WORKING PAPER 05/03

THE OPTIONS FOR UK DOMESTIC WATER REDUCTION: A REVIEW VERSION 1.0

Patrick Sim, Adrian McDonald, John Parsons & Philip Rees

PUBLISHED AUGUST 2005

For further copies contact the Working Paper Secretary,
School of Geography, University of Leeds, LS2 9JT
Telephone 0113 343 3300

Working Paper 05/03

The Options for UK Domestic Water Reduction: A Review

Version 1.0

Patrick Sim

Adrian McDonald

John Parsons

Philip Rees

August 2005

School of Geography
University of Leeds
Leeds LS2 9JT
United Kingdom

This report is part of the output from the *WaND* programme (Water and New Developments). WaND is an *EPSRC* funded initiative (Grant reference: GR/S18373/01).

This paper is an online publication which maybe updated from reader feedback and on-going research findings. A version number has been attached to this document to allow for this.

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 locally migration will also affect demand particularly in the South-East.

The water reduction trends that will have the greatest reduction effect on UK consumption are:

1. For new homes; metering and new efficiencies in design and construction (e.g. low flush toilets, heating and plumbing efficiencies)
2. For established housing; metering and modern washing machines

ACKNOWLEDGEMENTS

The *WaND* programme (Water and New Developments) is an *EPSRC* funded initiative (Grant reference: GR/S18373/01) to research sustainable water management with a focus on new housing schemes in the UK.

This paper is part of the *WaND* output and we would like to thank all of our collaborators and co-workers.

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 of each option and the likely 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 changes related to personal habit and affluence are also influential. Faced with finite water resources and the requirements of the water-shed demand side management is now the favoured strategy for managing the water needs of the population (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. Regarding 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). Compounding this is the fact that these regions are also highly populated and that housing demand is expected to increase over the next two decades (see table 1).

According to the *Government Actuary Department* the UK population is forecast to increase by approximately 200,000 every year till about 2025. Half of this (100,000 people per year) is estimated as 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 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, the percentage increases in their populace 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)

In 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 in households, 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. Demographically 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 consumption reducing effect across the UK. Though 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. England household projections to 2021 based on 2001 baseline

New Build Homes (to be built 2001 - 2020)	**Old housing stock 1-2 Occupancy**	**Old housing stock 3+ Occupancy**
Will comprise ~18% of households in England[1] (>20% in the south eastern regions)	Reduce from about 64% to 52% of households in England[1]	Reduction from ~ 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 Reduction Effect' 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 expected uptake and device efficacy, this determines the amount of water that is likely to be conserved across the UK in comparison to a similar uptake of standard (non-conserving) devices. Expected uptake has been estimated by applying a trend analysis based on current popularity and the likely prevalence in existing and new build homes (e.g. some options like water meters are mandatory in all new build homes). Device efficacy is based on the ability of the option to conserve water compared with today's typical devices, assuming that water use behaviour remains relatively unchanged.

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 4. Technology options for reducing water consumption and their expected effect on new-build housing and existing housing stock

Option	Current status and uptake factors	Expected Uptake between 2001 and 2020			UK Water Reduction Effect
		New Build Homes	1-2 Occupancy Old Homes	3+ Occupancy Old Homes	
Metering	Currently >20% household penetration	All	Some - Most	Some - Most	Major
Household Plumbing Efficiencies	Most likely in new build properties, includes the following:				Major
	6 litre toilets	All	Few-Some	Few-Some	
	Plumbing efficiencies	All	Few	Few	
	Efficient heating system	All-Most	Few-Some	Few-Some	
	Future Regulation	Few - Most	Few	Few	
New clothes washing machines	Currently >90% of all households (8 year life cycle)	All	All-Most	All-Most	Moderate
Dishwashers	Low penetration	Few-Some	Few-Some	Some	Small
Reduced Flow Showers	Future regulation? Showering becomes even more popular?	Some	Few-Some	Few-Some	Moderate
Toilet Flush Reduction (e.g. hippo)	Inexpensive and easy to install	Few	Some-Most	Some-Most	Moderate
Low Flush Toilet	Currently 6 litre future regulation could reduce this	All	Few-Some	Few-Some	Moderate
Water Butts (outdoor water use)	Future regulation	Few-Some	Few-Some	Few-Some	Small
Water Efficient Gardens	Possibly a feature in new build homes?	Few-Some	Few-Some	Few-Some	Small
Rainwater Collection (indoor water use)	Relatively expensive and complicated to implement	Very Few - Few	Very Few	Very Few	Very Small
Grey water Recycling	Relatively expensive and complicated to implement	Very Few	Very Few	Very Few	Very Small
Green Roof	Relatively expensive and complicated to implement	Very Few	Very Few	Very Few	Very Small

NB. Few ~ 10%, Some ~ 25%, Most ~ 75%

Significant Reduction Measures

The tabulated results for each conservation option are shown in table 4. The following conservation methods appear to be the most important to account for 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
- General efficiencies in new developments (e.g. reduced flow showers, reduced 'dead-leg' in piping, reduced leakage and low flush toilets). This maybe critical in the south-east of England where substantial development is expected, particularly if this is affected by new building legislation.
- 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 device (commonly called a 'hippo'), these are cheap and easy to install (take up in new homes is not expected to be great as they will already be using reduced volume cisterns)
- Reduced flow showers; these may become more popular particularly in metered homes. Maximum flow showers may also be limited by new regulation, as cistern capacity is currently.

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 Department* 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).

New Homes

New build homes can be expected to be more water efficient for a particular occupancy (see 'New Housing' section) because of new appliances and regulations.

As the great majority of new homes will be single occupant this estimate 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 consumption ~ (a/b)*c*d = 0.8 * 18% = +17%

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 remain 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 fairly constant in comparison to new homes.

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 are mostly single occupant and thus having 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 water company regulation down to plumbing and appliance guidelines. Legislation and guidance that affects water demand and consumption is discussed below.

The Water Framework Directive has been 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 Act 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) (BRE, 2005). The assessment provides guidance to assess the overall sustainability of a house from both developer and occupant perspectives. Water efficiency is one of the environmental measures of the assessment. The assessment is intended to promote sustainable design and construction. However as the scheme is voluntary and allows for flexibility as to which criteria are included in an assessment and as such does not compel the housing industry to build water conservative homes.

SOCIAL FACTORS

The phenomenon of varying water consumption takes place in an arena of changing social and 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 occupancies
- 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 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 at a particular time
2. habits and attitudes (to water use) practised at the time of interest

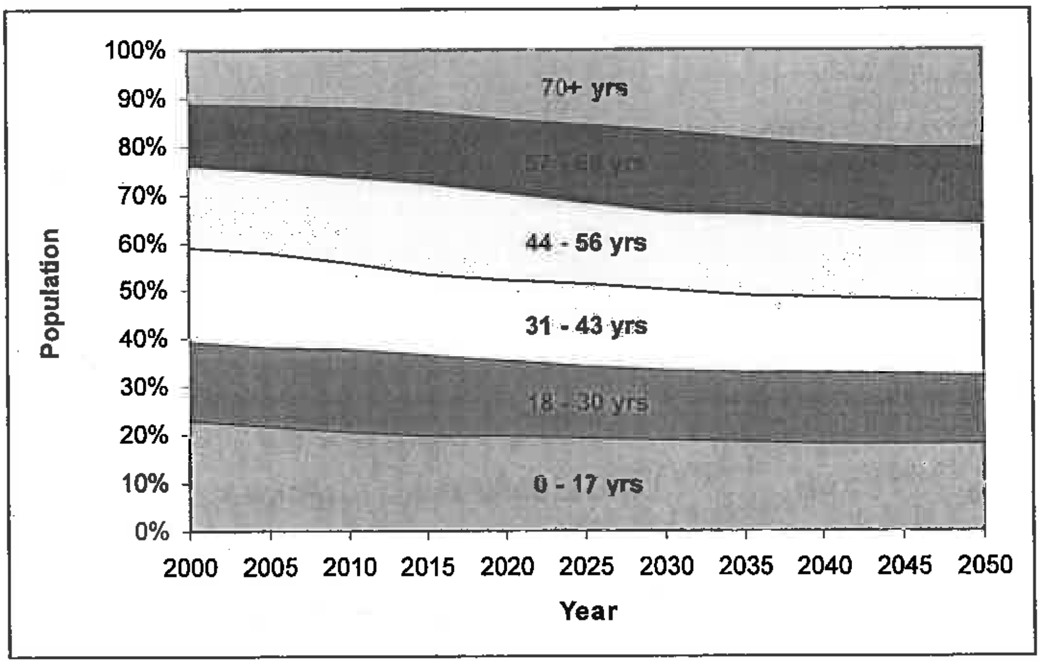

Figure 1. The projected age distribution of the UK population, 2000-2050 (Rees et al., 2005)

UK society is forecast to become an 'older' society driven by declining fertility, decreasing mortality and migration trends. 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 work for or against water conservation. Social trends are the most complex of the two elements involving the interacting effects of policy, economy, culture 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 water use. Example social trend factors, some from research in Holland, are shown in table 5. 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 5. 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 use remained largely unchanged from 36.0 to 25.5 litres per head per day
- Personal washing (from 33.5 to 46.5) and clothes washing (from 13.5 to 21.7) 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 6.

Table 6. 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 regarding the analysis of water consumption. 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 7. This outlines a change in paradigm regarding the role of water in society; it also suggests that changes in public attitudes and values are necessary.

Table 7. 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 (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. Also all homes built since 1989 have water meters installed by default. Moreover, 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).

Water meters are now found in over 20% of English and Welsh homes (see table 8). The *Environment Agency* has set water meter penetration targets of between 60-90% of households by 2030, however there is concern as to whether water companies will be able to meet this (Environment-Agency, 2003).

Table 8. English and Welsh homes with water meters

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

Analysis of domestic consumption monitor (DCM) records from *Yorkshire Water* carried out at *Leeds University* has shown that households on metered tariffs are typically smaller water consumers. This is true in both absolute (per household) and relative (per capita) terms. Metered households' had an average consumption of 214 litres per day (sample of 263 households). For the unmetered sample the average household consumption was 318 litres per day (sample of 758 households).

An analysis of the differences between metered and unmetered homes from *Yorkshire Water* DCM records suggest that metered households tend to have:

- Smaller household sizes (1.97 people per house compared to 2.56 in unmetered homes)
- Older average age (by approximately 10 years, see table 9)
- More water using appliances per-household and per-person

Table 9. Age distribution in metered household sample.

	Under 10 years %	10 to 54 years of age %	Over 54 years of age %	Total Occupants
Metered Households (n = 263)	6.8	38.7	54.6	517
Unmetered Households (n = 758)	11.4	57.5	31.1	1961

This has been reinforced by findings from *Essex & Suffolk Water's* 10 year *Study of Water Use* characterised optant households as having average occupancies of 1.8 and a rateable value of £288; opposed to 2.6 and £250 for non-optants (Essex&Suffolk-Water, 2003?).

The analysis of the *Yorkshire Water* DCM survey highlighted a relationship between socio-economic status and water metering, see figure 2. From the sample of 1,021 households, water meters were more likely in three of the 'top' four categories, whilst metering was less prevalent in the three 'lowest' categories.

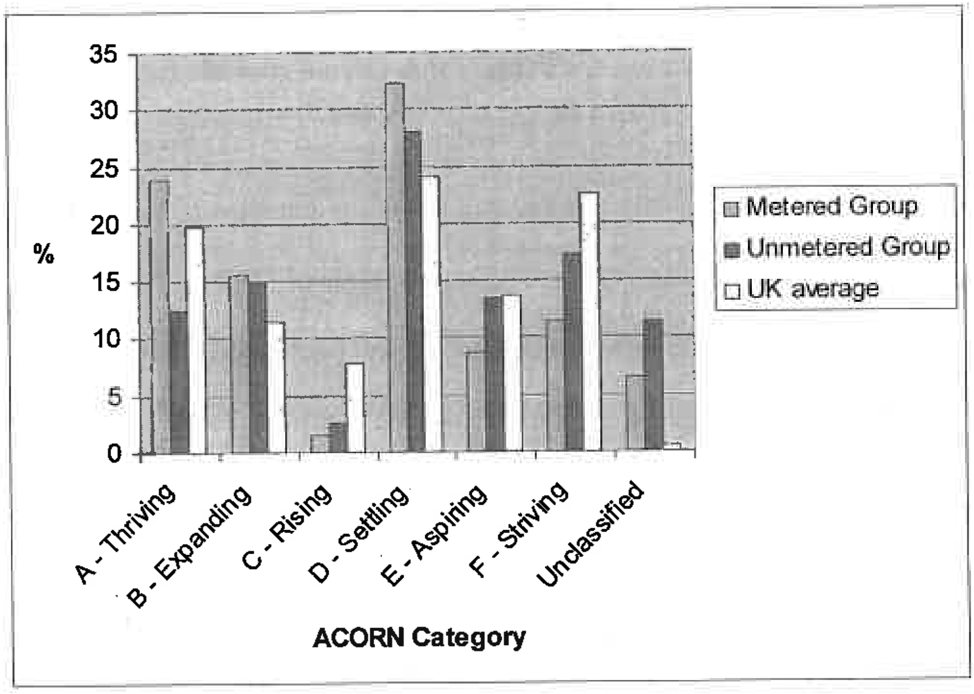

Figure 2. ACORN profile of metered and unmetered Yorkshire Water DCM survey group compared with 1998 average

The effect of bias is hard to establish with this survey though the number of households was fairly large. The profile of metered households is interesting and one explanation is that metering is an option taken up by households whose children have left home; this may explain the anomaly of lower consumption occurring in households with a greater number of water appliances.

Research reviewed by *UKWIR* estimated that compulsory metering would reduce typical household consumption by 10 to 15%, and that peak demand would also be attenuated (Baker and Toft, 2003). The propensity for consumers to switch was also examined and optant 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

The Effect of Metering

Metering has an important role in developing price-elasticity in the domestic water market. An analysis of consumption monitoring of 8,000 households in the UK between 1996 and 2001 calculated that the effect of metering resulted in an average 9% reduction in consumption (Baker and Toft, 2003). 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 is not doubted (Achttienribbe, 1998). *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.

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 causes new and generally more efficient devices to be purchased.

Water saving measures seem to be self-reinforcing with an observed 0.2% reduction in consumption occurring each month in the 8,000 household UK survey: however the longevity of this effect was not established (Baker and Toft, 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 preceeding switching.

As metering becomes more prevalent it is possible that this 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 (Baker and Toft, 2003). The danger of this conclusion is to expect that water savings practised by low users who opt for metering to be carried over to the whole population with compulsory metering.

Water Use Motives in Metered Households

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). There is evidence that metering encourages better water use through a number of motivational mechanisms (Van Vugt, 1999):

- Alterating of the reward structure, such that it becomes advantageous to reduce water consumption
- Increased personal efficacy through the ability to monitor consumption
- Paying for water use 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 'Late Adopters'

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 have demonstrated an average 15.2% reduction in consumption (Lawrence, 2004). 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 reductions diminish with the later the later the decision to opt for metering

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). Water efficient toilets use even smaller volumes which can potentially reduce the average daily water usage in a toilet from 50 to 20 litres per person (60% reduction). 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, this 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 by about 3 litres, approximately a third of a typical flush. This simple measure has been estimated to reduce household water consumption by 10-15%. However the efficiency of the flush is also reduced and it should be verified that double flushing doesn't lead to increased 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 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).

Other Toilet Technologies

Waterless and vacuum toilets could reduce average domestic water consumption by a third (approximately 50 litres/person/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 poor sewage infrastructure. Vacuum toilets are also 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 and Taps

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 them use less water 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 (note: average daily water usage is approximately 150 litres per person), also the Water Supply act of 1999 requires that an intention to install a bath of greater than 230litres be notified to the water supply company. Water usage is also generally reduced with good bath insulation as hot water top ups are not required as often.

Rainwater Collection

Collected rainwater is ideally employed for outdoor purposes and is preferable to grey water for gardening purposes, particularly for uncooked vegetable cultivation (WRAS, 1999b). Rainwater can also be advantageous for washing purposes, it's softness reduces detergent requirements. It is estimated that in Germany 100,000 rainwater systems are installed annually ranging from individual homes to industrial organisations (Environment-Agency, 2004c)

Typically rainwater is collected on the roof and transferred via guttering to water butts for storage; this arrangement has the following benefits:

1. The potential to reduce the typical 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

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

1. Rainwater collection and its benefits are seasonally unmatched; the summer months of greatest need are the times when the water butts will be at their lowest levels.
2. Water yield is determined by climate, roof size and storage capacity

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. Data for this development has 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* claim that using rainwater for all non-potable domestic applications can 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 a more sophisticated 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 the 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 has the potential to reduce domestic water usage by a third (Environment-Agency, 2001c). Additionally research suggests that less than 5% of 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 cycle only) and outdoor purposes (e.g. car washing and restricted gardening). There is also the additional benefit of reduced sewage volumes caused by the reduced through-put of water.

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).

Regarding grey water storage a tank of 1 cubic metre (1,000 litre) capacity is considered 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.

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 reuse	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 reuse for toilet flushing within single family households without minimum coliform regulation (Dixon et al., 1999). Compared to communal treatment 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) 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.

Research in the Netherlands has proposed that optimal grey water re-use can be achieved through 'cascading' (Terpstra, 1999). Cascading exploits the potential for waste water to be reused more than once in a domestic environment. This scheme involves water being classified dependent on its quality (shown in table 12). Class I water is the potable water supplied to the home, class water II is mildly dirty, class III is more so, whilst class IV is heavily contaminated. Using the class scale it is conceivable that some water can be reused up to three times before being expelled to the sewer (e.g. bathing, then washing machine initial cycle and then toilet flushing).

Table 12. Water quality and use for domestic purposes

Function	Input Water Class	Output Water Class
Bath/Shower	I	II
Washbasin	I	III
Washing Machine (Initial cycle)	II	III
Washing Machine (Final cycle)	I	II
Washing up (Hand)	I	IV
Food Preparation	I	IV
Toilet	III	IV

(Terpstra, 1999)

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), a figure not foreseen to reduce in the future. The historical performance of the

Bosch brand of washing machine is shown in figure 3, the figures 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 consumption is 150 litres/person/day). Grant suggests that water regulation during the 1970's was 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).

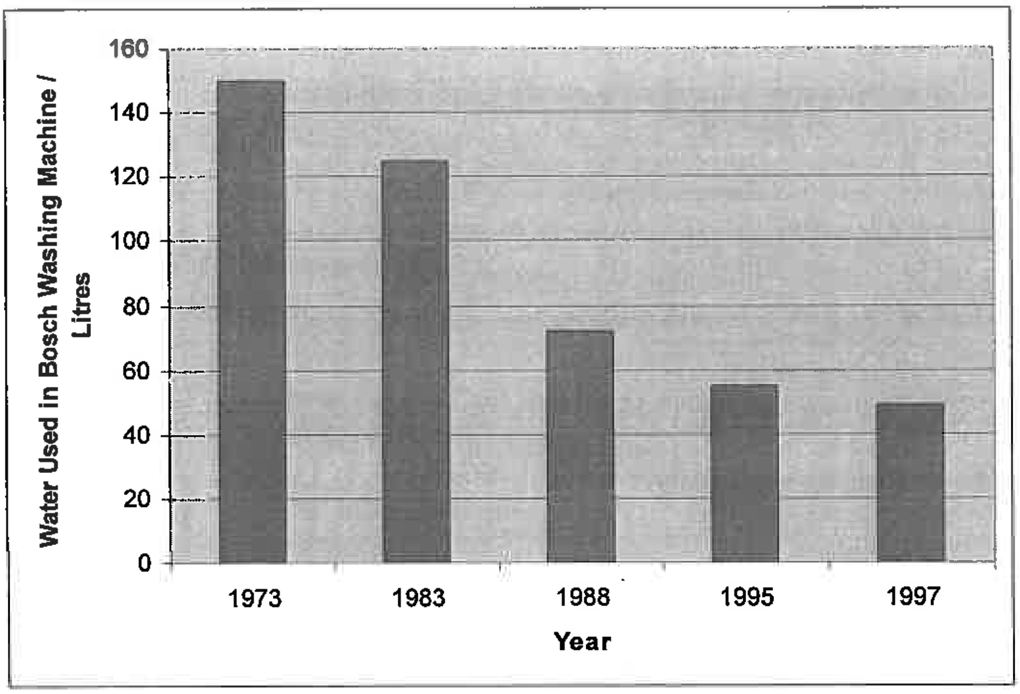

Figure 3. Water used by Bosch washing machines for 5kg hot wash (Grant, 2002)

The uptake of more efficient washing machines is dependent on the appliance lifetime (estimated at 8 years) which dictates its replacement rate. Currently the cost savings made by switching prematurely to a water efficient machine does not cover the purchase cost.

The absolute reduction in water used for clothes washing in the UK is offset by the increase in the number of washing machines and the frequency of washing. Also 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 wash more effectively than hand washing. The research carried out at *Bonn University* suggest that dishwashers consume less water than hand washing when washing more than 4 place settings (of 12 items) (Environment-Agency, 2004d). 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 for an optimum number of items.

The low penetration of dishwashers, 28% of all UK households in 2002 (National-Statistics-Office, 2002), and slow rate of take up suggest that they will not be a significant factor in medium term water consumption. Moreover UK census figures show that dishwashers are less common in smaller households - the types of households which will become more prevalent in the medium term.

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; figures of 25-30% reduction in tap water maybe overly optimistic (Environment-Agency, 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 13.

Table 13. 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	Power shower effect due to 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 new build homes as it is economically more advantageous to fit these during the building of a home rather than to retro-fit them 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, *South West Water* calculates this at 6.6%, in comparison in the US the *Environmental Protection Agency* suggests that during the growing season some households use 75% of their water supply for outdoor purposes (EPA, 2000).

In the UK during normal 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 becomes more prevalent. In the UK the proportion of water used for garden purposes can approach 50% of domestic uptake during the driest months (Environment-Agency, 2001b), at a time when this should be used be to satisfy more necessary needs and to prevent drought.

Water efficient gardens seek to create or enlarge low water use zones, '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. Relevant measures are presented in table 14.

Table 14. 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 houses 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 15. 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 15. The water efficient figure suggests that a further 25% reduction in water consumption can be achieved without significantly affecting water use habits.

Table 15. 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)

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 for their house type. However new home water consumption maybe mollified by future water regulation.

A study of the estimated water reduction in UK homes using *BATNEEC* (Best Available Technologies Not Entailing Excessive Costs) options came up with the following descending list of reductions (Grant, 2002).

- Reduced flush WC (saving 36 litres/person/day)
- Kitchen Sink (saving 16 litres/person/day)
- Washing Machine (saving 11 litres/person/day)

Grant reports that it is possible that for a home to reduce water consumption by 49% (from 150 to 76 litres per person/day).

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 16).

The figures in table 16 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 and Dutch domestic water supply, in North America it is a quarter

Table 16. Domestic water usage comparison between countries in recent years

Water use	UK[1] %	UK[2] %	Denmark[3] %	Netherlands[4] %	US/Canada[5] %
Toilets	35	31	27	29.1	33.3
Showers	<15.3[6]	5	36	28.6	15.6
Baths	20	15		6.7	6.7
Washing Machines	14	20	13	19.0	25.6
Tap	15.7[7]	24	17	9.9	15.6
Dishwashers		1		0.7	2.2
Other		4	7	6.0	1.1
Total	100	100	100	100	100

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. *Anglian Water* SoDCon survey of domestic consumption 1993-98 (POST, 2000)
3. *(Napstjert, 2002)*
4. 1995 Sample of 2,000 families (Achttienribbe, 1998)
5. Figures originally from *American Water Works Assoc.* (GVRD, 2004)
6. '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.
7. 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 16 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' washers which consume more water than 'front-loaders').

In California 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 17. 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 17. 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

NB Defined as "Best Estimate of Additional Cost-Effective Water Conservation Potential" (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).

CONCLUSION

The future social 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 will have a role in moderating demand in the medium term, these are:

Metering across all housing

Efficiencies in new homes; driven by modern, more efficient standard appliances and possibly by housing regulation.

As household occupancies reduce the option of metering will become economically advantageous to an increasing number of households. Metering is already the default option in some regions and in new homes. The trend towards increased metering is not forecast to reverse.

In new housing developments (e.g. Thames Gateway) modern housing efficiencies will reduce the increase in per-capita consumption caused by decreasing household size. This is driven by improving housing standards, home design innovations and more efficient appliances. This includes efficient toilets, reduced flow showers, water efficient dishwasher and washing machines, reduced leakage, plumbing and heating system efficiencies, and efficient gardens.

In established housing stock the following water reduction measures are expected to be the most effective (and popular):

Modern efficient washing machines (through natural replacement)

Metering (economic advantage)

Cistern displacement 'hippo' (low cost and simple installation)

'Water saver' showers (high prevalence and convenience)

The uptake of reduction measures such as plumbing efficiencies, cistern replacement, water efficient gardens and dishwashers are not expected to be as common in existing homes, primarily because of cost and lack of immediate return.

The prevalence and improving efficiency of washing machines means that they will be a major factor in reducing consumption as they are replaced by newer machines. However, the low penetration of dishwashers and their low savings mean that they will not significantly reduce water consumption.

Domestic water recycling schemes (both grey and green) are not expected to have a major impact in reducing water consumption in the medium term because uptake will be limited. Their cost and technical implementation being substantial, this includes green roofs. For similar reasons vacuum and composting toilets will not achieve significant uptakes to affect national demand.

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 consumption will be slight and probably negligible during dry periods of the year.

REFERENCES

Achttienribbe, G. E. (1993) *Journal of Water Supply:Research and Technology - Aqua,* **42,** 347-350.

Achttienribbe, G. E. (1998) *Journal of Water Supply:Research and Technology - Aqua,* **47,** 196-198.

Baker, W. and Toft, S. (2003) UKWIR, pp. 42.

BRE (2005) *EcoHomes [Online], Available from World Wide Web: http://www.breeam.org/ecohomes.html [Accessed 26th April 2005],* BRE.

Diaper, C., Jefferson, B., Parsons, S. A. and Judd, S. J. (2001) *CIWEM,* **15,** 282-286.

Dixon, A. M., Butler, D. and Fewkes, A. (1999) *CIWEM,* **13,** 322-326.

Environment-Agency (2001a) *Conserving Water in Buildings: Domestic Appliances [Online],* Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 1st February 2005].

Environment-Agency (2001b) *Conserving Water in Buildings: Gardening [Online],* Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 1st February 2005].

Environment-Agency (2001c) *Conserving Water in Buildings: Greywater [Online],* Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st Januray 2005].

Environment-Agency (2001f) *Conserving Water in Buildings: Flow Regulation and Leak Detection Devices [Online],* Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st January 2005].

Environment-Agency (2001g) *Conserving Water in Buildings: Urinals [Online]*, Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st January 2005].

Environment-Agency (2001i) *Conserving Water in Buildings: Water Efficient WC's and Retrofits [Online]*, Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st January 2005].

Environment-Agency (2001j) *Conserving Water in Buildings: Showers and Baths [Online]*, Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st January 2005].

Environment-Agency (2001k) *Conserving Water in Buildings: Plumbing and Heating Design and Management [Online]*, Environment Agency, Available from World Wide Web: http://www.environment-agency.gov.uk/subjects/waterres [Accessed 31st January 2005].

Environment-Agency (2003) *Demand Management Bulletin [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk/savewater [Accessed 31st January 2005].

Environment-Agency (2003a) *Water Efficency Awards 2003 [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk [Accessed 31st January 2005].

Environment-Agency (2004a) *Demand Management Bulletin (April) [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk/savewater [Accessed 31st January 2005].

Environment-Agency (2004b) *Demand Management Bulletin (August) [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk/savewater [Accessed 31st January 2005].

Environment-Agency (2004c) *Demand Management Bulletin (June) [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk/savewater [Accessed 31st January 2005].

Environment-Agency (2004d) *Demand Management Bulletin (October) [Online]*, Environment Agency, Available from World Wide Web: www.environment-agency.gov.uk/savewater [Accessed 31st January 2005].

EPA (2000) *Using Water Efficiently: Ideas for Residences [Online]*, US Environmental Protection Agency, Available from World Wide Web: www.epa.gov/owm/genwave.htm [Accessed 31st January 2005].

EPA (2004) *Water Efficiency Measures for Residences [Online]*, US Environmental Protection Agency, Available from World Wide Web: http://www.epa.gov/owm/water-efficiency/resitips.htm [Accessed 31st January 2005].

Essex&Suffolk-Water (2003?) Essex and Suffolk Water, pp. 9.

Grant, N. (2002) *Water Conservation Products: A Preliminary Review [Online]*, Watersave Network, Available from World Wide Web: http://watersave.uk.net/Presentations/Nick_pdf.pdf (Accessed 17th February 2005), Hereford.

GVRD (2004) *Residential Conservation Initiatives [Online]*, Greater Vancouver Regional District, Available from World Wide Web: www.gvrd.bc.ca/water/residential-conservation-initiatives.htm (Accessed 28th October 2004).

Herrington, P. (1996) *Climate Change and the Demand for Water*, HMSO, London.

Lawrence, C. J. (2004) South West Water.

Napstjert, L. (2002) *Water Savings in Copenhagen [Online],* WATERSAVE Network 4th Meeting, Available from World Wide Web: http://watersave.uk.net/Presentations/Lis.ppt (Accessed 11th December 2004), Loughborough.

National-Statistics-Office (2002), Vol. 2005 National Statistics Office.

National-Statistics-Office (2003) *Subnational Population Projections [Online],* National Statistics Office, , Available from World Wide Web: http://www.statistics.gov.uk/statbase/Product.asp?vlnk=13260&image.x=13&image.y=8http://www.statistics.gov.uk/lib2002/default.asp (Accessed 16th March 2005).

ODPM (2002) *Interim 2002 household projections: by region, 2001-2021 [Online],* ODPM, Available on World Wide Web: http://www.odpm.gov.uk/stellent/groups/odpm_control/documents/contentservertemplate/odpm_index.hcst?n=1572&l=3 (Accessed 15th March 2005).

Pacific-Institute (2003) *Waste Not, Want Not: The Potential for Urban Water Conservation in California [Online],* Pacific Institute, Available from World Wide Web: http://www.pacinst.org/reports/urban_usage/ (Accessed 18th October 2004).

Peck, S. W., Callaghan, C., Kuhn, M. E. and Bass, B. (1999) *Greenbacks from Green Roofs [Online],* Canade Mortgage and Housing Corporation, Available from World Wide Web: http://www.greenroofsystems.org/Greenbacks.pdf (Accessed 2nd March 2005).

Pinkham, R. (1999) *21st Century Water Systems [Online],* Rocky Mountain Institute, Available from World Wide Web: http://www.rmi.org/images/other/Water/W99-21_21CentWaterSys.pdf (Accessed 23rd November 2004), Snowmass, Colorado.

POST (2000) *Post Note 135: Water Efficiency in the Home [Online]*, Parliamentary Office of Science & Technology, Available from World Wide Web: http://www.parliament.uk/post/pn135.pdf, London.

Rees, P., Parsons, J. and Wilson, T. (2005) *UKPOP: a model and database for projecting local authority populations for the whole UK.*

Schrock, D. (1999) *Water-Efficient Gardening and Landscaping [Online]*, University of Missouri-Columbia, Available from World Wide Web: http://muextension.missouri.edu/xplor/agguides/hort/g06912.htm (Accessed 12th December 2004).

Shirley-Smith, C. (2001) *Water Reuse - Some Case Studies [Online]*, Metropolitan Water Company, Available from World Wide Web: http://watersave.uk.net/Presentations/index.html (Accessed 21st Januray 2005).

South-Australia-Water (2003) *How to Save Water in your Home [Online]*, South Australia Water, Available from World Wide Web: http://www.sawater.com.au/SAWater/YourHome/SaveWaterInYourHome/Fact+Sheets.htm (Accessed 21st December 2004).

Terpstra, P. M. J. (1999) *Water Science and Technology*, **39**, 65-72.

UKRHA (2004) *Saving The UK Water [Online]*, UK Rainwater Harvesting Association, Available from World Wide Web: www.ukrha.org (Accessed 21st December 2004).

UKWIR/EA (1997) *Forecasting Water Demand Components - Best Practise Manual*, Environment-Agency.

uSwitch (2005) *Meters from your water company [Online]*, uswitch.com, Available from World Wide Web: www.uswitch.com (Accessed 12th May 2005).

Van Vugt, M. (1999) In *Resolving Social Dilemmas*(Eds, Foddy, M., Smithson, M., Schneider, S. and Hogg, M.) Psychology Press, Ann Arbor, MI.

Westcott, R. J. and ODPM (2003).

Wijst, M. A. J. E. v. d. and Groot-Marcus, J. P. (1999) *Water Science and Technology*, **39**, 41-47.

WRAS (1999a) *Conservation of Water: An IGN for Architects, Designers and Installers*.

WRAS (1999b) *Reclaimed Water Systems: Information about Installing, Modifying or Maintaining Reclaimed Water Systems*.

WRAS (2001) *Water Supplies to Washing Machines and Dishwashers*.