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Central Bedfordshire Council

Evidence base for water efficiency measures

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Executive Summary

Central Bedfordshire Council is currently consulting on a new Development Strategy, for adoption in spring 2014. The Development Strategy will be the main planning document for Central Bedfordshire, and will set out new policies for development. This is planned to include a sustainability policy to reduce environmental impacts, including the impact on water resources, of new developments. To allow for flexibility of how this policy is delivered, the Council envisages giving developers scope to aggregate water savings across the whole proposed development or provide financial compensation for water savings unable to be made on site.

To consider how the policy might be implemented, the Council commissioned a study to identify the range of technologies that can be installed in new homes and retrofitted in existing homes to help conserve water. A review of currently available technologies is therefore presented in this report.

In addition, a water efficiency calculator has been developed. It allows the user to estimate a volume of water that the Council might want to offset from a newly planned housing development by retrofitting water appliances in older properties located in the other areas. The calculator is an Excel based spread-sheet and its electronic version accompanies this report.

Contents

Tables

Figures

1 Introduction

Central Bedfordshire Council is currently consulting on a new Development Strategy, for adoption in spring 2014. The Development Strategy will be the main planning document for Central Bedfordshire, and sets out new policies for development including how many houses and jobs are needed and where they should go; and more detailed policies which will be used to determine planning applications.

The predicted growth in Central Bedfordshire will put additional stress on water resources, making it essential that any new development is as water efficient as possible. This justifies water efficiency standards to be set at a level higher than those set nationally. The Council will therefore require that new housing meets efficiency standards equivalent to Code Level 5 for water.

This is supported by the Council's Climate Change Risk Assessment (CCRA), which identified that the Central Bedfordshire area is within a region with predicted scarcity of water resources. The study highlights Anglian Water's assessment of deployable water output for the region, which estimates that even in a 'typical' rainfall scenario they will face a shortfall of 70% in deployable water supply by 2020. The study highlighted that climate change alone is likely to cause significant water supply shortages.

The Council's viability assessment indicates that Code level 5 for water is financially viable, however it is recognised that different developments face different constraints and there will be instances, due to technical or other restrictions, where this cannot be delivered in every new home or, even on site.

The Council therefore proposes to allow for flexibility on how this policy is delivered, giving developers scope to aggregate water savings across the whole development or provide financial compensation for water savings unable to be made on site.

This will support existing householders in Central Bedfordshire in reducing their water consumption and at the same time limiting the net additional demand on water supply in the wider Central Bedfordshire area. This will follow a similar model as that proposed for allowable solutions for Zero Carbon Homes.

This report has the following objectives:

a) To identify the range of technologies that can be installed in new homes and retrofitted in existing homes to help conserve water.
b) For each technology type provide a description of what it is, what it does and how it saves mains water use, the advantages and disadvantages of the technology, along with a typical price to purchase and install, and typical volume of water saved.
c) Provide an overview of the range of communal scale options available e.g. large scale rain water harvesting systems, including details of typical costs and water saving, how the technology works, advantages and disadvantages etc.

2 Water use in the home

This section provides background information, identifies what is known about how water is used in the home, and provides some context for the use and expected savings from water efficiency devices.

We use water in and around the home for personal washing, cooking, drinking, cleaning, washing clothes, dish washing, flushing the WC, watering the garden, washing the car, etc. In 2010, the average water use per person in the home across England and Wales was 146.1 litres/person/day; this compares to Anglian Water's figure of 144.7 litres/person/day[1]. These are average figures and water use varies considerably between households and from day to day. Factors that affect water use in the home include:

- **Occupancy.** The number of people living in the property will affect the total water used. Per property water use will increase with increasing occupancy, but the relationship is not linear, so multi-occupancy properties will typically use less water per person than single occupancy dwellings.
- **Behaviours and habits**. There is a large range of water using behaviours both within individual properties and between properties. Variations can be seen in whether we take a bath or shower, how long we shower, whether we leave the tap on when cleaning our teeth or not, how often we wash the car at home, how often we wash up, etc.
- **Types of water using devices and appliances.** Differences in the types of WC, washing machines, dishwashers, types of shower, etc., will affect water use.
- **Garden type and size.** This can have an impact particularly during warm summers.

Therefore it is convenient to classify water use into 'micro-components' based on the device or appliance being used[2]. Each UK water company is required to develop a water resources management plan by law and as part of this process, water companies need to understand their customers' current water use in order to determine trends for future use and identify areas where demand savings could be made. The water industry therefore collects data on micro-components for their areas of operations. In 2008 the Market Transformation Programme published results for micro-component monitoring in new and older properties[3]. The older properties, about 450 in the sample, were all built prior to 1999. The newer properties, about 70 in the sample, were all less than 5 years old (but prior to the introduction of the Code for Sustainable Homes or the revised Water Regulations). The split of micro-components for both samples is shown in Figure 1.

From the figures contained in Figure 1 it is evident that the biggest water uses are: WC flushing, tap use (washing, drinking, cleaning, cooking etc.) and bathing/showering. These 3 categories account for about 80% of water use in the home, explaining why many water efficiency devices and measures are targeted at these areas. The external water use figure is low, but these are annual average figures; during warm, dry summers we would expect this proportion to be higher. Peak summer demand is often a constraining factor for balancing supply and demand, which is why it is important to conserve water in the garden.

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[1]Service and delivery – performance of the water companies in England and Wales 2009-10. Ofwat.
[2] Water resources planning guideline. Environment Agency. October 2012.
[3] BNWAT28: Water consumption in new and existing homes. MTP. 2008.

Looking at the difference in water use between the older and newer properties, the main differences are WC flushing and showering. In newer properties the proportion of water flushed through the WC is less, which is due to the fact that newer properties will have WCs with lower flush volumes. The reason for the increase in the proportion of water used by showers is more complex. There has been a shift from taking baths to taking showers, there has been an increase in 'power showers' with higher flow rates, and there seems to be a trend for showering more frequently.

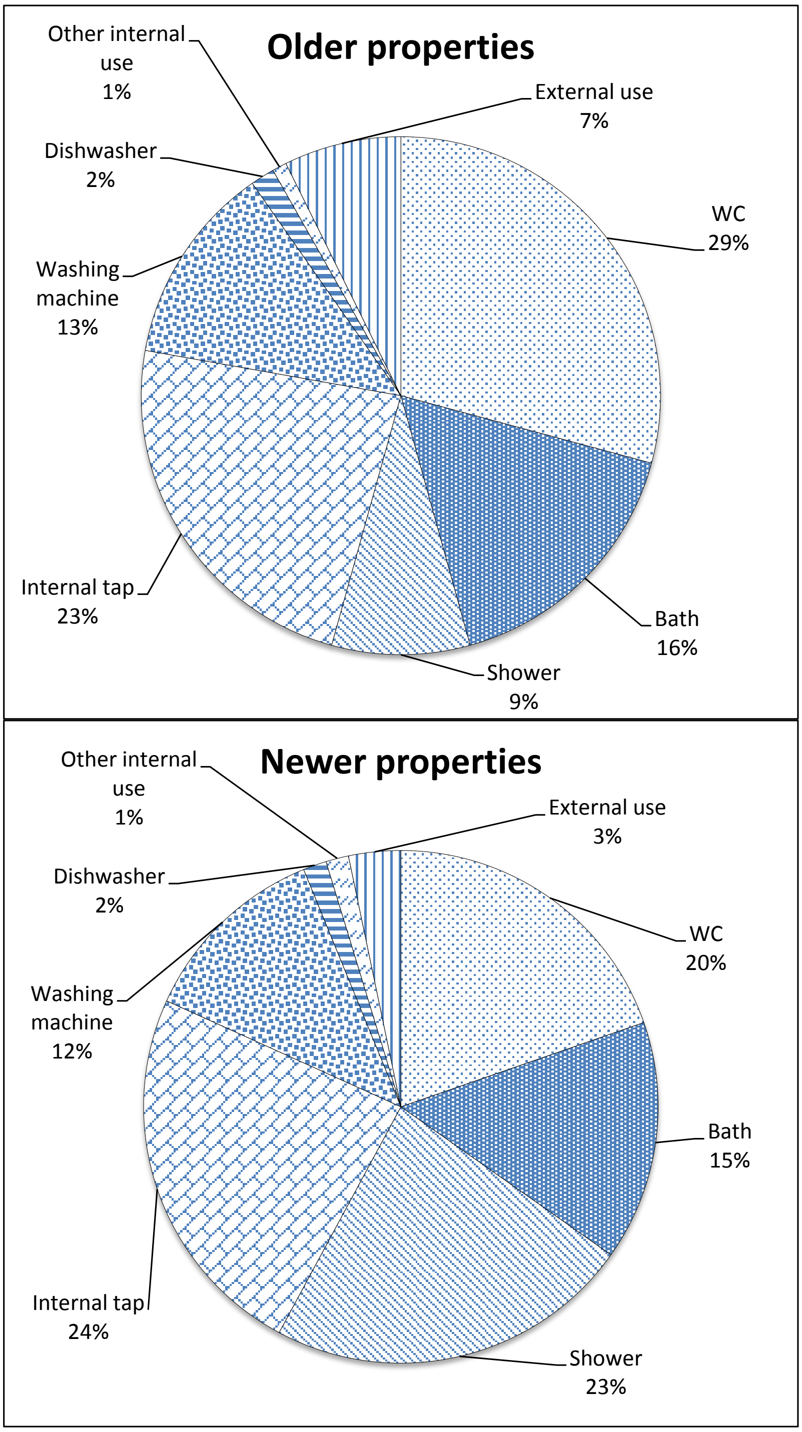

Figure 1 Micro-components of water use in the home

3 Overview of water efficiency technologies

This section of the report provides an overview of the range of water efficiency and water conservation technologies, devices, and appliances where they are available for use within the home. For each application the pros and cons related to water efficiency are discussed; along with the factors relevant to the potential water savings and suitability for retrofit or new build. Additional detail including technical variants, water savings and costs are presented in tables in Appendix A.

3.1 WCs or toilets

3.1.1 Introduction

WC flushing can account for about 20% to 30% of average household water consumption. The amount of water flushed depends on the flush volume of the WC cistern and frequency of flushing per day. The maximum flush volume is determined by regulations (the current maximum being 6 litres/flush), but older properties can have flush volumes of over 12 litres/flush as indicated in Figure 2, which shows how flush volumes have decreased over time[4]. The most commonly sold WCs currently are 6 litre single flush units and 6/4 litre dual flush units; these meet the minimum requirements for new installations. For dual flush systems, the flush volume calculated as the 'effective flush volume' based on assumptions about the proportion of large flushes to small flushes; a 6/4 litre dual flush WC will often quote an effective flush volume of 4.5 litres (this obviously depends on who uses it).

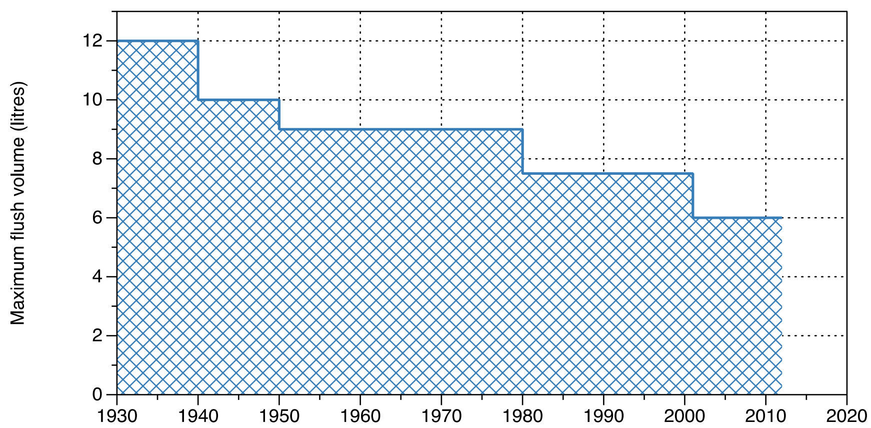

Figure 2 Change in WC maximum flush volumes over time

The options for implementing water savings from WCs are to:

- Install a WC with a lower flush volume.
- Retrofit a variable flush device into an existing WC cistern.
- Install a cistern displacement device.

[4] Conserving water in buildings. Environment Agency. 2007.

- Use rainwater or recycled water to flush the WC.

These are discussed below.

3.1.2 New build water efficiency options

The main solution for new builds is to either use rain or recycled water for flushing the WC (see section 4) or fit a WC with lower flush volume. Many manufacturers also supply lower flush variants of their WC designs, these include the following (effective flush volume shown in brackets):

- 6/3 litre dual flush (3.8 litre)
- 4.5/3 litre dual flush (3.4 litre)
- 4/2.6 litre dual flush (3 litre)
- 4.5 litre single flush
- 4 litre single flush.

Examples of WCs with all these flush volumes can be found on the 'Water Label' web site[5].

There is also a new innovation in WC flushing technology for homes and businesses launched earlier this year. This is a WC with a flushing volume of 1.5 litres, which is air assisted to ensure that waste is removed and carried along the waste pipe effectively[6]. The product has WRAS[7] approval for use in the UK.

3.1.3 Retrofit water efficiency options

These options aim to reduce the flush volume of an existing WC. They are aimed at the larger single flush WCs with a flush volume of six or more litres.

Table 1 Retrofit devices for WCs

Device	Potential water saving	Pros / Cons
Dual flush retrofit device	Up to 30% of original flush volume. Expect 1.5 to 2.5 litres per flush saving on most applications.	Developed for pre 2001 WC cisterns (i.e. greater than 6 litre flush volumes) these devices have also been installed on single 6-litre flush WCs. A plumber normally retrofits them, but the operation can be carried out in about 5 minutes. Once installed they have been reported to produce reliable savings, and are extensively used by water companies for retrofits in homes. The units should not be fitted on WCs with a flush volume of less than 6 litres.
Cistern displacement	Between 0.5 litre/flush to 2.5 litre/flush depending	Quick and easy to install in a cistern, they rely on displacing a fixed volume from the water in the cistern. They come in two main sizes: small

[5] http://www.water-label.eu/home.asp
[6] The Propelair WC (see http://www.propelair.com)
[7] Water Regulations Advisory Scheme (www.wras.co.uk)

device	on installation and type.	(nominally 1 litre) and large (nominally 2 litres). The actual amount saved depends on the make and model, and how it is installed. If the volume of water displaced from the cistern is too large, then the flush effectiveness can be reduced leading to double flushing, which reduces the benefits. Selecting an appropriate device for the type of WC should avoid this issue.

3.2 Showers

3.2.1 Introduction

Average water use from showering typically accounts for about 9% to 23% of water use in the home (See Figure 1). The amount used in individual homes will vary depending on the flow of water from the shower and the length of time that people spend in the shower.

There are approximately 19.5 million showers installed in homes across England and Wales. Sales and subsequent stock levels of showers have increased significantly, particularly since the late 1980s[8], see Figure 3.The ownership of showers is split fairly evenly between mixer showers (including power showers) at 52% and electric showers at 48%.

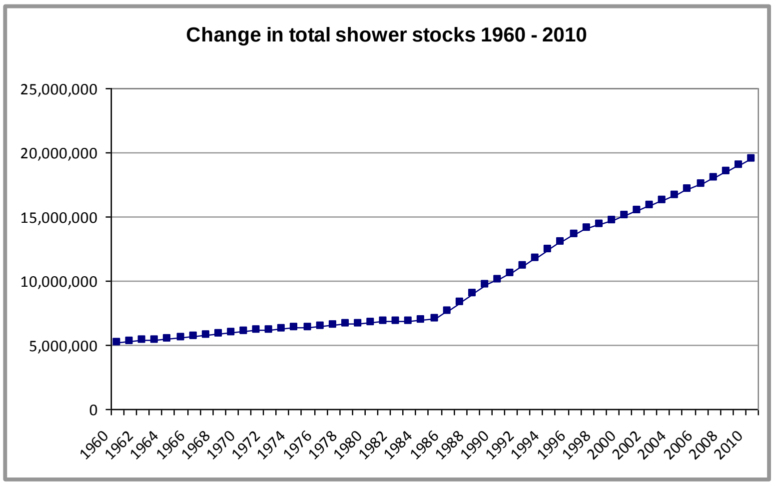

Figure 3 Growth in shower installations

Showers can be classified into 3 groups:

- **Electric showers**. These are showers that are fed by a cold water mains supply and directly heat the water via an electric element. The temperature is regulated by the flow of water and the number of elements heating the water. The flow of water through these showers is therefore a function of the desired water temperature and the pressure in the water supply feeding the property. Typical flow rates for this

[8] BNWAT02: Shower Consumption and Performance. MTP. 2011.

type of shower are in the range of 5 to 8 litres/minute. From a water conservation perspective, the normal advice is that flow restrictors or water efficient showerheads should not be fitted to this type of shower.

- **Mixer showers (no pump).** These showers are normally fed from the cold and hot water system. They may be fed by mains pressure or from a header tank, depending on the type of plumbing system in the property. Flows from these showers typically vary from 5 to 15 litres/minute. Showers fed from the header tank are normally at the lower end of this range, showers fed directly from mains pressure are likely to be at the mid to high end of this range. Flow restrictors or water efficient showerheads may be fitted to these showers.
- **Power showers.** These are mixer showers that are fed from a pumped supply. Typically these showers will have a flow rate above 12 litres/minute, potentially up to 20 litres a minute. Flow restrictors or water efficient showerheads may be fitted to these showers.

3.2.2 New build water efficiency options

The main option for water efficient showers in new buildings is to fit a water efficient showerhead (see next section). The other option is the recycling shower unit in which used water is held in a storage tank and recycled during a portion of the showering process in place of fresh water. Whilst these do exist, they are a very niche product with a very limited manufacturing base (most of the company examples are based in Australia)[9].

3.2.3 Retrofit water efficiency options

Options for making showers more water efficient rely on either reducing the flow of water through the showerhead or reducing the amount of time spent in the shower. It is generally considered that reducing the flow through the showerhead provides a more reliable water saving than trying to modify the time people spend in the shower. This is largely because showering is behavioural, that is people tend to shower for different lengths of time for various reasons – relaxing, freshening up, hair washing, shaving, as well as just getting clean[10].

[9] BNWAT02: Shower Consumption and Performance. MTP. 2011.
[10] Pullinger, M., Browne, A., Anderson, B., & Medd, W. (2013). *Patterns of water: The water related practices of households in southern England, and their influence on water consumption and demand management.* Lancaster University.

Table 2 Retrofit devices for showers

Device	Potential water saving	Pros / Cons
Water efficient shower head	Savings in the range of 5 to 11 litres/use can typically be expected (in those situations where users take long showers the saving can be greater).	Water efficiency shower heads broadly operate in one of two ways. They either produce an aerated spray or reduce the flow through the device. The aerated showerhead appears to deliver a higher flow than it actually does, providing the user with the experience of a power shower but with significantly less water. The low-flow showerheads restrict the volume of water flowing through the showerhead, most designs of low flow showerheads use specific flow nozzles to reduce the impact on the user experience. These devices are very quick and easy to install and normally result in a flow through the device or between 6 to 8 litres/minute. These devices should not normally be fitted to electric showers.
Shower flow restrictors	Savings in the range of 5 to 11 litres/use can typically be expected (in those situations where users take long showers the saving can be greater).	These devices normally fit between the shower hose and the existing showerhead. They simply restrict the flow of water through the showerhead. They are quick and easy to fit, although they may not look as elegant as a low flow showerhead. Because they just restrict the flow through the existing head, they may have a greater impact on the user experience than equivalent low flow showerheads. These devices should not normally be fitted to electric showers.
Shower timers	Uncertain	These are devices that are intended to remind the user how long they have been in the shower and rely on the user modifying their behaviour and showering for a shorter period. There is very little quantitative evidence on their long-term impact on water savings.

3.3 Taps and tap fittings

3.3.1 Introduction

Tap use (hot and cold water) accounts for about 25% of water use in the home for activities such as washing, drinking, cooking, cleaning, shaving, teeth cleaning, plant watering, etc. Many of the tap uses are for filling vessels (kettles, cups, saucepans, washing up bowls, etc.) and in these cases the options for saving water are limited. For the remaining uses the flow from the tap is running straight to waste (for example washing hands, cleaning teeth, rinsing dishes, etc.). In these cases (for the domestic property) there is the option to fit a tap device and reduce the flow through the tap, or change behaviour through advice and education to waste less water by reducing the time that water flows to waste.

3.3.2 New build water efficiency options

The options for new build properties are low flow taps or taps supplied with tap inserts to reduce the flow. Low flow may be induced through a flow restrictor or through the use of a spray, aerator laminar flow device in the tap outlet. These types of tap can be used throughout the property in basins and sinks. For taps where full flow is required, e.g. in kitchen sinks where full flow is preferable to the user for filling vessels and bowls, there is the option of installing a 'click tap'. These are lever operated taps, where as the lever is lifted, resistance is felt. If a higher flow is needed, the lever can be pushed past this step.

The range of water saving is difficult to predict as there are many variable to consider: the pressure in the water supply to the tap, the way in which the user normally uses the tap, the specific use of the tap, etc. However, fitting a low flow tap is likely to reduce the flow of water for uses where the water is running straight to waste. The tables in Appendix A show ranges of savings for different types of tap.

There are many variants of low flow taps for new builds, and a comprehensive list can be found on the water label website[11].

3.3.3 Retrofit water efficiency options

The retrofit options for taps are essentially the same as for new builds, i.e. replacement taps or tap-inserts which can be bought separately. For kitchen taps there is the option for fitting a devices such as Tapmagic or Miracle Tap. At low flows, the Tapmagic device delivers a spray pattern suitable for washing hands, etc. As the flow is increased, the device opens up to allow full flow to fill the basin or vessel. The Miracle Tap allows the user to select a low flow aerated flow or a more powerful spay.

The recent Energy Saving Trust/Waterwise Green Deal guidance[12] suggests that savings for average households are in the region of 1 litre/day. Theoretically a tap insert could give a higher flow saving, but when retrofitting it is not always possible to fit inserts to every tap, and therefore a lower estimate has been provided in the Green Deal guidance.

3.4 White goods

This section covers washing machines and dishwashers, which account for about 15% of household use.

Over time, the volume used by dishwashers and washing machines has tended to decrease. This is most likely a result of trying to achieve lower energy consumptions. Most modern washing machines use about half the water and energy of the average 10-year-old machine. New washing machines now use less than 50 litres of water per 6kg wash and the most

[11]http://www.water-label.eu/home.asp
[12] Green Deal Guidance for the Water Sector. EST/Waterwise. November 2012.

efficient machines claim less than 40 litres. For dishwashers, the most efficient machines use about 10 litres to wash 12 place settings[13].

[13]Waterwise website.

4 Rainwater harvesting and grey water recycling

Rainwater harvesting and grey water recycling are methods of conserving water not through reducing its use through the device or appliance, but through replacing the use of mains fed water with water collected from the roof or through recycling water that has already been used within the property. There are systems for harvesting rainwater and recycling grey water for individual households, groups of households and commercial properties. Designing, installing and using rainwater harvesting or grey water recycling systems can be complicated and there are plenty of sources of detailed information[14,15,16,17,18] on designs and operations in bespoke case studies. This section of the report provides a brief overview of rainwater harvesting and grey water recycling, and considers the implications for their use in domestic properties.

In an Oxford University (2007)[19] report, four of background studies are analysed, which consider household water consumption: Bioregional; EA; Entec and SDC, the first three being focused on new build only. These studies vary in the level of potential water savings they propose, although there is consensus that much can be done through the installation of existing more efficient technologies, requiring little behavioural change and that there is no premium for these water-efficient products. Such changes are potentially straightforward for both new build and the existing stock.

Further savings are predicted through more of a focus on infrastructure and supply-side issues, with the installation of rainwater and greywater systems. This also requires a certain level of behavioural change to adapt to these new systems. Whilst these are suitable for new build, such systems are less feasible for existing buildings due to the cost and difficulties of retrofitting.

There appears to be little data available on consumption and savings potential in existing households in relation to water and none of the reports look at historic and future trends for consumption in the UK stock as a whole. Therefore it is difficult to establish the overall level of savings that might be possible across the country. A more detailed bottom-up model of consumption, as developed for the energy sector, would be of benefit here. The Entec report does provide an estimate of future consumption resulting from new additional buildings, which serves to underline the importance of addressing water efficiency as part of any new development, particularly given the wider environmental impacts associated with increased water abstractions.
Key messages and areas of consensus from these reports are:

- There are parallels with energy efficiency and conservation and relevant lessons to be learnt within the water sector.

[14] Rainwater and Grey Water: Technical and economic feasibility. MTP. 2007.
[15] Rainwater and grey water: A guide for specifiers. MTP. July 2007.
[16] Rainwater and grey water. Review of water quality standards and recommendations for the UK. MTP. July 2007.
[17] C539 Rainwater and grey water use in buildings. Best practice guidance. CIRIA. www.ciria.co.uk
[18] UK Rainwater Harvesting Association. www.ukrha.org.
[19]Reducing the environmental impact of housing. Environmental Change Institute. University of Oxford (2007).

- There are significant inefficiencies in the water supply infrastructure and consumption.
- The focus should be on demand reduction rather than increasing supply.
- Water is a very regional-specific issue and the South East of England is likely to be under the most pressure from increased demand accompanied by low rainfall.
- Greater water efficiency is a crucial aspect of increased levels of development.
- Failure to address improved water conservation and efficiency will have complex and far-reaching effects on water flow in rivers, pollution levels and ecology.
- A substantial increase in water efficiency (25-40%) is achievable through available technology with little or no associated cost and no required behavioural change.
- Greater savings are possible through grey-water and rainwater systems, particularly in new-build, whereas retrofit costs for existing buildings may be prohibitive.
- Water consumption is highly dependent on household size (occupancy levels).

4.1 Rainwater harvesting

Rainwater harvesting and water reuse:

- Large-scale rainwater harvesting
- Small-scale rainwater harvesting with water butt
- Grey water recycling

Rainwater harvesting is the capture of rainwater for other purposes. Most commonly this is recognised as collecting rainwater from a roof via guttering into a water butt for garden watering. This type of reuse is becoming increasingly common in the UK and several water companies offer water butts at a discounted price. Rainwater recycling can also be implemented at a large scale. For example, large buildings can collect the water from the roof area into big tanks and use it for toilet flushing. Wessex Water head office in Bath uses rainwater to flush all of the toilets within the office which holds more than 500 employees.

Rainwater harvesting requires a large collection area (typically roof area) and a holding tank for the resource until it is required. There may be a delay between the rainfall event and the demand and so the water must be stored. In some cases, depending on the residence time of the tank, treatment of the rainwater might be required to prevent it from stagnating until it is used. Treatment of rainwater will require energy use and therefore increase the carbon emissions associated with this intervention. The pumping of rainwater from an underground storage tank would also increase energy use.

Rainwater harvesting, as the name suggests, is dependent upon rainfall events and thus rainfall patterns typical of a specific area. Rainwater recycling would in theory, help to reduce water consumption during times of peak demand, as during these times gardens would be watered and previously the water for this would be obtained from the mains supply. With the installation of a water butt, the garden could be watered via this reservoir. However, this is only if the water butt is full. There is a risk that the rain water system may run empty during periods of hot dry weather and thus the reservoir (water butt) or toilet flushing system would have to be backed up from the main supply. Therefore, although a popular measure, there is an uncertainty as to how reliable the yield derived from rainfall might be long term. Although a good measure in theory for peak lopping summer demand, in practise there is a significant risk that the water butts may be empty. The same problem applies in dry years, which are used for water resource planning and applicable to the definition of water neutrality.

Small scale rainwater collection, like water butts, can be implemented easily into individual domestic properties. Larger scale units would require significant building and civil works both externally (tanks to collect the water) and internally (to install the appropriate infrastructure to be able to treat and transport the recycled water). If treatment is needed, then this entails a further level of complexity which could render the option unfeasible or uneconomic. Larger reuse systems are likely to be more appropriate to new builds rather than for retrofitting projects.

Rainwater harvesting normally relies on collecting rainwater run-off from a roof, filtering and storing the water for use in the garden, flushing WCs and for use in clothes washing. Treatment (disinfection) of the rainwater is sometimes included in rainwater harvesting systems.

Rainwater harvesting systems are available commercially from small units for individual households to larger systems for small communities. Storage tanks can be above ground (plastic tanks and water butts) or below ground (plastic or concrete tanks). The complexity of rainwater harvesting systems ranges from very simple tanks fed from a downpipe from a roof, mounted on a flat roof, with a gravity feed to a ground level WC; all the way to large underground tanks with multiple levels of filtration, treatment, and pumping to all the WCs and clothes washing appliances in a single household or multiple households.

It is possible to use rainwater-harvested water for all WC, clothes washing and garden use (saving about 35% to 50% of mains water– see Figure 1). However, this relies on having a sufficiently large collection area and storage tank, depending on the average rainfall frequency in the local area.

4.1.1 Individual household systems

Domestic systems typically cost from about £1300 up to £4000 plus installation costs, depending on size of tank. Cheaper options might be available but would require installation by an experienced person. The lowest costs are achieved with a new build. Excavation works for the tank are additional requirements as is a plumbing network for the rainwater appliances and commissioning of the control appliance. Other works such as drainage and soak-aways have to be completed with or without rainwater harvesting. The incremental cost to install a rainwater harvesting system for a private house should be around £700.

4.1.2 Communal scale systems

The rainwater harvesting systems to feed multiple dwellings will vary in design and size depending on precise specification. They will feature a storage tank or a battery of tanks and will be site specific in terms of pipe layout and ancillaries.

A communal scale system will have higher excavation costs compared with a single household system due to the larger tank and internal plumbing costs depending on the number of toilets/applications but may have a quicker 'pay back' period due to the size of roof and higher usage.

Rainwater harvesting can be used as part of a sustainable drainage system (SuDS) scheme capturing water at source for reuse. The use of rainwater harvesting can contribute to meeting some of the design criteria for SuDS such as by helping to reduce surface water run-off volumes from frequent rainfall events by providing interception and local storage.

4.1.3 Example case studies

Preston Water Efficiency Initiative[20]

The aim of the Preston Water Efficiency Initiative was to pilot an innovative water demand management project in Preston, Surrey that reduced levels of water consumption of tenants living in social housing through:

- the installation of a pilot rainwater harvesting system, refurbishing bathrooms and retrofitting water efficiency equipment and devices to existing properties; and
- A small scale and complementary awareness campaign to help change people's attitudes towards water consumption.

A key part of the initiative was the piloting of a retrofit rainwater harvesting system in order to provide water that could be used in toilets. The system was installed on a block of twelve flats. This enabled one system and one storage tank to be installed to serve all flats. The block that was selected was also scheduled for a major bathroom refurbishment programme, which enabled the internal pipe work for connecting the toilets to the storage tank to be fitted at the same time as the refurbishment took place. The system dispenses with the roof tank and water is pumped straight from the outside collection tank under pressure to toilets and potentially washing machines as well. Mains water is available to top-up the system when the rainwater is depleted.

There were considerable problems is getting the system up and running. This included delays in getting all the pipework completed, pumps running effectively and electrical issues. Further issues with the pumps and switchover between rainwater and the mains top-up between September 2008 and March 2009 meant only selected periods could be included in the water savings analysis (a total of fifty-four days). During these periods water consumption reduced by 5.2 percent compared to the post refurbishment water use, resulting in water use of 91 litres/person/day or 154 litres/household/day (based on actual occupancy of 1.7). These figures were not comparable with the results from the general refurbishment and retrofit programmes, as the initial consumption is lower:

- Pre water use 117 litres / person / day
- Post refurbishment 96 litres / person / day
- Post rainwater harvesting 91 litres / person / day

One issue found with the system was that because both the rainwater and mains water top-up has to be pumped from the tank to the toilets, in the event of a power cut the water to the toilets is cut off. It was not possible to have a back-up mains supply directly connected since this would contravene Water Regulations.

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[20] Preston Water Efficiency Initiative, Final Report. Waterwise. March 2009.

The total cost of the rainwater harvesting system was £35,471 or £2,956 per property. Asset life was estimated at 25 years. The cost per cubic meter of water saved was £30 or in other words 3 pence per litre of water saved. This can be compared with Anglian Water' water supply charges of £1.52 per cubic metre plus standing charge of £30 per year[21].

4.2 Grey water recycling

Grey water recycling involves collecting water from certain wastewater producing activities and using this for toilet flushing. Shower water, bath water and washing up water are examples of the types of wastewater that would be collected. This water would contain large amount of detergents and surfactants and would therefore require treatment before it could be stored and then used when required.

Practical grey water re-use systems usually limit the scope of collection to bathing water as this is easiest to collect and treat. Therefore, the major applications of grey water systems are in buildings where bathing or showering takes place such as houses, hotels and leisure centres.

Systems generally consist of a collection tank, filtration, treatment, disinfection and pumped delivery system. They tend to be more complex than rainwater harvesting systems because of the need to remove potential pathogens.

Once grey water has been treated it is most commonly used for flushing WCs. It can be applied to single households, small communities or commercial buildings (such as hotels where this is high volume of bathing/showering). It is possible to use recycled grey water to replace all of the WC flushing, which would save about 20% to 30% of the household use (see Figure 1), but this would depend on the volume of water that could be recycled and stored.

The cost of a greywater recycling system will depend upon the size of the house; the prices start at approximately £2000 for new builds plus installation costs.

4.3 Considerations for household use

The Code for Sustainable Homes includes the use of rainwater harvesting and grey water recycling systems in individual households and for communal use. Example schemes for these systems in individual household applications are given in Figure 4 and Figure 5 for illustration purposes.

[21] Standard rate for 2013-14 for metered properties; checked in July 2013 http://www.anglianwater.co.uk/household/your-account/tariffs/standard-rates/.

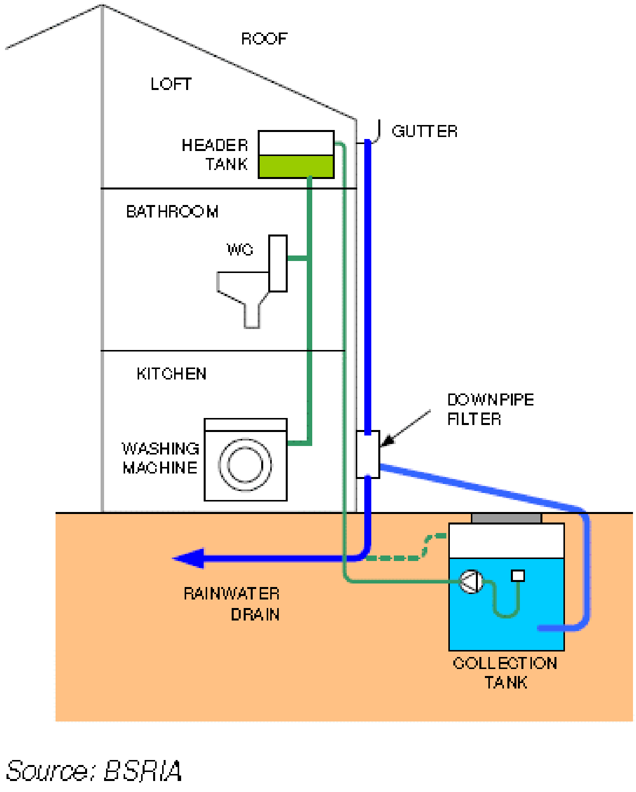

Figure 4 Typical rainwater scheme

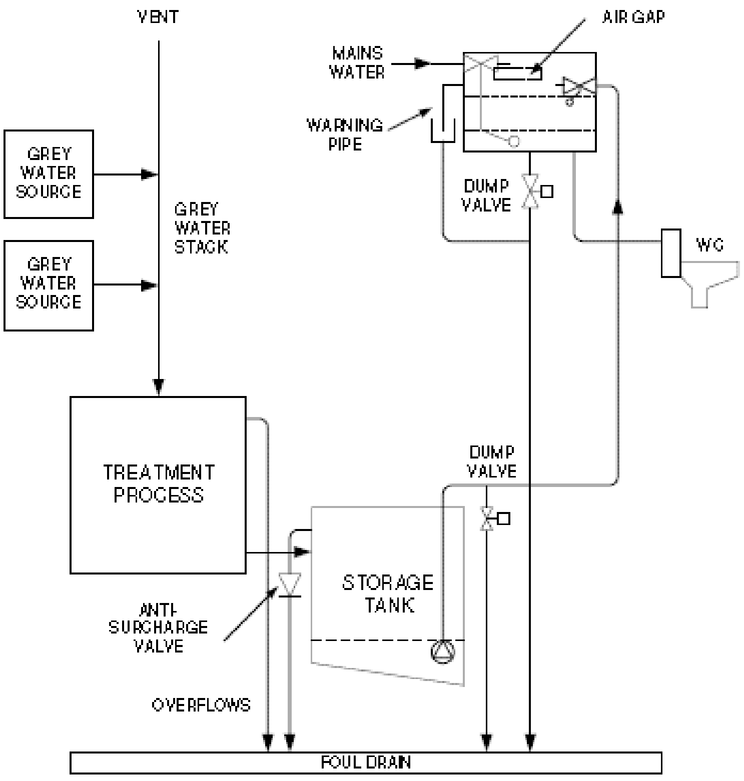

Figure 5 Example schematic of grey water system with header tank

There are a number of considerations that need to be addressed for using these systems in households.

All rainwater harvesting and grey water recycling systems require maintenance to ensure that they maintain optimal performance. For communal systems a commercial service provider will normally carry out maintenance on behalf of the community. For individual households it is possible to carry-out DIY maintenance on simpler systems, more complex systems will require the services of a professional. The majority of rainwater tanks come with a manufacturer's warranty of 15 years but because they have no moving parts and are made of inert materials they are likely to have a significantly longer service life than the warranty period; supplier estimates suggest that tank life up to and over a hundred years is possible. Other static parts also commonly come with a supplier warranty, often for 2 years, but the actual service life is again expected to be longer than that. Pumps, if present, will require maintenance and most manufacturers offer a warranty but often for only 1 year. The service life of a pump is likely to be in the region of 10 years.

All but the simplest systems will use energy for pumping and treatment. The Environment Agency produced a report in 2010[22], which concluded that "*Buildings using harvested rainwater or treated greywater typically increase greenhouse gas emissions compared to using mains water*". However, suppliers are continually developing their systems, and the actual energy and carbon used will depend on the specific application.

There are standards that should be followed for systems and pipework. BS 8515:2009 covers the design, installation, water quality, maintenance, and risk management of rainwater harvesting systems. There should be no cross-connections between recycled water pipework and potable water plumbing pipes; all pipework and fittings need to meet BS 6700:2006, 6.1.12.3. All systems will need a mains water back-up, in the event of storage running low, and therefore backflow prevention, providing category 5 protection, should be fitted upstream of, or at the point, where the two systems meet. This should be in the form of a Type AA or AB Air-gap conforming to BS EN 13076 and BS EN 13077 respectively.

Maintenance of these systems should be frequent; it is assumed that activities such as pumps maintenance and cleaning of roof and gutters should be performed annually, whilst cleaning of the tank should be carried out every three years[22]. Other sources, for example BS 8515:2009, suggest additional annual inspection and maintenance of the system components including annual tank cleaning activities if no information is given by the manufacturer.

Many of these systems installed in the UK required higher maintenance frequencies then those stated in guidance documents. This has been caused due to unplanned maintenance to correct faults, many of which were related to incorrect installation. Another common reason for failure within these systems are issues with pumps due to fouling by debris or because of electrical issues.

One specific issue for consideration for communal RWH systems includes a situation where properties are individually metered and where individual gardens are present. Since the proportion of rainwater used by individual households cannot be regulated this may cause disproportionate volumes of rainwater to be used by individuals.

[22] Energy and carbon implications of rainwater harvesting and greywater recycling. EA. 2010.

Water efficiency measures addressing outdoor use:

- Hosepipe flow restrictors
- Hosepipe siphons
- Hose guns (trigger hoses)
- Drip irrigation systems
- Mulches and composting

The typical family uses about 7% of their water outdoors[23]. There are several areas in the garden where small changes could result in significant water savings.

Climate change is also expected to impact on peak demand due to increased discretional external use. Hotter summers, mean that people are likely to use more water both for bathing, watering the garden and filling swimming pools. Currently about 6% of household water is normally used in the garden, but on hot days this can already rise to over 50%[24].

The most obvious saving is to recycle rain water which has been discussed in section 4. In addition mulching could be used. Mulches such as pebbles, gravel, cocoa shell, chipped bark, and grass clippings not only keep away water-loving weeds, but also keep the soil cool, decrease evaporation, and reduce soil compaction. Many people use hose pipes to water the garden which can waste large amounts of water if left running. Instead watering cans could be used, or a trigger gun on the end of the hosepipe would allow more control over the watering and hence less wastage. This can also be applied to car washing.

These options which target outdoor use attempt to limit discretional water use i.e. non essential use, which is likely to be during peak times, as garden watering is not necessary during the winter months. The application of these options however is limited as they may only be up taken in houses that have gardens. In older, inner city areas for example where there are more likely to be flats and less likely to be properties with large gardens, the promotion of such interventions may not be as relevant or successful.

Outdoor use is largely governed by behaviour, even more so than indoor use and as a result wise water use would be more likely after receiving and responding to appropriate advice.

With the threat of climate change resulting in hotter drier summers a switch to drought resistant plants should be encouraged. This could be done via a partnership with a garden centre for example: the promotion of drought resilient plants in combination with offers on water butts and trigger guns for hosepipes. Drought resistant grass seed is available and developers should be encouraged to use this on new developments. Councils should also be encouraged to use drought resistant plants as they use significant volumes of water to water parks and recreational areas. Harrow Council in London however have decided to stop using hanging baskets as they believe the baskets need too much watering and maintenance and are not therefore "environmentally sound"[25]. They have also decided to replace traditional trees with foreign species which can cope better with dry, hot conditions and allowing sections of parks to revert to wild areas which need less watering and maintenance than lawns and flower beds. It should be noted however that these types of measures might not

[23] Ref MTP: BNWAT27: Domestic external water use: An overview, 2008
[24] source: Environment Agency
[25] http://www.harrow.gov.uk/downloads/hp_julyaugust_06_for_web.pdfhttp

be appropriate in areas where local characteristics, area-specific landscaping and biodiversity aspects must be considered.

These interventions would reduce water use during peak times, but the yield from such interventions is extremely hard to predict accurately due to the behavioural and the seasonal aspect of this water use.

5 Water Efficiency Calculator

An Excel based water efficiency calculator (CBC Water Efficiency Calculator.xlsx) was developed for Central Bedfordshire Council. The calculator allows the user to calculate the savings that need to be offset by the retrofit programme, and then calculates the number of properties and devices that need to be retrofitted using 3 pre-defined scenarios. An overview of the calculator is shown in Figure 6.

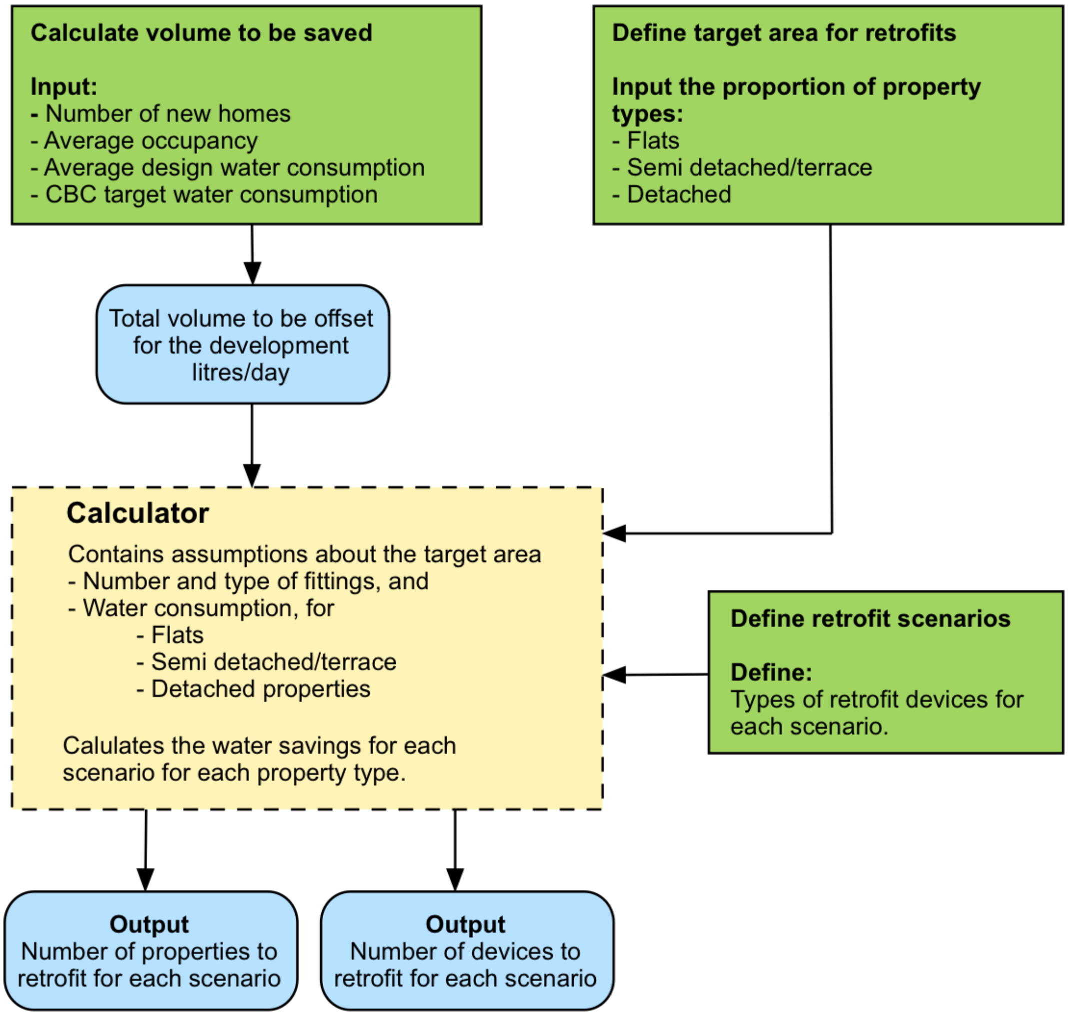

Figure 6 Overview of the calculator

5.1 Assumptions

A number of assumptions were made in order to develop the spreadsheet, these are listed in the sections below.

5.1.1 Property types

It was assumed that all dwellings can be categorised by one of three property types, namely:

- Flat;

- Semi-detached or terrace house; or
- Detached house.

In addition, an assumption was made on the typical layouts of the above property types, allowing the number of appliances installed to be estimated. These are given in Table 3.

Table 3 Assumed number of appliances per property type

Property type	Number of appliances					
	Bath with mixer tap	**Shower**	**Power shower**	**WC**	**Hand basin**	**Kitchen sink**
Flat	1	1		1	1	1
Semi-detached/ Terraced	1	1		2	2	1
Detached	2		2	3	3	1

5.1.2 Appliance characteristics

Typical appliance characteristics were assumed from available literature and engineering judgement. The assumptions are presented in Table 4 and Table 5.

Table 4 Assumed appliance characteristics for flats and semi-detached/terrace houses

Installation type	Capacity/flow rate	Unit
WC (single flush)	7.5	litres
WC (dual flush)	(NB 1)	litres
Taps (excl. kitchen taps)	9	litres/minute
Bath (where shower also present)	155	litres
Shower (where bath also present)	12	litres/minute
Bath only	(NB 1)	litres
Shower only	(NB 1)	litres/minute
Kitchen sink taps	9	litres/minute
Washing machine	11	l/kg dry load
Dishwasher	1.4	l/place setting
Waste disposal unit	(NB 1)	l/use
Water softener	(NB 1)	l/person/day

Note 1: This appliance was assumed not to be installed.

Table 5 Assumed appliance characteristics for detached houses

Installation type	Capacity/flow rate	Unit
WC (single flush)	7.5	litres
WC (dual flush)	(NB 1)	litres
Taps (excl. kitchen taps)	9	litres/minute
Bath (where shower also present)	155	litres
Shower (where bath also present)	16	litres/minute
Bath only	(NB 1)	litres
Shower only	(NB 1)	litres/minute
Kitchen sink taps	9	litres/minute
Washing machine	11	l/kg dry load
Dishwasher	1.4	l/place setting
Waste disposal unit	(NB 1)	l/use
Water softener	(NB 1)	l/person/day

Note 1: This appliance was assumed not to be installed.

The characteristics given in Table 4 and Table 5 were used to calculate the water consumption values (in litres day person per day) with the use of the Water Efficiency Calculator for New Dwellings. The results are given in Table 6.

Table 6 Calculated PCC values for three property types

Property type	Water consumption (PCC) (litres/person/day)
Flat	151.42
Semi-detached/Terraced	151.42
Detached	167.33

5.2 Calculation method

The calculation method in the spreadsheet (CBC Water Efficiency Calculator.xlsx) is based on the aspiration to offset a volume of water from a newly planned housing development by retrofitting water appliances in older properties located in the adjacent areas.

All input and output elements are found in the 'Inputs and Outputs' sheet within the calculator, explained in sections 5.2.1.

The green shaded cells require manual input; for illustration purposes the numbers were provided in all screenshots within this report. The grey shaded cells are calculated.

5.2.1 Inputs & Outputs tab

The top part of the calculation allows the quantification of the total volume of water to offset from the new development. The bottom part requires information on the target retrofit area as shown in Figure 7.

Please note that it is advisable to identify a retrofit area(s) that are approximately 5 times bigger than the required number of retrofit properties under each scenario. This is because on average only 20% of properties are able to take part due to various limitations, for example technological or due to unwillingness of the property owners.

Inputs

Characteristics of the new development		
	Number	**Unit**
Number of new homes in the development	1000	number
Average occupancy for the development	2.5	people/property
Design water efficiency of a new dwelling	125	litres/person/day
Target water consumption of a new dwelling	105	litres/person/day
Target saving per person	20	litres/person/day
Target saving per property	50	litres/property/day
Total volume of water to offset from the development	50,000	litres/day

Characteristics of the retrofit area		
Property type	**Proportion of property type**	
Flat	0.3	
Semi-detached/Terraced	0.5	
Detached	0.2	
	1	Note: must = 1
Occupancy of the retrofit area		
Number of 1 bedroom properties	1000	
Number of 2 bedroom properties	3000	
Number of 3 bedroom properties	3500	
Number of 4 bedroom properties	500	
Number of 5 (or more) bedroom properties	300	
Total	**8300**	It is advised that this number is 5 timer greater than the number of properties required for retrofit (see cell D67).
Target occupancy of retrofit area	2.24	people/property

Figure 7 Inputs required for the water calculator

Outputs of the calculation allow the retrofit scheme planners to quickly identify the numbers of fixtures and fittings required for three separate retrofit scenarios:

a) Scenario A assumes the following retrofits:
   - Low flow shower-head(s) with flow rate of 8 l/min.
   - Small cistern displacement devices (Save-a-flush) in all WCs.
   - Tap inserts in all bathrooms.

b) Scenario B assumes the following retrofits:
   - Low flow shower-head(s) with flow rate of 8 l/min.
   - Dual or variable flush devices (EcoBETA) in all WCs.
   - Tap inserts in all bathrooms.

c) Scenario C assumes the following retrofits:
   - Low flow shower-head(s) with flow rate of 6 l/min.
   - Dual or variable flush devices (EcoBETA) in all WCs.
   - Tap replacements with flow rate of 3.4 l/min in all bathrooms.

The scenarios were used to calculate water consumption (PCC) values and resultant water savings post-retrofit. The results are presented in Table 7.

Table 7 Calculated PCC and water saving values for three scenarios

Property type	Estimated PCC post retrofit Scenario A	Estimated PCC post retrofit Scenario B	Estimated PCC post retrofit Scenario C	Savings Scenario A	Savings Scenario B	Savings Scenario C
	Litres/person/day					
Flat	130.49	126.03	111.46	20.93	25.39	39.96
Semi-detached/Terraced	131.21	126.75	115.63	20.21	24.67	35.79
Detached	131.45	126.99	116.83	35.88	40.34	50.5

An example of scenario outputs is given in Figure 8. The outputs provide the cost of appliances per retrofit scheme and a total cost and cost per litre of water saved. All three scenarios can be easily compared.

In addition, a blank template has been created for Scenario D, which allows a user to populate it with their own selection of devices using a built-in drop-down list.

In order to create a new scenario, the user will need to use the main water efficiency calculator (Artesia water calculator for CSH and BR Part G using CLG method.xls) to work out the reduced water consumption for the selected retrofit appliances. The instructions for using the workbook are included in the first and second sheets. The workbook has been populated with the default assumptions (described in section 5.1.2). The user needs to first decide what water efficiency devices will make up the new scenario; then the user should edit the flow or volume data for that specific device in the workbook, reducing the flow or volume by the water saving for the specific water efficiency device. The water savings details for each water efficiency device are shown in the 'Water Efficient Technologies' tab of the 'CBC Water Efficiency Calculator' spreadsheet.

The new 'Total water consumption' values (from cell G26 in the 'The Calculator (Table 1)' tab in 'Artesia water calculator for CSH and BR Part G using CLG method.xls' should then be typed into the 'Inputs & outputs' tab of the 'CBC Water Efficiency Calculator' spreadsheet in column K (the three green cells) . All other calculations within this workbook will be updated automatically.

Outputs

Number of devices per scenario required to achieve the total volume of water savings needed to offset the development

	Device	Number of properties	Number of devices	Device costs (£)	Installation costs (£)	Total costs (£)
Scenario A						
	Low flow shower-heads with flow rate of 8 l/min	924	1109	£22,182	£27,727	£49,909
	Small cistern displacement devices (Save-a-flush)		1756	£2,634	£8,780	£11,414
	Tap inserts		1756	£8,780	£43,902	£52,682
	Total cost			£33,596	£80,410	£114,006
	Cost per litre of water saved					**£2.28**
Scenario B	**Device**	**Number of properties**	**Number of devices**	**Device costs (£)**	**Installation costs (£)**	**Total costs (£)**
	Low flow shower-head with flow rate of 8 l/min	780	936	£18,719	£23,399	£42,119
	EcoBETA		1482	£14,820	£37,049	£51,868
	Tap inserts		1482	£7,410	£37,049	£44,459
	Total cost			£40,949	£97,497	£138,446
	Cost per litre of water saved					**£2.77**
Scenario C	**Device**	**Number of properties**	**Number of devices**	**Device costs (£)**	**Installation costs (£)**	**Total costs (£)**
	Low flow shower-head with flow rate of 6 l/min	517	620	£12,397	£15,497	£27,894
	EcoBETA		981	£9,815	£24,537	£34,351
	Tap replacements with flow rate of 3.4 l/min		981	£49,073	£44,166	£93,239
	Total cost			£71,285	£84,199	£155,485
	Cost per litre of water saved					**£3.11**
Scenario D	**Device - please select from dropdown list below**	**Number of properties**	**Number of devices**	**Device costs (£)**	**Installation costs (£)**	**Total costs (£)**
		0		£0	£0	£0
				£0	£0	£0
				£0	£0	£0
				£0	£0	£0
				£0	£0	£0
	Total cost			£0	£0	£0
	Cost per litre of water saved					**£0.00**
	Maximum number of properties across all scenarios	924				

Figure 8 Example outputs from the water calculator

5.2.2 Supporting calculations and information

Three additional sheets are provided within the spreadsheet:

a) "Supporting calcs" which contains a summary of all assumptions. These can be changed by a user if required and the changes would automatically apply to the input and output values.

b) "Progress tracking" which allows the user to track how much water has been saved so far per scheme and therefore what the gap is to total target savings. This sheet requires the user to input the number of houses (per property type) that have already been retrofitted. The results are given in the output section; if the savings achieved to date exceed the target savings then the cell will automatically be coloured in green; if the savings are below the target value the cell will automatically be coloured in red.

c) "Water efficient technologies" which contains a list of all water efficient appliances currently available on the market together with their typical costs. These can be updated manually and the changes would automatically apply to the input and output values.

APPENDIX A

The tables below provide some additional information on the variants of the different water saving devices that can be obtained. It doesn't list every make and model, but provides information on the main categories of device. Where examples of devices are quoted, these are commonly used devices by water companies and water efficiency practitioners; other products with similar performance may be available. The potential savings are based on either the Code for Sustainable Homes calculation method, the Green Deal water efficiency guidance or the Waterwise Evidence Base. These are referenced as follows:

A1 Using the CSH calculator methodology.
A2 Green Deal Guidance for the Water Sector. EST/Waterwise. 2012.
A3 Water efficiency evidence base review. Environment Agency. June 2012.

Replacement WCs:

Type	Potential savings	Savings reference	Cost range	Comments
Dual flush WC 6/4 litres	5.9 litres/person/day	Compared to single 6 litre flush[A1].	About 0 to 15% higher than standard single 6 litre flush. Typical cost range is between £150 and £225; the average cost is £170.	See: www.water-label.eu
Dual flush WC 6/3 litres	8.9 litres/person/day			
Dual flush WC 4.5/3 litres	11 litres/person/day			
Dual flush WC 4/2.6 litres	13 litres/person/day			
Single flush 4.5 litres	6.6 litres/person/day			
Single flush 4 litres	8.8 litres/person/day			
Propelair 1.5 litre flush WC	20 litres/person/day		Between £440 and £675 per device depending on volumes ordered.	www.propelair.com

WCs - Retrofit devices:

Type	Potential savings	Savings reference	Cost range	Comments
Dual or variable flush devices (e.g. Ecobeta)	8.8 litres/person/day 16 litres/person/day	Based on 2 litres/flush saving(A2) using the CSH usage rate. ESW Ecobeta study(A3) (based on average occupancy of 2.5)	About £10	www.waterwise.org.uk
Small cistern displacement devices (e.g. save-a-flush)	2.3 to 5.5 litres/person/day	0.52 to 1.25 litres per flush(A2)	£1 to £2	
Large cistern displacement devices (e.g. hippo)	4.9 to 9.3 litres/property/day	1.1 to 2.1 litres per flush(A2)	£1 to £2	

Shower devices:

Type	Potential savings	Savings reference	Cost range	Comments
Aerated or low flow shower-heads	8 litres/person/day with a range of 5 to 10.5 litres/person/day	A2	£10 to £100	See: www.water-label.eu
In-line flow restrictors	8 litres/person/day with a range of 5 to 10.5 litres/person/day	On the basis that the devices restrict flow to 6 to 8 l/min	£4 to £10	

Tap replacements:

Type	Potential savings	Savings reference	Cost range	Comments
Tap with flow rate of 6 l/min	4.7 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]	Typical cost range is between £40 and £50; the average cost is £45.	See: www.water-label.eu
Tap with flow rate of 5.4 l/min	5.7 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]		See: www.water-label.eu
Tap with flow rate of 5 l/min	6.3 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]		See: www.water-label.eu
Tap with flow rate of 4.8 l/min	6.6 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]		See: www.water-label.eu
Tap with flow rate of 3.7 l/min	8.4 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]		See: www.water-label.eu
Tap with flow rate of 3.4 l/min	8.7 litres/person/day	Compared to a 9 l/min tap using the CSH calculator[(A1)]		See: www.water-label.eu

Tap retrofits:

Type	Potential savings	Savings reference	Cost range	Comments
Tap inserts	1 litre/property/day	A2	£5 to £20	

Rainwater harvesting systems:

Type	Potential savings	Savings reference	Cost range	Comments
Rainwater harvesting system – single property, new build	20 to 50% of mains water use		Typically £1500 to £4000; dependent upon the house size and storage tank capacity. Installation costs typically between £200 and £700 but some suppliers include these in the overall system cost. Maintenance costs in addition.	
Rainwater harvesting system – single property, retrofit	20 to 50% of mains water use		Typically more than within new builds. Indicative costs are between £2500 and £6000 per property.	
Rainwater harvesting system – communal scale, new build	20 to 50% of mains water use		Overall cost per house lower than for single house installation.	
Rainwater harvesting system – communal scale, retrofit	20 to 50% of mains water use		Overall cost per house lower than for single house installation. Indicative costs are in the region of £3000 per property.	

Greywater recycling systems:

Type	Potential savings	Savings reference	Cost range	Comments
Greywater recycling system – single property, new build	20 to 50% of mains water use		From £2000; dependent upon specific site requirements.	
Greywater recycling system – single property, retrofit	20 to 50% of mains water use		Typically more than within new builds. Indicative costs are in the region of £3000 per property.	
Greywater recycling – communal scale, new build	20 to 50% of mains water use		Overall cost per house lower than for single house installation.	
Greywater recycling system – communal scale, retrofit	20 to 50% of mains water use		Overall cost per house lower than for single house installation.	