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Revised Options for UK Domestic Water Reduction

A Review

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This paper is an online publication which updates the original version from August 2005. This version is updated using respondent feedback and more recent research findings.

Though the whole paper has been revisited the following sections have undergone significant revision: The Impact of Conservation Options, Significant Reduction Measures, Very Low Flush Toilets, Rainwater Collection, Grey Water Recycling, Dishwashers, New Homes, and the Conclusion has also been updated.

ABSTRACT

Demand pressure on UK water supplies is expected to increase in the next 20 years driven by increasing population, new housing development and reducing household size. Regionally and at town level migration will also affect demand particularly in the South-East which is forecast to have a larger than average growth in population and house building.

The water demand moderating trends that are considered to have the greatest effect on UK consumption, in approximate order, are:

1. Metering
2. Low flush toilets
3. Normal showers
4. Efficient washing machines
5. Dishwashers
6. Cistern displacement devices (in existing homes with large cisterns)
7. Water efficient gardening measures can play an important role in reducing demand during critical drought periods.

ACKNOWLEDGEMENTS

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CONTENTS

List of Figures

List of Tables

INTRODUCTION

The aim of this document is to review and compare domestic water reduction options with a specific focus on the UK. The range of conservation devices considered in this report includes water efficiency, sufficiency, substitution, and reuse options. As well as examining the effectiveness of each water-saving option this report also considers the future uptake and effect on UK domestic consumption.

In the post-war period there has been a trend in the UK of increasing domestic water consumption both in per capita and absolute terms. The main drivers of water demand are increasing population, household numbers and reducing household size. Additionally lifestyle factors related to personal habit and affluence are also influential. Faced with finite water resources and the need to satisfy the requirements of the water-shed the water sector now perceives demand-side management as the favoured strategy for managing water needs (UKWIR/EA, 1997).

Though demand reduction is generally desirable across the whole of the UK it is the south-eastern regions which have the greatest need. The two reasons for this are limited water resources and increasing housing pressure. Water, resources are not evenly distributed across the UK and the South-Eastern regions receive some of the lowest rainfall in the country as well as possessing stretched abstraction resources (Westcott and ODPM, 2003). Drought restrictions seen in 2005 have also occurred in 2006 during which six southern water companies instigated hosepipe and sprinkler bans before the onset of summer, five of them on a company-wide basis (OFWAT, 2006). Compounding this are the facts that these regions are also highly populated and that housing demand is expected to increase at a rate above the national average over the next two decades (see table 1).

According to the *Government Actuary's Department* (2004) the UK population is forecast to increase by approximately 200,000 every year till about 2025. It is estimated that half of this increase (100,000 people per year) will be driven by natural change (the rate of births being greater than deaths) whilst the other half is accounted for by net migration (immigration being larger than emigration).

The UK government intends to satisfy housing need by stimulating building in the regions; the *Thames Gateway* and *M11 corridor* proposals are examples. Over the next two decades the East, South East and London Government Office Regions are expected to undergo a collective increase in population of over 2 million people (National-Statistics-Office, 2003). Though already amongst the most populous regions in England, their percentage population increase will be above the national average (see table 1).

Table 1. Population projections for the English Government Office Regions

Government Office Region	**2005 Population (000's)**	**2021 Population (000's)**	**Percentage change**	**Absolute change (000's)**
North East	2,531.9	2,505.4	**-1.0%**	**-26.5**
North West	6,820.1	7,030.8	**3.1%**	**210.7**
Yorkshire and The Humber	5,035.9	5,281.8	**4.9%**	**245.9**
East Midlands	4,297.6	4,662.2	**8.5%**	**364.6**
West Midlands	5,341.8	5,578.7	**4.4%**	**236.9**
East	5,535.2	6,139.0	**10.9%**	**603.8**
London	7,475.8	8,244.8	**10.3%**	**769.0**
South East	8,166.0	8,910.4	**9.1%**	**744.4**
South West	5,063.9	5,600.7	**10.6%**	**536.8**
England Total	**50,268.2**	**53,953.8**	**7.3%**	**3,685.6**

NB. These projections are 2003 based (National-Statistics-Office, 2003)

Over the next twenty years the total number of homes in the UK will have to increase not only because of population enlargement but also to support the trend towards smaller household size. Household projections into the 2020's indicate that the East, South East, London and South West will undergo the largest absolute and relative increases, see table 2. In these four regions approximately 2.5 million new homes are forecast, an increase in housing stock of over 20%.

Interestingly the percentage increase in new housing across England (18.2%) is far larger than the population increase (7.3%); however the total number of new houses is about equal to the increase in population (approximately 3.7 million). This equivalence reflects the fact that the majority of new housing will be for single occupants. The average household size in England will reduce by nearly 10% from approximately 2.42 to 2.20 persons between 2005 and 2021.

This increase in population and households will impact water consumption. The concentration of housing activity in the south and east of England and the lack of water resources mean that these regions have the most urgent need for water reduction measures.

Table 2. Household projection to 2021 for the English Government Office Regions

Government Office Region	2001 Household Estimate (000's)	2021 Household Projection (000's)	Percentage change	Absolute change (000's)
North East	1,073	1,132	**5.5%**	**59**
North West	2,822	3,131	**10.9%**	**309**
Yorkshire and The Humber	2,085	2,341	**12.3%**	**256**
East Midlands	1,735	2,052	**18.3%**	**317**
West Midlands	2,158	2,445	**13.3%**	**287**
South West	2,098	2,549	**21.5%**	**451**
East	2,259	2,750	**21.7%**	**491**
London	3,170	4,097	**29.2%**	**927**
South East	3,348	4,025	**20.2%**	**677**
England Total	**20,750**	**24,522**	**18.2%**	**3,772**

(ODPM, 2002)

THE IMPACT OF CONSERVATION OPTIONS

This analysis is intended to give an indication as to which conservation options will have the greatest effect in moderating domestic water demand across the UK. Though domestic consumption is likely to rise in the medium term, conservation options still play an important role in reducing the rate of increase.

The comparison considers the conservation impact of each option on old and new homes separately; this has been done because the household make up, water saving features and regulation differ significantly between the two. Projected numbers of new build and old housing stock are shown in table 3.

Table 3. Household projections for England in 2021 based on 2001 baseline

New Build Homes (built between 2001 - 2020)	**Existing housing stock 1-2 Occupancy**	**Existing housing stock 3+ Occupancy**
Will comprise around 18% of households in England[1] (>20% in the south eastern regions)	Reduced from about 64% to 52% of households in England[1]	Reduction from about 35% to 29% of households in England[1]

[1](ODPM, 2002)

In this review water conservation options are assessed from the point of view of UK implementation, particularly with respect to climate, national norms and practices. The uptake and success of water conservation have been assessed on a number of factors:

1. Absolute and relative water reduction
2. Cost and ease of implementation and operation
3. Acceptability (social, legal, health)

The concept of ‘Water Demand Reduction Potential’ relates to the ability of a conservation option to reduce consumption on a national basis; shown in the tabulated results in table 4. This has been estimated as the product of the likely national uptake of the device and its water saving performance compared to standard UK appliances and practices. Thus for a water device to significantly reduce national water demand it must save water and also be adopted by a significant proportion of UK households. Expected uptake has been estimated by applying a trend analysis based on current popularity and considering the factors that would affect prevalence in existing and new build homes (e.g. some options like water meters are mandatory in all new build homes).

This analysis involved extending current uptake trends and does not factor-in unforeseen or paradigm-shifting occurrences (e.g. consecutive years of drought, radical legislation). The reduction effect estimation is based on current behaviour norms and does not consider the effect of changing household numbers or changes in behaviour (e.g. more frequent showering).

Table 5 provides details of how device water saving estimations, used in table 4, were calculated.

Table 4. Expected demand reduction effects of water efficiency options based on their performance and likely uptake in new-build and existing housing stock

Option	**Current status and uptake factors**	**Likely uptake by 2025**		**Approximate Reduction in per person consumption in a home compared to 2001 standard appliance (Litres/person/day)**	**Water Demand Reduction Potential**
		New Build Homes	**Existing Homes**		
Metering	28% of households 2006/07 (regional variation)	All	Half /Most	15	Major
6 litre Flush Toilet	Regulatory standard since 1999	All	Half	10	Moderate
Normal Flow Showers	Typical in new homes though power-showers are also becoming more popular	Half-Most?	Some-Half	12-20	Moderate
Efficient clothes washing machines	>90% of households have a washing machine (~8 year life cycle)	Most	Most	5	Moderate
Dishwashers	Low penetration	Few-Some?	Some-Half	4-7	Moderate
Cistern displacement device (e.g. hippo)	Inexpensive and easy to install	Not Fitted	Some-Half	4	Moderate
Reduced flow basin taps	Very low current penetration	Few-Some	Few	6	Small
Water Butts (outdoor water use)	Penetration hard to assess	Some-Half	Some-Half	~2.4	Small
Water Efficient Gardens	A feature in future new homes?	Few-Some?	Few-Some?	~4.5	Small
Grey water Recycling	Relatively expensive and complicated to implement	Very Few-Few?	Negligible	~75	Very Small
Rainwater Collection (indoor water use)	Relatively expensive and complicated to implement	Very Few-Few?	Negligible	~75	Very Small

Assuming 2001 frequency of use for each appliance
NB. Few ~ 10%, Some ~ 25%, Half ~ 50%, Most ~ 75%

Table 5 explains how demand reduction values in Table 4 were calculated.

Estimated Per Capita Water Savings

Table 5. Estimations of per capita water savings for domestic water efficiency options

Option	Compared to	Estimated reduction in per person consumption in a home (Litres/person/day)
4/2 litre Dual Flush Toilet	Standard Toilet	20[a]
Household Metering	Non-metered average household demand	15[b]
6 litre Flush Toilet	Standard Toilet	10[c]
Normal Flow Shower	Standard Bath	20[d]
Normal Flow Shower	Power shower	12[d]
Full size Dishwashers	Hand dishwashing	7[e]
Reduced flow basin taps	Normal basin taps	6[f]
Efficient clothes washing machines	Standard efficiency washing machine	5[g]
Mini Dishwashers	Hand dishwashing	4[h]
Cistern displacement device	Standard Toilet	4[i]
Water Efficient Gardens	Typical garden water usage	~4.5[j] (averaged over year)
Water Butts	Typical garden water usage	~2.4[k] (averaged over year)
Grey Water Recycling	Average per capita consumption	~75[l]
Rainwater Collection	Average per capita consumption	~75[m] (averaged over year)

[a] Based on a 4/2 dual flush toilet (assuming 3 litre average) compared to an estimated average cistern size of 8.4 litres for South and Eastern England in 2001 and a flushing frequency of 4.2 times per day (Herrington 1996), *WRc* (2006) estimated average cistern size as 9.4 litres.
[b] From *National Water Metering Trial* (OFWAT 2000), figure based on a 10% reduction on average 2001 per capita unmeasured consumption, see Metering section
[c] Figure based on a 6 non-dual flush toilet compared to an estimated average cistern size of 8.4 litres for South and Eastern England in 2001 and a flushing frequency of 4.2 times per day (Herrington 1996).
[d] Comparison between a 5 minute 9.5kW standard shower using 4.6 litre/minute, a 5 minute power shower using 10 litre/minute, and a standard bath of 70 litres Environment Agency (2001j) figures. The reduction figure represents the average daily saving that would occur if a 5 minute normal shower were taken, instead of a power shower or bath, once every two days. A five minute standard shower uses approximately 25 litres of water, a power shower 50 litres.
[e] Dishwasher saving based on Stamminger et al. (2004) assuming 4 washes of 20 litres compared with 20 handwashes per week of 10 litres with an average household occupancy of 2.5
[f] Based on *BRE Ecohomes* figures, 12 uses per person per day, 1 litre flow for normal taps and 0.5 litre for reduced flow taps.
[g] Comparison between *BRE Ecohomes* volume figure of 40 litres for a high efficiency washing machine and 60 litres for a standard machine, Herrington (1996) frequency of use (4.3 per household per week) in 2001and average household occupancy of 2.5 people per home (OFWAT, 2007).
[h] Mini Dishwasher saving based on assumption of 4 washes of 10 litres compared with 7 handwashes per week of 10 litres for a single occupant home
[i] Assuming 1 litre displacement and an average toilet flushing frequency of 4.2 times per day in 2001 (Herrington 1996). Note *WRc* figures suggest a flushing frequency of 4.5 per person per day.
[j] Roughly estimated as half of the combined Herrington (1996) annual averaged microcomponent quantities for lawn sprinkling (4.3 litres/head/day) and 'other garden use' (4.8 litre/head/day) in 2001.
[k] Estimated as half the Herrington (1996) annual averaged value of 4.8 litre/head/day for 'other garden use' in 2001.
[l] Based on 50% reduction of 2001 per capita potable water demand, see Greywater Recycling section
[m] Based on 50% reduction of 2001 per capita potable water demand, see Rainwater Collection and Greenroof sections.

Significant Demand Reduction Measures

The tabulated results for each conservation option are shown in table 4. The following conservation methods appear to be the most promising means of reducing, or moderating, domestic water demand over the next 20 years.

- Metering; the trend towards metering will continue, perhaps given impetus by the increase in smaller occupancy households which stand to benefit financially and default meter installation in new build houses
- Normal flow showers and low flush toilets. These may be critical in the south-east of England where substantial development is expected.
- Efficient clothes washing machines; the replacement of existing appliances will increase the penetration of more efficient machines.

These options may also be significant, though their uptake and effect is less certain:

- Toilet displacement devices (commonly called a ‘hippo’) are inexpensive and easy to install. These devices are best suited for installation in larger cisterns which means they are only applicable in existing homes.
- Dishwashing machines deliver greatest water savings in higher occupancy homes. New homes, typified by smaller household occupancies, will probably realise smaller demand reductions by using mini models.
- Water efficient garden practices; though garden usage is a small component of annual domestic water demand this usage peaks during the warm summer months. Garden efficiency measures can play a role in reducing demand during critical drought periods.

A SIMPLISTIC ESTIMATION OF CONSUMPTION CHANGE

This calculation estimates the impact on UK domestic consumption solely from population and household building forecasts assuming that current consumption habits remain unchanged. This analysis gives an indicative figure for the possible change in total domestic water consumption between 2001 and 2021.

According to the *Government Actuary's Department* (2004) the UK population is forecast to increase by approximately 200,000 every year to about 2025. Housing stock will grow at a faster rate, increasing by about 20% by the mid 2020's (ODPM, 2002). This analysis considers the two major consumption groups; new build homes and existing homes (termed 'older' homes).

Older Homes

Older homes are defined as those that were in existence before 2001. As the great majority of new homes will be single occupant the average household size in older homes will be higher, and possibly constant.

There are opposing consumption pressures on older homes. Increasing water meter penetration and improving appliances act to reduce consumption in homes; however this is counter-balanced by the historical trend of increasing consumption. Also the total number of older (pre-2001) homes decreases with time as they are either knocked down or converted into new homes. This estimation assumes that the total consumption of older homes will remain near constant.

New Homes

New build homes can be expected on average to be more water efficient than older housing for a particular occupancy (see 'New Housing' section) because of new appliances and regulation.

As the great majority of new homes will be single occupant this estimation assumes that all new homes will be single occupant (generally the group with the highest per capita consumption).

Assuming that single occupant households currently use 180 litres/person/day (a)

UK average consumption is approximately 150 litres/person/day (b)

Increase in homes (the majority of which will be single occupancy) = 18% (c)

[see table 2]

Water efficiency factor of new homes (compared to existing stock) ~ 0.8 (or 80%) (d)

[see 'New Housing' section for more details]

Proportion change in total domestic consumption ~ (a/b)*c*d = +17%

Net Effect

This simple estimation suggests that total domestic water consumption will increase by approximately 17% between 2001 and 2021. This is driven mainly by the increase in new homes (which on average have fewer occupants and thus exhibit higher average per capita consumption). However this does not factor in changes in habit and lifestyle that affect consumption behaviour and also assumes that the total consumption of established homes will remain the same.

Across the UK average household occupancy will reduce and this is likely to have two effects:

- Average per capita consumption will increase
- Average household consumption will decrease

This estimation does not take into account radical and unforeseen developments (e.g. water price hikes, efficiency drives, severe drought events etc.) which may, or may not, lead to greater water efficiency.

POLICY AND REGULATORY EFFECTS

Statutory and advisory guidelines that influence domestic water use act at various levels, from watershed and water company regulation down to plumbing and appliance guidelines.

The Water Framework Directive was transposed from EC law in 2003 and is administered by the *Environment Agency* in England and Wales. A major theme of this legislation is river basin management, where consumption activities in a supply region are carried out in a manner that is sustainable and sensitive to the needs of 'downstream' stakeholders. Demand-side management is implicit to the concept of water-shed management and the legislation signifies that the UK government recognises that reducing per-capita consumption is an appropriate response to satisfying future water needs.

The 2003 Parliamentary Water Act regulates business practices across the UK water industry, which underwent privatisation in 1989. The Act is notable in that it compels water companies to:

1. Increase competition
2. Pursue sustainable water resources
3. Further water conservation
4. Pay more attention to consumer concerns

The role of water companies in the future of the industry is critical, for the Act makes them responsible for ensuring sustainable operations and by extension managing customer expectations and water behaviour.

In the UK *DEFRA* (Department for Environment, Food and Rural Affairs) issues water supply regulations which regulate domestic water use. The regulations encompass domestic water appliances and plumbing practices; for instance the 1999 regulations restrict all new toilet cisterns to a maximum volume of 6 litres. Another form that water regulations take is the plumbing and appliance guidance notes issued through the *WRAS* (Water Regulations Advisory Scheme).

EcoHomes is an environmental assessment method developed by the *BRE* (Building Research Establishment Ltd) (2005). This provides guidance to assess the overall sustainability of a house during development and occupation. Water efficiency is one of the environmental measures of the assessment. The assessment is intended to promote sustainable design and construction. However the scheme is voluntary and allows flexibility as to which criteria are included in an assessment. Though the *EcoHomes* standard does not compel developers to build water conservative homes it has been recognised as a leading initiative for sustainable housing practices by the DCLG. In the consultation paper '*Proposals for Introducing a Code for Sustainable Homes'* (DCLG, 2005) the holistic *EcoHomes* approach to sustainability is advocated as a compulsory housing standard. The consultation paper also suggests an average of 125 litres/head/day as a per capita consumption target for newly built homes, compared with an average 2005 England and Wales consumption of 151 litres/head/day (OFWAT, 2006).

A parallel initiative is that of the M*ayor of London* Office (2006) which has proposed an essential water standard for new homes to achieve 110 litres per person per day in its *Draft Supplementary Planning Guidance*. This would be achieved in all new housing through the installation of water efficient devices and harvesting rainwater for gardening purposes.

SOCIAL FACTORS

The phenomenon of varying water consumption takes place in an arena of changing socio-economic factors. The general increase of per capita water consumption in the post-war period has been driven by a number of social factors, notably:

- Increasing general standard of living and affluence
- Declining household occupancy
- Increasing population
- Generally ageing society

These factors affect water demand, but also their affects change with time. Society can be viewed as a set of generational groups, each having a specific average consumption at a particular point in time. The affect of a particular generation's consumption at a specific point in time is a function of:

1. population size at that time
2. habits and attitudes (to water use) practised at the time of interest

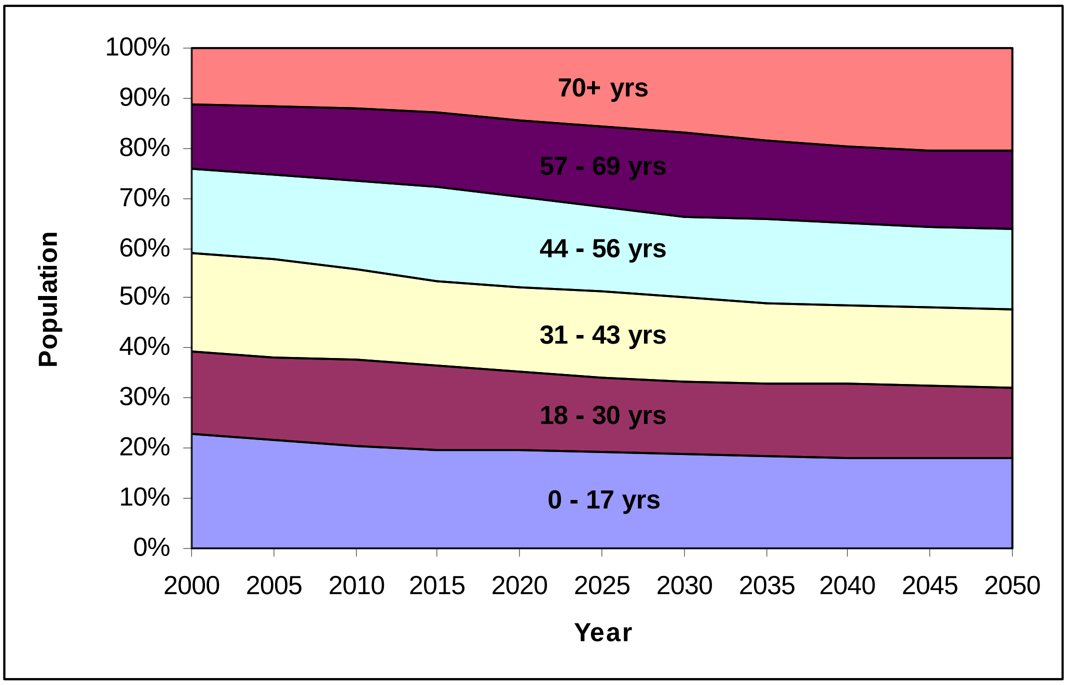

Figure 1. The projected age distribution of the UK population, 2000-2050 (Rees et al., 2005)

UK society is forecast to become an 'older' society driven by declining fertility and decreasing mortality. Results from modelling work carried out at Leeds University are shown in figure 1.

Generational habits and attitudes involve social trends and people's intrinsic needs, which can increase or decrease demand. Social trends are the most complex of the two elements involving the interacting effects of policy, economy, social values and technological factors on popular habits. Education and information initiatives are significant elements, depending on their popularity and efficacy. Social trends influence decisions such as buying cars and cultivating gardens, and these items affect domestic water use. Example social trend factors, some from research in Holland, are shown in table 6. The long term course of social trends and their effects are difficult to predict, but substantive data on these trends allow inferences to be drawn.

Table 6. Examples of Social Trend Factors (established and hypothetical)

Factor	*Effect*
Increased affluence and standard of living in the post-war period	Increase of water using appliances in the home (numbers and type)
Women entering the labour market (Wijst and Groot-Marcus, 1999)	Women spend less time at home
Nutritional changes (Wijst and Groot-Marcus, 1999)	Changing food preparation methods and faecal composition.
Later Childbirth & fewer children	Smaller households
Young people prefer showering to bathing (Achttienribbe, 1993)	Showers generally use less water than baths
Increase in multi-generational households	Sharing of water for some purposes
Perceptions about public water potability	Increase in bottled water sales

The effect of social trends can be seen in historical micro-component data. In an analysis of per-capita consumption for the South and East of the UK between 1976 and 1991 (Herrington, 1996) a number of observations were made:

- WC water usage reduced from 36.0 to 25.5 litres/person/day

- Personal washing (from 33.5 to 46.5 litres/person/day) and clothes washing (from 13.5 to 21.7 litres/person/day) represented the majority increase in total consumption

Between 1976 and 1991 per-capita consumption increased by 21% (from 121 to 147 litres per head per day). This significant change is driven by underlying social trends e.g. the increase in shower and washing machine ownership and their more frequent usage.

Intrinsic needs are significant for certain groups of water users (e.g. the elderly, disabled and households with children) in these cases water use is moderated or dictated by practical and physiological requirements. Examples of intrinsic need (from research in the Netherlands) are shown in table 7.

Table 7. Examples of Intrinsic Needs

Intrinsic needs	
Factor	*Example Effect*
Physiological & Age requirements	Older people use the toilet more often (Achttienribbe, 1993)
Gender preferences	Women bathe more often than men (Achttienribbe, 1993)
Domestic requirements	Households with children wash clothes more often (Wijst and Groot-Marcus, 1999)

From a historical and social perspective attitudes are significant factors that affect water consumption. With regard to social influences Sharp (2006) proposed three dimensions of response that governs individual water use behaviour, these are; passive or active disposition, motivation by either individual or common need, and whether water is perceived as a right or commodity.

New attitudes to water use will affect demand in the future, one possible social shift is towards the 'Soft Path' (Pinkham, 1999) shown in table 8. This outlines a change in paradigm regarding the role of water in a generally more sustainable society.

Table 8. Paradigms of water use

Old Paradigm	**New Paradigm**
Human waste is a nuisance	*Human waste is a resource*
Stormwater is a nuisance	*Stormwater is a resource*
Build to (satisfy) demand	*Manage Demand*
Use water once then discard	*Reuse & Reclamation*
Grey infrastructure	*Green infrastructure*
Centralisation	*Decentralised treatment*
Collaboration = Public Relations	*Collaboration = Engagement*

(Pinkham, 1999)

An aspect of consumption behaviour is the popular conception of what water represents; one view is that people in the UK generally consider water as a commodity rather than a social and environmental resource (Strang, 2004) in (Environment-Agency, 2004b). Moreover, public engagement in water reduction maybe harder to achieve now that municipal stewardship of the industry has been replaced by private ownership. However, dramatic and effective reductions in water consumption have been achieved in privatised water regions. Between 1991 and 2000 *Copenhagen Energy*, the water utility supplier to the Danish capital, affected a 20% reduction in per capita consumption from 164 to 131 litres per day (Napstjert, 2002).

DOMESTIC WATER REDUCTION OPTIONS

This section reviews each of the major reduction options which can be applied in the UK. The reduction options considered are listed below.

Metering

Since April 2000 most customers in the UK have been able to ‘opt’ for a free water meter (these household are often termed ‘optants’). Though optants have the right to revert back to an unmeasured tariff within a year the meter remains installed. Additionally all homes built since 1989 have water meters installed by default and new occupants of a house with an installed water meter are not normally able to pay for their water at an unmeasured rate (uSwitch, 2005).

During 2005-06 water meters were installed in approximately 28% of English and Welsh homes (OFWAT 2006b) which has been achieved from a low base in the middle 1990’s (see table 9). The *Environment Agency* has set water meter penetration targets of between 60-90% of households by 2030, however there has been concern as to whether water companies will be able to meet this (Environment-Agency, 2003).

Table 9. Water meter take up in English and Welsh homes

Year	% of households metered
1996/97	8
1997/98	11
1998/99	14
1999/00	17
2000/01	19
2001/02	21
2002/03	22

(Environment-Agency, 2003)

Characteristics of Metered Households

Households on metered tariffs are typically smaller water consumers, during 2005/06 the average metered per capita consumption in England and Wales was reported by OFWAT (2006a) as 136 litres per person per day compared to the unmetered figure of 151 litres. Metered homes also have a lower average occupancy in all English and Welsh water companies; in the period 2005/06 the average occupancy of metered homes was 2.1 people compared with 2.5 people for unmetered (OFWAT 2006a).

Research reviewed by *UKWIR* (NERA, 2003) examined the propensity for consumers to switch to metering and concluded that such households were typically:

- Motivated by financial gain from metering (i.e. lower bills)
- Single or two person households; these being more likely to switch than larger households
- Faced by an increase in their unmeasured bill, even if the expected gain from metering was the same
- Detached households were found to be more likely to switch, even after compensating for the effect of higher unmeasured bills

There is evidence that meter uptake has a relationship with water conservation awareness, for example *Southern Water* in the UK reported that metered customers were significantly more likely to possess water butts and displacement devices (Environment-Agency, 2004c). Metering may also encourage better water use through a number of motivational mechanisms (Van Vugt, 1999):

- Altering the reward structure, such that it becomes advantageous to reduce water consumption
- Increased personal efficacy through the ability to monitor consumption
- Paying for the amount of water used reinforces personal responsibility
- Metering promotes trust that others will also act responsibly i.e. what others pay reflects their water responsibility
- If metering is considered a generally fair scheme it may encourage other water conservation initiatives

The Effect of Metering

Probably the best indication of the effect of universal metering in the UK is that of the *National Water Metering Trials*. The trials, which operated between April 1989 and March 1993, involved the metering of 48,000 properties on the Isle of Wight and comparing their consumption with that of the largely unmetered population of neighbouring Hampshire. The analysed results were published by *Southern Water Services* in “Water Consumption on the Isle of Wight 1988-1997” and reported by OFWAT (2000). The results suggest that universal metering could realise a 10% reduction in annual average consumption. The study also identified that metering had reduced peak demand during warm periods by about 30% and the use of external meters also contributed to a reduction in distribution leakage.

Metering has an important role in developing price-elasticity in the domestic water market. Similar demand reductions to the *National Water Metering Trials* were obtained from an analysis of consumption monitoring of several thousand households in the UK between 1996 and 2001 (NERA, 2003) which calculated that the effect of metering resulted in an average 9% reduction in consumption. This figure varied between 2 and 14% depending on the volumetric charge; yielding a price elasticity estimate of -0.14.

A survey of 1,000 Dutch families in the 1990's found domestic price elasticity difficult to correlate though its effect was not doubted (Achttienribbe, 1998). Establishing and measuring elasticity in the short term is difficult because of the low bulk cost of water compared to the 'up-front' cost of water efficient investments (e.g. a new washing machine). In the longer term there is an expectation that elasticity will take effect as appliance replacement leads to generally more efficient devices to be preferentially purchased.

Once a meter is installed there is some evidence that water saving measures become self-reinforcing with an observed 0.2% reduction in consumption occurring each month in a UK household survey: however the longevity of this effect was not established (NERA, 2003). Analysed data from eight consumption monitors identified a downward trend in consumption over at least 36 months following meter switching (Environment-Agency, 2004a). The analysis found no evidence for a "bounce back" increase in consumption. Regarding the pre-disposition of optants the research identified a reduction in consumption between 8 and 11 percent during the two year period preceding switching.

As metering becomes more prevalent it is possible that it will be accompanied by a general increase in economically-grounded water consciousness. The reductions reported by *UKWIR* would probably take place in a scenario of compulsory metering (NERA, 2003). There is danger in expecting water savings practised by low users who have pre-opted for metering to be demonstrated across the whole population under compulsory metering. However, involuntary and late optant meter customers should not be expected to become ‘worse’ water consumers than if they had remained unmetered. On balance the evidence suggests that as a group they will exhibit decreased water consumption motivated by financial gain, though this effect is likely to be widely divergent in uptake and practice.

South West Water have reported that households recently switching to metering between 2003 and 2004 had demonstrated an average 15.2% reduction in consumption (Lawrence, 2004). From OFWAT (2004) figures it is calculated that during this period approximately 41% of *South West Water’s* billed households were paying on a metered tariff. This demonstrates that late switching households can still effect significant reductions. Though their consumption is still generally greater than the overall average for metered households; suggesting that the later a household opts for metering the smaller the water reduction it will demonstrate after it has done so.

Toilet Flush Volume Reduction

Toilet flushing constitutes typically one-third of the water use in a UK home. In the past UK toilet cisterns have generally used 9 or 7.5 litres per flush, the 1999 Water Regulation by-laws have limited all newly installed cisterns to 6 litres (WRAS, 1999a) and 6 litre cistern toilets are now common in new housing. There are also toilets on the UK market which flush at below 6 litres. In addition ‘dual flush’ toilets allow users to select a reduced flush as well as full volume flush depending on the material to be washed away, and these measures can translate to a greater than 20% reduction in daily water use (Environment-Agency, 2001i).

Cistern displacement devices (e.g. "hippos" and household bricks) reduce the flush volume. This simple measure has been estimated to reduce toilet water consumption by 10-15%. However the efficiency of the flush is also reduced and it should be verified that any consequent double flushing (caused by an inability of the reduced flush volume to clear the pan) doesn't lead to increased overall water consumption. Also, installation should be checked to ensure there is no leakage from the cistern.

Water can also be conserved with a delayed action inlet valve in the cistern. Unmodified cisterns waste water unnecessarily as they begin to refill during the flush operation, thus more than the original volume of water is used. The delayed inlet valve prevents this by starting the refill only after the flush operation has ceased. Estimated savings per flush with a seven litre cistern are 1.4 litres at 3-bar pressure to 3.5 litres at 10-bar compared with unmodified cisterns (Environment-Agency, 2001i).

Very Low Flush Toilets

Though all new toilet cisterns must not exceed 6 litres, it is possible for toilets to operate below this and smaller volume cisterns are available on the UK market. The *Propelair* toilet technology has demonstrated flushing at much lower volumes by employing pneumatic air pressure to assist the flush process. In prototype form it has undergone trials at the *WRc* headquarters in Swindon and demonstrated effective operation using 1.5 litres per flush (Butler, 2006). This volume is a quarter of the current maximum cistern limit and approximately one sixth of the estimated average UK flush volume (~9 litres) (WRc, 2006). In terms of use the only major difference between this toilet and normal toilets is that the lid must be closed before flushing can take place.

Waterless Toilet Technologies

Waterless and vacuum toilets could reduce average domestic water consumption by a third (saving approximately 50 litres per person per day) by removing the need to use water in a toilet. In terms of installation these are not economically competitive with conventional toilets; an exception is in peri-urban and rural locations where composting toilets are advantageous because of the lack of sewage infrastructure. Also, vacuum toilets are of a technical complexity that makes them impractical and expensive for domestic housing.

Though usually associated with offices and public buildings urinals do have the potential to reduce domestic water consumption. Traditional urinals with water flushing must be installed correctly otherwise they may actually use more water than a sit-down toilet (Environment-Agency, 2001g). Waterless urinals also exist with various methods of water conservative blockage and odour reduction.

Reduced Pressure Showers

Approximately 20% of UK domestic water is used for bathing and showering (Environment-Agency, 2001j). Water usage in showers is very dependent on user habit and preference. A ‘typical’ shower session is estimated to use a third of the water and energy as a bath however a ‘power-shower’ can use more water in 5 minutes than a typical bath. Thus water efficient showering can be achieved through measures that reduce the showering time and water through put.

Thermostatic mixing valves enable preferred water temperatures to be selected more swiftly than with separate hot and cold taps. The advantages are two fold; less water is lost at the start when the temperature is being selected and a user is more likely to stop the shower when applying shampoo.

‘Water saver’ showers simulate the effect of a power-shower but without the high flow rate. This is achieved by creating fine water droplets or by aerating the water flow, these showers can operate at flow rates of between four and 9 litres per minute, approximately half the consumption of a power-shower (Environment-Agency, 2001j).

The performance of various flow rate showers is compared in table 10. Though all of the non-power ratings use less water over 5 minutes than a standard bath it should be noted that showering more often (particularly in a ‘power shower’) may increase overall consumption.

Table 10. Shower flow rates

Description	**Ultra-low water use**	**7.2kW electric**	**9.5kW electric**	**"Water saver"**	**"Power shower"**
Flow rate	1.5 l/min	3.5 l/min	4.6 l/min	4-10 l/min	12 + l/min
Application	Limited non-household application	UK domestic	UK domestic	Mains pressure water or pumped	Mains pressure water or pumped
Comment	Atomising	Usually perceived as poor performance	Better comfort than 7.2kW	Power shower feel, cold feet possible	
Water use for 5 minute shower	7.5 litres	17.5 litres	23 litres	20-50 litres	75 litres
% of 70-litre bath	11%	25%	32%	28-71%	107%

(Environment-Agency, 2001j)

Baths

Bath volumes depend on their shape and size; modern baths typically require at least 60 litres of water. Very large baths can require over 300 litres and the Water Supply act of 1999 requires that an intention to install a bath of greater than 230 litres must be notified to the water supply company (note: average daily water usage is approximately 150 litres per person). Water usage can also be generally reduced through good bath insulation as hot water "top ups" are not required as often.

Rainwater Collection

Collected rainwater can be employed for outdoor purposes such as gardening and car washing, it can also be used inside the home for toilet flushing and clothes washing (advantageously the softness of rainwater reduces detergent requirements). It is estimated that in Germany 50,000 domestic rainwater systems are installed annually by commercial providers (Environment-Agency, 2006)

However the benefits of rainwater collection are limited by the following:

1. Rainwater collection and some of its benefits are seasonally unmatched e.g. the summer months of greatest need are the times when rainfall will be at their lowest levels.
2. Water collection is determined by climate, roof size and storage capacity.
3. The microbial hazards present in rainwater limit its use within the home.

The simplest form of collection involves channelling rainwater from the roof via guttering to water butts for storage. The collected rainwater is only fit and available for outdoor or use, however this arrangement has the following benefits:

1. The potential to reduce water consumption of a UK household by about 6 percent (Environment-Agency, 2001b)
2. Reduces the load on the storm water drainage system, with the potential to increase ground water penetration and reduce storm flooding

Further reductions in consumption can be achieved by using rainwater for non-potable indoor tasks; however this requires an automated water management system and a separate non-potable water supply system in the house (see Green Roofs section).

A recent example of rainwater harvesting in the UK is the *Millennium Green* housing project; the overall winner of the *Environment Agency* Water Efficiency Award in 2003 (Environment-Agency, 2003a). This development of 24 homes is supplied with non-potable rain water (for washing machines, toilet flushing and gardening use) from underground storage tanks. These storage tanks receive collected rainwater and have an 18 day supply capacity; if the tank volume becomes low they are automatically filled by potable mains water. The development also incorporates water efficient devices such as shower units, dual flush toilets and aerated taps. This development has reportedly shown a 50% reduction in mains water consumption.

The non-potability of rainwater is underlined by analysis which has demonstrated that coliform concentrations do not decrease significantly during storage and may actually increase. Poorly designed water tanks have been observed to develop coliform concentrations greater than 24,000 CFU per 100ml (Diaper et al., 2001).

The *UK Rainwater Harvesting Association* and *Environment Agency* (2006) claim that using rainwater for all non-potable domestic applications could reduce household water consumption by around 50% (which corresponds with the performance of *Millennium Green*), with payback periods of "between 10-15 years" (UKRHA, 2004).

Green Roofs

Green roofs are an alternative form of rainwater collection. They involve the cultivation of roof based reed-beds which filter rainwater, which can then be reused. Green roofs offer a number of benefits which include; home insulation, storm water management, sound reduction, air quality and microclimate effects (Peck et al., 1999). This technology can be taken a step further by coupling it to a grey water treatment system within the home to also recycle indoor waste water. This involves pre-treating grey water before filtering it through the roof reed-bed, the resulting water (made up of treated grey water and rainwater) has a low turbidity and pathogen count and is suitable for non-potable indoor water use (Shirley-Smith, 2001). It is suggested that this water be tinged with a green dye to help ensure that it is not confused with potable water.

Compared to other water reduction measures green roofs are elaborate and relatively expensive, and are uncommon in the UK at present. For a grey water recycling green roof the cost saving from reduced water supply was estimated as £70 for a six person household in 2001, approximately one-third of the annual water bill (Shirley-Smith, 2001).

Grey Water Recycling

Reusing water from sinks, baths and showers could reduce domestic water usage by a third (Environment-Agency, 2001c) and research suggests that less than 5% of total domestic consumption need be of potable quality.

Recycled waste water (grey water) would mainly be used for toilet flushing, though it can also be used in washing machines (initial cycles only) and outdoor purposes (e.g. car washing and non-edible plant watering). There is also the additional benefit of reduced sewage volumes caused by the reduced through-put of water. Liu et al. (2007) reports that a typical home produces enough grey water for the purpose of toilet flushing.

Grey water requires treatment to be fit for non-potable re-use inside the home, especially if stored for any length of time before use. The health risk is mainly associated with faecal material carried away after human washing, this risk increases with household occupancy as the probability of an infected individual rises. Grey water has been observed to contain up to 10^5 faecal coliforms per 100 ml with the potential to increase in number over a 48 hour period (Dixon et al., 1999).

The size of grey water storage tank thus represents a trade-off between health risk and efficiency i.e. enlarging storage volume increases grey water re-use capacity but also lengthens the average storage period. Recent research suggests that smaller sized storage capacities, with a grey water re-use potential of 60% or less may represent the best re-use performance against water quality arrangement (Liu et al, 2007). An earlier study on grey water storage considered a tank of 1 cubic metre (1,000 litre) capacity to be adequate for a wide range of household occupancies (Diaper et al., 2001). A mismatch between grey water storage capacity and consumption will lead to sub-optimal water saving, and the consumption habits of a household will affect this.

Table 11. Conceptual analysis of risk from grey water re-use

	Lower Risk	**Intermediate Risk**	**Higher Risk**
Population	Small population (single family)		Large population (multi-occupancy)
Exposure	No body contact (sub-surface irrigation)	Some contact (WC flushing, bathing)	Ingestion (drinking)
Dose-Response	<1 Virus per sample <1 Bacteria per sample		>1 Virus per sample $>10^6$ Bacteria per sample
Delay before re-use	Immediate re-use	Re-used within hours	Re-used within days

(Dixon et al., 1999)

Consideration of the risk analysis in table 11 led the researchers to advocate grey water re-use for toilet flushing within single family households without minimum coliform regulation (Dixon et al., 1999). Compared to communal re-use single family application is more socially acceptable and has a lower health risk however it is also more costly to implement.

Commercial experimentation with grey water recycling has occurred in the Netherlands. The company *Hydron Midden Nederland* intended to develop an urban area of 30,000 homes supplied with communal grey water (Environment-Agency, 2003) supplied from a treatment plant employing coagulation and filtration. The project built initial housing with separate drinking and grey water supply. To begin with both of these supply systems were fed with potable water, during which connection errors were discovered. During the second phase treated non-potable grey water was supplied, but it was then discovered “that a few connections were mixed up” (sic) and that some people had been ingesting grey water over a number of weeks. Additionally in 2000 a virus (*Norovirus*) was detected in the grey water supply.

The project came to the conclusion that these errors and mishaps were inevitable and that the cost of ensuring acceptable biological safety would make grey water supply unfeasible. The project came to an end and the Dutch government has since banned piped grey water distribution.

The complicated plumbing and the variability of water use make grey water cascading unrealistic compared to cheaper and easier to operate reduction alternatives. Terpstra suggests that this scheme is probably most feasible in an apartment block or district scale, achieving economies of scale for treatment and storage.

Washing Machines

In the UK washing machines use approximately 14% of domestic water (Environment-Agency, 2001a). These appliances have achieved a high penetration with a machine present in 93% of UK households in 2002 (National-Statistics-Office, 2002). The historical performance of a brand of washing machine is shown in figure 2, the values suggest that almost a two-third reduction in water requirement has been achieved over the last 3 decades with modern machines using less than 50 litres per wash (note: average per capita consumption is 150 litres/person/day). Water regulation during the 1970’s has been identified as a driver for appliance reduction innovation (Grant, 2002). Currently in England and Wales the 1999 Water Supply

Regulations limits all new horizontal axis washing machines to 27 litres per kilogram of wash load (WRAS, 2001).

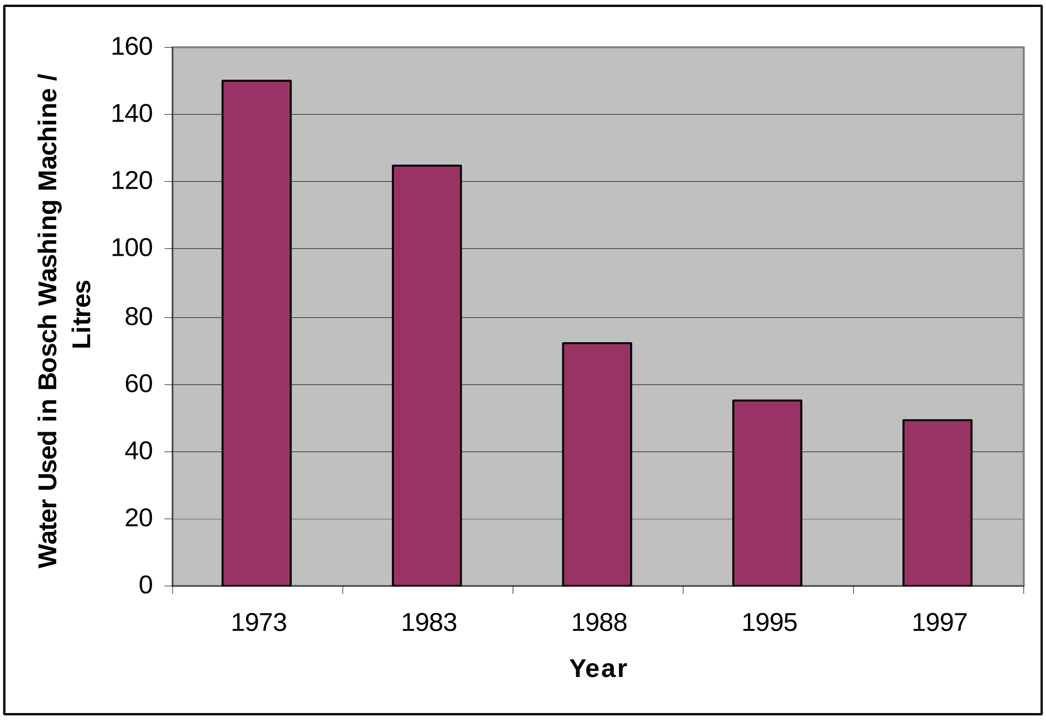

Figure 2. Water used by *Bosch* washing machines for 5kg hot wash (Grant, 2002)

The uptake of more efficient washing machines is dependent on the "appliance" lifetime (estimated at 8 years for washing machines) which is the average number of years of appliance use before replacement. Currently the cost saving made by switching prematurely to a water efficient washing machine does not cover the purchase cost.

It should be noted that additional water savings being achieved by new models of machine are tailing off. Efficiency is also dependent on good habit, for example running a washing machine at full loads. Good water habits maybe most effectively encouraged through educational and economic means (e.g. water metered price-elasticity).

Dishwashers

Properly used, dishwashing machines are more water efficient and can wash more effectively than hand washing. Research carried out by Stamminger et al. (2004) at *Bonn University* reported by the *Market Transformation Programme (2006)* suggest that dishwashers consume less water than hand washing when washing more than 4 place settings (of 12 items). The study estimated that dishwasher's used 20 litres of water for each wash and that hand washing typically used over three times as much water to clean a full dishwasher load. Additionally, a very wide range of water usage was observed in the study group during hand dishwashing, in some cases using more than ten times the amount of water used by the dishwashing machine.

The MTProg (Market Transformation Programme, 2006) comparison of hand and machine dishwashing backs the findings of Stamminger and recommends the increased uptake of dishwashers to decrease water consumption. In its comparison study MTProg suggests that in the UK typically around 63 litres of water is used to wash 140 items by hand, dishwashers require at most 20 litres (representing a water saving of nearly 70%). Moreover water saving increases even further (to around 85-90%) when compared to washing under a running tap (~150 litres).

As dishwashing machines usually use a fixed volume of water regardless of the amount of washing, unlike hand washing, they are at their most efficient when loaded full. However the Market Transformation Programme identified the following barriers to take up: appliance cost, perceived consumer doubts about water and energy efficiency, and available space in the home.

The potential for dishwashers to reduce total domestic demand is constrained by their low penetration, 28% of all UK households in 2002 (National-Statistics-Office, 2002) and estimated more recently by MTPRog (2006b) at "around 27% of households" compared with approximately 50% in Germany and the Netherlands. The slow rate of dishwasher take up suggests that they are unlikely to be a significant demand factor in the medium term.

It is hard to determine how popular dishwashing machines will be amongst new home occupants the majority of whom will be single or two occupants (and likely have a lower daily washing quota) and may also lack the space to fit the appliance. Smaller dishwashing machines are available (down to a capacity of 4 place settings) though they tend to be less water efficient than full size machines they still remain more efficient than typical hand washing.

Regulating Domestic Water Flow

There are some advantages to regulating water flow (i.e. limiting the maximum flow rate in water supply pipes). The benefits depend on the usage and the water-responsibility of the user, for example flow regulation to showers will probably reduce consumption, whilst for baths this will not be the case. Generally flow regulation is most beneficial in areas of high water pressure or in habitations with poor water use habits; though the Environment Agency has considered figures of 25-30% reduction in tap water maybe overly optimistic (2001f).

Leak detectors reduce water loss during a leak and ordinarily will not reduce household consumption. The detectors work by monitoring water flow in pipes; when a flow begins a timer is started, if the flow continues past a set time the flow is cut off.

Heating Systems

Water and energy efficiencies are often symbiotic because heating and plumbing systems are interconnected. Fairly simple heating efficiency techniques can also reduce water wastage, this includes;

- minimising the length of hot water pipes between the points of heating and use will reduce the amount of water drawn off whilst waiting for warm water (the 'dead-leg')
- hot water pipes should be placed above cold ones to reduce heat transference
- insulating long pipes prevents heat loss

Mains pressure heating tends to use more water than gravity fed systems because of their higher flow rate. In areas of high mains pressure architectural advice recommends the fitting of pressure reducing valves to reduce flow (WRAS, 1999a). Appropriate mains pressure systems can deliver efficiency savings, see table 12.

Table 12. Mains pressure heating efficiency measures

Measure	**Water saving**	**Other advantages**
Small-bore pipes	Reduced dead-leg	Taps run hot (or cold) more quickly
Tap aerators	Illusion of more flow	Eliminates splashing
Low water-use shower	Less than a bath	Feels like a power-shower due to water pressure
Flow regulation	Reduces waste when taps left running	Flow to each outlet is balanced, shower temperature stabilised

(Environment-Agency, 2001k)

These improvements will be most prevalent in some new build homes as it is economically more advantageous to fit these during the building of a home rather than to retro-fit into an existing home. It is possible that some of these efficiencies may become mandatory in the future, which would affect subsequent home building.

Water Conservative Gardening

In the UK the proportion of water used for garden watering is relatively small, the Market Transformation Programme (2007) estimates that 4% of annual total UK domestic demand is used for outdoor purposes. In the UK wide regional variations exist in garden water use in part caused by regional differences in rainfall.

In the UK during non-drought years garden use is not a priority to address. However garden reduction measures have a significant contribution to make during dry periods, when garden watering usually becomes more prevalent. In the UK the proportion of water used for garden purposes has been known to approach 50% of domestic uptake during the driest months (Environment-Agency, 2001b) - at a time when it should be used be to satisfy more necessary needs and to prevent drought.

Water efficient gardening seeks to create or enlarge low water use zones in a garden (see table 13), 'xeriscaping' is the ultimate practise of this where drought resistant plants are selected on the basis of their compatibility to the local climate and environment.

Table 13. Water efficient garden measures

Measure	**Comment**
Plant selection	Choose plants that can survive short periods of heat and drought
Soil improvement	Tilling and adjusting the pH of the soil to encourage deep roots and optimum growing conditions
Lawn maintenance	Mowing tall and frequently, proper nitrogen fertilisation
Mulching	Conserves soil moisture
Irrigation	Use soaker or drip irrigation; most effectively done early in the morning or in the evening
Shade and hard surface reduction	These reduce 'hot spots' leading to increased water evaporation
Maintenance	Ensuring plant health, judicious pruning and refraining from fertilizing during drought periods

(Schrock, 1999)

NEW HOMES

Newly built homes are more sustainable to construct and inhabit than previous generations of housing stock. This has been driven by modern regulation, housing innovation and market factors; for example all new houses in the UK are now metered by default.

All new build homes are subject to current water regulation (e.g. 6 litre toilet cisterns) and their expected water efficiency can be estimated, shown in table 14. Moreover, by applying optimum water saving options (i.e. toilet, shower, bath, washing machine and dish washer) the likely performance of a water efficient new build house can be estimated, this is also shown in table 14. The water efficient figure suggests that a further 25% reduction in water consumption can be achieved without significantly affecting water use habits.

Table 14. Household water use: standard versus water efficient

Water use component[1]	**Standard New Build**		**Water Efficient New Build**		**Standard vs Water Efficient**
	Volume per use (litres)	Per capita consumption (l/h/d)[2, 3]	Volume per use (litres)	Per capita consumption (l/h/d)[2, 3]	Water use reduction %
Toilet	6	28	4[5]	17	39
Shower	45	25	30	17	32
Bath	85	30	80	28	7
Taps (Internal)	-	12	-	10?	17?
Washing machine	60	13	40	9	31
Dish washer	20	8	15	6	25
Garden	-	6	-	5?[5]	17
Sub-total [4] (l/person/day)	-	122	-	92	Overall 25% reduction

[1]Component ownership levels are assumed constant for all types of new build
[2]Assumed average household occupancy of 2.5
[3]Frequency of use assumptions developed from "A scenario approach to water demand forecasting" (Environment Agency, 2001)
[4]Excludes other non-specific uses that collectively may approximate to an additional 20 l/h/d
[5]Rainwater collection or grey water recycling could halve toilet and garden water consumption, resulting in 81 litre/person/day

(Environment-Agency, 2003)

Innovative housing development centred on sustainable design can deliver impressive efficiencies. *BedZED* (Beddington Zero Energy Development) in South London is a housing development which employs numerous efficiency measures including 4/2 litres dual flush toilets, recycled rainwater for toilet flushing, and leading efficiency washing machines amongst others. Figures published by *BioRegional* (Lazarus, 2003) suggest that total per average per capita water demand is in the region of 91 litres per person per day. This performance is even more impressive when the component of collected rainwater water, estimated at 15 litres per person per day, is subtracted which yields an average per capita potable demand of 76 litres per day. Moreover this 50% reduction on average UK potable consumption may have been achieved with no requirement on the part of *BedZED* occupants to alter their water use behaviour.

The forecast increase in new build homes is a major factor in increased water consumption. Crucially the majority of these will be single occupant and these households typically have the highest per-capita consumption. However new home water consumption maybe mollified by future water regulation and building standards (DCLG, 2006) which may set water consumption design targets.

WATER REDUCTION IN OTHER COUNTRIES

It is instructive to look at water reduction measures in other countries; however socio-economic and environmental differences often mean that reduction priorities are not universally transferable from one country to another. Western Australia is an example where a recent survey identified that 47% of domestic water was used in the garden and that showering (16%) and washing machine (13%) consumption were both greater than toilet flushing (10%) (South Australia Water, 2003); these figures are a complete contrast to those of the UK (see table 15).

The figures in table 15 suggest strong water consumption similarities in western countries, in particular:

- Toilet flushing consumes approximately a third of domestic water
- Showering and bathing consumes approximately a third of UK, Danish and Dutch domestic water supply, in North America it is a quarter

Table 15. Domestic water usage comparison between countries in recent years

<table>
<tr><th>Water use</th><th>UK[1]
%</th><th>Denmark[2]
%</th><th>Netherlands[3]
%</th><th>US/Canada[4]
%</th></tr>
<tr><td>Toilets</td><td>35</td><td>27</td><td>29.1</td><td>33.3</td></tr>
<tr><td>Showers</td><td><15.3[5]</td><td rowspan="2">36</td><td>28.6</td><td>15.6</td></tr>
<tr><td>Baths</td><td>20</td><td>6.7</td><td>6.7</td></tr>
<tr><td>Washing Machines</td><td>14</td><td>13</td><td>19.0</td><td>25.6</td></tr>
<tr><td>Tap</td><td rowspan="2">15.7[6]</td><td rowspan="2">17</td><td>9.9</td><td>15.6</td></tr>
<tr><td>Dishwashers</td><td>0.7</td><td>2.2</td></tr>
<tr><td>Other</td><td></td><td>7</td><td>6.0</td><td>1.1</td></tr>
<tr><td>Total</td><td>100</td><td>100</td><td>100</td><td>100</td></tr>
</table>

Note: Domestic leakage values have not been obtained for the UK and Netherlands. US figures suggest 10% leakage (GVRD, 2004)

1. (Environment-Agency 2001a – j)
2. *(Napstjert, 2002)*
3. 1995 Sample of 2,000 families (Achttienribbe, 1998)
4. Figures originally from *American Water Works Assoc*. (GVRD, 2004)
5. ‘Bathing’ figure estimated as 20%, it is assumed that this does not include shower consumption. Thus shower consumption maximum is the upper value of the water balance difference.
6. Dishwashing is 7.7%, for both tap and dishwasher (Environment-Agency, 2001a); this is added to the ‘Tap’ total because this is the likely majority

Table 15 shows similarities in percentage water use for toilet and personal washing, generally the Northern European countries are more similar to the UK. North America with a larger per capita consumption still shows some similarities. Indigenous habits and practices are the likely explanation for national differences in water consumption (e.g. the high US figure for washing machines maybe attributed to the prevalence of 'top-loading' washing machines which consume more water than front-loading models).

Copenhagen Energy, the water supplier to the Danish Capital, recorded swift and sustained consumption reduction (from 108 to 93 litres per capita per day) over a 4 year period in a controlled test of approximately 500 residents (Napstjert, 2002). To what extent the Hawthorne effect (the tendency of participants to behave in a manner they consider 'desirable' to the survey) played in the Copenhagen survey is not clear however the company has overseen an overall 20% reduction in per-capita consumption between 1991 and 2000.

In California (USA) it is estimated that per capita domestic consumption can be reduced by 40% solely through updating inefficient appliances and reducing leaks (Pacific-Institute, 2003), the quantified results are shown in Table 16. Nearly half of this reduction (approximately 0.5 cubic km) can be achieved through upgrading toilet cisterns. Reduced flow showers and modern washing machines promise the next greatest absolute reduction in water consumption.

Table 16. Quantified reduction options based on California in 2000

Measure	Estimate of conservation (million cubic meters)	Estimate of Reduction in current use (%)
Toilets	518	57
Showers	148	24
Washing machines	136	33
Dishwashers	16	46
Leaks	284	80
Total	1,102	40

(Pacific-Institute, 2003)

In the USA generally, the *Environmental Protection Agency* recommends the following reduction measures in relation to 'equipment' (EPA, 2004):

1. Repair all leaks
2. Install ultra low flow toilets or use a cistern displacement device
3. Install low-flow aerators and showerheads
4. Purchase a high efficiency washing machine

The above are in order in which they are listed, whether this reflects priority or public acceptability is not clear.

China, which has a rapidly increasing economy and levels of affluence, faces the prospect of major consumption increases. The *Chinese Standardisation Administration* has enacted a compulsory standard for cistern volumes limiting them to 6 litres instead of the normal 9 or 12 (Environment-Agency, 2004c). Beijing authorities are expected to introduce progressive water tariffs in 2005 with the likely effect of raising prices by nearly 30% (Environment-Agency, 2004b).

In Australia a water efficiency labelling scheme is mandatory for new water using appliances, this applies to showers, tap equipment, toilets, washing machines and dishwashers (WELS, 2006). This allows water efficiency to be easily compared between products when customers choose products and works in a similar manner to energy efficiency labelling which is applied to retail appliances in the UK.

CONCLUSION

The future pressures on UK water consumption are clear; new house building, reducing household sizes, and rising population will act to increase total consumption. In the face of this there are water reduction strategies and trends which have a role in moderating demand in the medium term. Under some scenarios total domestic water demand can be reduced however if current water use habits continue demand will increase, and become less sustainable.

As household occupancies reduce the option of metering will become economically advantageous to an increasing number of households, and on balance it is expected that metering will lead to reduced household consumption. Metering is already the default option in some regions and in new homes. By the end of the 2020's the majority of UK homes will be metered.

In new housing developments (e.g. Thames Gateway) modern housing efficiencies will reduce the increase in per-capita consumption caused by decreasing household size. The major demand moderating factors are default metering, toilets (regulated to a maximum of 6 litres), normal flow showers and modern efficient white goods. In addition improved plumbing and heating will also contribute.

In existing housing stock the following are expected to be the have the greatest combined effect in reducing national demand, in diminishing order:

- Metering (economic advantage)
- Non-power showers (high prevalence and convenience)
- Cistern displacement 'hippo' (low cost and simple installation)
- Modern efficient washing machines (through natural replacement)

In existing homes the replacement of toilets with modern efficient models would reduce their demand significantly though the rate of replacement is slow and hard to assess.

Across all homes the use of reduced flow basin taps could be a significant demand reducing factor though their uptake has been very low over recent years. Water efficient gardening can play an important role particularly in reducing demand during drought periods.

However with these measures uptake is difficult to assess because of the “barriers” of initial cost, lack of immediate return and novelty.

The prevalence and improving efficiency of washing machines means that they will be a significant factor in reducing consumption as newer efficient machines replace old ones. Though dishwashers can save water in comparison to hand-washing their low uptake means that they probably will not significantly reduce UK water consumption.

Water butts can be expected to become more prevalent, however the small proportion of UK water used for outdoor purposes means that their contribution to reduced overall consumption may be slight though allied with water efficient gardening practices they may be important demand reducing factors during dry periods.

Though domestic water recycling schemes and rainwater collection for internal household use promise considerable savings in household potable water use they are not expected to have a major impact in reducing national water consumption in the medium term because of limited uptake. Their cost and technical implementation being substantial, this also includes green roofs. For similar reasons vacuum and composting toilets will not achieve significant uptakes to affect national demand.

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