Water Conservation Products

A preliminary review.
Watersave network.
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Summary

The wider uptake of currently available technologies could typically double the efficiency of many appliances and terminal fittings. Some of the water economy achieved by such technical improvements is likely to be offset by changes in bathing habits and increased affluence.

- Some efficiency measures will have an associated over-cost but the higher cost of some efficient appliances does not always need to be offset by water savings as the higher cost may be due to other features or qualities.

- Water efficiency is still not a major factor for consumers. People are wary of low water use items, which are assumed to be worthy, but of low performance. Performance measures as used in Which? reports and energy labels could provide a step towards challenging such simplistic assumptions.

- In the UK, regulatory pressure is likely to be required to enforce technical changes.

- Some technologies can be easily retrofitted whilst others are likely to be limited to new installations and refurbishment.

- Efficiency measures appear to be more cost effective and more environmentally benign than recycling or rainwater harvesting. Improved technologies and specific applications may change this balance.

- Water savings and performance can easily be countered by bad design, poor installation and lack of maintenance.

- Some of the saving due to technical improvements will be absorbed by increased bathing frequency, wider ownership of washing machines and increased affluence.

1. Introduction

This preliminary review aims to assess the state of the art and future potential for ‘water conservation products’. This has been interpreted loosely to include the following:

1. Retrofit innovations – ‘Hippos’, delayed action WC inlet valves, tap aerators etc.
2. Water using fittings and appliances – WCs, washing machines etc.
3. Design – plumbing layout, pipe sizing, garden design etc.
4. Reuse, harvesting and recycling.

In looking at actual technologies the paper starts to explore a number of related questions:

1. How does efficiency compare with recycling and harvesting?
2. Does reduced water consumption mean reduced performance and hygiene standards?
3. Are water efficiency measures cost effective?

This paper will focus on fittings and appliances with a passing mention of the many factors that influence the potential savings. These factors are explored in detail elsewhere (e.g. EA 2001) and in other Watersave reviews. They include:

1. Uptake
    a. Replacement period (e.g. washing machines or bathrooms)
    b. Fashion, trends
    c. Acceptability of technology
    d. Other drivers and barriers.
2. The proportion of total water uses by the component (e.g. an 80% reduction in water use for tooth brushing might be equivalent to a 5% reduction in WC consumption.
3. Rebound effects (longer showers, half flush used for facial tissues rather than bin).
4. Consumption trends, bigger baths, more frequent showers, cleaner cars, multi-head showers, recession or increasing affluence.

Whilst this paper focuses only on hardware, the author does not wish to suggest a purely technical approach to water efficiency, as it is likely that greater savings can be had by changes in personal habit. It is also clear that technical improvements can be negated by unforeseen changes in lifestyle (1, 3 and 4 in the list above).

1.1. Scope

This document should be seen as a discussion paper; the figures and assumptions need further checking and the simple models need refining. Each of the technologies from taps to WCs would justify a preliminary review of their own.

2. Principles

2.1. Definitions

A framework outlining generic approaches to water saving is very useful as the barriers and drivers for different technologies and approaches vary. Some suggested definitions:

Water *conservation*; doing less with less.
Particularly appropriate at times of drought or when camping but moderate application such as washing cars less often (but keeping lights and glass clean) may have some general applicability. Generally standards such as hygiene and aesthetics will usually suffer. Acceptability is very culturally dependent. We will ignore this category in this paper, as we are considering technologies that provide the same or better level of service as water-wasting ones.

Examples:

- If it's yellow let it mellow.
- Don't water lawns.
- Don't wash the car (as often).
- Take shallow baths and short showers.

Water *efficiency*; doing more with less.
This approach to water saving should be the least sensitive to issues of human interface, i.e. no lifestyle changes should be required. Efficient fittings should do the same job with less water. Often efficiency improvements lead to other advantages such as reduced energy consumption, lower noise, better performance etc.

Examples:

- Hydraulically efficient WC pans and cisterns (i.e. not just reduced flush volume).
- Optimised pipe dead legs and insulation.
- Optimised bath shape.
- Tap aerators and sprays.
- Shower head design.
- Efficient white goods.
- Garden design, drought tolerant plants and grasses, mulch.
- Fix leaks.

Water *sufficiency*; enough is enough.
This approach is one of optimisation. As with efficiency there should be no loss of effectiveness. Optimising water sufficiency usually involves technical and user input. For example baths can be optimised in shape and limited in size but users can still choose how deep to fill them. Similarly dual flush WCs promise savings dependent on correct use. Even habit dependent savings such as turning off taps when brushing teeth can be influenced by technical innovations, as we will see.

Examples:

- Hogs and Hippos and adjustment of WC flush volume to suit application.
- Dual flush.
- 'Ergonomics' – eco button on shower, water-brake taps.
- Flow regulation.
- Bath sizing.
- Control – auto or manual, e.g. turn off tap when brushing teeth or timed taps.
- Careful garden watering.

Water *subsitution*; replace water with something else such as air.
This is self-explanatory and covers technical solutions such as vacuum and compost toilets as well as simply using a broom rather than a hose to clean paths. Some alternatives to water may have a higher environmental impact (energy use of drying toilets, solvents for dry cleaning) than water but this may be justified if water is not available or disposal is limited.

Examples:

- Dry toilets.
- Waterless urinals.
- Vacuum drainage (uses some water but air used for transport).
- Clothes brush.
- Dry cleaning (not done for water saving).
- Hand-wipes (e.g. for remote toilets without water).
- Air for industrial cleaning processes.
- Broom rather than (or before) wash-down of floors.

Water *reuse, recycling and harvesting*; a potentially virtuous circle.
Definitions vary but for this paper we suggest that *reuse* refers to direct reuse with minimal treatment whilst *recycling* refers to a process of treatment prior to reuse. Direct reuse is generally a low cost option but requires a good availability and quality match between resource and sink to avoid the need for treatment and storage. Recycling introduces the need for extra energy and possibly chemicals for treatment. Other impacts should be considered if the aim of the scheme is environmental improvement.

Examples:

- Direct *reuse*:
    - Rainwater harvest
    - Water butts
    - Greywater irrigation (direct)
    - Process water reuse
    - Shared bath water
- *Recycling* – treatment, storage reuse:
    - Greywater recycling
    - Blackwater recycling

2.1.1. Why these categories?

Some products or techniques will fit neatly into a single category whilst others will feature efficiency, sufficiency, substitution and even recycling or reuse. For example a clothes washer-dryer or vacuum WC.

The proposed categories help provide simpler answers to questions about barriers and drivers. If we look at each category then the barriers and drivers are different and discussion can be more meaningful. For example *Water Conservation* is often challenged on grounds of hygiene, cost, perception or the difficulty in 'educating the public'. Some of these charges are relevant to some technologies in some categories.

We will look at some of these assumptions later.

The breakdown also provides a checklist that can be applied to product or system design when looking for potential savings.

2.2. The potential for technical solutions for demand management.

The following tables are offered as a preliminary summary of the potential savings from current and future technologies. It is intended as a starting point for discussion rather than prophesy.

The first table looks at frequency of use of micro-components. The last column shows the values used in this paper. A proper analysis of usage and trends is beyond the scope of this paper but crucial to understanding.

Use	% [1]	SODCON l/pe/day (1994) [1]	Assumed vol/use, litres [2]	so freq'/p [3]	Compare, frequency, EA 2001 [4]	**Assumed uses/p/day- for BATNEEC and future [5]**
WC	35	52.5	10	5.25	4.12	**4.12**
Bath	15	22.5	80	0.28	0.34	**0.34**
Shower	5	7.5	15	0.5	0.6	**0.6**
Kitchen sink	15	22.5	10	2.25	?	**2.25**
WHB	8	12	6	2	0	**2**
Wash m/c	12	18	100	0.18	0.157	**0.157**
Dishwasher	4	6	28	0.21	?	**0.214**
Outside	6	9	9	1	0	**0**
Totals	100%	150 litres				

Table 1. Assumptions for initial analysis of potential savings.

Notes:
[1] % from Anglian Water SODCON data 1994. l/p/d calculated for 4 person house.
[2] Assumptions to generate frequency data.
[3] Frequency calculated from previous data and assumptions.
[4] Frequency values interpreted from EA (EA 2001).
[5] Guestimate of frequency for a single scenario comparison of water saving for improved technologies in table 2. These figures are not definitive and only for use in the context of this paper.

Use	BATNEEC vol/use [6]	So BATNEEC Vol/day [7]	Reduction (% of SODCON figure) [8]	Technical potential: volume/use [9]	Vol/day [10]	% reduction from SODCON
WC	4	16.48	69%	3	12.36	76%
Bath	70	23.8	-6%	50	17	24%
Shower	20	12	-60%	6	3.6	52%
Kitchen sink	3	6.75	70%	2.8	6.3	72%
WHB	3	6	50%	2.5	5	58%
Wash m/c	45	7.07	61%	35	5.5	69%
Dishwasher	18	3.85	36%	14	2.996	50%
Outside	0	0	100%	0	0	100%
Totals		76	49%		52.8	65%

Table 2. Estimate of potential water saving with Best Available Technologies Not Entailing Excessive Costs (BATNEEC) and estimated future technologies.

Notes:
[6] Available technologies, 2001.
[7] Calculated from assumed frequencies in table 1.
[8] Reduction in water use compared with SODCON data.
[9] Guestimate of technical limit using current technologies.
[10] Calculated from frequency and [9].

Again, a scenario-based analysis is beyond the scope of this paper or the author's expertise but the broad issues must be considered in that they should influence technical design solutions. The figures should be seen as technical potential and assume water aware users.

3. Available technologies; analysis by category

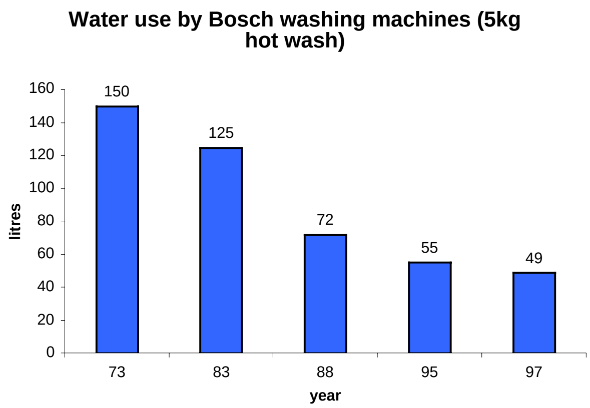
The EA fact cards (EA 2001) detail some currently available water saving technologies and techniques and represent the output from a desktop study of manufacturer's products carried out from February to April 2001. The project also produced a database of manufacturers and suppliers and a full collection of product literature that is held and maintained by the EA National Water Demand Centre.

The numbering and 'product' grouping of the cards will be repeated here:
1. Domestic Appliances.
2. Garden appliances/water efficient gardening.
3. Grey-water.
4. Rainwater.
5. Taps.
6. Supply restrictor valves.
7. Urinals, waterless, controls and washroom controls.
8. Waterless and vacuum toilets.
9. Water efficient WCs and displacement techniques/retrofits.
10. Showers and baths.
11. General management.

3.1. Domestic Appliances.

Discussion

The energy and water efficiency of dishwashers and washing machines has improved significantly over the last 10 years. Tests published by Which? suggest a discrepancy between the energy label water use and that measured in simulated use during their tests.



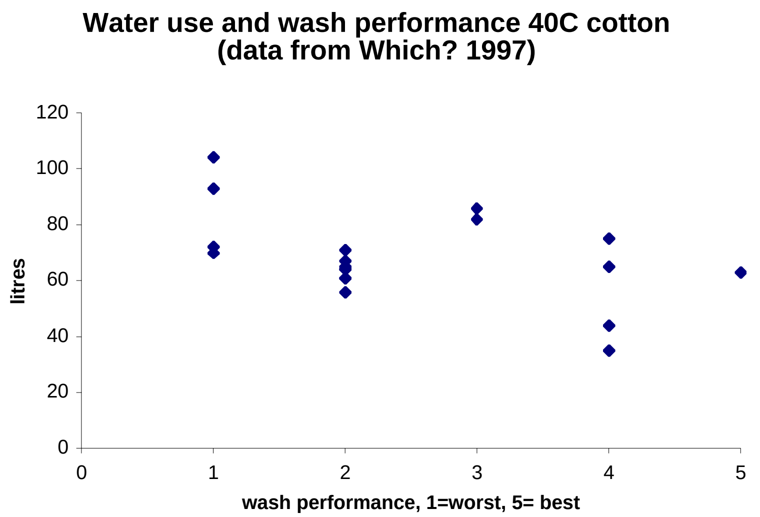
Graph 1. showing the trend in water use for Bosch washing machines. Data from Bosch product literature.

Obviously water and energy use per cycle depends on the program. The Water Regulations and EU Directive 95/12/EC specifies a maximum water consumption of 27 litres per kilogram of washload for horizontal axis clothes washing machines. Thus a 5kg load would use 135 litres compared with an increasingly common 50 litres of less.

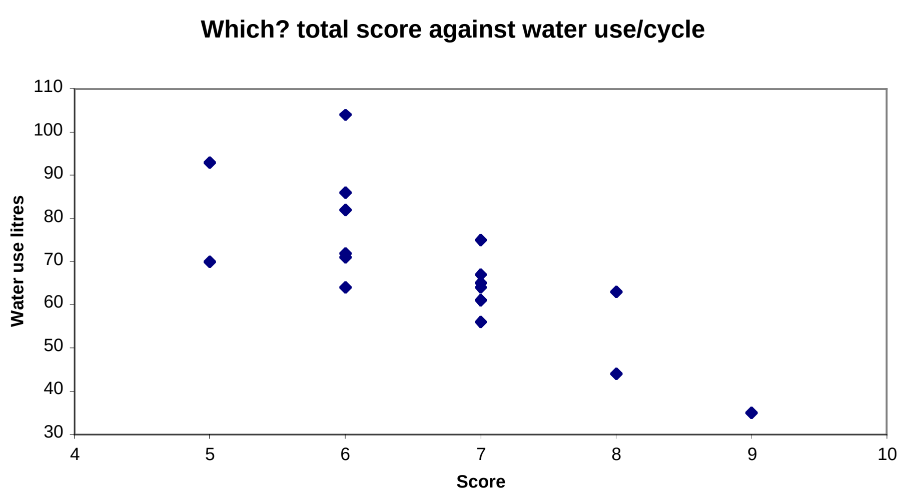
The bar graph shows the trend for reduced water use by Bosch washing machines, which suggests that the new Water Regulation may have been a useful conservation measure twenty years ago.

Water use and cleaning performance

Concern is often expressed about compromised hygiene and cleaning performance due to water efficiency measures so it is interesting to analyse available data to check this assumption. The first scatter graph below shows the wash performance and water use of machines tested by Which? on a 40°C wash. It is tempting to add a trend line suggesting that wash performance is inversely proportional to water use but this can be inverted by selective choice of sample. Also for a given machine, increasing the water use should increase the cleaning performance. What it does however show is that wash performance does not seem to be dependant on or guaranteed by high water use. The graph shows that the most water (and energy) efficient machine was as good or better at washing than all the machines except one. The other scatter graph shows the Which? total score (cleaning performance (22%), running costs (24%), spin efficiency (7%), water use (11%), time, rinse and balance (14%) drying (22%)) against water use. Again this would need to be repeated with more data for newer machines but the results seem to challenge at least two assumptions, namely that 'less water equals less performance' and that 'it is not worth buying a water efficient machine as there is no payback'. The second assumption is true, in terms of payback alone, for most current water costs and typical usage. However the graphs and other results suggest that the more water efficient machines offer other advantages and that water and energy (another interesting correlation) efficiency are merely a spin off of good design rather than something achieved at the cost of performance and price. Thus efficiency is a bonus and should not be required to demonstrate any, or at least not all, of any payback.



Graph 2. of wash performance and water use for the 19 washing machines tested by Which? in 1997 (more recent data only rated water use from best to worst).



Graph 3. of water use against the total test score for the 19 washing machines tested by Which? in 1997 (more recent data only rated water use from best to worst).

Water efficiency of dishwashers and washing machines is strongly influenced by use, as part-loads are much less efficient than full ones. Half load buttons and fuzzy logic are only a partial solution and may encourage people to use part loads. Some half-load dishwasher programs have been found to use the same amount of water as full ones.

BATNEEC (best available technology not entailing excessive cost)
Specifications constantly change and, as already mentioned, water use depends on the program and how the machine is tested. Washing machines using around 40 litres for a 5kg, 40°C cotton wash and dishwashers using around 14 litres per cycle (12 place settings) are widely available. Manufacturers claim that dishwashers are more environmentally friendly than hand washing as less water can be used but we think that the jury is still out when considering a real world life cycle assessment.

Future
It looks as if water use will level out at around 30–40 litres per wash. Technical innovations that may reduce water use further include ultrasonic agitation, easy rinse detergents with controlled dosing and more sophisticated control systems. Payoffs with other environmental and health issues are possible for example low temperature detergents that save energy but use enzymes, zeolytes versus phosphates etc. A machine using 40 litres per wash used every day for a family of four should use about 14.6 m^3 of water a year and about 365 kW.h of electricity. At a water and sewage charge of £1.50/m^3 and electricity price of 7p/kW.h this equates to £22 for water and sewage and £26 for electricity or about 13p/wash. Thus the drive for water saving is unlikely to be driven by running costs alone.

Trends that may offset savings include the demand for larger machines and faster wash cycles.

3.2. Garden appliances/water efficient gardening.

Discussion
Gardening and water use in the garden is a complex and controversial subject. All we will say here is that in the UK it is possible to garden using no mains water. Technical fixes such as drip irrigation and sprinkler timers are probably unnecessary complications for all but the driest parts of the UK and can lead to water wastage if incorrectly used or maintained.

Fashion is likely to be the greatest driver for water use in the garden, which could head towards a waterless, low maintenance future or large green lawns and leaking ponds and water features.

BATNEEC
Mains-waterless gardens are possible now with good design and appropriate planting. Water butts can provide a surprising amount of the water needs for all but the largest garden.

Future
More of the same perhaps with direct greywater reuse if extra water is required in summer. In dry climates and perhaps drier parts of the UK, the potential for direct greywater irrigation is considerable.

3.3. Grey-water and blackwater reuse.

Discussion
Commercial and experimental systems have been developed to treat and store light grey water, typically from baths and basins and reuse it for WC flushing. Manufacturers typically claim water savings of around 30-40%, i.e. it is assumed that all WC water is supplied by grey water. The theory and practice of greywater systems is covered thoroughly elsewhere but we will return to look at them in comparison with efficiency measures later.

BATNEEC
At least one commercial system is still available in the UK with the initial flush of systems having now died out. We cannot recommend greywater reuse at the single household level with current technologies because of poor cost effectiveness, poor reliability, high life cycle impact and unreliable water savings. Blackwater recycling already occurs indirectly via sewage treatment and discharge to rivers or groundwater but more directly in a number of trial schemes such as the now abandoned Beazer Homes trial with Anglian Water.

Future
Technological breakthroughs are required and I am sceptical about the future of domestic greywater systems in the UK. For water-stressed areas, blackwater recycling may have more potential on larger scale. New technologies include MBR and SBR sewage treatment plants, which are capable of producing high quality effluent suitable for reuse after disinfection. Life cycle impacts must be considered, particularly energy use and toxic by-products of disinfection.

3.4. Rainwater (other than garden butts).

Discussion
Properly collected and stored rainwater is generally accepted as suitable for use in WCs, washing machines and for garden use. Typically these account for around 50% of domestic use but as best practice WC and washing machine volumes have dropped by over 50% whilst bathing has increased this figure would need revising when considering new-build and major refurbishment works. Rainwater and greywater will be compared with efficiency measures later.

BATNEEC
A wide range of commercial systems is available and details are beyond the scope of this paper.

Future
Current systems are not usually cost effective, especially at the domestic scale and energy use for pumping is generally higher than for mains water. Future technical developments could include low cost variable speed pumps but reliability could not be sacrificed. Tanks are a major system cost but are probably a mature technology unless innovative solutions for new-build can be found with, for example, shared function.

3.5. Taps.

Discussion
Appropriate technologies depend on the use, kitchen, bathroom or commercial washroom. The main approach is sufficiency with optimised flow rates and good ergonomics.

As with washing machines, some of the more expensive models incorporate efficiency features such as the Hansa Ecotop cartridge. For mains pressure supplies, aerators or laminar flow devices will eliminate splashing whilst regulating flow rates and providing the illusion of more water flowing. Savings will be higher for lower levels of user awareness. For commercial washrooms spray taps offer around 80% reduction in flow rate but correct specification and adjustment of flow is crucial for user satisfaction. Generally flow rates are too high leading to splashing. Timed turn-off and electronic taps offer savings in commercial applications as well a real or perceived hygiene benefit.

BATNEEC
A wide range of fittings are available, see EA Fact Cards. Regulated sprays and aerators allow easy specification of flow rates. Hot and cold must be clearly and indelibly marked and operation should be obvious to avoid wastage as users try to find which position provides hot water.

Future
The widespread use of standard threaded outlets on tapware would allow the use of sprays, aerators and innovations. ‘Waterbrake’ cartridges and integrated adjustment of flow rate and hot water flow could become standard features at little extra cost. Ideas such as flow sensitive spray fittings (Tapmagic) have great potential. Electronic taps may have application in health and commercial settings but their appropriateness for domestic use is unlikely to be justified on sustainability grounds.

3.6. Supply restrictor valves.

Discussion
Flow restriction and pressure and flow regulation are mature technologies. Savings are variable and are dependent on user awareness. For new installations flow regulation is justified in terms of improved performance alone (balanced dynamic pressure, reduced splashing). Regulation by shower heads and aerators should also be considered where appropriate and can have efficiency advantages.

BATNEEC
Products are low cost and readily available.

Future
Wider use of existing technology, specification as part of building and Water Regulations. Regulators for pressures less than 1 bar are becoming available.

3.7. Urinals.

Discussion
The Water Regulations require that flushing is limited in frequency and volume and should only occur when a building is in use. Many installations, even new ones, do not meet this base specification. Also many technically compliant installations are wrongly adjusted or not maintained and so default to continuous operation using arbitrary volumes of water.

Manufactures offering water saving solutions quote impressive savings but these are usually based on arbitrary volumes rather than correctly set flushing rates that meet the old Byelaws or New Regulations.

Purpose designed waterless urinals have been available for over 100 years and there are many models on the market. Most use disposables or require a maintenance contract. This makes commercial sense for manufacturers and suppliers of such systems and this has driven the technology. After much research with an available system, BRE patented a chemical and consumable free solution many years ago. They say that since it was so simple and lasted indefinitely it had little commercial potential. Our own research has backed up the BRE findings and led to a number of potential designs that are being trialed.

BATNEEC
We suggest that waterless urinal operation can be achieved without the use of special chemicals or consumables.

Future
Waterless operation offers a number of advantages provided a system could be marketed that is cost effective and easy to maintain. From an environmental point of view water savings must not be offset by increased chemical consumption or other impacts.

3.8. Waterless and vacuum toilets.

Discussion
Current waterless toilets are not a simple direct replacement for the WC. For rural and suburban eco-houses and remote toilet blocks they can represent a best available technology but their widespread use is not considered likely in the UK at present. The EA fact cards provide some more detail and the book “Lifting The Lid” (Harper and Halestrap, 1999) is definitive for the UK.

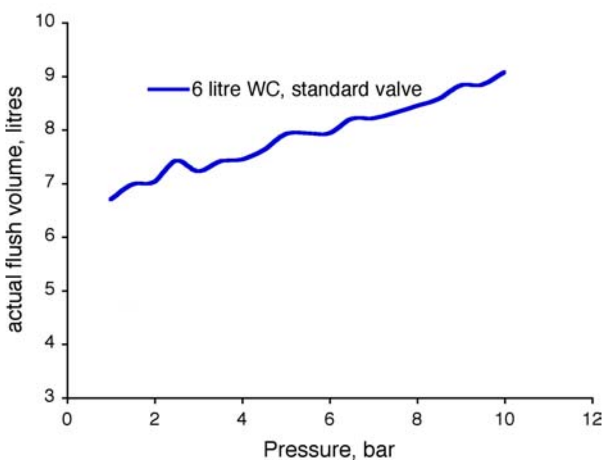
Vacuum toilets are not normally recommended for simple water saving except in extreme situations such as aircraft and trains.

BATNEEC
All available dry toilet systems are zero water use but some require electricity. Vacuum toilets use about 1.2 litres per flush.

Future
Dry toilet designs are evolving but are mostly intended for rural sanitation. Vacuum technology may have wider application but would require some technical problems to be solved if it is to be used on the domestic scale whether in individual dwellings of blocks of flats. Again cost and life cycle issues must be considered.

3.9. Water efficient WCs and displacement techniques/retrofits.

Discussion
WCs have traditionally represented the largest single use of water in dwellings and offices. As WC water use decreases and water use for bathing increases this balance will shift. Current regulations require WCs to flush with a maximum volume of 6 litres for a full flush and up to two thirds of this for a reduced flush if this is available. Actual flush volumes are almost always higher as the volume is measured with the water supply turned off. In reality water enters the cistern during the flush. Similarly when considering dual flush the average flush cannot be calculated simply using normal assumptions of ratios between solids and liquids uses. Trials with 6/3 and 6/4 litre litre dual flush WCs have delivered average volumes of between 5 and a little over 6 litres per flush – more research is needed.
Another factor that is hard to quantify is that of flush valve leakage. The problem is made worse in the UK by the low penetration of water metering which means that a customer faced with a leaking valve will, as with failing inlet valves, usually allow it to leak rather than pay a plumber to try and fix it.



Graph 4. indicating flush volume against supply pressure for a nominally 6 litre WC. A delayed action inlet valve will maintain the nominal volume at all pressures. Data from WRAS for 7.5 litre WC, scaled for 6 litre.

All these factors must be considered when evaluating real world performance as two 6-litre WCs may have very different water use over their life. The matrix below compares the pros and cons of single and dual flush as well as valves and siphons. Real data is required to lift the debate beyond personal opinion and anecdotes.

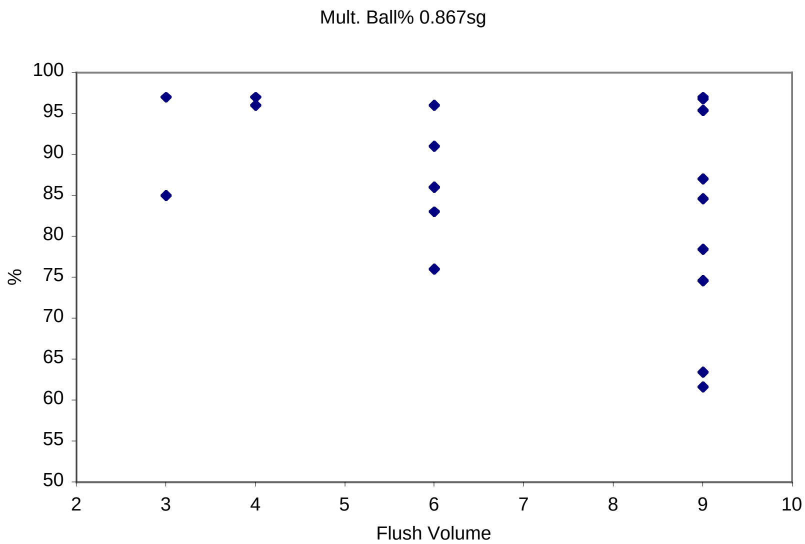
Objective discussion of such issues is clouded by the politics and vested interests that surround this surprisingly emotive subject.

Valve	**Syphon**
Fast flush. Easy operation. Dual flush easy to distinguish. Will eventually leak – hard to spot. Unfamiliar to UK plumbers. Mechanisms can stick open.	Leak-free. Robust. Familiar to UK plumbers. Parts widely available. Dual flush less elegant. Flow rate tends to be less.
Dual-Flush	**Single-flush**
Potential for water saving. Double flushing possible. Half flush may be insufficient for women's public toilets. Users may try both buttons. WC may be used as bin.	No user education or understanding required. Simpler mechanism.

Nominal flush volume and performance

Issues of actual flush volumes aside it is now illegal to install a new WC with a nominal flush volume greater than 6 litres. Poor everyday experience with older WCs using 9 and 13 litres and more recent low flush 7.5 litre models might not inspire confidence in 6 litre models. Obviously the more water that is put down a given pan, the better it will be cleared and further the contents will be carried along the drains. Experience however suggests that there is no clear correlation between the design flush volumes of a range of WCs and their performance. Some designs will release a deluge of 13 litres but still fail to flush the pan.

The graph below shows the number of standard test balls (as a percentage) that were flushed out of the pan for a range of WCs tested at Brunel and Heriot Watt Universities between 1980 and 2002. As with the washing machine data, caution is needed but similar conclusions can be drawn. The better performing WCs are clearly designed to be efficient in their function whereas some of the less efficient models rely on larger volumes of water to do the job by attrition.



Graph 5. showing the number of plastic test balls (as a percentage) cleared from the pan with a full flush for a number of WCs at their design flush volume. Data from student experiments at Brunel and Heriot Watt, 1980–2002, courtesy of Professor John Swaffield.

Clearly this is only one test and tests only measure what can be standardised rather than simulating real world requirements. We can expect performance for a given pan to improve as flush volume increases. The important observation is that flush volume alone is not a reliable indicator of flush performance.

Displacement devices and retrofits

Where an older WC uses more water than it needs a displacement device can be fitted to reduce the water use (EA fact cards).

Illegal Dual flush retrofits are available for siphon flush WCs and their legality is being reconsidered. Trials have shown average savings of 27% (Southern Water 2000) but all the issues and limitations of dual flush apply.

The Opella Ecofil delayed action inlet can be fitted as a retrofit device in most cisterns without compromising performance. Savings will depend on water pressure, flush duration and cistern refill time.

BATNEEC

At the time of writing very few WCs have been listed with WRAS under the new Regulations (one). Independently tested and self certified models are available at 6 and 3 litre dual flush and 4 litre single flush and others are going through the approvals process. Delayed action inlet valves are available which solve the issue of actual flush volumes being higher than when tested. Leak free siphon WCs are available with 6 and 4 litre single flush.

Future
Emphasis must be placed on actual flush volumes over the WCs life and there is room for regulatory control without which changes are unlikely to happen in the UK.
4 litres (full flush) is generally thought to represent a lower limit for use with existing gravity drainage but flush boosters are possible. These collect a number of flushes, possibly with greywater as well, and discharge then as a single larger flush ensuring good drain carry. This would reduce requirements to what is needed for pan clearance and scouring, perhaps 2 – 3 litres with suitable design.

Leak free and leak detecting inlet and flush mechanisms are possible but the industry is very price sensitive and their development is unlikely without regulatory pressure.

3.10. Showers and baths.

Discussion
Water efficient showers are a complex subject and even more so in the UK than say the US. Here we have electric showers, gravity fed and mains pressure hot water systems. The rest of the world tend to have mains pressure hot water systems so it is a simple matter to specify a shower head of a given flow rate and for users to find something that suits them.

Most ‘water saver’ showers introduce air or atomise the water drops to improve wetting for a given flow rate. The result feels like a ‘power shower’ but with perhaps 4–9 litres of water per minute rather than 12–20 that might be delivered by ‘power showers’. This is still more than many electric showers and some gravity fed showers will deliver. For safety reasons, flow regulators and water saver showerheads should not be fitted to electric showers without consulting the manufacturer. As the smaller droplets cool quickly users may experience cool feet due to the temperature drop between shower head and tray (Fiskum 1993).

Whilst undertaking reproducible performance tests for WCs is a major technical and legal challenge it is perhaps trivial compared with developing such objective comparisons for shower performance which is judged in terms of comfort and rinse performance. Other important but difficult to quantify factors which will effect water consumption include ease of temperature and flow control.

Baths are rather simpler but the water use is difficult to assess as they are used in different ways. Capacities are usually given to the overflow. Most UK catalogues specify the water volume without a person whilst some European manufacturers consider Archimedes and allow for an ‘average person’ so quoted figures may not be directly comparable.

The thermal mass of most baths is negligible compared with the water content but heat-loss will influence the amount of top-up for long soaks.

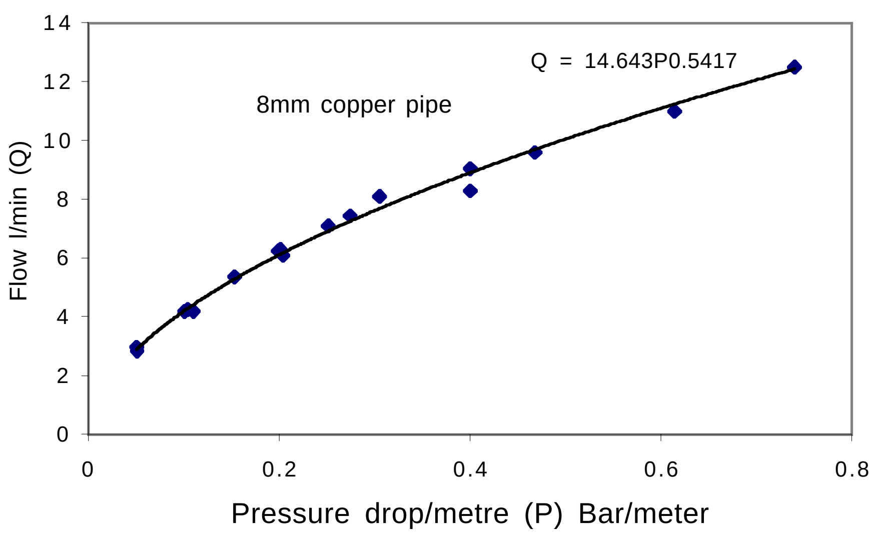
Bath shape will influence water depth for a given volume.

BATNEEC
More research is needed. Small baths are available but may not always be acceptable.

Future
Efficient but comfortable shapes, better insulation, low thermal mass.

3.11. Plumbing systems.

Discussion
Factors other than the appliances and terminal fittings also influence water efficiency in a building. For example water metering, supply pressure, hot water pipe sizing, length and choice of hot water system will all have an effect. Current recommendations suggest sizing water pipes and then going up a size to provide a margin of safety in terms of flow rate. With mains pressure water systems small pipes can be used and successful systems have been installed with 8 and 10mm microbore for kitchen sink and showers. Baths require a higher flow rate but the dead-leg is not an issue. Available design graphs and tables do not cover high flows in small pipes.



Graph 6. Results of tests to develop sizing charts for small bore pipe (Elemental Solutions).

BATNEEC
Water metering, optimised hot water dead-legs, optimised plumbing layout, thermal store combi boilers (if a combi is used). Also flow and pressure regulation (see section 6).

Future
Leak detection integrated with remote meter reading? Research and guidance for use of microbore pipe for hot water delivery.

4. Efficiency versus reuse and harvesting.

Over the last few years there has been much research-money and conference time devoted to rainwater harvesting and greywater reuse. Usually efficiency measures are mentioned in passing but, we suggest, are rarely given the same prestige or attention as recycling.

Some questions that can be answered for general and specific situations:

- Can efficiency measures provide a similar magnitude of water savings to reuse?
- How can most water be saved for a given capital cost?
- How does the life cycle impact of efficiency and reuse options compare?
- What other factors might influence the choice of approach?

4.1. Economics

A simple model is proposed that avoids the limits of simple payback whereby a Hippo will always 'beat' an efficient WC because the cost is so low. If we consider the net worth of a measure after n years we can plot the straight line graph (y=mx+c), or:

$W_n = (S-r).n - C$

Where:

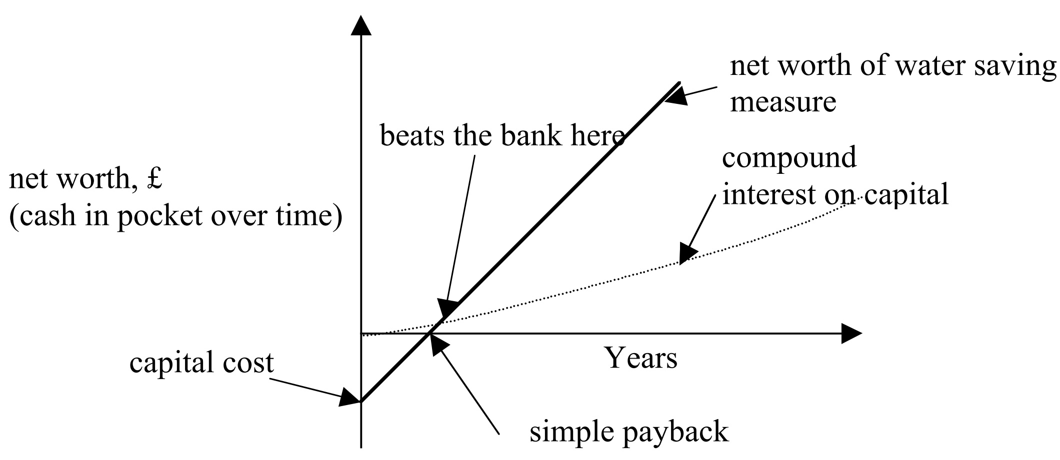
$\mathbf{W_n}$ is net worth of a measure over **n** years.

S is the annual saving.

r is any increased annual running cost.

C is the capital cost in the same units as W_n, r and S.

Interest on borrowed capital and inflation are ignored in this model but a comparison of the financial return can be plotted to show the income that could be had from investing the cost of the capital expenditure.

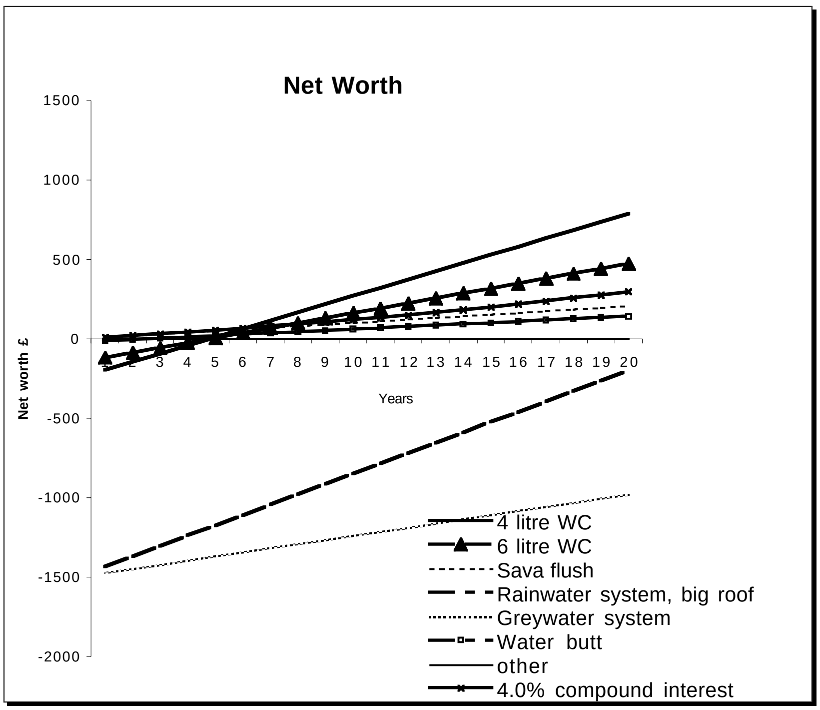


Graph 7. Net worth with time for a water efficiency measure. The compound interest curve compares the growth of interest on the capital cost if invested in a bank or building society rather than in water efficiency. The gradient shows the annual saving.

Using this format we can compare a number of measures:

Measure	saving	Of	m3 saved/year	Annual cost	capital cost	Annual saving £
4 litre WC	55%	35%	34.6	0	300	52
6 litre WC	33%	35%	20.7	0	150	31
Sava flush	11%	35%	6.9	0	2	10
Rainwater system, big roof	70%	53%	66.6	35	1500	65
Greywater system	70%	35%	44.0	40	1500	26
Water butt	50%	6%	5.4	0	20	8
other						0
4.0% compound interest	4%			Investment:	£ 300	4%

Table 3. spreadsheet showing data and assumptions for the graph below.



Graph 8. comparing the net worth of a number of measures using the assumptions shown in table 3.

Notes on graph:

Running costs for the rainwater system are assumed to be £5/year for electricity and £300 every 10 years for pump or other component replacement (conservative). A large (c.a. 100m^2) roof and reasonable rainfall (about 800mm) are assumed. Water is used for WC, washing machine and garden use. Water and sewage costs are £1.50/m^3.

Running cost for greywater system is assumed to be £20/year for chemicals and electricity and £200 every 10 years for pump or other component replacement (conservative). It is assumed that 70% of WC water use is met by greywater (optimistic).

Compound interest is on £300 (tax free), i.e. the assumed cost of a 4 litre WC.

Clearly when running costs, albeit optimistic ones, are included in the payback, rain and greywater systems are far less cost effective than efficiency measures.

For many situations the available rain yield is less than required for WCs and washing machines. Similarly with greywater systems, greywater production does not always match demand for WC flushing. This has been shown in a number of studies (EA 2000, Essex and Suffolk Water 2001). The graph assumes that rainwater discharged to the sewer without charge, a current loophole that some water companies are unhappy with.

Another model that allows cumulative measures to be plotted shows that for domestic situations, if the budget available for a reuse system is spent on efficient appliances then greater savings can usually be obtained for less cost although not all the measures will be economic (presentation at the National Water Conservation Group, DEFRA Dec 7th 2001). Efficiency measures also tend to reduce energy consumption and other costs.

4.2. Environmental impact

It is clear that grey and rainwater systems almost always use energy for pumping and even UV disinfection. Commercially available greywater systems also use disinfectants such as chlorine or bromine. Other considerations include the cradle to grave impact of tanks, pumps, electronics, pipes etc. All these impacts might apply to mains water and a common assumption is that decentralised or autonomous systems are environmentally preferable since water does not have to be treated to drinkable standards and pumped over large distances. In practice when we do the numbers small-scale systems have a significantly greater impact than the mains. In situations where water is scarce and measures such as desalination are being considered as supply options, then reuse and recycling may be viable. Similarly where there is a large demand for low-grade water for irrigation matched with a need for a high quality effluent then a virtuous circle may be created.

Another consideration is the effect on aquatic pollution if halogen treated greywater is discharged to sewers and rainwater is diverted from soakaways to sewer via the WC. Where combined drainage is used then rainwater reuse may have a beneficial effect on total pollution to watercourses.

Crettaz et al (1999) and Dixon (2001) compare rainwater harvesting and water efficient WC scenarios using life cycle assessment tools with perhaps surprising results. Whilst many of the assumptions are difficult to check, a comparison of their assumed energy use for rainwater pumping with that of actual monitored systems suggests that their figure is considerably lower. Despite this their analysis shows that the domestic rainwater reuse scenarios had a significantly higher environmental impact than the efficiency scenarios.

Clearly LCA interpretation will always be partly art as well as science but initial results challenge common assumptions.

4.3. Potential to offset water supply infrastructure

One of the drivers for water demand management is the cost, environmental and social impact of creating new resources such as reservoirs. Whilst I have seen no analysis it seems unlikely that even widespread uptake of rainwater systems would have significant effect on peak summer demand when supplies are most stretched. Greywater and blackwater recycling could theoretically reduce this demand but is unlikely to represent a least-cost solution, financial or environmental.

4.4. Effluent reduction (and stormwater attenuation)

Grey and blackwater reuse can reduce effluent volumes, which may be an important consideration on some sites. As mentioned above, consideration must be given to the chemical quality of this effluent before considering such reductions to be environmentally beneficial.

Rainwater reuse is often considered to reduce stormwater discharge and planning has been obtained on poorly drained sites with the condition that rainwater reuse is implemented. In practice, whilst total volumes of stormwater will be reduced, soakaways, balancing tanks and SuDS systems cannot normally be downsized when rainwater reuse is implemented. This is partly to cover failure of pumps and filters (perhaps due to extreme weather conditions) and partly due to the need to cope with prolonged rain when soils are saturated and rainwater tanks are full. Flash summer storms may well be retained but these are not the critical events for soakaways in heavy soil or river flooding.

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