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The economics of water efficient products in the household

Prepared for the Environment Agency by Elemental Solutions

June 2003

ea/br/e/std/v1

The Economics of Water Efficient Products in the Household

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The Economics of Water-efficient Products in the Household

Introduction

In the consideration of water-efficient goods the simple notion of 'payback period' is often used. This is calculated from the price difference between an efficient and an inefficient appliance (for example a washing machine), divided by the annual saving in the cost of water (assuming the property is metered). This is unlikely to represent the only benefit (or cost) to the customer. For example, an efficient washing machine will involve the use of less hot water thereby reducing the customer's energy bill. This wider view of costs and benefits reveals a potential mechanism for promoting the uptake of water-efficient goods.

In Water resources plan submissions to the Environment Agency and in their water efficiency plans, no water company has seriously evaluated an appliance exchange programme. It is often suggested that (water) savings from conservation programmes are transient and therefore cannot be guaranteed into the future. However, appliances that work efficiently with a fixed volume (washing machine, dishwasher, toilet) should yield predictable and guaranteed savings.

This study aims to estimate these wider costs from the perspective of the domestic customer, and from the water company who could be in the position of implementing a wide scale retrofit program. In addition to water, wastewater, energy and detergent costs, CO_2 emissions, the residual life of appliances replaced, life span and reliability of the new appliance and energy label inaccuracies were all considered. The products reviewed include washing machines, dishwashers, toilets, showers and direct water heating appliances (combination boilers).

The report contains the findings from this desktop study, including the fact that for many appliances there is now no relationship between price and performance. Also the energy label, undoubtedly a success in improving energy (and water) efficiency, does not provide accurate enough consumption data for economic assessments to be made. Economic analyses from the perspective of the householder and water company are presented and conclusions include the potential implications for demand management policies and programmes in England and Wales.

The first part of the report looks at individual product groups of water-using appliances to determine the potential water savings and practical issues of implementing best available technologies.

Whilst product development is in constant flux, the aim has been to try and identify market trends and examine relevant real-world issues rather than purely hypothetical scenarios.

The brief and budget do not extend to a full market survey but every effort has been made to identify 'typically available products'.

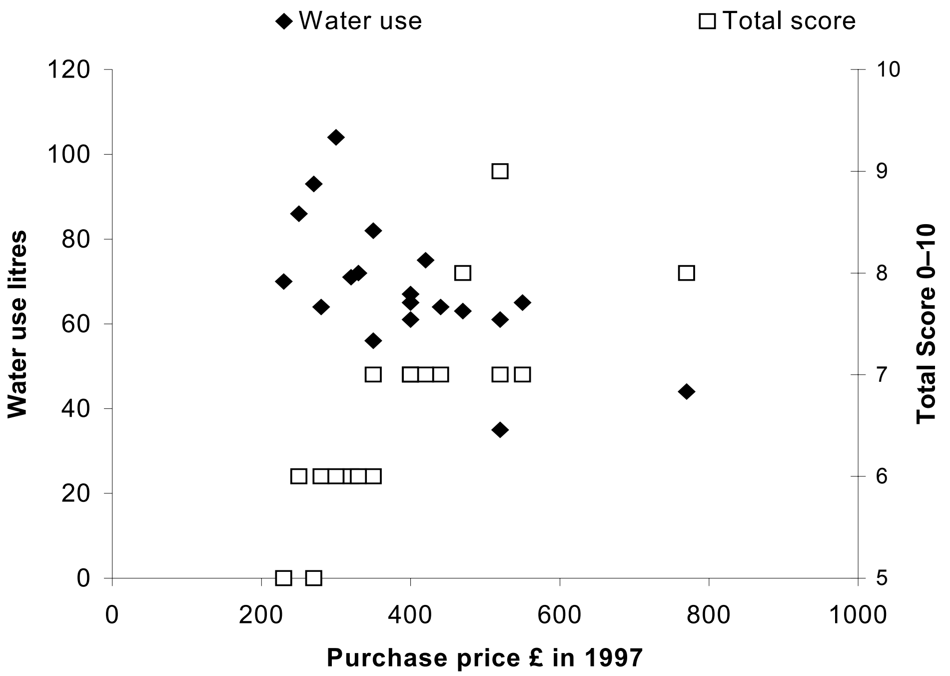
Independent performance data is in short supply but where this has been available it has been used. For example the Consumer Association carries out independent testing of dish washers and washing machines and these data have been used in preference to manufacturers claims as stated on energy labels.

1 PRODUCT REVIEWS

1.1 Wet white goods – Dish washers and Washing Machines

In 2001 77% of households own a washing machine and the growth in ownership seems to be levelling out. Meanwhile dishwasher ownership continues to rise from 6% of households in 1985 to 25% in 2001 [Environmental Change Institute (DECADE) in dti 2003]. With over 17 million washing machines in use, around 1.2 million reach the end of their life each year in the UK [Simon et al 2001].

We have looked briefly at price and performance issues of washing machines and dishwashers twice before. The first time was for the Agency's Conserving Water in Buildings Fact Cards and the second was for the Watersave Network review of water-efficient technologies. Graph 1 illustrates the usual assumed pattern of higher cost for more efficient machines which then allows a payback to be calculated. Whilst acknowledging this over-cost for efficient machines, we had previously argued that much of the extra cost is due to improved quality and features, with efficiency being a by-product of good design rather than a bolt-on feature that can have a direct cost attributed to it [Grant 2002]. The graph is based on 1997 data and shows that more expensive machines tended to use less water and achieved a higher 'total score' based on 'Which?' test criteria. The 'total score' was based on the following weighting: cleaning performance 36%, running costs, 18%, spinning efficiency 12%, water consumption 12%, time, rinsing, out of balance load and noise: 22%.



Graph 1 Water use and 'value' against cost for washing machines. Data from 'Which?' 1997.

However, based on the latest 'Which?' data, the old assumption that more efficient machines cost more no longer seems to stand. This has been confirmed by newspaper advertisements and window-shopping with AA rated washing machines available for less than £200.

Whilst the de-coupling of price and efficiency supports our hypothesis, the argument is of little use within the current brief when considering white goods, as there is no inherent over-cost to explain. We will however return to the argument when considering other product groups that have not been subject to market transformation.

> “With a near saturation of A rated models in the market place the revision of EU energy label is necessary to incentivise consumers to differentiate during purchasing decisions, and to facilitate industry commitments or minimum standards to drive market transformation.”

Market Transformation Program; Policy Brief, UK energy consumption of washing machines. 19/01/03.

This suggests that energy labels have had a very positive influence on machine efficiency. The prominent display of the ‘Energy Efficiency Recommended’ logo and Energy label rating in adverts indicates that the label matters and is currently used as a positive tool in marketing.

Looking forward from say 1995 this outcome was not widely predicted. In the ‘Decade’ second year report [Boardman et al 1995] the section on Energy Labels and washing machines stated:

> “The EU Energy label for washing machines has been approved by the European Commission. The likely effect of this measure is uncertain as the label lists other information, including wash performance …, spin speed and noise. The complexity of the washing machine label may mean that the effect is limited, though retail training may improve effectiveness.”

Certainly from my own experience as a domestic purchaser of a fridge and washing machine in 1999 and 2000, the sales staff were rather bemused that I should be bothered about the details of the Energy Label. This situation has changed.

A personal observation

Whilst I cannot offer a proper historical account or evaluation of the Energy Label, I have been interested to watch it develop. Two presentations from the ‘Greening the Kitchen’ Conference (1995? hosted by the Environmental Change Unit at Oxford University) stick in my mind. The first was from a representative of UK manufacturers and distributors: he made the point that consumers are not interested in energy savings however worthy they may be. The second was, I think, Dutch and he stated the problem of global warming and the need for action. He then said how manufactures, academics and politicians in his country got together and set targets for energy-efficiency. When they reconvened they found that they had exceeded the targets and the resultant goods actually cost less to manufacture and had other benefits.

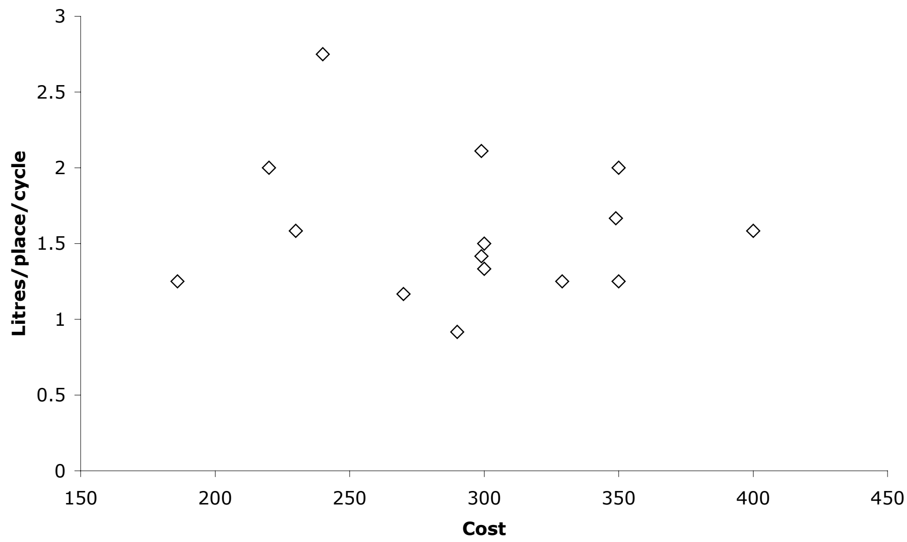
It may be that lessons can be learnt relating to currently floundering proposals to develop a water efficiency label as in Australia.

1.1.1 Appliance exchange programmes, subsidies and vouchers

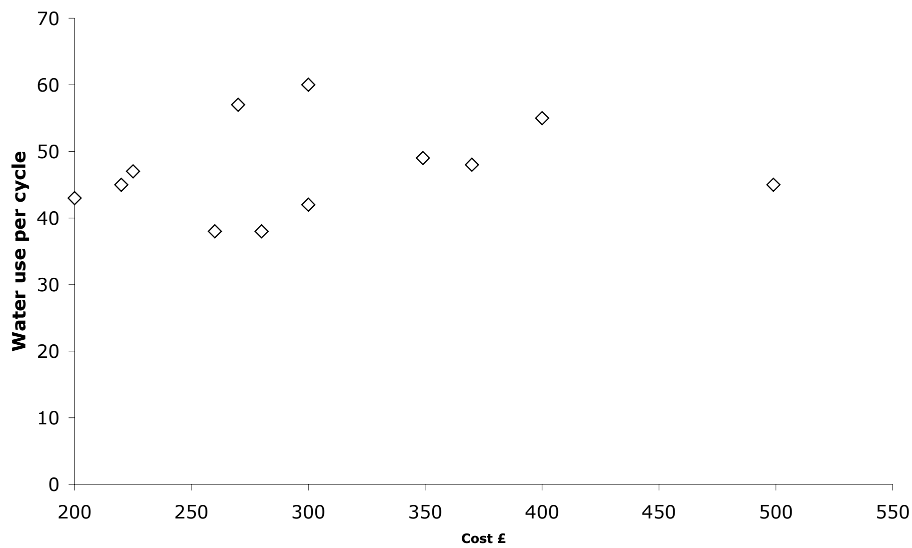
If the purchase of best available technologies is to be encouraged by subsidies then the subsidy has to reflect the required incentive to ‘consider water use’ rather than the cost to offset an assumed price difference between efficient and inefficient machines. If subsidies are considered for early replacement of inefficient machines then the benefit in terms of water and energy savings is easier to guarantee. However, the cost-effectiveness and environmental cost of scrapping a working machine would have to be examined and quantified.

The following two graphs, based on data from the 'Which?' Product Picker web site January 2003, illustrate the issue. Clearly the size of the data set is crucial since it is easy to pick say 5 machines to illustrate a positive, negative or neutral correlation between efficiency and price. Adding some of the

North American top loading washing machines that are now available would provide a definite positive slope suggesting that cheaper machines are more efficient.



Graph 2. Water use per place setting against machine cost for dishwashers.



Graph 3. Water use per cycle against machine cost for washing machines.

The correlation between price and reliability and overall performance (but not energy and water efficiency) remains, with the better machines tending to cost more.

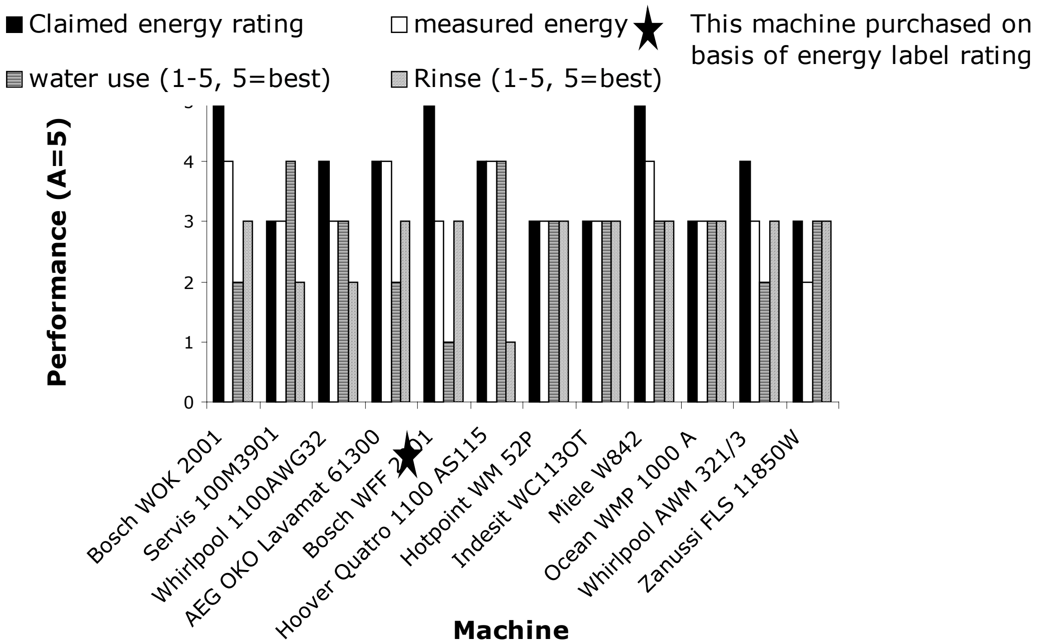
1.1.2 Energy-Labels and Eco-Labels

Without independent evaluation of appliances for possible recommendation or subsidy we are dependent on energy label information, which is supplied by the manufacturer. The consumer association 'Which?' have found the accuracy of energy labels to be wanting. Such discrepancies could be challenged under Trading Standards.

The following extracts from the 'Which?' web site are reproduced here as they raise a number of relevant issues:

'Which?' Online August 2000– extract:

> *"Inefficient Energy Labels*
> *In the past, we've often found energy label ratings on domestic appliances to be inaccurate. However, we didn't test them for this report because we believe the way manufacturers test the efficiency of washing machines does not reflect the way people actually use them. Instead, we've looked at the cleaning performance and annual running costs of the machines on the most commonly used 40°C cotton wash program. Our results did not always tally with the information on the energy labels. For example, the Hotpoint Ultima Aquarius was the cheapest to run at around £11 a year, yet its energy efficiency rating is C (the lowest rating). This same model is rated A (the highest rating) for wash performance, but we found it was the worst machine on test for removing stains."*



Graph 4. Performance of 12 washing machines tested by 'Which?' in 2001.

Graph 4 shows the data for the 'Which?' January 2001 tests with the claimed and measured energy efficiency plotted on a scale of 1-5 where 5 corresponds to an A rating for energy. The machine highlighted with a star was purchased by the author in 2000 after much research into water and energy use. The WFF 2001 replaced the WFF 2000, which was previously selected by 'Which?' as a best buy whilst also having the lowest water and energy consumption of all the machines on test.

The WFF 2001 was claimed to be an improvement on the WFF 2000 and the product literature promised an A rating for energy and 52 litres per wash on a 60C cotton cycle. Our own informal monitoring agrees with 'Which?' with a typical water use of around 80 litres per cycle. The machine was about £200 more expensive than the cheapest machines at the time, which, in hindsight, would have used less water and energy.

The purpose of this anecdote is to point out that a water and energy consultant who went to considerable trouble, managed to pick the worst performing of the twelve machines that 'Which?' tested in January 2001, because of inaccurate labelling.

EU Eco-Label

Whilst there seems to be little uptake of the Eco-Label for washing machines or dishwashers in the UK the requirements form a useful benchmark and the committees are addressing many of the issues raised in this report.

	Washing machine	Dish Washer
Water use	12 litres/kg	0.625 S[1] + 9.25 litres
Energy	0.17 kW.h/kg	(criteria not found)

Table 1 Eco-Label minimum requirements

These figures translate to 60 litres maximum water use for a 5kg washing machine on a 60°C cotton cycle and 16.75 litres per cycle for a 12-place dishwasher. At first glance these figures seem very modest by today's standards for mass-market machines with few exceeding the Eco-Label water or energy usage.

The first 'ad hoc working group meeting for EU Eco-label criteria for washing machines' considered revising these figures in September 2002 but decided that reducing the required water consumption could lead to problems of poor rinse performance which is thought to be the limiting factor for reducing water consumption further. Graph 4 appears to support this. The group considered introducing a rinse test but concluded that more work was needed.

Exploration of the Eco-Label is incidental to the original brief for this project and so no attempt has been made to follow up on the latest activity.

Water Regulations

The Water Regulations stipulate a maximum water use of:

- 27 litres per kilogram load for washing machines–i.e. 135 litres for 5kg
- 48 litres per kilogram load for washer dryers–i.e. 240 litres for 5kg
- 4.5 litres per place setting for dishwashers–i.e. 54 litres for 12 place settings.

It is virtually impossible to purchase machines that exceed these maximum water use requirements.

Water label?

It would be possible to follow the lead of the Energy Saving Trust (EST) and allow manufacturers to add a water efficiency mark for machines using less than an agreed volume. Issues of rinse performance would need to be addressed but the volume testing is already carried out for the Energy Label and issues of verification and trading standards would need to be clarified.

The EST energy efficiency recommended label is simply awarded for machines exceeding a certain standard (A) and for water no further differentiation is warranted with current test methods. Candidates for a recommended label might have to use less than 12 l/kg (consensus of eco-label committee) or more controversially say 10 l/kg if rinse performance can be shown to be acceptable for the growing number of machines that exceed this performance. Future ratings could award a + rating for machines with good part load efficiency for example.

Other practical issues include the creation of a body to award and administrate such a label.

[1] Where S is the number of place settings.

1.1.3 Risk and uncertainty

In predicting savings, for example to determine the Average Incremental Social Cost (AISC) of a measure, we are faced with a number of uncertainties:

1. would the consumer have purchased a less efficient machine without a subsidy given the lack of price/efficiency correlation?
2. does the Energy Label guarantee performance?
3. rebound effects – e.g. will the machine be used for smaller loads if it is perceived to use less water and electricity?

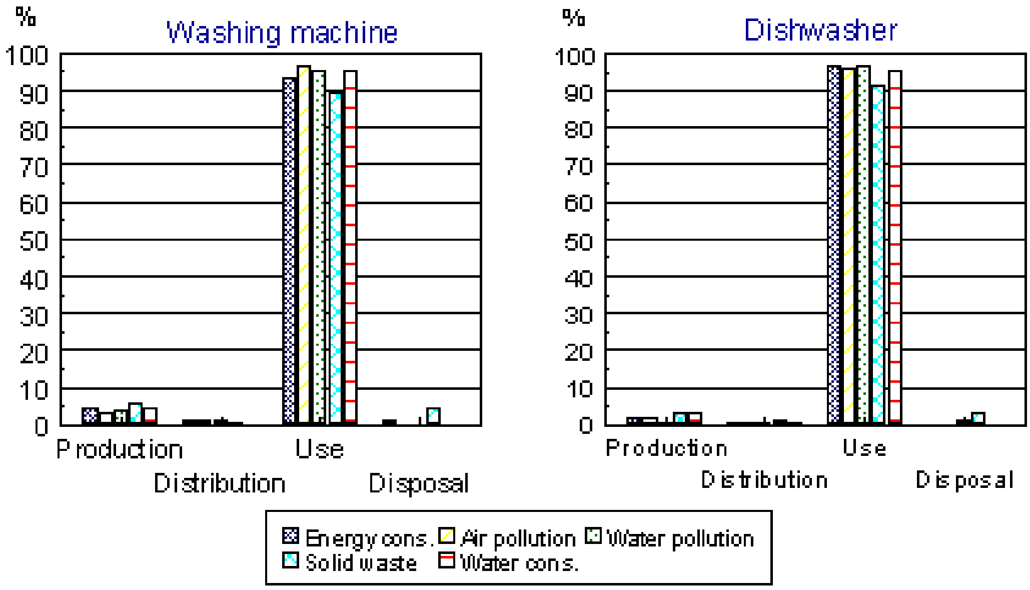
1.1.4 Life Cycle impacts

If the replacement of working but inefficient machines is to be considered, some attempt must be made to determine the environmental impact of manufacture and disposal. Discussions with a number of experts in the field revealed that a simple Ecopoints type assessment would be too simplistic and that there were no short cuts available to compare water and energy saving with disposal and manufacture impacts.

Having said this there seems to be some consensus that, for washing machines and dishwashers, around 90% of the total life time environmental impact is due to operation and only 10% is due to manufacture and disposal. However LCA is an inexact science and final weightings of different impacts are inherently subjective.

Graph 5 claims to show the percentage of life cycle environmental impact attributed to manufacture, distribution, use and disposal of dishwashers and washing machines. The graphs illustrate the importance of operational efficiency but do not show the relative environmental impact of, say, water use against solid waste or energy consumption. The environmental impact of manufacture and disposal is said to be equivalent to about one year's operation so doubling the operational efficiency should provide a fast 'environmental payback'. Whilst newer machines may use half the water and energy of older machines, detergent use is not necessarily reduced and so the total impact of operation is less than halved.

We researched the literature to search for equivalence between the impact of detergent, water and energy but without success. As a crude working assumption (to be challenged) we suggest that if product replacement is financially viable then the ecological savings will also offset the embodied impact of manufacture and disposal.



Graph 5. Life Cycle Impact. Graphs reproduced from the Electrolux Web site.

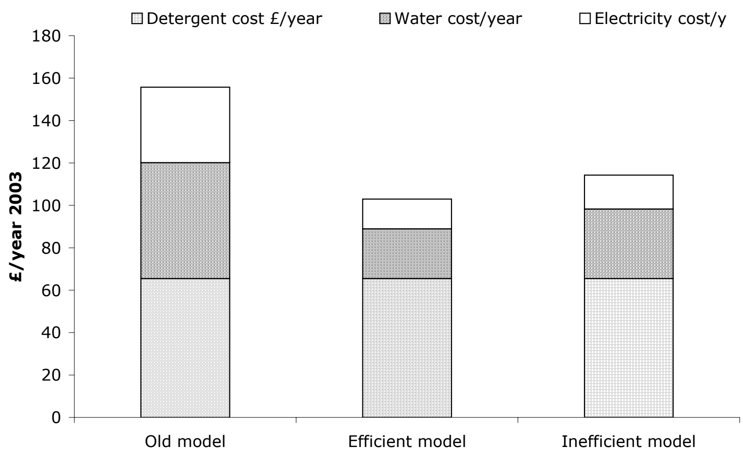
1.1.5 Life Cycle costs

The following graphs illustrate the annual running costs of a range of machines based on 'Which?' test results for water and energy use and the following assumptions:

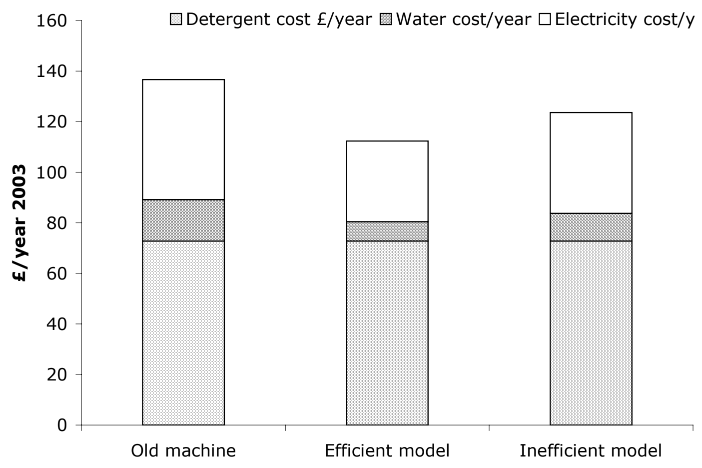
	Washing m/c	Dish washer
Uses per day	1	1
Water & sewerage cost	£1.5/m^3	£1.5/m^3
Electricity cost	6.5p/kW.h	6.5p/kW.h
Water hardness	Medium	Medium
Soiling	Medium	Medium
Detergent cost	18p/load	20p/load (inc' rinse aid)

Table 2 Assumptions for calculating annual running cost of dish washer and washing machines.

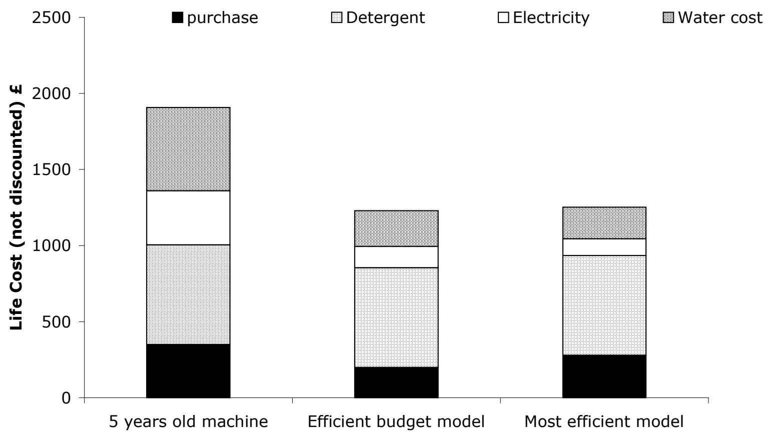
Graphs 6, 7 and 8 illustrate the high proportion of running cost attributable to detergent assuming accurate dosing and medium hardness and soiling. In practice detergent use is likely to be poorly controlled and so offers the greatest opportunity for improvement (to reduce environmental and financial costs).



Graph 6 Annual running cost of typical washing machines.



Graph 7 Annual running cost of typical dishwashers.

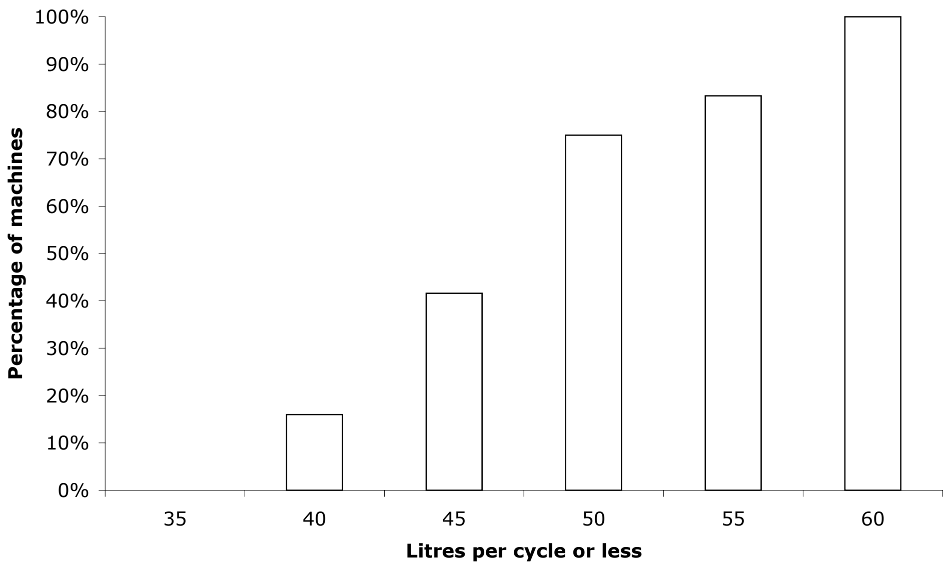


Graph 8 Life cost of 4 washing machines.

1.1.6 Water use trends

Washing machines:

If the trend continues most machines will soon have an A rating for energy and water use of 60 litres or less (on a 60°C cotton cycle for a 5kg load). Of the twelve machines most recently tested by 'Which?' 75% used 50 litres or less per wash and all used less than the 60 litres specified in the Eco-Label criteria, see Graph 9.



Graph 9. Water use per 5kg cycle for 12 washing machines. Data from 'Which?' Online Product Picker January 2003.

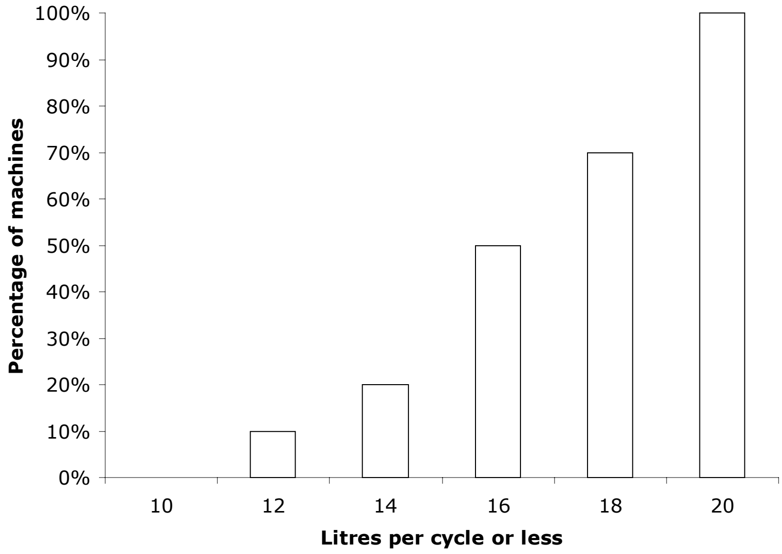
Further efficiencies can be achieved by improved control of water (e.g. for part loads) but this would not show on the current Energy Label. Surveys have shown that 2–3 kg is an average load rather than the full 5kg which is the typical capacity.

A trend towards machines with a larger capacity of 6 or even 8kg could, unless used at full capacity, further reduce part load efficiencies.

The greatest potential to reduce running costs and (based on our assumption) environmental impact would be through improvements in detergent formulation and control of dosing to match water hardness, load size and fabric type. Some machines are claimed to control the number of rinse cycles based on foam or turbidity of the rinse water but we have not found any studies to show how detergent dose may then alter water consumption. Again it seems likely that the next direction is in improved control but the current label contains no incentive to achieve this.

Dish washers

As with washing machines the trend is towards A ratings for energy and low water use. Of the ten machines with a 12 place setting capacity recently tested by 'Which?' all used 20 litres or less and 50% used 16 litres or less, see Graph 10.



Graph 10. Water use per 12 place setting cycle for 10 dishwashers. Data from 'Which?' Online Product Picker January 2003.

1.1.7 Conclusions – white goods

The performance of new machines is converging with steady elimination of inefficient models. It seems likely that the main driver has been the energy label and the obvious prestige of A ratings. The small variations in water use between current models, regardless of price, effectively prevents any reliable predictions of possible benefit from a subsidy scheme. Other uncertainties include the accuracy of manufacturer's claims and real world variations such as part-load efficiency, which is not measured by the current energy label methodology.

The drop in price of efficient machines does mean that early replacement of an old machine may be economic depending on local water and sewerage prices and the reliability of the new machine.

Not everyone in the white goods industry is convinced of the benefits of energy label driven trend. Some think that wash times and rinsing performance have been compromised to achieve good energy label ratings. The alternative direction is for North American style machines with faster wash times and larger capacity. Whilst these machines are far more efficient than their predecessors they could pose a future obstacle to water saving (by influencing the market as well as direct import).

It seems likely that current models have reached the limit of water and energy efficiency as measured by Energy Label test methods with full loads. Real-world improvements could be achieved by improved part-load efficiency and control of detergent dosing or by further education of users to only wash full loads with the minimum amount of detergent appropriate to the level of soiling and water hardness.

Detergent costs are the largest running cost for dish and washing machines and are likely to represent a significant life cycle impact, possibly greater than water or energy.

1.2 WCs

1.2.1 Introduction

Particularly in older properties, WCs typically account for most water used in the home and so become the first target for any efficiency measures.

1.2.2 Base case

UK WC cistern volumes were reduced from 13 litres in the 1960s to 11 then to 9.5 litres with dual-flush becoming compulsory in 1981. Pull and release gave a 'half' whilst pull and hold gave a full flush. This remained law until 1993 when 7.5 litres was introduced as the maximum flush volume and dual-flush was banned because of anecdotal reports of double flushing causing increased water use compared to single flush.

From 1st January 2001 the Water Supply (Water Fittings) Regulations (1999) now specify a maximum flush of 6 litres and allow dual-flush and valve flush mechanisms. The Regulations have been interpreted to allow internal overflows rather than the previous requirement for an external warning pipe.

9 litres is often assumed as an average volume for existing WCs, for example when assessing the impact of a replacement program.

Whilst 6 litres may have been considered the base case for new purchases manufacturers claim that about 75%–80% of sales are now dual-flush although most of these will be 6/4 litre rather than the lower 6/3 [National Water Conservation Group Minutes of meeting 1st October 2002].

With care, WCs can have a very long service life and are most likely to be replaced for reasons of style rather than failure.

1.2.3 Available technologies

Format

Most UK WCs are of the wash-down type (rather than the siphonic pan that is almost universal in the US). Suites are usually in one of 5 configurations; close coupled, low level, high level, back to wall concealed cistern and wall hung concealed cistern (see Figure 3). The different formats are mainly chosen on the basis of style and fashion with high level seen as traditional and close coupled and concealed as modern or 'European'. Commercial installations tend to favour concealed cisterns for ease of cleaning and vandal resistance and many domestic ones have recently selected this format for style too.

These formats and styles raise at least two issues relevant to this report:

1. Price – often price reflects the format. i.e. concealed suites tend to be more expensive to manufacture, sell and install whilst low-level suites tend to be cheaper – perhaps with a plastic cistern. Thus prices need to be compared within product groups.

2. Will a replacement fit? Matching preferred style and technology – water saving WCs may not be available in the desired style or the replacement may not fit the existing space.

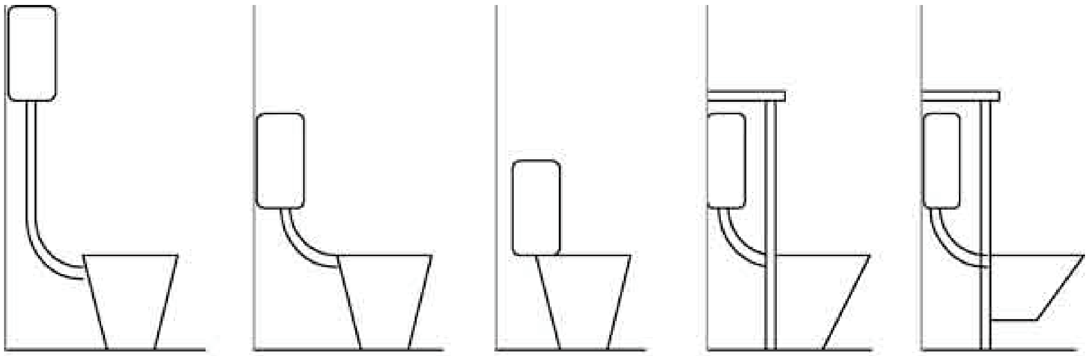


Figure 3. WC formats.

Whilst every country in the world offers a range of styles, it seems likely that the UK has the widest range. In Germany and Scandinavia there are (different) dimensional standards to allow replacement using the same screw holes and without leaving an unsightly shadow of the old.

A related issue is colour and style with bathroom suites matching the WC. This can be both a barrier to WC 'upgrade' or a driver if you don't like your pink and/or chocolate bathroom. The current market is dominated by 'white' but an analysis of past and future trends is considered outside the scope of this project.

Personal anecdotal experience suggests that someone who is happy with his or her coloured bathroom will not usually be happy with a white replacement WC. Similarly, whilst modern sanitary ware can complement very old or rustic interiors, ornate basins and modern WCs will often clash.

1.2.4 Flushing mechanisms

Available flushing mechanisms can be divided into valves and valve-less, and the former can be subdivided into single and dual-flush or (for domestic installation) into drop-valves and flap valves. A full explanation of the differences and associated issues is outside the scope of this report. In the UK the only valve-less flush mechanism currently available is the traditional siphon, which was a legal requirement under the Water Byelaws. Other valve-less systems exist, some as prototypes but at least one, the Niagara Flapperless, in a commercial WC.

Currently most dual-flush WCs are based on drop valve mechanisms as these allow the use of double buttons which can make the mode of operation obvious.

For siphons the regulations now require any dual-flush device to default to full flush. This has been interpreted as ‘ hold down the handle for a half flush’, ie the reverse logic to the dual-flush siphons of the 1980s.

Although this has been made this way so that the default is the full flush for fear of the newer lower half-flush being inadequate, this requirement seems to be questionable on a number of grounds:

1. The original claim that the part-flush default wasted water due to double flushing seems to be based on anecdotal evidence only [Keating and Lawson 2000].
2. Although poorly analysed, trials by Anglian Water [Environment Agency 2001] showed users preferred mechanisms with the older logic.
3. Part-flush default should encourage trial and error and forced learning in a domestic situation whereas the part-flush with the new logic would be unlikely to be discovered by accident.
4. Some of the population grew up with the old system and tend to pull and hold, just in case.

These issues will be examined in more detail later.

The following list is believed to be an accurate summary of available WC specifications in the UK at the time of writing.

Valve flush
- 6-litre drop valve
- 6-litre flap valve
- 6/4 dual-flush (drop valve)
- 6/3 dual-flush (drop valve)
- 4/2 dual-flush (drop valve)

Siphon flush (6/4 dual-flush is not yet on the market at the time of writing)
- 6-litre single flush
- 4.5 litre single flush

Flushing valves (direct from the mains) are not permitted for use with domestic supplies. At the time of writing the status of previously illegal dual-flush retrofit devices is being reviewed and so they will be considered in this report.

Valves and siphons
The issue of valves and siphons is contentious but, unfortunately, cannot be ignored for this report due to the potential water wastage issue. Rational debate has been difficult due to the political and commercial issues involved.

It will be many years before we have a sufficient body of UK-specific evidence to show how serious a problem valve leakage will be, but what we do know is that:

1. Valves will leak.
2. Durability testing is important but:
    a. not all valves on the market are appropriately tested.
    b. random failure can occur at any time perhaps due to the non-laboratory conditions.
3. Only around 20% of UK households are metered so, for most householders, leaving a valve leaking incurs no cost.
4. Leaks of up to about 2.5 litres per hour are difficult to spot and may not register on water meters. Such a flow equates to around $22m^3$/year per leak.

However for the purpose of this report we have ignored leakage in our calculations due to the lack of UK-specific data.

Dual-flush
The status of dual-flush changed overnight from 'illegal' to 'recommended' on the 1st January 2002. The Water Regulations require a clear indication of operation and a maximum part-flush of two thirds of the full flush. Typically this means 6/4 litre dual-flush but 6/3 is available as is 4/2 (not UK tested).

In Australia and Germany 6/3 is becoming the norm whilst in Scandinavia 4/2 is now usual.

1.2.5 Real world water use and savings

Nominal flush volumes (7.5, 6 etc) do not necessarily reflect actual flush volumes.

There are a number of issues and variables, some of which can be designed out of products whilst others are due to human behaviour and are hard to predict.

Yet again, the UK situation is unique. As we will see from the available trial data any proposals for WC replacement, or incentives to purchase 'water saving technologies' from new, will, at best, offer modest savings. Thus, as with future developments of white goods, the details are crucial if we are to achieve predicted savings rather than water wastage. With maximum permitted flush volumes of only

6 litres, quite small variations and uncertainties become very significant. A greater understanding is crucial to:

1. achieve better predictions of demand.
2. prevent active promotion of the ‘wrong’ measures or barriers to ‘better’ measures.
3. identify possible requirements for future regulations, standards, promotion, labelling and technology procurement programs.
4. inform water-saving promotional and ‘point of sale’ materials so that householders can be educated (e.g. WC leak detection, cistern flush adjustment etc).

Trial Data

Perhaps surprisingly, there is very little good data available on which to base predictions of water saving from ‘low flush’ WCs. The following table summarises what we have been able to find.

Trial	WC	Theoretical [1]	Measured	Size of Sample
Seattle [2]	6/3	3.6	4.73	40 WCs. 20 homes
Oregon [3]	6/3	3.6	4.92	50
Canada [4]	6/3	3.6	4.20	?
Bradford [5]	6/3	3.6	4.6	6
Bradford [5]	4/2	2.4	4.6	4
Hereford 1 [8]	4/2	2.4	3.83	1
Hereford 2 [9]	4	4	3.74	1

Table 4. Domestic low flush WC trials.

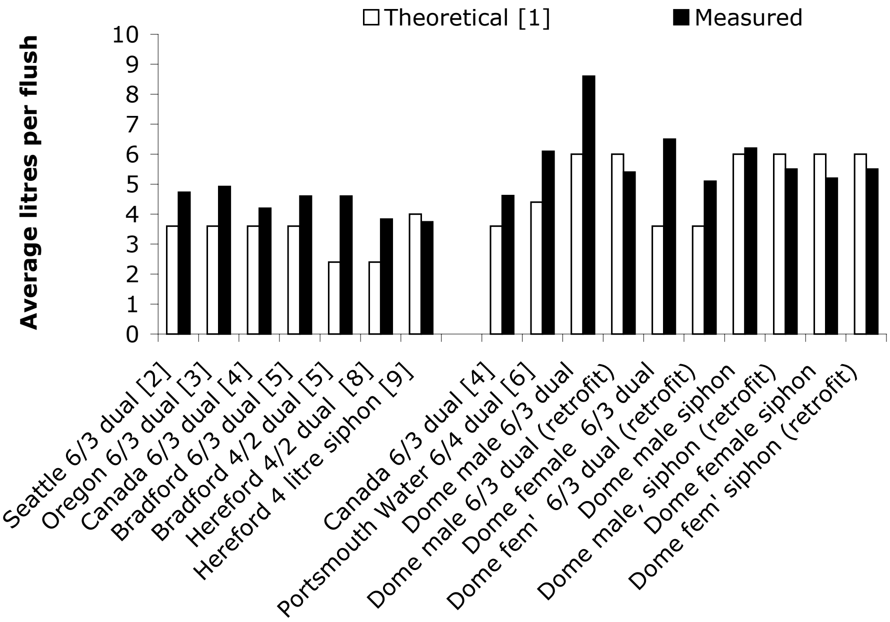
Trial	WC	Theoretical [1]	Measured	Size of Sample
Canada [4]	6/3	3.6	4.62	?
Portsmouth [6]	6/4	4.4	6.1	2
Dome male [7]	6/3	<6	8.6 (5.4)	177 m+f
Dome female	6/3	3.6	6.5 (5.1)	177 m+f
Dome male (siphon)	6	6	6.2 (5.5)	160 m+f
Dome female (siphon)	6	6	5.2 (5.5)	160 m+f

Table 5. Commercial low flush WC trials.

Notes on tables (see end for references):

1. Theoretical average flush based on 4 part to 1 full flush i.e. =(4p+1f)/5
2. Aquacraft, Inc.,2000. Seattle Home Water Conservation Study. In Koeller 2002.
3. Pacific Northwest National Laboratories, 2001. In Koeller 2002.
4. Canada Mortgage and Housing Corporation. Presentation at Watersave Network, summarised in Koeller 2002 and report on web site: www.cmhc.ca
5. Trial of dual-flush WCs designed for 4/2 litre flushing but adjusted to 4/2 and 6/3. Coincidentally both settings gave the same average flush volume but the range was 3.1–6.1 litres/flush @ 4/2 and 3.7–4.9 litres @ 6/3. The most likely reason being jamming of the mechanism but this was not reported during the trial.
6. Trial of 2 dual-flush WCs in women’s toilets at Portsmouth Water office. A Neve 2002.
7. Millennium Dome results. Figures in brackets are after repair and retrofit as jamming valves were identified when the data was analysed. S Hills et al 2001.
8. 5 year monitoring with water meter and flush counter and 4/2 dual-flush WC. 3 male and 1 female.
9. 4-litre siphon flush WC, 1 male 1 female, short-term trial.

None of the results in the table were thought to include any inlet valve or flush valve leakage in the usual sense.



Graph 11 illustrating the data in the table.

Components of real world variations

Some factors are directly related to product design, some relate to installation and others to user behaviour.

Adjustment of flush volume

Some WCs are designed to be of a fixed flush volume and the only way to change this is to modify the mechanism. These WCs have a fixed and non-adjustable inlet valve.

UK WCs with siphons have a bottom water level (end of flush) set by the siphon dimensions and the top water level set by the inlet valve, which is usually adjusted to an indelible top water line, which should indicate the flush volume. Some inlet valves will 'bed in' over time and the water level can rise. Some (non equilibrium) valves may allow a variation in water level (and so increased or decreased flush volume) as the static water pressure changes. As many siphons are 'universal' the flush volume can often be changed by adding or removing plugs or flaps to achieve, 9, 7.5 or 6-litre flush volumes.

Some drop-valves and many flappers achieve the required flush volume by varying the bottom water level and this can often be adjusted after installation.

If a WC gives an ineffective flush, the plumber or user may try to increase the flush volume. Thus whilst all WCs available for purchase should have a 6-litre maximum flush this does not guarantee that they will be installed at that volume. In the US kits are available that raise the overflow so that the water level can be raised to increase the flush.

A longer term issue is repair and retrofit of new mechanisms which can lead to incorrect flush volumes. Whilst the top water level must be indelibly marked in WC cisterns in order to meet the Regulator's specification, the bottom water level depends on the flush mechanism installed and may be adjustable. Many after market products are adjustable to allow them to be used in cisterns of different shapes and sizes. This has been found to be a significant problem in the US where flappers are the norm but can also happen with drop-valves and siphons.

The issue of manufacturing and installation tolerances is not addressed by the regulations and variation above or below the stated flush volumes can be expected.

Double flushing

If the flush fails to clear the pan then a second flush is required. Whilst this problem has been associated with dual-flush in the UK, it is likely to be become a more regular problem as flush volumes drop. In the US the first wave of 6-litre ultra low flush (ULF) toilets (based on the siphonic pan) often failed to perform as well as the older high flush models and this led to double flushing and even blockage. More recent studies suggest that whilst performance still varies considerably among models, there are now many ULF models that either match or out-perform high flush models. What was found was that the existing test standards were too easily passed and this led to new tests being developed to rank performance, see *labelling* below.

In the worst case a poor efficiency 6-litre WC might be thought to behave as a 12/6 dual-flush with two flushes required to clear solids, including in some cases, single sheets of paper.

Discussions with local plumbing merchants suggest that the cheaper 6-litre WCs that they sell (not independently certified) do not flush very well at all.

From our own experience in actually carrying out the tests with suites that have been extensively field tested, we are confident that the Water Regulations Performance Specification for WCs (http://www.defra.gov.uk/environment/water/industry/wsregs99/wcspec/index.htm) provides a sufficiently stringent set of tests. A WC suite that just passes these tests should perform significantly better than a WC that just passed the previous British Standard tests.

A potentially serious issue is that very few manufacturers seem to be putting forward suites for independent testing and approval and many manufacturers have simply changed the flushing volume of existing WCs that passes the old, less stringent tests at 7.5 litres. Thus we predict that poor performance and double flushing is likely to increase in the short term unless manufacturers are required to achieve the performance standard. We would like to see this hypothesis tested by some random testing of 6-litre suites.

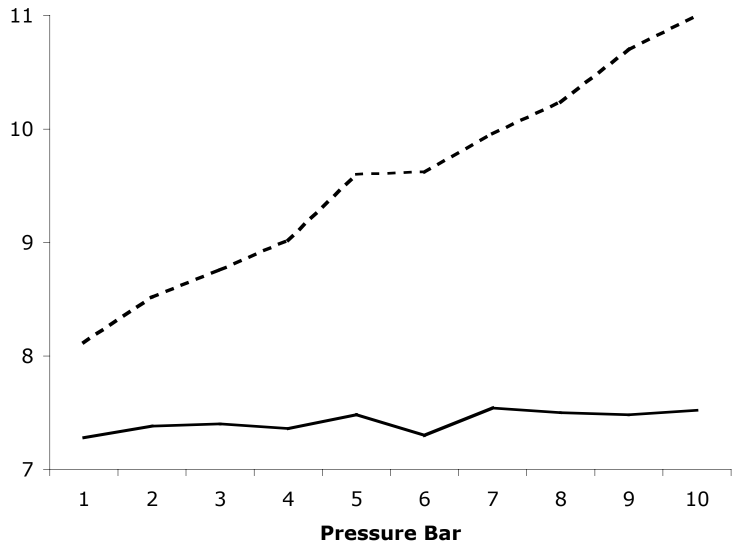
User behaviour

Some valves and all flappers can be held open by keeping the button or lever pressed. Since cisterns usually retain a volume of water this typically provides a greater flush and is a trick often learnt by users with under-performing WCs. Studies in the US and Canada have reported that some users consider this the normal way to operate a 'low flush' WC.

With dual-flush another variable is added. Users may be curious and try both buttons (short term effect whilst novelty wears off?), the operation may be unclear (instructions are required but unsightly) or the user may not want to risk a half flush if there is paper to clear. Where it has been measured, [i.e. the trials listed in the table and Keating and Lawson 2000] trials have shown the ratio of full to part-flush to be in the range 1:0 (ie only full flush used) and 1:2 (1 full to 2 part flushes) rather than the often adopted assumptions of 1:3 or 1:4.

Refill

In the UK (but not the US) WCs are tested for flush volume with the water supply turned off. In practice water enters the cistern during the flush cycle and depending on flush duration and speed of refill this extra volume will vary. The WRc carried out some tests and one result is plotted in Graph 12 (EA Demand Management Bulletin No 30 Aug 98). Portsmouth Water carried out two in-situ measurements of WC flush volume with the water on and off as part of their dual-flush trial and the result is shown in Table 6.



Graph 12. Flush volume against pressure for Torbeck inlet valve.

	2001 water off	2001 4 bar	2002 water off	2002 4 bar
Full flush	5.8 litres	6.6-litres	5.7 litres	6.8 litres
Short flush	3.7	3.5	–	–

Table 6. Portsmouth Water Dual-flush WC trial; testing of nominal flush volume and real flush when connected to water supply.

Delayed action inlet valves (e.g. Opela Eco-Fill) address this issue but this is not reflected in the nominal flush volumes quoted. As the flush mechanism is 'trying' to stop as the refill water flows in, the extra water does little to help the flush performance and the suite would be performance-tested with the water turned off anyway. This is an issue that should be addressed in a labelling scheme and future regulations.

Mechanical problems

A number of studies (for example the Millennium Dome WC trials) have reported problems with valve mechanisms sticking. There is plenty of anecdotal evidence that this is a common problem particularly if installation is not carried our properly. Siphons tend to fail-safe (there is no loss of water whilst the WC is not being used) although any mechanical failure could lead to impaired flush performance and the lever may need to be pumped to start the flush.

1.2.6 Recommended technologies

If the goal is to encourage the installation of water saving technologies, we must first decide what constitutes a water efficient WC. Yet again we are faced with a peculiarly British situation as we might be replacing 7.5 litre leak free WCs with 6-litre WCs that will at some point leak or jam. In the US and Canada not only were previous flush volumes much higher (perhaps 18 litres) but it is reasonable to expect the new technology to leak less than the old even if only because the new valve is less worn. Thus their predictions based simply on reduction in flush volume should be conservative.

The least controversial or politically sensitive[2] definition is to consider WCs that meet the latest regulatory requirements as efficient when compared with older models. Thus we might consider a scenario where older WCs are replaced by WCs with a maximum flush of 6 litres and approved dual-flush is allowed.

If we are to go beyond current minimum requirements, either for replacements or as an alternative to 6 litres, then the science is less clear as we can see from the data in the table of trial results above. The simplistic solution, which has been followed by a number of specifiers, is to prescribe dual-flush as a best available technology and to push for its adoption. Whilst dual-flush can offer savings, particularly in domestic situations, there is no reason to believe that it is synonymous with water saving as the data summarised in Tables 4 and 5 show.

Whilst we understand that it would not be possible for a government department to return to recommending valve-less WCs on water efficiency grounds, the current recommendation of government departments for dual-flush (ie valves at present) appears, to say the least, premature, and inappropriately prescriptive – see Table 7.

If we need a water-efficient specification that goes beyond the minimum requirements of the Water Regulations then we suggest an average flush volume of 4.5 – 5 litres. From the available evidence this would translate to 6/3 dual-flush or 5 litres or less single flush. This is based simply on available data for short-term trials and makes no allowance of leakage or other factors, which are understood to be politically sensitive.

This standard can be met by a number of proven commercial WCs available in the UK and independently tested and certified to the Regulator's Specification.

OBJECTIVES AND TARGETS Market Transformation effects which are necessary and sufficient to deliver the MTP projected P1 and P2 outcomes (above)	**ACTION PLAN** Actions which are necessary and sufficient to deliver the market transformation target (left) *(Action owner in brackets)*	**CP £k***	**Status (Ref, P1, P2)** **Start and Finish Dates**	**CI ****
Ensure public domain product information Briefing Note: under construction Target Date: Effect: 1. This could 'pump-prime' the market for new products.	Publicise dual flush WCs as example of Best Practice (MTP) Ensure availability of information on correct use of WCs (*manufacturers*)		2003-P1(2004)	06
All WCs installed to have maximum 5 litre flush volume by 2011 Briefing Note: BN DW WCs 1 Target Date: Effects: 1. Inefficient high water using WCs will not be sold.	Incorporate changes to Water Supply (Water Fittings) Regulations (*Defra*)		2003- 2011	01
25% of WCs installed to have dual flush by 2006 Briefing Note: BN DW WCs 1 Target Date: Effects:	Incorporate changes to Water Supply (Water Fittings) Regulations (*Defra*)		?- 2006?	03 04

Table 7. Draft recommendations from the Defra MTP web site recommending dual-flush as best practice.

[2] For example the valve-siphon, internal-external overflow and dual-single flush debates have raged for many years. Technical issues cannot be considered in isolation of trade barriers and harmonised standards, or for that matter, country specific issues such as water meter penetration or training or registration of plumbers.

Similarly the 'DETR's Buyers Guide' (now DEFRA) includes the following recommendation:

> "Specify.
> . . .
> • the most water efficient fittings, e.g. spray and/or push button taps; low volume dual-flush WC suites; urinals with suitable control devices or waterless urinals; dishwashers with an economy cycle and washing machines with "half load" programmes; or eco-locks and the facility to recycle water."

The draft Enhanced Capital Allowance specification for WCs is currently suggesting 4.5 litres effective flush as a requirement but this is based on 4.5 litres single or 6/4 dual with an assumed ratio of 1:3 long to short, which from the available data is an optimistic assessment for dual flush.

1.2.7 Testing and approvals

Under the old Water Byelaws it was difficult to install non Water Byelaw Scheme (WBS) approved fittings WCs in any new building, ie where a building inspector or Byelaw Inspector may see it. Typically all written specifications required WRc approval. Whilst flush performance varied between models none were prone to leakage.

All this seems to have fallen apart under the Water Regulations and the new equivalent, WRAS approval, is now the exception rather than the rule for WCs.

The only third party UK approvals that we could find were WRAS and KIWA (see references for contact details). Some manufacturers claim to be awaiting the new CE mark for WC suites and cite this as their reason for not pursuing WRAS approval. Informal discussions with plumbers and merchants suggest that the whole issue of certification has fallen apart and that anything goes so long as it has a nominal flush volume of six litres or less.

In the context of this project the main issue is flush performance as a pan that will not flush will either be subject to repeat flushing (perhaps even for paper only) or will be modified to give a bigger flush.

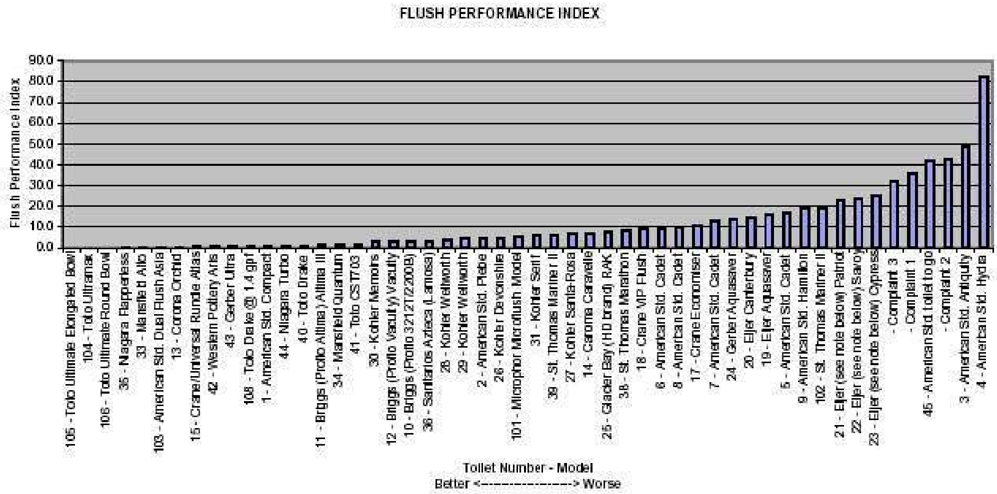
1.2.8 Labelling

There is currently no labelling scheme for WCs in the UK and no independent product testing by consumer organisations (cf wet white goods).

Current attempts to initiate a water efficiency label have floundered although a resurrection is likely following discussion in the Water Bill. To be useful a label needs to differentiate between apparently similar products. As with the energy label, it seems likely that performance ratings would have a crucial role. Without a performance rating, customers might opt for the maximum allowable flush or even obtain older WCs as has happened in North America with illegal imports from Canada. This would be on the, seemingly reasonable, assumption that larger flush volumes equal better flush. Experts in the US have been pushing for such a rating system and a number of tests have been developed in order to identify suitable suites for recommendation. Alternatively if the public decided to buy 'green' then manufacturers might be tempted to compromise performance to obtain a better water rating– particularly if subsidies were available. This might then lead to customer dissatisfaction with performance and a subsequent backlash.

Previously it has been argued that anything that passes the Secretary of State Specification (SoS) is good enough but the same argument can be applied to washing machines which must be *fit for purpose* yet are rated for wash and spin performance on a scale from A to G. In practice for WCs performance varies considerably along a continuum:

Graph 13 illustrates the large variation in measured performance for 52 WC suites tested by the National Association of Home Builders in the US; note that shorter bars represent better performance.



Graph 13. Flush performance for a range of 6-litre WCs tested in the US [reproduced from NAHB 2002].

The Secretary of State (SoS) specification includes performance tests that provide numerical values that could be aggregated to provide a numerical performance relating to bowl cleansing and drain carry without incurring extra test costs. Alternatively a new test may be justified such as the toilet paper and miso (fermented soya bean paste) test being developed in the US to address issues of blockage of low-flush WCs. This test provides a numerical rating (grams of miso flushed) that could be converted to a letter rating as in the energy label.

The various tests measure different aspects of performance and so a range is required to prevent designs being made to pass a laboratory test rather than real world challenges. Thus a pan with too small a trap could pass the SoS tests but suffer blockage with the US miso and toilet paper test.

Whilst 6 litres is the maximum permitted flush volume, as we have seen, this can be higher when connected to a water supply. Thus a 6-litre WC with delayed action valve may use less water than say a 5.5 litre WC (depending on refill rate etc) but a simplistic label might rate the 6-litre WC as, say, G (lowest) and the 5.5 as, say, C. Thus, even if the Regulator's Specification does not change, a water label should be based on actual flush volume at say 2 bar. This would differentiate between 2 WCs with a 6-litre nominal flush but one using 5.9 litres at 2 bar and the other 7 litres at 2 bar. Such an efficiency gain can be achieved at manufacture for minimal over-cost and without altering flush performance but seems very unlikely to happen without a suitable driver or regulation.

Given the considerable potential for wastage, the issue of leakage should be acknowledged. Fail-safe flush mechanisms exist (e.g. siphons) and leak detection is possible although only currently available as an aftermarket retrofit and only for flapper flush valves (i.e. the Fluidmaster Leak Sentry).

For dual-flush the long and short flushes can be similarly measured but an agreed equivalent average flush volume might be beyond the scope of a label (due to uncertainties about typical use). However separate supporting literature should indicate a realistic equivalent based on real world tests rather than the 1:4 ratio currently used in advertising and as the basis of manufacturer’s claims.

Any argument that such subtleties are too complicated for a point of sale label should be challenged. Otherwise we will end up with a specification which, at best, fails to promote innovations and at worst actually discriminates against best practice.

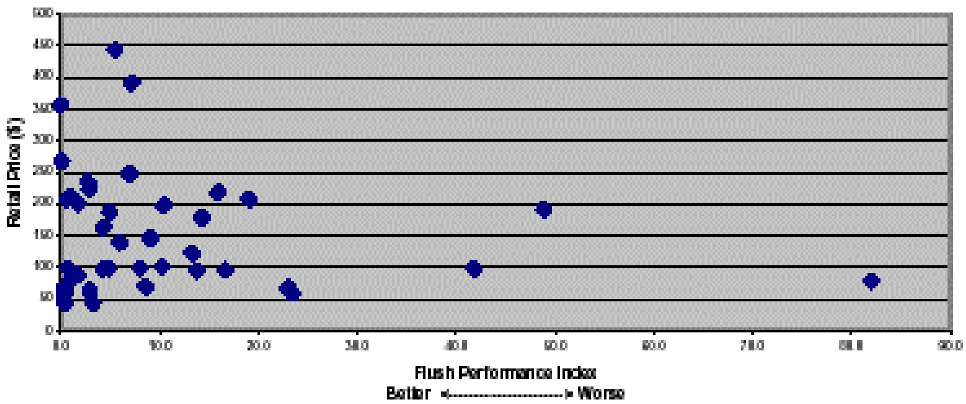
Such a 'best practice' specification or benchmark might be applied to labelling (perhaps unlikely) or at least to recommendations and ratings under the MTP, the Enhanced Capital Allowance program, an appliance exchange program or water efficiency educational literature.

1.2.9 Price

Price comparisons are more complicated than for white goods, as WCs tend to be fitted and perhaps supplied by plumbers. The ease of installation and the amount of ‘making good’ required will vary considerably for retrofit installations. An additional important consideration is that many houses have more than one WC and the trend is towards en-suite and more toilets per house.

Price tends to reflect design and quality rather than water efficiency. The situation is perhaps similar to that of white goods a few years ago where the cheaper machines tended to be less efficient in terms of performance and resource use whilst the better machines cost more.

When the normal flush volume was 7.5 litres, 6-litre WCs were generally more expensive. In the US where 6-litre WCs have been on the market for a number of years now, even flush performance seems to be de-coupled from price as Graph 14 below indicates.



Graph 14 Purchase price against flush performance for a number of WCs tested in US. [Reproduced from NAHB 2002}.

UK WC price and performance

It was hoped that sufficient approved WC suites could be found so that the performance variable could be eliminated. Unfortunately without independent testing and approval we cannot be sure that any base-case low-cost WC will be fit for purpose or even legal.

Budget suites – not WRAS or Kiwa approved

Generally low-level suites are cheapest with trade prices starting around £55+Vat for an all ceramic pan and cistern, from a well known manufacturer, with 6-litre single flush or 6/4 dual drop valve. Close coupled suites tend to cost more with a budget model being available for around £75 - again with 6-litre siphon or 6/4 dual for the same price.

High-level suites tend to be chosen for the period style and are not really covered by budget models. For ‘simplicity’ they will be excluded from the analysis.

Back to wall concealed suites start at around £100 with 6-litre siphon or £116 with 6/4 dual-flush. Off-the-floor wall hung suites (including brackets) start at around £115 with siphon and £130 for 6/4 dual-flush [all prices trade, ex Vat and excluding seat, verbal quotes Aquaheat Hereford].

Cheapest third party certified

Currently there are very few WC suites that have been independently certified. Talking with manufacturers, WRAS and Kiwa we were only able to find 11 suites with independent testing to the UK, SoS specification (Feb 2003). Of these two are not yet on the market and so no price was available.

No low-level suites were found and all third party approved suites were either close coupled or concealed cistern. Only two 'budget' models were found and these were retailed at £77+Vat (retail, 6-litre drop valve from B&Q) and £168 + Vat (trade) for a 6/4 dual-flush, drop valve suite.

Although a number of concealed cisterns have been tested the only approved suite was a 4.5 litre siphon flush WC selling for £260 (retail).

Model	Manufacturer	Tested	Cert No.	Format	Full flush	Part flush	Flush mechanism	Price ex Vat	Trade Retail	Notes
Adagio	Shires	WRC/NSF	207022	CC	5.7	4	Drop valve	168	Trade	
Barcelona	Siamp	KIWA		CC	6	6	Drop valve	77	RRP	B&Q
Geo	Caroma	WRC/NSF	207013	CC	6	3	Drop valve	590	RRP	
Harmony	Caroma	WRC/NSF	207012	CC	6	3	Drop valve	341	RRP	
Leda	Caroma	WRC/NSF	207014	CC	6	3	Drop valve	445	RRP	
Madrid	Siamp	KIWA		CC	6	6	Drop valve			B&Q not avail
Newport	Caroma	WRC/NSF	207015	CC	6	3	Drop valve	363	RRP	
Ifö Cera ES4	Solution Elements	WRC/NSF	209103	BTW	4.5	4.5	Siphon	260	Trade	
Riviera	Siamp	KIWA		CC	6	6	Drop valve	361	RRP	B&Q
Valencia	Siamp	KIWA		CC	6	6	Drop valve			B&Q not avail
Ventura	Armitage	WRC/NSF	204011	CC	6	6	Siphon	337	RRP	doc m?

Table 8 showing approved WC suites at the time of writing (March 2003). Prices will vary depending on terms and exact specification.

1.2.10 Practical considerations of domestic toilet replacement

From the householder's perspective it is impossible to make general statements about the economics of WC replacement, or product choice from new, due to the range of compounding variables. For a water company there will be regional variations but other variables will average out. However it may be possible and sensible to target the most cost effective cases first.

Without considering extremes or households with their own sewage treatment (<4% of UK) we can consider a realistic low scenario of a working couple living in a new house in the North West versus an equally realistic family of 5 with 3 kids and one working partner in the South West. The new house has two 7.5 litre WC but the family in the South West have an older 9-litre WC. Both replace them with a 6/3 dual-flush toilet bulk purchased and fitted for, say, £200 per WC:

	Low scenario	High scenario
Water & sewerage	£1/m^3	£2.5/m^3
House size	2 people	5 people
WCs per house	2	1
Flushes/person.day	4 (both working)	5 (young kids and one partner at home)
WC volume/flush	7.5	9
Metered WC use/y	£22	£205

Retrofitting 4.6-litre equivalent flush WCs @ £200/WC:

Retro' cost	£400[3]	£200
Saving/flush	7.5-4.6 = 2.9	9-4.6 = 4.4
Annual saving	£8.47	£100
Simple payback	47 years	2 years.

[3] In reality installing 2 WCs would not cost twice as much as installing one.

The two scenarios have a ratio of 23:1 on simple payback due to the compound variables. From a Water Company perspective it is permissible to use average figures as the extremes will cancel.

Starting assumptions (provisional as regional data may be available):

WC uses per person per day	5
Flush volume of 'old' WC	9 litres
Best practice (6/3 or 4.5 single)	4.6 litres actual average flush from evidence
Flush volume of standard new	6.2 litres (modest inflow allowance).
Household size	2.5 people
WCs per household	1.7 [Southern Water – personal communication]

Cost data (will change quickly)	
Cost of 4.6-litre equivalent retrofit	£200 – provisional estimate.
Over-cost of 4.6-litre from new[4]	£90 (third party certified - price expected to drop)
Over-cost of 4.6-litre from new[5]	£0 (not third party certified)

It seems reasonable to expect that, for new installations, no over-cost need be attributed to a WC that fits a simple 'low flush' specification (e.g. DEFRA, MTP) as budget WCs are available with 6/4 dual-flush cisterns. A higher specification, for example leak free or leak detecting mechanisms, easy maintenance features or delayed action inlet valves may all add cost to a basic specification as could general quality of design and manufacture.

Thus, as with white goods, the most important action required would be to ensure that promoted technologies will actually save water whilst encouraging refinements in product designs that will lead to real water savings over the life of the WC.

The above assumptions can be used as a basis for estimating an Average Incremental Cost (AIC) for a voucher scheme for a particular water company but the following issues need to be considered:

1. What do we assume for the base case default purchase?
With most WC production now claimed to be dual-flush (6/4) it seems unreasonable to assume 6 litres as the default purchase without incentive.

2. What is the real long-term water saving for a 'low flush WC'?
Will valve operated WCs deliver long term savings compared with valve-less models of similar or even higher flush volume?

3. What is the residual life of an existing WC?
Given that WCs have a finite life whether due to wear and tear or fashion, it does not seem reasonable to calculate the discounted benefit over the full life of the replacement WC as after, say 5 years, the existing WC may have been due for replacement, already being, say 10 years old. It is estimated that around 140,000 WCs are sold each year for new build whilst about 300,000 are replacements (BRE/MTP Briefing note WC1 Jan 31 2003). It is thought that 50% of domestic WCs are replaced every 16.5 years but it is not known how many of the same WCs are replaced regularly whilst others remain in place for considerably longer.

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[4] Both third-party approved, like compared with like.
[5] Neither third party approved, like compared with like.

For new installations there are a number of similarities with white goods namely:

1. An over-cost need not be assumed for low water use models in a mature market.
2. If offering vouchers to encourage purchase of ‘low flush’ WCs – what would the default purchase have been?
3. Cost and performance can be de-coupled.
4. There is an issue with self-certification and manufacturer's claims.
5. Real world performance is more complicated than nominal cycle (ie flush) volumes suggest – prediction is uncertain.

Some differences (in the context of the economics of demand management) are also worth listing for completion:

1. Unlike washing machines, there is often more than one WC per household.
2. White goods have almost universal sizing and are easily replaced (plug and go).
3. WCs may last 2-3 times as long as white goods, fashion permitting.

1.2.11 Replacement programs

Where an existing WC is to be replaced then the savings are theoretically greater but the cost is higher and more difficult to evaluate because of installation issues.

The much-publicised WC replacement programs in the US are often cited as an example to follow in the UK and it is worth noting some major differences between the two situations.

	US	UK
Water and sewerage cost	\$1.20/m^3 (approx NYC)	£1.50/m^3
Existing WC volumes	18 litres	9 litres
New Flush volume	6 max	6 max
Existing flush technology	flapper	siphon
Replacement flush tech’	flapper, drop valve, flapperless (rare)	valves, siphon
Existing leakage	high	very low
Standard WC format	yes	no
Metering	yes	20% approx.

Table 9. Similarities and differences between the UK and US in the context of WC replacement program economics.

1.2.12 Retrofit devices

Cistern displacement devices have been studied at length and will not be examined here. Instead we will look at the possibilities for dual-flush retrofit devices, which have been trialled by, among others, Southern Water. These devices are currently illegal but since they have been shown to produce water savings the situation is, at the time of writing, being re-considered by DEFRA.

The current legal situation with regards to dual flush retrofit is worth mentioning in passing if only to flag up the fact that it is a mess.

A wide range of issues are raised that are beyond the scope of this project:

1. The market is running free of the Regulations.
2. There is widespread confusion as to what is now legal and this changes regularly as new interpretations evolve and leak out.
3. WRAS approval of individual components is used to imply compliance of a whole suite (eg it is implied that ‘a WRAS approved flapper can be legally fitted to an existing WC’).
4. Unsubstantiated claims are made about water savings from retrofitting valves to old siphon suites.

Dual-flush retrofit trials

Two trials of retrofit dual-flush devices, one by Southern and the other by Anglian Water reported very different savings. The Southern trials averaged 27% reduction in WC water consumption (i.e. about 8% reduction in total domestic demand) whilst the Anglian Water Trial averaged only 4% [EA 2001].

With the exception of an electronically actuated dual-flush valve, both studies only tested siphon based retrofits although a number of retrofit valves are now on sale. What we can be fairly sure of is that dual-flush siphon retrofits do not, as was previously claimed, waste water although there is considerable uncertainty about the actual savings that can be achieved.

Whilst clearly flawed, the Anglian Water trial compared the old style dual-flush siphons which default to part-flush and the type that are now approved under the regulations for new installations which default to full flush. Whilst actual savings were uncertain, the trial supported our own belief that the traditional logic is more intuitive. Also the part-flush default should force learning in a domestic situation whereas the reverse logic could be used at full flush forever without the hidden part-flush being discovered. Clearly this is still a matter of speculation pending more evidence. Whilst not quite as dangerous, to have both systems installed would be like cars having arbitrary placement of brake and accelerator pedals.

Since many existing 9-litre siphons can be converted to old style dual-flush ‘for free’ by simply removing a plug and adding an instruction sticker, we suggest more research is warranted. For commercial and public applications there are health and drain blockage concerns with a part-flush default (dual or interruptible) and so a different requirement is needed than for domestic. Other aspects of the Water Regulations (and Building Regulations for that matter) are different for domestic and commercial situations so this should not be a barrier.

Whereas a single reduced flush volume should give similar savings for metered and un-metered properties, dual-flush requires some ongoing effort. Where water is un-metered (or the users are not part of a trial) savings might reasonably be less. Interestingly the traditional part-flush default (and some interruptible flush devices) require ‘effort’ to achieve pan clearance and so savings should improve with learning rather than diminish with ‘bounce-back’ effects as the novelty wears off.

Dual-flush retrofit householder economics

As with WC replacement the economics for the householder will vary. Using the same scenarios as before:

	Low scenario	High scenario
Water & sewage	£1/m^3	£2.5/m^3
House size	2 people	5 people
WCs per house	2	1
Flushes/person.day	4 (both working)	5
WC volume/flush	7.5	9
Metered WC use/y	£22	£205

Retrofitting dual-flush @ £40/WC		
Retro cost	£60 (not 2x cost)	£40
Saving/flush	2 (guestimate)	2.6 (Southern trial)
Annual saving	£5.84	£59
Simple payback	10 years	0.7 years.

The authors of the Southern Water trial calculated potential savings for a retrofit program based on the following assumptions:

2.6 litres/flush saving x 5 flushes/person.day x 2.5 persons/property
= 32.5 litres/property.day.

Costs were calculated as £10 for the unit plus £10 for fitting based on 1,000 units. This seems optimistic but Southern Water's recent costing exercise came up with £20/WC based on 66,000 properties. The Anglian report assumed a fitting charge of £38 which seems more realistic. If the units were supplied free for DIY installation then it is very likely that many would not be fitted.
If the traditional dual-flush logic were to be allowed then many cisterns could be converted for the cost of the information and an instruction sticker.

A further complication is recent promising trials of a simpler interruptible flush siphon, the legality of which is due to be considered by WRAC but which uses the same operational logic as the traditional dual-flush.

The economics from a water company perspective are calculated later.

1.2.13 WC conclusions and recommendations

Summary

- Some regulations and recommendations relating to water efficiency appear to be more likely to be based on anecdotes, calculations, and political considerations than scientific evidence and real world testing.
- Most WCs now being manufactured for sale in the UK are claimed to be dual-flush (6/4 litre).
- The issue of valve leakage (long term) and jamming (shorter term) is not addressed by manufacturing standards or laboratory testing. This is a known problem but of unknown magnitude.
- Retrofit of dual-flush siphons to 9-litre WCs could save between 4 and 27% of WC water consumption – explanation of the disparity in results is required – perhaps another trial is needed or new analysis of the Anglian Water data.
- The traditional style dual-flush siphon, which is illegal under the Water Regulations appears to be superior (in a domestic setting) to the full flush default model now required. Many traditional 9-litre WCs can be converted by simply removing a plug and displaying instructions on the cistern.
- Householder cost benefits (assuming metering) will vary considerably (more than an order of magnitude) because of compound variables such as household size, water and sewage cost, existing WC flush volume, occupancy, number of WCs and personal metabolism.
- Uncertainties (technical and human) greatly limit the accuracy of predictions of savings and cost effectiveness.

Provisional recommendations

- Investigate retrofit of traditional dual-flush following up on Anglian Water's work but consider modifying existing siphons in-situ. Actual savings? Number of WCs with dual-flush siphons installed?
- Continue to develop a benchmark for best practice based on evidence and risk.
- Provide incentives for proven best practice and ensure that innovations such as delayed action inlet valves and leak detection/prevention are acknowledged.
- Focus on measures that will raise the standard of all new WCs over time. Labelling, testing.

1.3 Showers

1.3.1 Introduction

As WC flush volumes have fallen and bathing habits have changed, some households use more water for baths and showers than for WC flushing.

UK showers can be usefully divided into 3 main types, electric heated, gravity and mains-pressure or power showers.

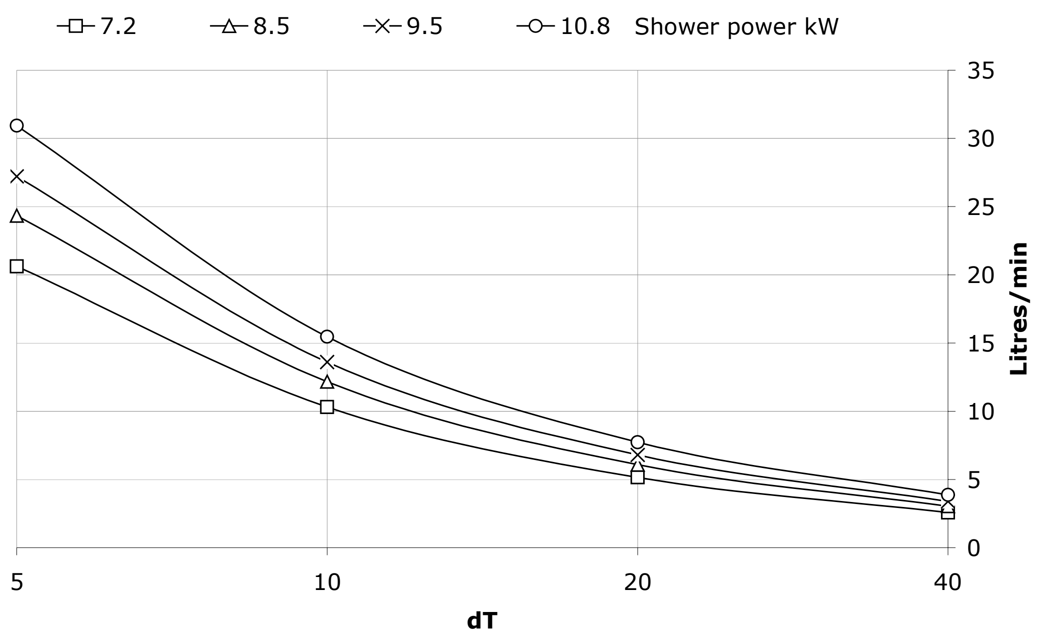
1.3.2 Electrically heated

Cold mains water is heated directly as it passes through the unit. Flow is limited by electrical power and required temperature rise:

litres/min=(kW X 1000 X 60)/(4190 X ∂t)

Thus for a 30K temperature rise (10°C mains 40°C shower):

Shower power (kW)	Flow l/min for 30K rise
7.2	3.4 l/min
8.5	4
9.5	4.5
10.8	5.2



Graph 15 of electric shower flow rate with temperature rise, 7.2–10.8 kW.

Thus for electric showers flow rates are modest, especially in winter when water temperatures are lower and desired shower temperatures higher. Although flow rates are low there is no limit to the time that can be spent in an electric shower as the hot water will never run out.

1.3.3 Low-pressure gravity fed

Traditionally UK hot water systems have been gravity fed. The available head of hot water at the showerhead can vary from under 1m to 10m for a basement in a taller house. Greater than 10m is effectively mains pressure.

Often the flow rate from such an arrangement is considered unsatisfactory and a pumped shower is installed (see below).

The flow rate can be increased by the use of large drench heads and low restriction mixer valves.

'Water saver' showerheads and flow regulators do not usually work with less than 1 bar dynamic pressure.

Figure 10. A large 'drench' type shower head which can deliver very high flow rates.

1.3.4 Pumped or mains pressure fed (> 1 bar)

This is the usual arrangement outside the UK with hot and cold water delivered to taps and shower at mains pressure (1-3 bar). In the UK pumps are sometimes used to boost gravity systems.

In the UK mains pressure systems might be from storage (mains pressure cylinder or thermal store) or from a multipoint or combi boiler. A recent innovation uses mains pressure cold water with a venturi to entrain low-pressure hot water. For the purposes of this study the result is a mains-pressure shower.

With mains pressure available, very high flow rates are possible and the capacity of the heating system may be a limiting factor. Storage systems are limited by the combination of hot water cylinder volume and recovery rate (boiler size and heat exchanger capacity). Combi boilers heat the incoming mains water directly and flows (assuming a 35K temperature rise) are in the range of 9.5 to 21 litres per minute depending on boiler power. In winter these might directly relate to maximum shower flows but in summer a cooler shower and warmer mains water will increase these flow rates.

With pressures greater than about 1 bar the hydraulics of the showerhead change. In the US water saving showerheads are distributed as part of water efficiency programs and these tend to use the water pressure to atomise the water flow thus providing enhanced wetting with less water. Some systems use a venturi to entrain air to a similar effect.

Such devices can give the effect of a powerful shower whilst only using 6–10 litres of water per minute. Optimised designs can operate as low as 4 litres per minute and 6 litres can be very acceptable with atomising designs. In the US since January 1994 heads with a flow rate of 2.5 US Gpm (9.5 litres/minute) at 80 Psi (5.4 bar) are the maximum that can be fitted.

There are a number of issues however. In typical cold UK bathrooms, atomising and aerating heads can lead to a 'cold feet' effect as the fine droplets cool quickly. Also these showers can be noisy and the fine spray, increased droplet surface area and hotter water (to overcome cold feet effect) can aggravate moisture problems in bathrooms. A number of trials with instantaneous gas boilers (combi and multipoint) have required a hot basin tap to be left running in order to create enough flow for the boiler to cut in or for the temperature to stabilise!!

Such showers may be more appropriate in commercial situations such as sports centres. Our own limited trials suggest that many people are not satisfied with such devices in a domestic setting. A proper trial was beyond the scope of this study but BRE [Pitts et al 2000] and the Norwegian Building Research Institute [Fiskum 1993] have carried out research, which suggests, as might be expected, a positive correlation between flow rate and comfort. It is likely that optimised designs could improve efficiency and limit excess flows without impairing performance but such products are probably not commercially available at present.

Thus the most likely route to water efficiency for non-enthusiasts would be to regulate flow rates to an acceptable 'water sufficient' level. For electric showers, no intervention is required as flow is limited by power input. For gravity showers, appropriate choice of shower head and the use of restrictors could help and for pumped and mains pressure showers, dynamic flow regulators can be used.

These measures simply limit maximum flows without improving efficiency and the devices can easily be removed. Thus the main function is to limit the user's freedom to increase the flow rate higher than the 'owner' has set.

Multi spray panels can deliver very high flow rates but have previously been limited to the luxury market. A recent trend is for low-cost multi-head showers with up to 8 showerheads.

Figure 13 shows a range of 'water saver' showerheads. From left, three air-entraining models designed to work at about 10 l/min, two atomising heads that work well at 6 l/min and a flow regulator for use with showers.

Figure 11 Some water saver showerheads for use at mains pressure.

Figure 12. An atomising showerhead in use.

Figure 13 Standard showerhead at mains pressure but regulated to 6 l/min.

1.3.5 Other factors

The ergonomics of temperature and flow controls, dead legs and other factors will also influence total water use (see EA water saving fact cards). Even factors such as cubicle design will have an influence as a sealed and well detailed cubicle or wet room will allow far higher flow rates than say a fabric shower curtain over the bath, without causing water damage.

1.3.6 Water use compared with baths

It is well known and easily proven (take a shower in a bath with the plug in) that showers can use much less water than baths. However:

- showers tends to be taken more frequently than baths.
- water use depends on the time spent in the shower.
- high flow rate 'power showers' (>12 l/minute) may use as much or more water than a bath, limited only by the capacity of the hot water system.

The trend is towards higher flows so a new shower is likely to be of higher flow than older low power electric models or restricted gravity fed designs. Thus the currently available public domain data on water-use due to showering is unlikely to be appropriate when predicting future water use due to increased showering.

1.3.7 Labelling

Labelling of showers has been discussed, for example in the National Water Conservation Group, and largely dismissed. The mains reasons given are:

- A 'shower' is a combination of components (valve, heating system, head(s) and cubicle) often sold separately.
- The UK has a wide range of hot water system pressures from 10 metres gravity feed to over 10 bar mains pressure feed.
- Labelling a shower, as water 'efficient' will be seen as a negative factor at point of sale as it means low flow.

For pressures greater than 1 bar, self-regulating showerheads are available which allow a flow rate to be specified up to a standard pressure (e.g. 5 bar). This is believed to be the situation in the US. The current UK situation with universal showerheads for mains and gravity systems means that very high flows are possible when used at mains pressure.

As already noted, electric showers are limited in flow by the available current and other technical limitations of instantaneous heating.

Showerheads could be labelled for flow rate if the pressure were to be stated and non-removable flow regulators (rather than restrictors – see the Agency's water saving fact cards) could be integrated to give a maximum flow at mains pressure.

For a shower label to actually encourage rather than discourage uptake of efficient (in the proper sense of the word) fittings it would need to indicate performance as well as flow. Possibilities include ratings for pressure on the skin, rinse efficiency, temperature stability and temperature drop from head to feet. Such tests are under development [e.g. Fiskum 1993] and whilst very complex, some useful quantifiable tests should be possible.

It may be that a label would be best designed for 'damage limitation' rather than best available water saving practice. This assumes that prevention of flows greater than say 9 or 10 litres per minute might be a higher priority than encouraging the uptake of very low flow showerheads by a small minority of enthusiasts.

Further speculation is beyond the scope of this report.

1.3.8 Shower conclusions and recommendations

Summary

- Generally, up to a limit, more water equals a better shower experience.
- 6–10 litres a minute should be adequate for a good shower if the head is well designed.
- Efficiency is difficult to evaluate due to the qualitative nature of showering but quantitative tests could be developed and calibrated by real people.
- Most available showers will have a maximum flow rate that is dependent on water pressure (c.f. US showerheads which must be regulated).
- Controls and dead-legs also influence water use but are difficult to specify or change.
- There are many different technologies in the UK, which makes standard bolt-on solutions difficult.
- Flow regulators can be used above 1 bar to limit maximum flow rates to a 'water sufficient' level.
- Generally showers use less water than baths but high flow showers (>20 l/min) can use more water than a bath and showering tends to be more frequent than bathing.
- Any flow regulators/restrictors or water-saver showerheads can be easily removed or replaced to 'boost performance'.
- A water saving label could discourage sales.
- Depending on boiler size, combi boilers can deliver between about 9 and 20 litres per minute with winter water temperatures.
- Whilst multihead showers were previously aimed at the luxury market, low cost models are now available and manufacturers see this as a potential growth area.

Provisional recommendations

- More research is required – e.g. analysis of available micro-component water usage data, development of performance measurements for showers and research into spray design to optimise efficiency (comfort and cleansing/water required).
- Issues (legal, social, technical, practical) around setting maximum flow rates could be re-examined.
- Whilst fraught with difficulties, a performance test might enable a labelling system to function and so encourage better <u>efficiency</u> at manufacture and point of sale. Without this, higher flows will be associated with better showering and 'luxury', and a water efficiency rating based only on flow (ie low = water efficient) would discourage most purchasers.
- Metering is likely to be an important driver to reduce shower water use or encourage good practice at purchase.
- Encouraging householders with baths to purchase a shower could be economic as the whole cost would not need to be borne by, for example, the water company.
- Flow regulators (6–10 l/min?) could be made available for customers with mains pressure or pumped showers.

1.4 Direct Hot water systems – an initial review

1.4.1 Introduction

Combination boilers account for over 50% of the domestic boiler market and this is predicted to rise.

Whilst 'combis' offer a number of advantages over conventional boiler and cylinder arrangements, the issue of water wastage has been the subject of concern in demand management circles for some time [e.g. Howarth 1995]. The problem is that when starting from cold, it can take a long time for hot water to reach the tap. After the tap is turned on, a pressure sensor tells the boiler to fire in hot water mode. The boiler then goes through a purge cycle and fires. The primary water circuit then heats up and this then heats the secondary (mains) water to the tap. All this can take over a minute which is frustrating and a waste of water and energy.

The actual volume of water wasted depends on patterns of usage, user requirements (warm or hot required) household size and heating season. No robust figures are known.

If the issue of warm-up losses can be addressed then combi boilers or a combi-storage hybrid could actually offer water savings by reducing dead-legs if installed with smaller pipes made possible by the mains pressure – e.g. 8 or 10mm to kitchen tap.

1.4.2 Solutions

A number of solutions are used. Some boilers leave the fan running which saves a few seconds by avoiding the purge cycle but electricity is wasted, fan life is reduced, the constant noise can be irritating and warm up is still required. Others keep the heat exchanger warm. This 'keep warm facility' wastes energy and the heat exchanger is not usually insulated. Sometimes this facility can be turned off or controlled by a timer. The third solution us to use a small hot water store in the primary (boiler water) or secondary (mains water) water circuit. This is usually insulated so heat loss should be low but this figure is rarely, if ever, reported in the SEDBUK database (Seasonal Efficiency of Domestic Boilers in the UK. www.sedbuk.com).

SAP 2001 includes definitions of the various boiler types and equations for the seasonal efficiency of instantaneous and storage combination boilers. The equations are unlikely to be accurate for smaller thermal stores where significant heatloss will be along pipes and other connections. The SAP/SEDBUK equations estimate efficiency loss (i.e. a percentage to be subtracted from the measured boiler efficiency) as a function of volume and insulation thickness. These assumptions may be reasonable for larger stores (>150 litres say) but are likely to give incorrect values for smaller (say 20 litre) stores.

1.4.3 Associated issues

Whilst we are primarily considering water use, a more important environmental and economic consideration for boilers is energy use. Because of the possibilities for a potential trade off between water saving and energy efficiency (eg keep warm facility) any attempts to influence policy (Building Regulations, Water Regulations, MTP etc) to promote water efficiency must be integrated with energy considerations. An ideal design should save both water and energy.

1.4.4 Drivers

Whilst users may perceive a 'benefit' from 'inefficient' showers, the water wastage due to combi warm up is simply a nuisance, which might reasonably disappear due to market pressure. The main environmental concern is that any energy cost to achieve this, which might not be accurately reflected in the SEDBUK and SAP ratings. With a realistic assessment of this energy cost/benefit, manufacturers would be encouraged to design out inefficiency.

1.4.5 Hot water systems conclusions and recommendations

Summary

Combination boilers can waste water and energy whilst causing annoyance. Solutions are available but the associated energy cost/benefit balance is not yet fully considered in the SEDBUK or SAP rating scheme, which is the current decider for carrots (grants and labels) and sticks (Building Regulations, performance specifications).

Provisional recommendations

This section is very much a preliminary review, which was carried out by talking with energy consultants and reading general literature followed up by an exploration of the SEDBUK database. The SAP method was skimmed but the assumptions were not fully explored or modelled. Because of time and budget constraints, no attempt was made to contact any specialists involved in developing the SAP and SEDBUK ratings but it is likely that much useful work has already been done and that some of these recommendations may be naive.

- More research is required to determine:
    - Actual water wastage due to boiler warm up (water company micro-component metering, 'Trace Wizard' or 'Identiflow' trials etc).
    - Energy cost of thermal stores (and conventional hot water storage) and keep warm facilities.
    - Product and market trends.

- The SEDBUK rating needs to address the energy and water cost-benefit of thermal stores and keep warm facilities and manufacturers need to measure and report this.

2 OPTIONS APPRAISAL; PRACTICALITIES AND HOUSEHOLD ECONOMICS

2.1 Introduction

This section looks at the economics of a number of appliance replacement options for each product group. These options range from providing incentives for householders to purchase more efficient products when buying new, to appliance exchange programs where old inefficient, but functioning appliances, are removed and replaced with more efficient models. The economics from a water company perspective are covered in the next section.

2.2 White Goods

2.2.1 Option 1 – incentive to choose water efficient machines

As discussed in the white goods section, the differences in water and energy use between machines have reduced to the point where:

1. The differences are small enough to make product differentiation unreliable by energy label data alone.
2. Driving water use even lower may be counter-productive unless the labelling scheme were to measure rinse performance and part-load efficiency.
3. Most products are now 'water and energy efficient' so any water company economic calculation would have to assume that many purchases would have been water efficient by default.

For dishwashers the daily water use is low enough that variations only account for a few litres per day as the data in the report shows. Thus further analysis for dishwashers will not be carried out.

From the householder's point of view, whilst lower energy and water use would have a payback, the energy label data does not seem accurate enough to allow such a calculation to be made reliably. At best, cost savings will be modest. Optimising detergent use and choosing a reliable machine with low maintenance costs can have greater economic environmental, savings.

If further improvements are to be made it seems likely that the energy label will need to evolve to reflect real world use with frequent part loads and poor control of detergent dosing etc.

Even for washing machines, meaningful cost benefit calculations cannot be carried out either for the householder or the water company, as claimed performance variations are less than the 'noise[6]'.

2.2.2 Option 2 – appliance replacement

Since water and energy efficiency have improved significantly over the last few years, this scenario is perhaps clearer as most new machines can be expected to use half the water of older machines.

The main uncertainties when calculating the economics are:

1. Residual life of the old machine.
2. Energy label inaccuracies for new machine.
3. Life span and reliability of the new machine.

Whilst any number of scenarios can be calculated the following example is illustrative:

Base case is a 5-year-old machine, which has to be replaced after another 5 years at an estimated cost of £250 at current prices. The replacement machine is assumed to have an annual running cost of £60

[6] E.g. disparity between energy label and actual, part load efficiencies, user behaviour, variable features such as 'extra rinse' cycles etc.

at current prices assuming water and energy use will drop slightly and detergent use will also be reduced – possibly controversial assumptions but close enough for the example.

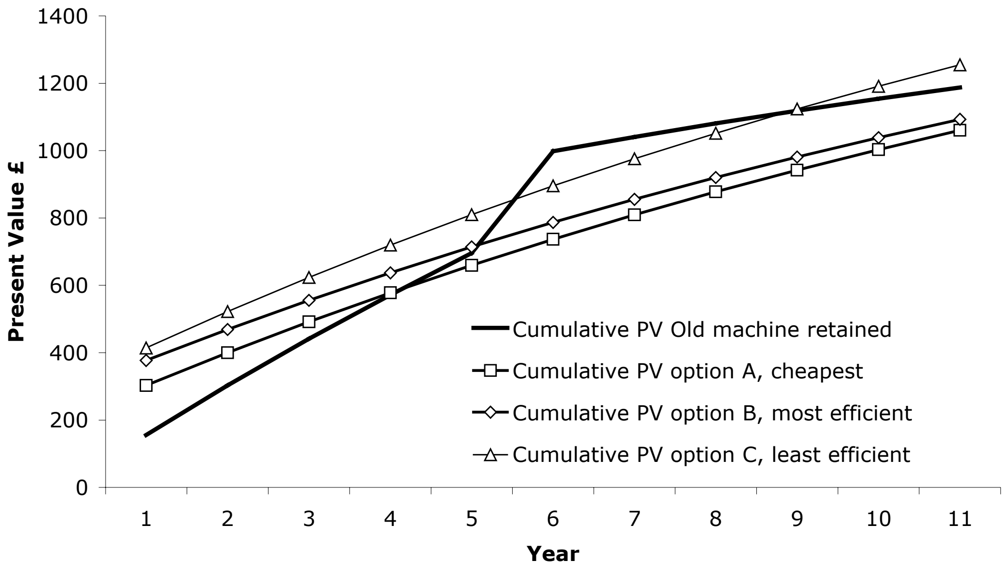
Option A is a currently available budget machine with good water and energy efficiency whilst option B was most efficient on test in a recent 'Which?' trial. Option C was the least efficient machine tested.

	Base case	Option A	Option B	Option C
Capital cost	zero then £250 after 5 years	£200	£280	£300
Water use/cycle	100 litres	43	38	60
Electricity use/cycle	1.5 kW.h	0.588	0.462	0.672
Detergent/cycle	18p	18p	18p	18p
Washes/week	7			
Electricity Cost p/kW.h	7p			
Water and sewage cost	£1.50/m3	£1.50/m^3	£1.50/m^3	£1.50/m^3
Annual running cost	£155.70 (£60 when replaced)	£103	£97.20	£114.20
Discount rate	6%			

Table 14. Assumptions used to plot the life cost graph below,

Graph 16 below shows option A to be the least cost option over a 10 year period based on these assumptions. The graph also shows the difference in life cost between the three new machines.

It is important to note that Graph 16 only illustrates one possible combination of usage and cost assumptions and suggests a saving for two of the options. However the saving is modest and, given the uncertainty of the various assumptions, this supports the current wisdom that a working machine should be retained. However it may be economically viable for an individual household to replace a working machine if usage is high and water and sewerage charges are above average.



Graph 16. The cumulative life cost for four options discounted at 6%.

2.2.3 Option 3 – incentive to purchase dishwasher for non-dishwasher households

The claim that dishwashers use up to 10 times less water[7] and energy than hand washing might suggest that consumers should be encouraged to purchase these machines.

[7] e.g. Professor Rainer Stamminger University of Bonn, various internet news stories but no paper found. Also 'Which?' and manufacturer's product literature for other claims.

Whilst simple experiments do show that hand washing can use more water than a machine, individual practice varies considerably. Clearly where dishes are washed under running taps water use will be higher but with care any difference may be small. Savings would need to be offset by any increased life cycle impacts, for example machine manufacture, maintenance and disposal and the more aggressive detergents and rinse aids required by machines. Even dishwasher households use the kitchen sink for washing up certain items and some users rinse dishes before placing them in the dishwasher and this further complicates the assumptions.

Whilst a proper evaluation is beyond the scope of this research caution is advised until real life data can be obtained, eg via SODCON or similar water company studies. Further research would certainly be interesting as the myth or reality of dishwashers being the green option is taking hold.

2.2.4 Other recommended options

There seems to be clear evidence that, for all the original scepticism, the energy label has driven manufacturers to design more efficient machines. It seems likely that refining the label to award improvements in real-world water and energy efficiency, whilst ensuring performance is not compromised, is a good direction to go. A simple Water efficient approved label comparable with the Energy Saving Trust label may be a useful tool for promoting water efficiency but would require a body to endorse and administer[8] it.

2.3 WCs

2.3.1 Option 1 – dual-flush retrofit

Where appropriate and if made legal, dual-flush retrofit appears to present a cost effective option for demand management in a domestic setting.

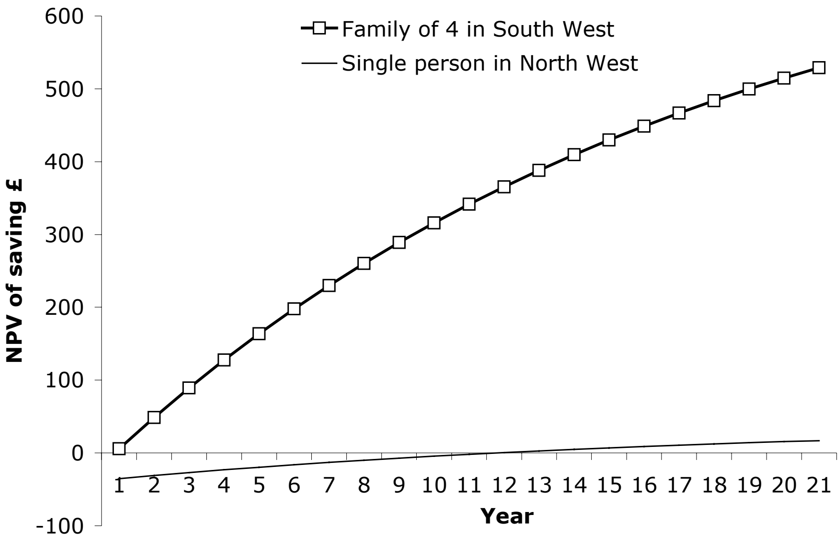
Domestic economics

As already outlined, the economics will vary considerably from house to house. Varying just household size and location from 4 people in the South West to a single person in Northumbria and using the following assumptions we can plot the cumulative saving against time discounted at 6%:

WC uses/person.day	5	5
Water & sewage cost	2.5	1
Population	4	1
Number of WCs	1	1
Days/year	365	365
Discount rate	6	6
Installed cost/WC	£40	£40

Table 15. Assumptions for the two scenarios plotted in Graph 17.

[8] The Energy Saving Trust label is simply based on the Energy Label data without further testing or evaluation so at a basic level, only requires agreement on the threshold standard.



Graph 17. Net present value of saving for two scenarios with 6% discount rate.

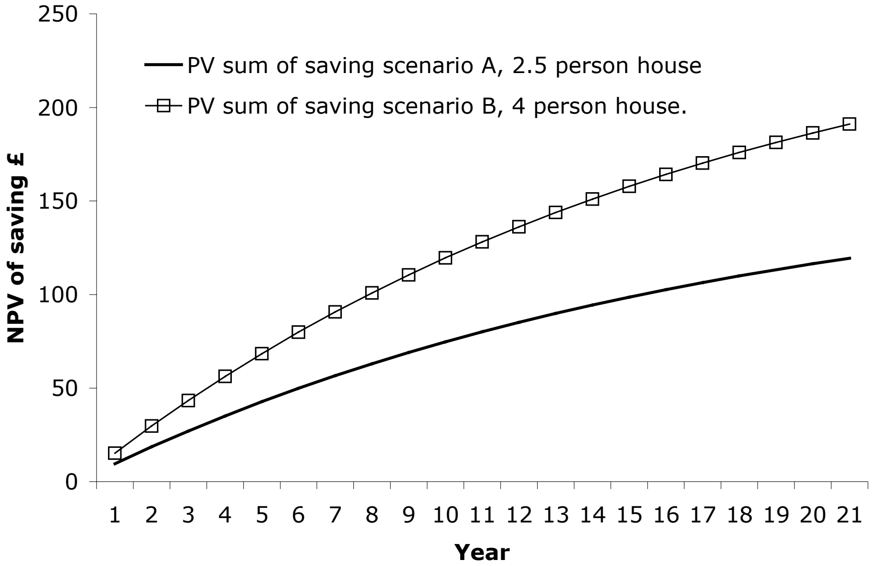
2.3.2 Option 2 – incentive to purchase 'ultra low flush' from new

As with white goods there is evidence that efficient WCs can be produced for little over-cost. Also in common with white goods, now that all flush volumes must be below 6 litres, it is difficult to predict accurate real world savings between models. The uncertainty is increased now that valve mechanisms introduce the issue of leakage and sticking mechanisms. Graph 18 indicates the modest savings that are likely and which could easily be negated by any increased maintenance costs or leakage or a more complex mechanism.

Again the economics will vary but as an example we will consider the potential saving to be had from installing a 4.6-litre equivalent flush WC rather than a 6-litre WC. Zero over-cost was assumed but the axis can be shifted to represent any over-cost.

	scenario A	scenario B
WC volume	4.6	4.6
WC uses/person.day	5	5
Water & sewerage cost	1.5	1.5
Population	2.5	4
Number of WCs	1	1
Days/year	365	365
Discount rate	6	6
installed cost/WC	150	150

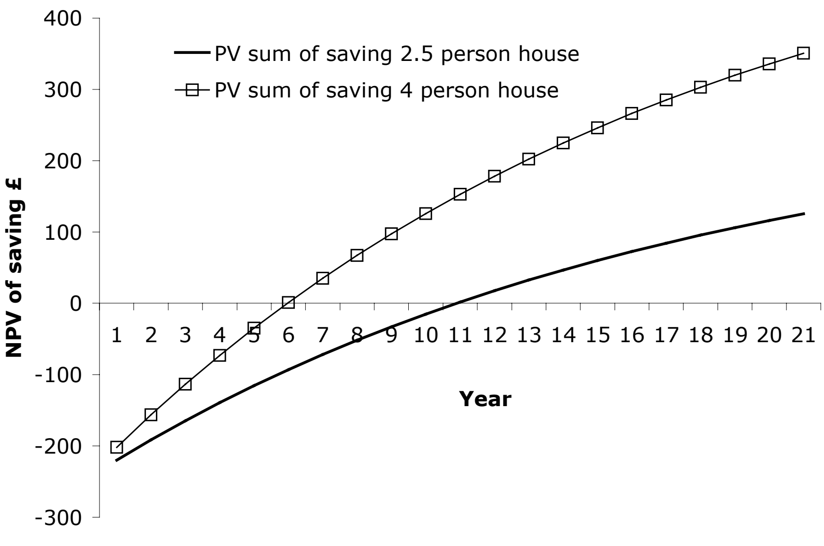
Table 16 showing assumptions for graph below. 4.6-litre WC installed instead of 6-litre.



Graph 18. Discounted NPV of saving when installing a 4.6-litre effective flush in place of a 6-litre flush WC.

2.3.3 Option 3 – appliance replacement

As with white goods, whilst the cost of replacing an existing working appliance is greater than for new installations, the savings are potentially greater. Again there will be considerable variation between households. Graph 19 shows the discounted NPV of savings against time when a 9 litre WC is replaced by one with a 4.6 litre effective flush (e.g. 6/3 dual flush). The installation cost is assumed to be £200 and all other assumptions are as before, i.e. £1.50/m^3 water and sewerage charges, 5 WC uses/person.day and 6% discount rate.



Graph 19. 9 litre WC replaced with 4.6 litre WC.

A similar exercise can be carried out as for washing machine replacement, where 10 or 20 year life costs are plotted with the 'do nothing scenario' including natural WC replacement. Thus a future replacement cost is borne now in exchange for reduced water bills. A more complex model is required if averages are to be calculated based on assumption about the current age distribution of installed WCs flush volumes and life span.

2.4 Showers

Since shower water use depends on even more variables and uncertainties than the other areas examined no attempt will be made at an economic evaluation between the numerous possible scenarios. Instead we will use the example of a 10.8kW electric shower replacing a bath but acknowledge that the usage assumptions are not robust.

	Bath	**Electric Shower**
Volume per use	80 litres	6 l/min x 6 minutes = 36 litres
Uses/person.day	0.34 [EA 2001].	0.6 [EA 2001]
Heating	30 C ∂t by gas	10.8 kW electric
Efficiency	75%	100%
KW.h	3.48 kW.h[9]	1.08 kW.h[10]
Kg CO_2/kW.h	0.19	0.41
Kg CO_2/bathing	0.66 for heating only	0.44 for heating only.
Energy cost/kW.h	2p	7p
Water & sewerage cost£1.5/m^3	£1.5/m^3	
Water/person.year	9.9m3	7.88
Kg CO_2 (water)	9.9 (9.9 x 1 kW.h/m^3)	7.88
Water cost/p.y	£14.85	11.83
Energy cost/p.y	£8.64	16.56
Kg CO_2/p.y	**91.8 kg**	**104.24 kg**
Total cost	**£23.49**	**£28.39**

Table 17 comparing baths and showers but note sensitivity to varying assumptions.

These assumptions seem to suggest little difference but that baths are cheaper and more ecological than showers but note:

- The shower was assumed to be electric (cost and CO_2 penalty).
- Showering was assumed to be almost twice as frequent as bathing (bathers may also shower).
- A shorter (or longer) shower is possible.
- Bath water could be heated by electricity (3 x the cost).
- The electric shower has no standing losses (compare hot water cylinder).

2.5 Direct water heating

Due to time and budget constraints a full appraisal of water and energy related to water heating was not possible as part of this project. However it is unlikely that savings could ever be great enough to justify an appliance exchange program on water saving grounds alone. The main avenue for action would be to ensure that water wastage considerations are included in any future performance requirements that are developed. Some sophisticated modelling is required to balance energy and water considerations where these might conflict[11].

[9] ((80 litres x 30K x 4190J/kg)/(3600 seconds x 1000)) x 1.25.
[10] 6 minutes @ 10.8kW.h = 0.1h x 10.8kW.h.
[11] A conflict is not inherent but cheaper solutions to the warm up problem might be energy wasteful – e.g. compare with trace heating of dead legs and pumped secondary water loops.

3 APPLIANCE REPLACEMENT; WATER COMPANY ECONOMICS

3.1 Introduction

The complex issues of calculating the economics of demand and supply side measures is covered in depth by others elsewhere, for example UKWIR and Environment Agency, 1996. For the purposes of this report we have focussed on practical issues relating to specific product groups.

This report has identified number of issues that present a barrier to appliance exchange or similar programs. For example if for a given product, savings are uncertain, water use labelling is inaccurate or installation is complicated by issues of compatibility, then we are not in a good position to estimate the economics of a replacement or promotion program.

For the purpose of this section we will temporarily put aside fixable issues such as accuracy of manufacturers claims so that a range of Average Incremental Costs (AIC) can be determined. **The results presented in this report should be considered as worked examples rather than absolute values, which must be calculated using project-specific data.** The six scenarios have been selected to illustrate a range of issues and should not be considered as recommendations of optimum demand management strategies nor should they restrict the exploration of other demand management options.

3.2 Method

Values for AIC or Average incremental Social Cost (AISC) are often quoted but are meaningless without a statement of assumptions used. For the purposes of this work we have not attempted to include a social cost but where there is a social cost or benefit this has been stated. Similarly the social and environmental cost or benefit of water saved has been ignored, as this is very location specific.

To calculate the AIC of a proposed efficiency measure we have used the following formula:

$$AIC = \frac{C - S + m}{10.W}$$

Where:
C = discounted present sum of the cost of the water saving measure in pounds sterling, over time horizon of option
S = discounted present sum of opex saving for water and sewerage not pumped and treated (£)
m = discounted present sum of maintenance cost of water saving measures (zero for these examples)
W = discounted present sum of total water saved, megalitres.
The result is in pence/m^3.

Calculations were carried out using a spreadsheet developed by the Environment Agency based on the principles of UKWIR and Environment Agency 1996.

3.3 Assumptions

The main variables when calculating the AIC of a proposed measure are:

- Discount rate
- Opex savings
- Loss of revenue
- Cost of implementing measure (including administration)
- Timeframe
- Implementation period
- Life of option
- Water saving

Discount rate
A discussion is outside the scope of this report however at the time of writing the Treasury quote 3.5%. For shorter-term measures small changes in the discount rate have little effect.

Opex savings
If less water is delivered and subsequently treated as sewage then savings will result. We have used an estimate of 6p/m^3 from OFWAT but the value is not critical (Day 2003).

Loss of revenue
Revenue loss has been ignored in our calculations as OFWAT have indicated that revenue lost by water efficiency measures can be recouped:

'Where demand management is part of efficient water resource plan we will:
- *allow capital & operating costs in price limits*
- *make allowance for the expected loss of revenues (if measured demand affected)'*

George Day, OFWAT. Speaking at the Watersave meeting, Loughborough, 11 December 2001.

Cost of implementing measure
This might be the cost of installing a given water efficiency measure such as dual-flush devices or replacement WCs or it might be a voucher or subsidy that represents the required incentive for a householder to choose a water efficient option.

Timeframe
A 30-year timeframe has been used.

Implementation period
Whether a thousand water saving devices are installed over one year or 10 years will not change the calculated AIC within a 30 year timeframe. In reality the situation will change over time. Thus if we look at say a voucher scheme to encourage purchasers to choose the most efficient washing machines, it is likely that the market will have changed considerably in even one year so that the scheme, or at least the calculated AIC might be inappropriate. We do not know how the market for say WCs or washing machines will go in even two years time. For example all products might evolve towards a common standard driven by market forces so that differentiation is not possible. Alternatively a more sophisticated labelling scheme might be able to identify even greater real world variations between products so that a voucher scheme becomes very relevant. As a third scenario consumers may demand bigger and faster washing machines that use more water. With this scenario the potential savings (or reduced 'wastage') might be more significant but the required incentive might be greater as consumers would actually have a preference for the 'wasteful' machine, a situation analogous to showers.

Such concerns about the difficulty in predicting trends are particularly justified when options are being evaluated over a 25 to 30 year timeframe. The choice of implementation period is closely tied to the life of proposed options discussed below.

Assuming that proposed measures are voluntary then the period over which an option is implemented will depend on the rate of natural uptake and the rate at which a measure can be practically implemented including any lead times.

Life of options
The life assumed has a very significant influence on the calculated AIC. When evaluating new installations, ie an efficient product is purchased in preference to a less efficient one, then the product life is used and we might assume that the efficient and inefficient product have a similar life span. Where a part worn appliance is replaced with new or modified to improve performance (e.g. dual-flush retrofit or WC replacement) then we suggest that the residual life of the old product should be used in preference to the life of the new product or the expected life of the retrofit device.

The average replacement period for long life products such as WCs is less than the average product lifespan because of fashion and refurbishment.

Water saving
Where possible trial data should be used rather than assumptions based on theoretical reductions. Until savings can be measured on a large sample under non-trial conditions, even trial data must be treated with caution. Some of the problems with predicting water savings are outlined in the product review section.

3.4 Sensitivity and risk

Some values such as discount rate and variable opex may vary over time and between regions but can be agreed and will be common to all options being considered. Other variables such as installation period and cost of measures must be estimated for the purposes of hypothetical examples as presented here but can be tied down for a specific project. The third category of variables are currently less certain either due to lack of reliable data or dependence on other factors such as untried technologies, rebound effects, price elasticity, social and economic trends etc. This category includes figures for water savings and life of options.

Thus it is recommended that a risk analysis be carried out to estimate the likelihood of savings for a range of scenarios. Obviously this is complicated by more than one uncertain variable.

Table 18 illustrates a range of options based on the following common assumptions:

Variable		Source
Discount rate	3.5%	Treasury
Variable opex	6p/m^3	Estimate discussed above
WC flushes/person.day	5	Widely agreed figure
WCs per household	1.7	Southern Water (SW) (34,000 sample)
Occupancy	2.5	SW, average. Metered (2) and un-metered (2.6)
Time period NPV	30 years	
Av'ge flush for existing WCs	9-litres	
Best practice WC	4.6 litres/flush average (e.g. 6/3 dual, 4.5 single)	
Old washing machine	100 litres/cycle, 5 years residual life	
Default new washing m/c	60 litres [1]	
Best practice new washing m/c	50 litres [1]	
Washes/week	7	

Notes on assumptions
[1] see product review section which suggests that default purchase could have lowest water use. The figure here is to illustrate saving if a difference of 5-10 litres per cycle can be identified for example by a refined energy label.

scenario	From	To	Installation period yrs.	Life of option yrs.	Unit cost £/hhold	Unit saving (unit is household) litres/day	Range of AIC p/m^3
1	Standard WC	Dual-flush retro	5	5–15 (10)	£40 installed	32.5	19–66p (33p)
2	Default purchase WC	4.6-litre average flush	10	15-30 (20)	£20-50 (£20) voucher	6.25–12.5 [2] (9.4)	19–178 (34)
3	9-litre WC	4.6-litre average flush	10	5–15 (10)	£400-250 (£350) installed	61	88–699 (176)
4	Existing old washing machine	Efficient new washing machine	3	3–6 (5)	£100–250 (200) voucher to full cost	50	93–466 (229)
5	Standard purchase washing machine	Efficient new washing machine	3	10	£20-50 (£20) voucher	5-10 (5)	58–312 (121)
6	Standard shower	Water saving showerhead	5	5	£40 fitted & tested	5–30 (10)	72–463 (227)

Table 18. Provisional assumptions and AIC calculations for 6 scenarios.

Discussion on table of scenarios:

The scenarios in Table 18 are intended as a starting point for development and discussion rather than as reliable benchmarks. For each option the least certain variable(s) are given a range of values. Two calculations are then performed to show the best and worst case. The figures in brackets are suggested values.

Scenario 1

The cost and water savings (2.6 litres per flush) figures are from Southern Water and, whilst provisional, are based on their dual-flush trial and quotes for installation of retrofit devices. A figure of £20/WC has been quoted so we have assumed £40/household with a little margin. The only value varied was the 'life of option' which is the residual life of the converted WCs. Newer WCs might have a longer residual life but should also have a lower flush volume so savings will be less.

Considering a 10-year residual life of the converted WC we get an AIC of 33p.m^3 with a discount rate of 3.5%. Raising this to 6% increases the AIC to 37p. If the water saving proves to be only half what is expected (1.3 litres/flush) then at 3.5% discount rate and 10 year life, we get an AIC of 72p/m^3 with a water saving comparable to a low cost displacement device.

At the time of writing we await formal confirmation of the legality of dual-flush retrofits.

Scenario 2

This scenario looks at the economics of encouraging buyers to choose an efficient WC at point of sale. The problems with identifying best available products and default purchase are discussed in the product review section. This hypothetical example assumes that a future label scheme can differentiate between available models but that there is minimal inherent over-cost associated with more efficient WCs. It is assumed that savings are between 0.5 and 1 litre per flush when compared with a default purchase. Although based on these assumptions the economics look promising, promotion of a given WC type without hard evidence of actual water savings would be unwise. When data and appropriate product labelling are available then a voucher price (after subtracting administration costs) can be calculated to achieve any required AIC. Obviously the higher the voucher price the better the likely uptake at the cost of a higher AIC.

Considering the bracketed values of 20 year life, £20 voucher cost and 9.4 litres/day water saving we get an AIC of 34p at 3.5% discount rate and 42p with a 6% discount rate.

Scenario 3
This scenario is based on the WC replacement schemes in the US. The installation cost would depend on many factors and it is possible that the customer could contribute. Issues of performance, leakage, and compatibility as discussed in the product review must be considered. The WC price is a guess based on 1.7 WCs per household. An alternative scenario would be to provide a voucher towards the cost of a new WC and this could be set at value that balances cost and rate of uptake but again some practical issues need to be resolved.

Scenario 4
Here we look at an appliance exchange program for older washing machines assumed to use an average of 100 litres per wash and with a residual life of 3–6 years. The replacement machine is assumed to use 50 litres/wash. Particularly because of the short residual life of the old machine (it would be due for replacement anyway) the economics are not particularly good. Many consumers might jump at the chance of a new efficient machine given the incentive of a voucher but the uncertainties about default purchase and the problems of administration probably rule out this option even before we consider life cycle issues.

Scenario 5
As with scenario 2, this option would require a reliable method of differentiating between the performance of available products. In order to calculate the AIC, an assumption has to be made about default purchase behaviour. If a differentiation can be made then an incentive scheme (vouchers, discounts, bulk purchase of efficient machines etc) should drive the market towards more efficient machines for purely commercial reasons. Hence even an apparently uneconomic scenario could contribute to market transformation on a wide scale. The same argument applies to other products.

Scenario 6
Showering presents different problems for economic prediction as the trend is for increased use and higher flows. Insufficient data was available for us to make meaningful AIC calculations so the figures in the table should only be taken as an example.

4 CONCLUSIONS

This study set out to calculate the cost benefit of a number of domestic demand management measures from the perspective of householders and water companies. In the event, more questions have been raised than answered but a number of interesting and unexpected results have emerged.

1. When water efficiency is addressed at point of manufacture, this can be achieved with little or no over-cost. However, replacing or upgrading existing fittings will always incur an additional capital cost.

2. For all the original scepticism, the Energy Label does appear to have been successful in transforming the white goods market towards higher energy, and as a by-product, water efficiency. Not surprisingly, manufacturers are likely to design products to meet the label requirements and are unlikely to include features that do not earn credits or avoid penalties. It seems likely that white goods are approaching the limit of efficiency in terms of the measured parameters, but differentiation could still be measured and progress encouraged by refinement of the label. Whilst an evaluation of labelling was only incidental to this study, a number of issues have been raised that could inform the ongoing debate about a possible water efficiency label scheme.

3. From the householder's perspective the running costs of appliances are unlikely to feature heavily on a buyer's list of priorities. Water Companies can take a longer-term view and compare demand-side measures with resource development. As expected, dual-flush retrofit stood out from the crowd, being a relatively low cost measure with proven savings. Potentially greater savings could theoretically be achieved by replacing older 9-litre WCs with the most efficient models now available but the cost is higher and there are a number of risks relating to actual water saving and long-term reliability of valve mechanisms.

4. A major variable that has been highlighted when considering retrofit and product replacement programs is the life of the measure, which is used to calculate the AIC. Typically this has been the expected life of the new product but with the market moving towards water-efficiency (in terms of measured parameters) it is more reasonable to use the residual life of the old product that is being replaced. This may be a suspect prediction as products are changed because of fashion and economic trends rather than at the end of their natural life.

5. Any scheme that is to promote efficient goods, requires a best practice performance specification and a way of differentiating between products. The study shows that the accuracy of the Energy Label has been found to be questionable and that a number of real-world variables might lead to performance differences between apparently identical products. Examples include part-load efficiency of washing machines and dishwashers or the actual flush volume of WCs when connected to a water supply. A related issue is the equivalent effective flush of dual-flush WCs when compared to single flush. Currently programs such as the proposed Enhanced Capital Allowance Scheme use ratios of full to half flush based on human metabolism rather than field data of user behaviour.

6. Once 'better products' can be identified and differentiated then there is considerable potential to encourage the market to move in the right direction. Voucher and discount schemes to encourage the purchase of the most efficient technologies are likely to have an impact beyond calculated AIC benefits as manufacturers not meeting such standards would be at an economic disadvantage.

7. Whilst most product groups seem to be heading towards water efficiency, water use for personal bathing is increasing. More research is needed to identify trends and potential savings. Because of the wide range of installed technologies we have effectively dismissed 'water saver' shower head retrofits in the context of this study but would push for consideration of labelling and regulations for mains pressure and pumped showers as has happened in the US and is being considered in Australia. Whilst not considered in this study, we believe that bath sizes are also increasing. Improvements in hot water systems mean that for many modern households, virtually unlimited hot water is available on demand.

8. Our estimated costs for the six scenarios examined give ranges in pence/m^3 that appear competitive with resource development. This suggests that they are at least worthy of further investigation in the form of pilot studies.

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