Journal of Sustainable Development
www.ccsenet.org/journal.html
Vol. 2, No. 1
March 2009

Carbon Dioxide Emission Savings Potential of Household Water Use Reduction in the UK

M.J. Hackett & N.F. Gray (Corresponding author)
Centre for the Environment, Trinity College
University of Dublin, Dublin 2, Ireland
Tel: 353-1-896-1639 E-mail: nfgray@tcd.ie

Abstract

The relationship between household water use and energy consumption was examined to establish whether the conservation of water within a domestic environment offers significant potential for saving energy, thereby reducing household carbon dioxide emissions. Average UK water usage is 55,121 L $ca^{-1}yr^{-1}$. The supply of this volume of water and its subsequent treatment by the water companies is equivalent to just 38.6 kg CO_2 ca^{-1} yr^{-1}, although this is not currently included in the primary footprint. So water consumption per se does not significantly effect CO_2 emissions. However, the heating water within the household using electricity requires 5,036 kWh $ca^{-1}yr^{-1}$, equivalent to a further 2,830 t CO_2 $ca^{-1}yr^{-1}$ with 57% of energy associated with use of heated tap water. Using gas instead of electricity to heat water can reduce emissions by 63%, equivalent to an average reduction of 4.36 t CO_2 yr^{-1} for a standard household (2.4 occupants). Water efficient appliances and the careful use of heated water in the home could reduce average household water use from 151 to 73 L $ca^{-1}d^{-1}$ as well as the volume of water required to be heated thereby reducing related emissions by 58% or 1,662 kg CO_2 $ca^{-1}yr^{-1}$, where electricity is used. Maximum CO_2 emission reduction is achieved by the use of solar collectors using gas as standby heating fuel. This, coupled with simple water conservation measures, emits as little as 130 kg CO_2 $ca^{-1}yr^{-1}$ a potential saving of 2.7 t CO_2 $ca^{-1}yr^{-1}$.

Keywords: Water conservation, Energy conservation, Carbon footprint, Carbon dioxide emissions, Water heating

1. Introduction

Water conservation is seen as a major factor both in ensuring sustainability of water supplies but also in saving energy and thus reducing CO_2 emissions (ICWE, 1992; POLIS, 2005; Brandes, 2006; Australian Government, 2007; McMahon *et al*., 2006; Gray, 2008). However, little quantitative analysis has been performed to assess how effective a mechanism water conservation is in relation to household and personal CO_2 primary or direct footprint management. Existing CO_2 calculators or models do not include water use as a quantifiable CO_2 source factor; with water treatment and supply coupled with wastewater collection, treatment and disposal treated as part of the secondary or indirect footprint (Kenny and Gray, 2009a). Energy associated with water use within the home, which is primarily for heating and possibly pumping in a small number of cases, is hidden as a component of the household energy service bill which also includes space heating, lighting and the use of non-water associated household appliances (Kenny and Gray, 2009b). Space heating is normally the largest household energy user followed by water heating (European Environment Agency, 2001; Shorrock and Utley, 2003). However, due to improved building regulations and energy saving initiatives such as loft insulation, double/triple glazing reducing thermostats by several degrees, space heating is becoming increasingly efficient (DTI, 2006; BRE, 2007). Therefore, it is inevitable that as these improvements in household design are implemented, the relative importance of water heating as a source of household and personal energy costs and CO_2 emissions will increase even further in the future.

The aim of this study was to examine the relationship between household energy consumption and water use to establish whether reducing water usage yields significant CO_2 emission reductions. A number of specific questions are addressed: (i) Does reducing the volume of water supplied and/or wastewater treated reduce CO_2 emissions per household in terms of the energy used to treat and transport water and sewage; (ii) What are the energy or CO_2 sources and outputs associated with household water use; and (iii) What effect does water conservation actions within the household have on energy usage and CO_2 emissions.

2. Methods

The volume of water supplied and treated is based on the average UK water consumption rate of 151 L $ca^{-1}d^{-1}$ (Ofwat, 2006), with lavatory flushing and internal tap use the largest sources of household water use together accounting for more than 50% of consumption (Figure 1) (Jefferson *et al.*, 2000; MTP, 2007h). Water usage, associated energy use and

subsequent CO_2 emissions were calculated and broken down into inputs, which comprise water treatment and subsequent supply, and outputs, which is the collection, treatment and disposal of wastewater. Both of these activities are normally carried out by the water companies. Carbon emissions from water and wastewater treatment were taken from the UK industry average identified by Water UK (2007) as 0.29 and 0.41 tonnes CO_2 ML^{-1} respectively (Section 3.1). Domestic processes included all energy-based activities relating to water use within the home, and in the majority of cases this is restricted to water heating. Energy associated with domestic water heating or other water related functions were determined from research literature, manufacturers' product specifications and personal communication with manufacturers (Vickers, 2001; Beko, 2007; Australian Government, 2007; Hoover, 2007; McMahon *et al*., 2006; MTP 2007c, d, e, f, g, j; Whirlpool, 2007a, b). Mean energy values were calculated per litre of water heated and processed for a UK household not employing water conservation action. The processes considered were tap use, showering, bathing, lavatory flushing, dishwasher and washing machine use (Section 3.2). Energy data as kWh was converted into CO_2 emission figures using the 2006 UK conversion factors for electricity and natural gas of 0.562 and 0.206 kg CO_2 kWh^{-1} respectively (Defra, 2008a,b). Unless stated, electricity was the fuel type assumed, however different fuel types were compared. The analysis was repeated for a household employing water conservation measures (Section 3.3).

3. Results and discussion

3.1 *Reducing the volume of water supplied and/or wastewater treated reduces CO_2 emissions from the treatment of water and sewage.*

Based on Water UK (2007) average company performance values, 0.29 and 0.41 g CO_2 are emitted for every litre of water supplied or wastewater treated respectively. Based on the average UK consumption rate of 151 L ca^{-1} d^{-1} this is equivalent to emission rates for water supplied and wastewater treated of 105.7 g CO_2 ca^{-1} d^{-1} or 38.58 kg CO_2 ca^{-1} yr^{-1}. However, this emission source is currently included in the secondary rather than the primary household CO_2 footprint (Kenny and Gray, 2009b).

The household conservation measures tested in this study reduced water usage by 52% (Section 3.3) leading to a reduction in per capita CO_2 emissions during its production and disposal from 38.6 to 18.6 kg CO_2 ca^{-1} yr^{-1}. With the carbon footprint of an average individual living in the UK currently estimated at 5.1 t CO_2 yr^{-1}, with the secondary footprint equivalent to a further 4.1 t CO_2 yr^{-1} (Defra, 2006), then the saving of 20 kg CO_2 yr^{-1} only represents 0.39% of an individual's annual primary CO_2 footprint, or equivalent of driving a modern 1.4 litre petrol car 126 km (Kenny and Gray, 2009b). However, when this is multiplied by the number of people connected to water mains and sewerage systems in the UK, then this figure becomes significant in terms of national emissions. In 2004/5 18,837 Ml d^{-1} of drinking water was supplied to the public distribution system (Gray, 2008) representing a daily CO_2 footprint of 5,463 t CO_2 d^{-1} and a further 7,535 t CO_2 d^{-1} for its subsequent treatment as wastewater. So, in England and Wales alone there are 52.7 million people connected to the mains so the potential saving for the water industry, if basic household water saving measures were introduced as described in this study, would be 1.054×10^6 t CO_2 yr^{-1}. The current industrial, commercial and public CO_2 emissions in the UK is 242×10^6 t CO_2 yr^{-1} (Defra, 2006) so household water conservation would reduce these secondary CO_2 emissions by less than half of one percent overall. The extra energy costs associated with water harvesting, provision of a personal water supply or a wastewater treatment system are unlikely to be cost effective in terms of CO_2 emissions due to constructional, operational and maintenance energy inputs (Gray, 2008). Centralized water supply and wastewater treatment are always going to be more energy efficient, although conservation of water use in the home does make a small but cumulatively significant reduction in emissions.

3.2 *The energy and CO_2 sources associated with household water use.*

Ninety-nine percent of energy consumption and CO_2 emissions of the water use cycle occur during the domestic use of water, primarily through water heating. Water usage and energy emissions for appliances are given in Table 1 while their frequency of use in an average UK house of 2.4 occupants (Shorrock and Utley, 2003) is given in Table 2. This includes 248 dishwasher and 278 washing machine cycles per household per annum (MTP, 2007a,b) with frequency of use of the shower, bath, tap and lavatory based on conservative estimates of normal practice (Vickers, 2001; Gray, 2008). This results in a water usage rate of 55,121 L $ca^{-1}yr^{-1}$, resulting in an energy consumption for domestic activities where electricity is the sole energy source of 5,036 kWh $ca^{-1}yr^{-1}$ (Table 3) emitting 2.83 t $CO_2ca^{-1}yr^{-1}$, which is equivalent to 2.87 t $CO_2ca^{-1}yr^{-1}$ including water and wastewater treatment. Tap use is the largest consumer of energy within the home, accounting for 57% of energy consumed and CO_2 emitted and so offers the greatest potential for emission reduction.

As fuel mixes vary within and between households the overall total CO_2 emissions, including water and wastewater treatment can vary between 1,052 to 2,869 kg CO_2 $ca^{-1}yr^{-1}$ due to the fuel mix alone. This indicates that the use of gas rather than electricity to heat water can save 1,818 kg CO_2 per annum on a per capita basis, a potential emission reduction of 63%. These results indicate that between 21 to 56% of the average UK primary CO_2 footprint can be accounted for by water heating, depending on the type of fuel used. This is slightly higher than previous estimates of

23% in the UK (Shorrock and Utley, 2003), the European average of 15% (EEA, 2001), and 28% in Australia (Milne and Riedy, 2007). . However, the exact percentage depends on the estimated personal CO_2 footprint, the fuel mix and actual hot water usage.

It is in the use of heated tap water that the greatest variability in energy usage between households is seen and where the greatest potential savings can be made. Kenny and Gray (2009b) showed that per capita home energy use fell by 27 and 34% respectively in two and three person households compared to a single occupancy household. Tap water use is the only factor associated with water use that is significantly affected by occupancy rate. So, for example, if we assume a 30% reduction in hot tap water usage for an average household of 2.4 occupants then the annual energy usage would fall from 12,087 to 10,003 kWh (Table 3). However, in this paper we have not applied this correction factor due to a lack of actual occupancy usage data.

3.3 *The energy and CO_2 sources associated with household water use where water conservation is applied.*

Household water and energy consumption can be significantly reduced by using water and energy saving appliances and more careful use of water in the home (Table 1). Typically this includes dishwasher and washing machines that are A rated for both energy and water use, low-power showers fed directly from the hot water cylinder, low flow taps and low volume flush toilets, rather than the UK market standard. Usage is also assumed to have changed through better practice: dishwasher cycles reduced from 248 to 225 and washing machine cycles reduced from 270 to 250 per household per annum, shower use increased from 6 to 7 $ca^{-1}wk^{-1}$ to replace the possible weekly bath, and hot water tap use reduced from 6 to 4 minutes $ca^{-1}d^{-1}$ (Table 4). These actions would reduce average water use from 151 to 73 L $ca^{-1}d^{-1}$ (Tables 3 and 5). Thus the use of energy efficient water-consuming appliances and moderately reduced water usage rates can achieve savings of 1,662 kg CO_2 $ca^{-1}yr^{-1}$, equivalent to a net saving of 58% (Table 6).

In 2005 >5 million households in Europe employed solar collectors or panels to transform sunlight into energy for space and water heating (SEI, 2008). Solar water heating does not appear to be a complete alternative to gas and electricity; rather it is a supplement to these energy sources. The problem is that excess heated water is produced during the summer and not enough in the winter (MTP, 2007i). Overall 60-70% of household water energy needs can be met, although this varies with location (SEI, 2008). Over sizing the units may increase the volume of heated water in cooler months but this causes serious problems of wasting excess water and problems of overheating in the summer (Alternative Energy Ireland, 2008). Expected average water temperatures using correctly sized solar panels (ISO, 2001) and hot water cylinders, assuming 50 litres per person per household, for central UK will be Spring 45-55^oC, Summer 80^oC (restricted), Autumn 50-60^oC and Winter 30-40^oC (SEI, 2008). In practice this would reduce per capita energy used to heat water in the home from 5,036 to 1,542 kWh $ca^{-1}y^{r-1}$ (Table 7), a 69.4% reduction of energy, and CO_2 emissions equivalent to 1,964 kg CO_2 $ca^{-1}yr^{-1}$ where electricity is used. If gas only was used as the standby heating fuel with solar collectors, emissions associated with water heating would be just 318 kg CO_2 $ca^{-1}yr^{-1}$, a potential maximum reduction in the personal emissions footprint of 1,964 kg CO_2 $ca^{-1}yr^{-1}$. The use of conservation appliances and behaviour (Table 5) in conjunction with solar collectors would reduce the standby energy requirement even further to just 633 kWh $ca^{-1}yr^{-1}$, equivalent to just 130 kg CO_2 $ca^{-1}yr^{-1}$using gas, equivalent to a potential emissions reduction of 2.7 t CO_2 $ca^{-1}yr^{-1}$.

The emission values in this paper are derived from industry standard values, and using average national consumption rates. However, consumption patterns, boiler types and efficiencies vary significantly between individual households. The study indicates that the more careful use of heated water in the home has significant emission reduction potential, although this needs to be confirmed through detailed household input-output studies of carbon emissions, and detailed analysis of energy saving of specific water conservation and water heating case studies.

4. Conclusions

- The industry related CO_2 emission per capita from the supply and subsequent treatment of wastewater at a consumption rate of 151 L $ca^{-1}d^{-1}$ is 38.6 kg CO_2 ca^{-1} yr^{-1}. Current conservation measures can reduce this by 20 kg CO_2 ca^{-1} yr^{-1}. The extra energy costs of subsidizing water supplies such as water harvesting, or the provision of personal water supply and wastewater treatment are unlikely to be sustainable options in terms of CO_2 emissions.
- Average UK water usage of 55,121 L $ca^{-1}yr^{-1}$ results in an energy consumption for domestic activities, where electricity is the sole energy source, of 5,036 kWh $ca^{-1}yr^{-1}$ emitting 2,830 kg $CO_2ca^{-1}yr^{-1}$, which is equivalent to 2,869 kg $CO_2ca^{-1}yr^{-1}$ including water and wastewater treatment.
- The selection of fuel type to heat domestic water can have significant implications on CO_2 emissions. Using gas instead of electricity to heat water can reduce emissions by 63%, equivalent to an average reduction of 4.36 t CO_2 yr^{-1} for the standard household modelled.
- Water conservation measures could reduce average water use to 73 L $ca^{-1}d^{-1}$ reducing emissions by 58% or 1,662 kg CO_2 $ca^{-1}yr^{-1}$.

- Maximum CO_2 emission reductions associated with water use in households is achieved by the use of solar collectors and gas as standby heating fuel. This can be further reduced by the use of water and energy conservation appliances and behaviour which would emit just 130 kg CO_2 $ca^{-1}yr^{-1}$ a potential saving of 2.7 t CO_2 $ca^{-1}yr^{-1}$ compared to standard usage using electricity as fuel source.

References

Alternative Energy Ireland (2008). *Solar energy.* Alternative Energy Ireland, Blessington, Co. Wicklow, Ireland. http://www.aei.ie/ Accessed 19th June, 2008.

Australian Government (2007). *Water Efficiency Labelling and Standards (WELS). FAQ.* http://www.waterrating.gov.au/faq/index.html. Accessed 31st May 2007.

Beko (2007) *Washing Machines.* http://www.beko.co.uk. Accessed 16th August 2007.

Brandes, O.M. (2006). *Thinking Beyond Pipes and Pumps.* POLIS Project of Ecological Governance, University of Victoria.

BRE (Building Research Establishment) (2007). *Ecohomes and Ecopoints*. http://www.bre.co.uk. Accessed 31st August 2007.

Defra (2006). 2005 Experimental Statistics on carbon dioxide emissions at local authority and regional level, Department for Environment, Food and Rural Affairs, London http://www.defra.gov.uk/environment/statistics/globatmos/index.htm Accessed 19th June, 2008.

Defra (2008a). *Guidelines to Defra's GHG conversion factors: Annexes updated April 2008.* Department for Environment, Food and Rural Affairs, London.

Defra (2008b). *Guidelines to Defra's greenhouse gas (GHG) conversion factors for company reporting -annexes.* Department for Environment, Food and Rural Affairs, London.

DTI (2006). Strategy for Sustainable Construction. Department of Trade and Industry, London. http://www.berr.gov.uk/files/file37182.pdf. Accessed 4th September 2007.

European Environment Agency (2001). *Household energy Consumption*. Indicator Fact Sheet. http://www.themes.eea.europa.eu/Sectors_and_activities/households/indicators/energy/hh06households.pdf. Accessed 19th June 2008.

Jefferson, P., Seaton, R.A.F., Parsons, S., Judd, S.T., Stephenson, T., Fewkes, A., Butler, D. and Dixon, A., (2000). An interdisciplinary approach to the assessment of water recycling technology options. *Int. J. Water*, **1**, 102-117.

Gray, N.F. Gray (2008). *Drinking Water Quality*. 2nd edition. Cambridge University Press, Cambridge.

Hoover (2007). *Washing Machines.* http://www.hoover.co.uk. Accessed 16th August 2007.

ICWE (1992). *The Dublin Statement.* International Conference on Water and the Environment, Dublin.

ISO (2001). *Thermal solar systems and components. Solar collectors. Test methods.* EN12975-2:2001. International Standards Organization, Geneva.

Kenny, T and Gray, N.F. (2009a). Comparative performance of six carbon footprint models for use in Ireland. *Environmental Impact Assessment Review*, **29**, 1-6.

Kenny, T and Gray, N.F. (2009b). A preliminary survey of household and personal carbon dioxide emissions in Ireland. *Environment International*, **35**, 259-272.

McMahon, J. E., Whitehead, D.C. and Biermayer, P., (2006). *Saving Water Saves Energy.* http://www.mail.mtprog.com/CD_Layout/Day_1_21.06.06/1615-1800/ID167_McMahon_final.pdf. Accessed 14th August 2007.

Milne, G. and Reidy, C., (2007). *Energy Us: Introduction.* Australian Greenhouse Office. http://www.greenhouse.gov.au/yourhome/technical/fs40.htm. Accessed 28th May 2007.

MTP (2007a). *BNDH06: Ranking of energy saving measures in the home.* Version 5.2. Market Transformation Programme. http://www.mtprog.com. Accessed 30th March 2007.

MTP (2007b). *Sustainable Products 2006 : Policy Analysis and Projections*. Market Transformation Programme. http://www.mtprog.com. Accessed 11th July 2007.

MTP (2007c). *BN DW Shower: Actions to improve shower design and efficiency – Briefing Note relating to policy scenario objectives in Policy Brief.* Market Transformation Programme. http://www.mtprog.com. Accessed 12th July 2007.

MTP (2007d). *BNW21: EC Energy Labelling of Domestic Dishwashers: Current usage and future requirements for policy review.* Market Transformation Programme. http://www.mtprog.com. Accessed 14th August 2007.

MTP (2007e). *BNDWBATHS: Actions to improve bath design and efficiency – Briefing Note relating to policy scenario objectives in Policy Brief.* Market Transformation Programme. http://www.mtprog.com. Accessed 16th August 2007.

MTP (2007f). *BNWAT07: Baths – water efficiency performance tests.* Market Transformation Programme. http://www.mtprog.com. Accessed 16th August 2007.

MTP (2007g). *BNWAT21: Performance standards for water-using products – an overview.* Market Transformation Programme. http://www.mtprog.com. Accessed 16th August 2007.

MTP (2007h). *Product Overview: Water.* Market Transformation Programme. http://www.mtprog.com. Accessed 11th July 2007.

MTP (2007i). *BNDH21: Solar water heating for housing. Market Transformation Programme.* http://www.mtprog.com. Accessed 16th August 2007.

MTP (2007j). *BNWAT06: Showers – water efficiency performance tests.* Market Transformation Programme. http://www.mtprog.com. Accessed 16th August 2007.

Ofwat (2006). *Security of supply, leakage and water efficiency*. 2005-06 report. Ofwat. http://www.ofwat.gov.uk. Accessed 19th June, 2008.

POLIS (2005). *At a Watershed*. POLIS Project of Ecological Governance, University of Victoria.

SEI (2008). *Passive solar energy.* Sustainable Energy Ireland, Dublin.

http://www.sei.ie/index.asp?locID=264&docID=-1#PassiveSolar Accessed 19th June, 2008.

Shorrock, L. D. and Utley, J.I., (2003). *Domestic Energy Fact File*. BRE (Building Research Establishment), London.

Vickers, A. (2001). *Handbook of Water Use and Conservation.* Waterflow Press, Amherst, Massachusetts.

Water UK (2007). *Towards Sustainability 2005-2006.* UK water industry Sustainability Indicators 2005/2006. Water UK, London. http://www.water.org.uk. Accessed 14th March 2007.

Whirlpool (2007a). *Dishwashing*. http://www.whirlpool.co.uk. Accessed 16th August 2007.

Whirlpool (2007b). *Washing*. http://www.whirlpool.co.uk. Accessed 16th August 2007.

Table 1. Mean water and energy consumption rates by domestic activity used for households employing market average (i.e. industry standard) water use appliances and in parentheses water conservation appliances, both using electricity as the sole energy source.

Appliance or Activity	Water use		Energy use	
	Litres per unit use	units	kWh per unit use	units
Dishwasher	17 (12)	L per cycle	1.21 (1.05)	kWh per cycle
Washing machine	63 (45)	L per cycle	1.09 (1.02)	kWh per cycle
Shower	33 (18)	L per shower	4.31 (2.28)	kWh per shower
Bath	86 (65)	L per bath	11.18 (8.45)	kWh per bath
Tap	10 (5.7)	L per min.	1.31 (0.74)	kWh per min.
Lavatory	5.2 (3.3)	L per flush	Not applicable	

Table 2. Estimated frequency of use of domestic water consuming appliances and activities for a standard UK household (2.4 occupants) consuming 151 L water $ca^{-1}d^{-1}$.

Appliance or activity	Number of uses per capita			Number of uses per household		
	d^{-1}	wk^{-1}	yr^{-1}	d^{-1}	wk^{-1}	yr^{-1}
Dishwasher (cycles)	0.3	2	103	0.7	5	248
Washing machine (cycles)	0.3	2	114	0.8	5	274
Shower (no.)	0.9	6	312	2.1	14	749
Bath (no.)	0.1	1	52	0.3	2	125
Tap (min.)	6.0	42	2,190	14.4	101	5,256
Lavatory (flushes)	5.0	35	1,825	12.0	84	4,380

Table 3. Average water and energy consumption rates for water consumption in the U.K. (151 L $ca^{-1}d^{-1}$) on per capita and per household (2.4 occupants) basis.

Appliances and activities	Water use (litres)				Energy use (kWh)			
	Per capita		Per household		Per capita		Per household	
	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}
Tap	60	22,010	145	52,823	7.8	2,861	18.8	6,867
Shower	28	10,343	68	24,823	3.7	1,345	8.9	3,227
Lavatory	26	9,399	62	22,557	Not applicable			
Washing machine	20	7,193	47	17,262	0.3	124	0.8	298
Bath	12	4,472	29	10,733	1.6	581	3.8	1,395
Dishwasher	5	1,705	11	4,092	0.3	125	0.8	300
Total	**151**	55,121	363	132,289	**14**	5,036	33	12,087

Table 4. Estimated frequency of use of domestic water consuming appliances and activities for a standard UK household (2.4 occupants) employing conservation appliances and activities.

Appliance or activity	Number of uses per capita			Number of uses per household		
	d^{-1}	wk^{-1}	yr^{-1}	d^{-1}	wk^{-1}	yr^{-1}
Dishwasher (cycles)	0.3	2	94	0.6	4	225
Washing machine (cycles)	0.3	2	104	0.7	5	250
Shower (no.)	1.0	7	364	2.4	17	874
Bath (no.)	0.0	0	0	0.0	0	0
Tap (min.)	4.0	28	1,460	9.6	67	3,504
Lavatory (flushes)	5.0	35	1,825	12.0	84	4,380

Table 5. Water and energy consumption rates for water consumption using conservation appliances and approach in the UK (73 L $ca^{-1}d^{-1}$) on per capita and per household (2.4 occupants) basis.

Appliances and activities	Water use (litres)				Energy use (kWh)			
	Per capita		Per household		Per capita		Per household	
	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}	d^{-1}	yr^{-1}
Tap	23	8,322	55	19,973	3.0	1,082	7.1	2,596
Shower	18	6,370	42	15,288	2.3	828	5.5	1,987
Lavatory	17	6,023	40	14,454	Not applicable			
Washing machine	13	4,688	31	11,250	0.3	106	0.7	255
Bath	0	0	0	0	0	0	0	0
Dishwasher	3	1,125	7	2,700	0.3	98	0.6	236
Total	**73**	26,527	175	63,665	**6**	2,115	14	5,075

Table 6. Comparison of per capita energy and CO_2 emissions between standard water use and those employing conservation measures. [e] Energy usage unknown as number of fuel mixes used.

Source	Standard water use			Conservation water use			Net saving		
	Water (litres)	Energy (kWh)	CO_2 (kg CO_2)	Water (litres)	Energy (kWh)	CO_2 (kg CO_2)	Water (litres)	Energy (kWh)	CO_2 (kg CO_2)
Inputs		-[a]	16.0		-[a]	7.7		-[a]	8.3
Processes		5,036.3	2,830.3		2,114.6	1,188.4		2,921.6	1,641.9
Outputs		-[a]	22.6		-[a]	10.9		-[a]	11.7
Total	55,121	5036	2,868.9	26,527	2,147	1,207.0	28,594	2,956.5	1,661.9

Table 7. Estimated per capita seasonal percentage replacement of water heating by passive solar collectors and standby energy requirement and saving under standard conditions described in Table 3.

Source	Normal energy required (kWh)	Replacement by solar heating (%)				Standby energy required (kWh)	Energy saving (%)
		Spring	Summer	Autumn	Winter		
Tap	2,861	60	95	75	50	858	70.0
Shower	1,345	60	90	70	45	454	66.3
Washing machine (40°C cycle only)	124	90	100	90	75	14	88.8
Dishwasher	125	80	100	90	65	20	83.8
Bath	581	60	90	70	45	196	66.3
Total	**5,036**					**1,542**	**69.4**

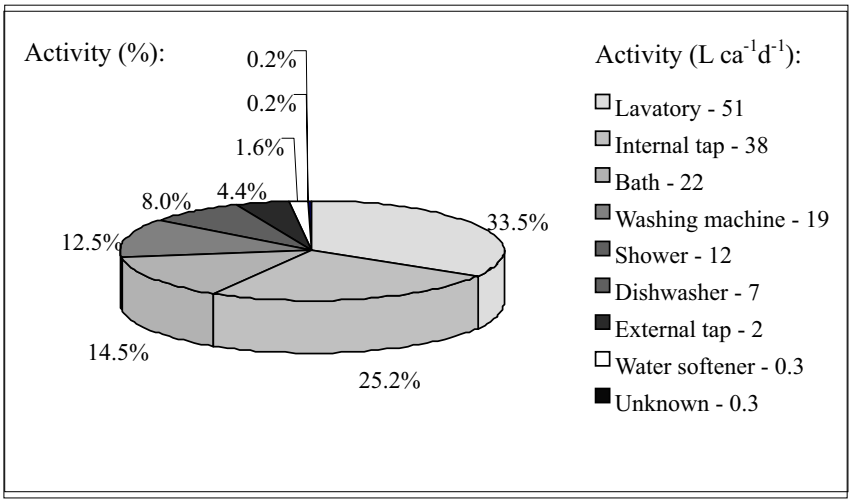

Figure 1. Household water use by activity, in England and Wales for 2007, on an actual (litres) and percentage basis (adapted from MTP, 2007i).