only adopt less good solutions where really necessary.

* E.g. boilers

Immediate practical applications of a water hierarchy could be to constrain the water saving measures that can be applied to meet particular Code levels. For example, measures to achieve Code levels 1 and 2 could be limited to demand reduction, and higher levels could require an equivalent minimum contribution from demand reduction measures. There is a wide range of alternative or complementary approaches using a hierarchy.

Recommendation 1. Establish Code water principles, calculator objectives, and a water hierarchy to guide ongoing development of the Code approach to water efficiency.

5.2 Reviewing the Code water calculator

5.2.1 Microcomponent basis

A microcomponent calculator approach is reasonable in principle and research data makes it feasible in practice. Household and per person water use reported by microcomponent studies are similar to those found in longer term monitoring studies. However, care must be taken when applying the results from studies to calculator design, and there are many ways that the evidence base for a water calculator can be improved.

5.2.2 Elements of a consistent Code calculator

The changes in water use achieved by applying water efficiency measures Three elements of a water calculator need to be mutually consistent to be effective:

- 'Typical' results – calculator results for a 'typical' sanitaryware specification;
- Water savings* – The reduction in water use reflected in calculator results from applying the range of available water-efficient sanitaryware and equipment;
- Targets – Code water target levels.

The proposed principle that there should be a reasonable statistical relationship between calculator results and measured water use provides a starting point for considering the effectiveness and consistency of the current calculator.

5.2.3 Comparison of calculator results with measured water use

<u>'Typical' Calculator results vs. average UK household water use</u>

Average water use for UK households is ~150 litres / person / day. Results from the Code water calculator for 'code default', and 'typical new' sanitaryware specifications are 212.0 and 195.5 litres / person / day respectively. This comparison suggests calculator results are broadly ~45 – 60 litres / person / day (~30% – 40%) higher than average. The scale of difference means cannot be explained by any inherent shortcomings in the comparison.

<u>Calculator results vs. measured household water use</u>

Supporting the general comparison above, Table 17 shows that, for households where data on both sanitaryware specification and measured water use is available, average calculator results are at least 60 litres / person / day higher than measured water use.

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* Strictly, the calculator calculates water use by microcomponent and not water savings from efficiency measures. References to savings should be read as the difference in calculated water use between the 'typical' fitting and an alternative with lower calculated water use.

	Comparison for All datasets				Comparison excluding BedZED			
	Calculated	Measured		Difference	Calculated	Measured		Difference
Dataset size	373				308			
Median	187.8	105.8		-78.6*	195.0	113.6		-74.9*
Average	186.6	121.2		-65.4	194.0	131.6		-62.4
No. above average	192	142	38%	-	156	109	35%	-
No. Below 80	0	94	25%	-	0	50	16%	-

This is the median of the differences between calculated results and measured water use for each household (rather than the difference between the values in the two columns to the left).

Table 17. Summary comparison of calculator results for know sanitaryware specifications vs. measured household water use.

Conclusions from comparison of calculated vs. measured water use

The comparisons suggest that calculator results for 'code default' or 'typical' sanitaryware specifications are at least ~45 – 60 litres / person / day too high. They do not correspond with average daily water use reported for the UK as a whole or measured in either microcomponent studies (on which the calculator is based) or longer term monitoring studies. A similar gap emerges when calculated results for households with known sanitaryware are compared against measured water use.

Current scope for water savings

The difference between calculated typical water use and successive Code water levels is currently very large. Regardless of other considerations, the overall level of water savings implied by the difference between 'typical' result and Code levels is not supported by the evidence from microcomponent and other water use studies.

The reductions in calculated water use resulting from the specification of water-efficient (compared to 'typical') sanitaryware are also potentially large. This makes it theoretically possible to reach Code water levels 1-4 in the current calculator by specifying water-efficient sanitaryware. Reaching higher code targets is also possible, usually requiring installation of rain or grey water systems. I.e. 'typical' results, water savings, and targets are mutually consistent under current calculator algorithms and Code methodology.

Current scope for savings with user acceptability limits

The review looked at current calculator results if minimum limits to calculator inputs are established. With these limits a sanitaryware specification that reaches Code level 1 with the current calculator is essentially a 'best acceptable' specification. Code level 2 cannot be reached without rain or grey water systems and levels 3+ cannot be achieved at all.

Conclusions on scope for water savings

The water savings implied by the difference between the current 'typical' calculator result and Code levels are very large; there is no evidence that this scale of savings is credible. The Code allows a wide range of input values for flow rate and volume per use to be entered with no minimum limits, and all reductions are rewarded by the calculator. The temptation is for specifiers to push beyond the limits of user acceptability to meet Code targets particularly if fittings can subsequently be easily modified by householders. Approaches elsewhere (WaterSense) set minimum limits on flow rates consistent with the principle that they must not "negatively impact overall user satisfaction".

5.3 Revising calculator algorithms

The main role of the calculator is to drive water efficient fittings, but stakeholders expect a reasonable statistical correlation between calculator results and measured outcomes.

5.3.1 Revisions to algorithms that will affect 'typical' results

The review identified evidence to support changes to calculator algorithms that would reduce 'typical' calculator results:

Average flow intensity

The largest part of the difference between calculated and measured water use is likely to be due to an underestimation of two related things:

- Overestimation of average flow intensity – users rarely use fittings like taps and showers at their maximum flow rate. Average flow intensity is the term adopted in this review (and proposed for the calculator) for the ratio between the average flow rate selected by users and the specified maximum design flow rate of fittings such as taps and showers. The current calculator was revised to include a 2/3 "use factor" to address flow intensity, but in our view this does not full account for the effect. The average measured flow rate of a 9 litre per minute tap may be closer to 4 litres per minute than to 6 litres per minute as assumed in the current calculator.
- Non-linearity of average flow intensity – the tendency that, as the design flow rate of a fitting such as a tap or shower increases, householders use them at a lower percentage of their maximum flow. E.g. the average flow selected for a 6 litre per minute electric shower might be 6 litres per minute (100%), for a 12 litre per minute mixer shower it might be 10 litres per minute (~85%), and for a 20 litre per minute "power shower" it might be 15 litres per minute (~75%) – i.e. there is a non-linear relationship between user selection of flow rates relative to maximum flow rate of the fitting.

Revised frequencies of use factors

Part of the difference between calculated and measured water use can be explained by the derivation of frequency of use values in microcomponent studies. Analyses systematically exclude valid data corresponding to householders being away from home. Including the data would result in lower frequencies of use implying lower long-term average water use.

The review suggests that reliance on Identiflow microcomponent study data leads to an overestimation of frequencies of use by up to 15%, i.e. actual frequencies of use may be 85% of the reported values. The actual extent of overestimation is likely to be lower, but there was insufficient reported information to determine a more accurate figure. The revised calculator algorithms have been illustrated assuming frequencies of use modified to 95% of those reported in the source studies.

The review identified an updated Identiflow microcomponent dataset of 'new' properties: WRc CP337. This forms the basis of a published Market Transformation Briefing Note (Market Transformation Programme, 2008b) and frequency and duration of use factors proposed in this study are derived from this information.

Frequency of use factors are critical to the functioning of the calculator. It should be possible to establish the modified, long term average frequencies of use by re-analysing existing datasets and changing the approach to analysis and reporting of microcomponent studies as part of future research.

Bidets

The review team supports the view of the majority of the expert stakeholder group that bidets should not be considered to give rise to a fixed quantity of additional water use. The rationale is that where bidets are used they can fulfil the same function at least as efficiently as alternatives.

Conclusions on factors affecting 'typical' calculator results

The high 'typical' calculator result is largely attributable to inadequate allowance for average flow intensity, i.e. the fact that on average fittings are used at much below their design maximum flow rate. The higher the design maximum flow rate, the lower the average flow intensity is likely to be. This is particularly important for showers which have a wide range of possible flow rates, and this non-linear effect is also not addressed in the current calculator. Another contributory factor is the overestimation of frequency of use factors resulting from adoption of figures from microcomponent studies without modification to allow for analysis in those studies that removes data corresponding to householder absences.

Recommendation 2. Modify the calculator so the result for 'typical' sanitaryware is 135 – 150 litres / person / day.

- **a. Update frequency and duration of use factors used in Code water calculator algorithms based on WRc CP337.**
- **b. Revise Code water calculator algorithms to include average flow intensity for showers and reduce the average flow intensities for taps from the current 2/3 'use factor'.**
- **c. Revise Code water calculator algorithms to include non-linear average flow intensity for showers.**
- **d. Remove bidets from the Code water calculator.**

Recommendation 3. Ensure current and future Code water calculator revisions account for microcomponent study methodology when adopting or deriving factors for use in calculator algorithms.

5.3.2 Revisions to algorithms that will affecting water savings

A calculator with a lower 'typical' result (as recommended above) implies that calculated reductions from water efficiency must also be smaller. Each of the microcomponents to be included in a revised calculator that has the potential to affect (mainly reduce) the scope for water savings is considered below along with options for changes to associated calculator algorithms. Introduction of minimum limits is discussed separately and is not reiterated for each fitting.

Fitting averaging for taps, showers and baths

There are a number of reported or conceivable 'trade-off anomalies' in the current calculator. One such anomaly is potential 'game playing' by installing multiple fittings to reduce average volume/use or flow rate and hence calculated water use. Stakeholders did not volunteer concerns about fitting averaging.

The treatment of flow rate averaging with respect to different types of taps (mixers, separate hot and cold taps with different flow rates) at the same basin and showers (mulit-setting shower heads), poses interpretational challenges for assessors and issues of consistency and quality assurance for the Code. These are not affected by the actual averaging method.

The review looked at various approaches and algorithm designs to address this issue including 'worst fitting', banded fittings, separation of washbasin and hand basin calculations, and weighted averaging. For each algorithm it considered:

- Likely effectiveness in reducing conceivable 'game playing';
- Likely effectiveness in increasing or maintaining incentive for water efficient design (based on the review team's judgement on preferred specification outcomes);
- Additional complexity and hence scope for unpredictable outcomes.

The algorithms for taps, showers and baths in the revised calculator illustration use a weighted average design flow rate or fill volume as shown for a generalised fitting in Table 18. Weightings for each type of fitting were based on balancing the three considerations above and, as with the current simple averaging approach, are not evidence based.

[Fittings] specification information		Weightings				Results
[fittings] design flow rates/volumes (in descending order)		Number of [fittings]				
		1	2	3	more	
[Fitting] 1	12	100%	60%	50%	40%	6
[Fitting] 2	9		40%	30%	30%	2.7
[Fitting] 3	2.8			20%	20%	0.56
More [Fittings]					10%	
					Weighted average	**9.3**
					Average (for comparison)	7.9

Table 18. Weighted average design [fitting] flow rate / volume – lookup table.

Basin taps

The current calculator methodology effectively assumes that all tap water use is 'flow-based'. The UK literature and international calculation and specification-based approaches acknowledge that a proportion of basin use and some if not all kitchen sink use is functional, 'event-based' use (to fill vessels, the sink/basin, for cooking and drinking, etc.).

The review did not identify evidence that would serve as the basis for setting a fixed proportion of water use for basin taps (covering washbasins in bathrooms and hand basins in WC rooms). The revised calculator illustration assumes 10% fixed use at basin taps based on the view that it was important to establish the principle of fixed water use at basin taps in the calculator algorithm. This slightly reduces the scope for water savings from measures that reduce basin tap flow rates.

Kitchen taps

Future Water (DEFRA, 2008) reports that around drinking and cooking accounts for 7% of average per person water consumption. The review has interpreted this as 7% of average UK daily water use of 150 litres / person / day, i.e. 10.36 litres / person / day. This was used to derive a revised frequency of use factor for kitchen taps. The fixed proportion of water use accounts for around 80% of 'typical' kitchen tap water use. This significantly reduces the scope from measures that reduce kitchen tap flow rates.

Showers

The review identified issues for showers relating to non-linear average flow intensity and fitting averaging. These have been discussed above and the solutions are implemented in the revised calculator illustration.

Baths

The review identified issues for baths relating to fitting averaging and interpretation of manufacturers' data on fill volume to overflow.

Conclusions on microcomponent algorithms affecting water savings

The review identified conceivable potential 'game playing' related to averaging of multiple basin and sink tap, shower and bath fittings. Of the options looked at, weighted averaging was considered to provide a good balance between reducing the potential for 'game playing', maintaining incentives for water efficient specification, and avoiding additional calculator complexity.

There is evidence suggesting a large proportion of water use at kitchen taps and some of the water use at other internal taps is a relatively fixed volume (events such as filling a vessel or basin) and not dependent on flow rate. There was stakeholder support for introducing a fixed volume element to the calculator algorithms for taps, and examples of this approach were found in the review of previous UK and international water calculators.

Recommendation 4. Modify calculator algorithms to reduce water savings scope.

a. **Where fittings have varying specifications, use weighted averages in water calculator algorithms for: design flow rate for multiple basin taps; design flow rate for multiple kitchen/utility room taps; design flow rate for multiple showers; and fill volume to overflow for multiple baths.**

b. **Revise Code water calculator algorithms for basin taps and kitchen sink taps to include a fixed proportion of water use.**

5.3.3 Revisions to algorithms for whole-house systems

Water use or savings for whole house systems such as water softeners and rain and grey water systems depend on other water uses within the home.

Water Softeners

The current calculator algorithm ignores the mains water used for regeneration if it makes up less than 4% of the water used in the dwelling.

Stakeholders generally supported including the full water use of plumbed in water softeners in the calculator results.

As water softeners regenerate after supplying a given quantity of water it would seem that the regeneration frequency on a per person basis could be derived as part of the calculator algorithm. The revised water softener algorithm is included in the calculator illustration.

Recommendation 5. Revise the Code water calculator algorithm for water softeners to include all water uses supplied by the softener and to derive regeneration frequency based on daily demand for softened water.

Rainwater and Greywater

Systems that harvest rainwater, or recycle greywater from baths and showers, for use in WCs and washing machines are explicitly encouraged in the Code. This implies that these systems are a more sustainable solution than the use of mains water. Some research challenges this.

In terms of the ‘need’ to install rain or greywater systems to reach Code levels, a common criticism of the current methodology from stakeholders during the review was that it is impossible to achieve the highest Code levels 5/6 without them. Feedback from a number of developers suggested it had been difficult to reach the mid Code levels 3 and 4 without rain or greywater systems.

In terms of handling in the calculator, stakeholders considered the current algorithm for rainwater collection to be overly simplistic. The initial qualitative review raised a number of issues about the ability of the calculator and the Code water section to drive appropriate application of rain and greywater systems.

Stakeholders agreed that the freedom to ‘trade off’ relatively high water use fittings (e.g. power showers) against water savings from collected water, potentially with a related trade-off of cold water savings against hot water use, is problematic.

It was widely agreed by stakeholders that water efficiency should be encouraged before considering water re-use systems, i.e. water saving options should be prioritised in a ‘water hierarchy’ (see section 5.1.2).

There are a range of practical and wider environmental concerns about the benefits vs. costs and risks of rain and grey water systems. These concerns range from the applicability of systems in different regions and urban contexts relative to water stress and useful saving potential through to issues related to their lifecycle environmental impacts, particularly CO_2 emissions compared to mains water supply and regional waste water treatment.

The literature review for this study identified research that raised question about the net environmental benefits of the broad application of rain- and greywater systems. The treatment of rain and greywater systems in the Code water methodology was not a specific area of focus for the calculator review. While it cannot be guaranteed that the literature review was comprehensive in this area, the findings in available reports suggest that the role of rain and greywater systems in meeting Code water levels should be reviewed in light of concerns about their lifecycle environmental impacts.

Notwithstanding wider considerations, the introduction of a water hierarchy provides the basis to take action now to limit the incentive provided by the Code for the installation of rain and greywater system. In terms of the calculator the adoption of the prospective British Standards calculations for these systems will provide a more robust assessment of savings potential. In terms of the wider Code methodology, a demonstration of the appropriateness of rain and greywater systems could be part of the assessment process.

Recommendation 6. Review the role of rain and greywater systems in meeting Code water levels.

Recommendation 7. Revise the Code water calculator algorithm for rain and greywater systems based on the prospective British Standards.

5.3.4 Calculator issues where no change is proposed

WCs

Stakeholders were broadly content with the calculation algorithm for WCs. However, the review identified a wide range of study results for the full : part flush ratio for dual flush WCs and there was equal debate amongst stakeholders about the correct value. The latest MTP study (MTP, 2008d) suggests a current ratio of ~1 : 1 but few would contest that dual flush WCs save water where they are used correctly. MTP suggests that with householder education, flush ratios could be ~1 : 3 by 2015. No change is proposed to the factors in the current algorithms on the principle that it is more important for the calculator to incentivise specification of water-efficient products than accurately model water use resulting from current behaviour.

Internal taps – shared issues

The flow intensity modifier for taps is likely to be non-linear in reality. Different tap types and designs will contribute to the range of actual ‘average’ uses. However, the review has derived a constant average flow intensity factor for taps from study data and this is used in the revised calculator illustration. The view taken was that the other changes to the tap algorithms (proportion of fixed use, weighted averaging of multiple fittings, and reduced frequency and duration of use factors) meet the calculator objectives.

If future research establishes a relationship between maximum design tap flow rate and average intensity of use or between different ergonomic tap designs (e.g. click lock) and average intensity of use, this could be reflected in future revisions of calculator algorithms.

Washing machines

No recommended change to the current algorithm for washing cycles.

Washer dryers with a condensing function can have significant water usage. Stakeholders supported including related water use in the calculator. The review has treated this as an additional microcomponent of water use and it is discussed in section 5.4.3.

Dishwashers

No recommended change to the current algorithm or Code approach.

5.4 Wider Code water methodology and scope

In addition to the current 'typical' calculator result being too high, this review identifies a range of practical problems with the status quo:

5.4.1 User acceptability and conflicts with standards

Under current calculator algorithms water use for the main end uses is directly proportional to flush volumes, flow rates, or volume per use. This combined with the large savings required to get from 'typical' to Code water levels (particularly higher Code levels) provides a very strong incentive to specify fittings with the lowest available flush volume/flow rate/volume per use.

British Standards establish minimum flow rate limits relating to fittings including sink, washbasin and hand basin taps and to showers; these are based on maintaining user acceptability. Whether or not these standards are up to date, their existence and implications for sanitaryware design are not discussed in the Code technical guidance.

The absence of any limits to calculator inputs allows designers to push sanitaryware specifications (particularly tap flow rates), down to and below any limits of user acceptability.

Study evidence, stakeholder feedback and anecdotal reports suggest that user acceptability is a real issue that affects the longevity of water efficiency measures and related savings. A proportion of householders will act directly to remedy dissatisfaction with fittings. International approaches reviewed, like Building Regulations, are predicated on maintaining functionality and user satisfaction; adopting a different approach in the Code seems questionable.

Limits to design flexibility

The review has identified a set of 'minimum' acceptability limits (i.e. most water efficient) for fitting specifications based on standards and stakeholder feedback. The limits are set out in Table 19. Selection of fittings with specifications below such a set of minimum levels, could be allowed subject to provision to the Code technical team of evidence of functionality and user acceptability. LEED employ a Technical Advisory Panel to validate such exceptions.

Fitting	Quantity	Minimum (at design pressure)	
WCs	Flush volume	4/2.6	Litres
Wash Basin Taps (in Bathrooms)	Flow rate	**6**	Litres/min
Handbasin (in WCs rooms) Pillar Taps		**4.2**	Litres/min
Handbasin (in WCs rooms) Spray or Spray Mixer Taps		**1.8**	Litres/min
Shower		**6**	Litres/min
Kitchen Sink Taps		**6**	Litres/min
Baths	Volume to overflow	165	Litres volume
Washing Machines	Volume per cycle	49	litres/cycle
Dishwashers		10	litres/cycle
Limits shown in bold are taken from published standards			

Table 19. Limits to design flexibility – minimum specification limits

Recommendation 8. Introduce limits to design flexibility to maintain functionality and user acceptability.

We recommend that limits are introduced, particularly at the lower end of the specification range for flow rates, flow per use, etc. of fittings and equipment (i.e. "minimum limits").

These should be set to protect technical function, usability and user satisfaction and are likely to be consistent with existing standards. Design outside these limits need not be strictly prohibited, but would require specific justification and approval to qualify for Code certification.

5.4.2 Methodology affecting calculator inputs and results

Pressure

Delivered pressure to homes varies considerably across the UK and this affects the impact of water efficiency measures considerably.

The current Code methodology requires the assessor to look up and enter maximum design tap and shower flow rates at a fixed pressure of 3 bar. Where actual plumbing pressure is lower, this practice combined with the specification of low flow fittings could contribute to unacceptably low flow rates in the completed dwelling. Where pressure is higher, savings from water efficient sanitaryware will be reduced.

Many stakeholders, including members of the review steering group, highlighted water pressure as an important issue for the calculator.

Moving to calculator inputs based design maximum flow rates at site/system water pressure (based on manufacturers product information and best available information on system water pressure considering delivered site pressure and plumbing system i.e. direct or indirect) would appear to be a solution. At the high pressure end this would provide a strong incentive for pressure regulation on the incoming main in direct plumbing systems.

Recommendation 9. Move to calculator inputs based on measurement or best estimate of site / system water pressure.

Occupancy

While the occupancy relationship cannot be included in the microcomponent part of the calculator, it could be allowed for by applying an occupancy factor to the total calculated water demand. This would increase the calculated water use for 1-bed dwellings with an assumed occupancy of 2, and decrease the calculated water use for all other dwellings.

The argument for such an adjustment is that it should produce a better correspondence between calculated and measured water use. The argument against, is that dwellings with different assumed occupancy but identical specifications (compared fitting by fitting) would have different calculated water use. Larger dwellings could be designed with less water efficient fittings than in smaller dwellings to meet any given target daily water use.

There is not a clear cut argument either way. Ignoring occupancy slightly favours smaller dwellings and including occupancy gives a greater boost to larger dwellings. On the other hand, ignoring private gardens (more common in larger homes) disproportionately helps larger dwellings. The fairest solution may be to include both, which would, as well as tending to bring calculated and measured results closer, have the additional benefit of aligning with Part G targets by including external water use.

Recommendation 10. Consider applying an occupancy factor to the Code water calculator figure for household water demand.

5.4.3 Scope – additional microcomponents and efficiency options

Waste disposal systems

Waste disposal systems are not currently included in the Code calculator. The proposals for amendments to Building Regulations Part G include them. Stakeholder feedback in this review supported the inclusion of waste disposal units in the Code calculator. Waste disposal units are included in the revised calculator illustration using frequency of use and volume per use figures quoted in a response to the Part G consultation.

External water use

The proposed Part G standard includes 5 litres / person / day for external water use. As the Code calculator excludes external water use, this means the proposed Part G standard of 125 litres / person / day is aligned with the CSH Level 1 target of 120 litres / person / day (+ 5 litres /person / day).

It seems sensible to keep the scope of the Code water calculator and the Part G calculator the same so that results are immediately comparable. Apart from contributing to harmonising the scope of the two approaches, adding a constant quantity of external water use to both calculator results and target Code levels makes no substantive difference.

Leakage

The current calculator does not include leakage. The default figure used by the industry for leakage is 17 litres / person / day but this is for all homes (new and existing) and we would expect the figure in the new build dataset to be lower than this. We believe the recent Identiflow microcomponent evidence base for new build homes provides information on average leakage.

Leakage is a fact and will be included in any measured data, so including it in the calculator would improve the relationship between calculated results and measurements. Including leakage in the calculator would also provide an incentive for consumer-side leak detection.

Condensing washer dryers

A large proportion of stakeholders felt that condensing washer-dryers should be included in the calculator, since they are growing in popularity and can be very high water using products. There does not seem to be a fixed method of calculating the water used by a washer dryer in its drying cycle and the information is rarely provided by manufacturers.

Additional water saving measures

The following additional water saving measures could be included in a future calculator if evidence to quantify associated savings can be developed:

- Reduced water draw offs – difficult to model savings; may be more appropriately covered through design requirements in Building Regulations.
- Reduced combination boiler start-up flow losses - further research needed to determine the viability (how can wastage figures be determined, do manufactures provide test details, etc.) discussed within the Technical Guidance (flagging any links to the SAP calculations).
- Delayed action inlet valves - requires additional information on water wasted with traditional valves for direct savings approach or revised WC testing regimes.
- Fitting durability and leak avoidance – requires additional information on comparative robustness and leak propensity of alternate fittings.
- Ergonomic product design e.g. well designed and self explanatory dual flush WC buttons, pause buttons on showers – hard to quantify savings.

Recommendation 11. Expand or consider expanding the scope of the water calculator as follows:

a. Add waste disposal units, in line with revised Part G.

b. Consider adding external water use to align Code water calculator results with results for the Part G calculator.

c. Add an allowance for leakage to the Code water calculator and consider including an equivalent saving for specification of leak detection and avoidance measures.

d. **Undertake a scoping study to determine the relative impacts of microcomponents of water use and saving measures not currently included in the calculator or addressed in the Code methodology. Use this as the basis for planning for the expansion of the calculator scope in future revisions.**

5.5 Code water section approach and administration

5.5.1 Assessor and specifier guidance

Detailed consideration of Code technical guidance is outside the scope of this review but a desire for expanded Code technical guidance was a strong theme in feedback from the assessor and specifier engagement.

Stakeholders said it would be beneficial for the Code technical guidance to provide more information on good plumbing design practice and specification.

Consistency of calculator results depends on uniform interpretation of manufacturers' product information and consistent translation of this into calculator inputs by Code assessors. The review identified uncertainty among assessors about how to interpret manufacturers' product information, e.g. for click-lock taps, and translate this into design maximum flow rate inputs to the calculator.

Code technical guidance could provide additional information in the following areas:

- British/European Standards;
- Product, plumbing and drainage design standards;
- Interpretation of manufacturers' technical product information, e.g. appliance water labels, flow and pressure graphs, and bath volumes;
- Specification of conflicting technologies such as electric showers and solar water heating and combination boilers and very low flow rate fittings.;
- Potential incompatibility of combination boilers with low flow fittings.

An issue related to the interpretation of product information is the level of precision allowed for calculator inputs. The current calculator allows specification information in litres / minute or litres / event to be entered to a precision of unlimited decimal places (2 decimal places implies accuracy to 1 centilitre, or about a tablespoon full). This misrepresents the level of accuracy that can be meaningfully measured and could be fixed in the calculator tool.

Recommendation 12. Expand and improve Code water technical guidance:

a. **Improve guidance on treatment of mixer taps and separate hot and cold taps with different flow rates at the same basin and multi-setting shower heads;**

b. **Improve guidance on interpretation of manufacturers' product specifications and translation into calculator inputs; and related to this**

c. **Limit all calculator inputs and outputs to values rounded to the nearest 0.5 litres. (This does not apply to internal calculator calculations as this would risk rounding errors.)**

5.5.2 Keeping the calculator up to date

<u>**Dealing with exceptions**</u>

The review recommendations above include limits to design flexibility and possible future inclusion of innovative product and plumbing system efficiency measures. These changes would benefit from the introduction of a reactive technical review mechanism that could, for example, adjudicate exceptions to design flexibility limits and decide how water use and/or savings for new products should be calculated. This may be achievable by extending the responsibilities of the existing Code technical team.

Regular reviews involving stakeholders

Stakeholders appreciated the opportunity to contribute to this review. Continuing involvement as part of regular calculator review cycles, would build trust and enhance the calculator's credibility amongst stakeholders. This dovetails with a technical need for the Code methodology to take account of the latest research on water efficiency, relationship with householder behaviour, developments in standards, and product innovation.

Recommendation 13. Establish appropriate review procedures for Code water section issues.

a. Establish a reactive Code water technical review mechanism;

b. Involve stakeholders in regular reviews of the water calculator.

5.6 Areas for further research

5.6.1 Microcomponent basis of the calculator

Future UK microcomponent water studies would need to report additional and different information if they are to most usefully inform a refined general microcomponent calculation model. Larger and more representative studies would also be helpful, as would access to the full datasets for past studies. Without such information, it may be difficult to refine a water use calculator to be reasonably 'predictive' of eventual measured water use.

Developing a standardised brief for future microcomponent research could help to ensure that it can contribute to improvement of a general microcomponent model for water use in new and existing homes.

Existing Anglian Golden 100 data (not available to this study) and future research could be used to refine the algorithms illustrated in this report, to update the constants used (e.g. for frequency of use over long time period, etc.) and to establish values based on research evidence where unfounded assumptions are suggested for temporary use in the interim.

5.6.2 Hot water

Hot water is an increasingly significant issue within the industry due to the dual benefits of energy and water savings. The existing microcomponent data does not allow hot and cold water to be split within each of the microcomponents algorithms. There is a potential to use the existing Anglian Golden 100 data to apportion a percentage of hot water use to each of the tap microcomponent algorithm and include a similar process for mixer taps for showers. However this would not identify situations where electric showers are fitted nor does it consider other complexities such as plumbing design. The issue is a complex one hot water use will depend on dynamics (plumbing design), heating system, shower type, and tap type. Further research could investigate the best approach to the introduction of hot water within the Code and Part G.

5.6.3 Monitoring of Code assessed homes

The Code was seen by stakeholders as a route for monitoring and collating data for new homes with known water efficient specifications. The Code could include provision or incentives for whole house or microcomponent modelling, the results of which could inform future reviews and calculator updates.

5.6.4 Further research identified elsewhere in this review

Section 5.3.3 discusses further research into the lifecycle impacts of rain and greywater systems and a review of their contribution to achieving target Code levels.

Section 5.4.3 discusses further research into additional microcomponents of water use and water efficiency measures that could be included in future revisions to the scope of the Code water calculator.

5.7 A way forward

The water section of the Code for Sustainable Homes aims to improve water efficiency and reduce water use in new homes. The water calculator is intended as the main tool to drive design and specification and to deliver this outcome. Almost all would agree that it should do so without risking technical function or householder satisfaction.

A water calculator developed as part of a government environmental assessment scheme and widely available as a piece of computer software is likely to be widely used. Even when users understand that a calculator cannot predict outcomes for individual dwellings, there will be a general expectation that statistically, for a large number of dwellings, the calculator results are comparable with measured results. While this is a reasonable expectation in principle, it would be wise to manage the expectations of stakeholders in this regard as the evidence for water savings attributable to improved sanitaryware specification alone is currently weak.

This review identifies difficulties with the current calculator and with the evidence base on which it is founded and which any successor must also use. A revised set of algorithms has been developed and illustrated. This builds on the current approach, makes use of an expanded evidence base including recent research focused on new dwellings, and draws on approaches from other countries.

The new algorithms illustrated are generally evolutionary and retain much of the structure of the calculations in the original calculator. On the other hand, due to some large changes in key constants used (particularly frequencies of use) the results produced by the calculator for a ‘typical’ specification are significantly lower than previously. Another effect of the changes is that the scope for savings from water efficient fittings is much reduced.

A criticism of the original water calculator is that it tended to drive some fitting specifications below the level of user acceptability. Introducing minimum limits without other changes to the calculator, radically cuts the scope for water saving and for reaching mandatory Code level 1 and 2 targets. By comparison, with the same minimum limits, the revised algorithm offers a reasonable range of options for reaching Code level 1 and 2, and hence also the proposed Part G target.

It remains difficult to reach middle levels of the Code and very difficult to reach higher levels without rainwater or greywater systems, and here we question the implied blanket incentive for and validation of these systems.

While many performance scales recognise that as performance improves it gets harder to make further progress, the mandatory water targets in the Code become increasingly harder (between level 1 and 3 a 15 litre/per/person saving is required and between level 3 and 5 a 25 litre/person/day calculated saving is required).

The final question we were asked to consider in the context of our review was whether the target levels that are currently set within the Code are appropriate. The preceding discussions suggest that there are multiple reasons to review the mid to top (level 3 to 6) water use targets in the Code. A decision on whether to amend the targets should take account of the tension between some of the proposed principles for the calculator set out earlier. In particular it must weigh the effectiveness in driving water efficient design and specification against user expectations of a reasonable statistical correlation between calculator results and measured outcomes.

Our view is that in the long term the Code will be more effective in supporting water reductions in new homes if the calculator remains credible. That credibility will be continually in question if, to make higher Code level targets achievable, the calculator overestimates water savings achievable through water efficient fittings alone or strongly drives the installation of technologies that later prove problematic.

Recommendation 14. Review higher target levels of the Code and relative spacings of the targets along with the range of water efficiency options currently available to meet each target level.

The requirement for or contribution of rain and greywater systems to meeting targets should receive particular considerations as previously outlined. The analysis in this report is structured with a view to enabling such a review of the targets. Many of the other issues discussed in this summary (wider policy and regulatory agenda and alignment, standards & householder satisfactions, etc.) would also need to be considered.

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