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Water efficiency as a means of reducing carbon emissions in Northern Ireland (NI) water

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ABSTRACT

The water and sewerage sectors' combined emissions account for just over 1% of total UK emissions, while household water heating accounts for a further 5%. Energy use, particularly electricity, is the largest source of emissions in the sector. Water efficiency measures should therefore result in reduced emissions from a lower demand for water and wastewater treatment and pumping, as well as from decreased domestic water heating. Northern Ireland Water (NI Water) is actively pursuing measures to reduce its carbon footprint. This paper investigated the carbon impacts of implementing a household water efficiency programme in Northern Ireland. Assuming water savings of 59.6 L/prop/day and 15% uptake among households, carbon savings of 0.6% of NI Water's current net operational emissions are achievable from reduced treatment and pumping. Adding the carbon savings from reduced household water heating gives savings equivalent to 6.2% of current net operational emissions. Cost savings to NI Water are estimated as £300,000 per year. The cost of the water efficiency devices is approximately £1.6 million, but may be higher depending on the number of devices distributed relative to the number installed. This paper has shown clear carbon benefits to water efficiency, but further research is needed to examine social and cost impacts.

Key words | carbon emissions, cost savings, greenhouse gas emissions, water efficiency

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INTRODUCTION

A recent report by the United Nations stated that urgent action is needed to prevent and mitigate the impact of extreme events caused by climate change (UNEP 2012). The main reason for climate change is the increase in greenhouse gas (GHG) emissions caused by anthropogenic activities (IPCC 2007). The term GHG emissions refers to emissions of the 'basket of six' GHGs, i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). To calculate the total global warming potential of these GHGs, emissions of each GHG are converted to tonnes of carbon dioxide equivalent (CO_2e). GHG emissions in terms of CO_2e are commonly referred to as carbon emissions, and the terms are used interchangeably in this paper.

The water and sewerage sectors' combined carbon emissions account for just over 1% of total UK emissions, while water heating in the home accounts for a further 5% (OFWAT 2010). The sectors' emissions are not insignificant (they are equivalent to those from all buses in the UK (OFWAT 2010)), and there is a responsibility on the sectors to play a part in contributing to the UK emissions reduction target (Environment Agency 2012). NI Water is the largest single electricity user (DOENI 2011), and the sole provider of water and sewerage services, in N Ireland. The company does not currently have GHG emission targets, although the Department for Regional Development has identified as a priority the establishment of appropriate targets to reduce emissions in NI Water (DRD 2010).

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Water efficiency has been recognised as an essential part of adapting to and tackling climate change, as well as improving the resilience of water and wastewater systems (Waterwise 2010). There has to date been limited research in NI Water into the impact of water efficiency measures on carbon emissions, and the aim of this paper is to fill that knowledge gap. The objectives of the paper are to:

- determine average household water savings from a water efficiency programme suitable to NI Water;
- calculate carbon savings to NI Water from reduced household water consumption;
- determine carbon savings to households from reduced hot water consumption;
- assess the cost effectiveness of these measures for NI Water.

The focus of the paper is on household water efficiency; measures to improve water efficiency in industrial and business applications are outside the scope of this paper.

METHODOLOGY

The analysis investigates the carbon impacts of improving household water efficiency. A water efficiency programme is assumed, taking into account the current situation in N Ireland. There are a range of methods and devices for reducing water usage, including pressure reduction programmes and specific water saving devices. NI Water has already implemented an extensive programme of pressure management on the water mains network (and few properties are now supplied with excessive pressure), but has to date carried out only limited distribution/installation of water saving devices, such as low-flush cisterns and efficient shower heads. The focus of this paper is therefore on water saving devices. Water and carbon savings are determined using values from the literature and information from NI Water's Annual Information Return. A simple cost analysis is also conducted using NI Water's current electricity and carbon costs and typical costs for water efficiency devices. The final part of the analysis discusses the results and suggests areas for future research.

ANALYSIS

Water balance

NI Water serves 672,816 households, with a total household population of 1.7 million. The overall water balance for NI Water, along with details on total household consumption, is presented in Figure 1, while the breakdown of water use in an average household is given in Table 1.

Household water savings

There is a range of methods and devices for reducing household water usage. Estimates of water savings can vary considerably, partly due to a lack of data, but also because of differences in existing water use patterns and differences in the products used. The values quoted in Table 2 were selected from UK data and were considered applicable to the N Ireland setting. Savings are not cumulative, e.g. a household water audit and a shower timer are unlikely to give total savings of 15 L/prop/day. Also, certain devices are particular to specific situations. Cistern displacement devices are only applicable in large (old fashioned) cisterns, whereas dual variable devices can be used in smaller (more modern) cisterns. Efficient shower heads are suitable for standard showers, but not for electric showers, which are typically already low-flow (with the exception of 'power showers'). As some devices are more expensive to install than others and some require building work, it is unlikely that all applicable water saving devices would be installed in the one household.

NI Water promotes water efficiency to its customers through a number of methods, including education schemes and distribution of water saving devices, but the scheme to date has had a relatively low reach. In 2011–2012, the total number of cistern devices distributed to households was 2946, of which an assumed 1423 were installed. Twenty-two water butts were distributed as part of a one-off promotion, while 4489 water audit packs were given out to households. Bearing in mind the current water efficiency programme in NI Water and the barriers to the installation of certain devices (e.g. cost, building disruption), this paper considers a 'quick fix' scenario using water saving devices that are relatively inexpensive and straightforward to install (Table 3).

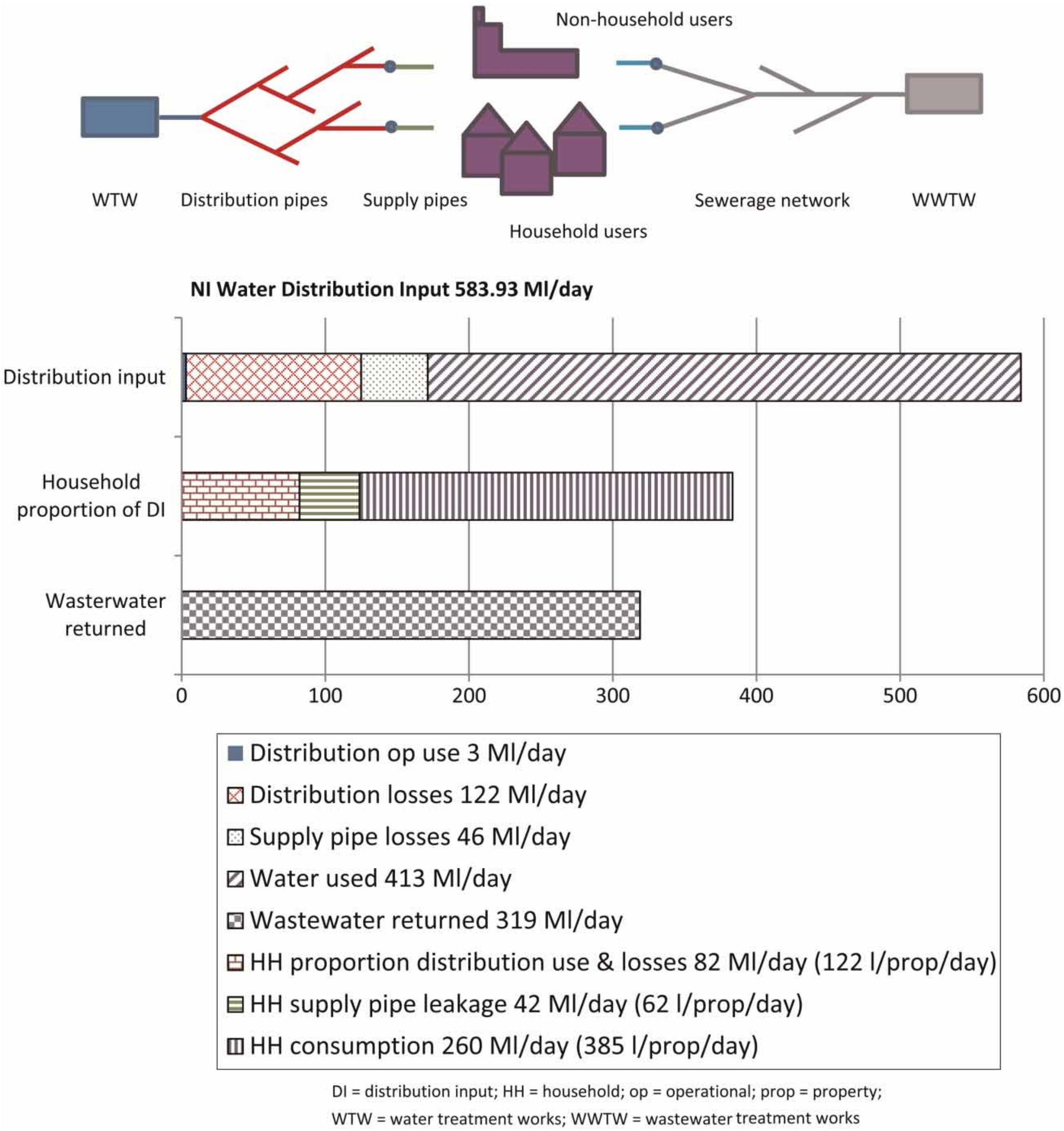

Figure 1 | Water balance in NI Water.

Carbon savings for NI Water

Household water savings result in lower carbon emissions from NI Water's operations from reduced water treatment and pumping, as well as from decreased wastewater pumping. The emissions from wastewater treatment are assumed to remain unchanged; while water efficiency measures reduce the volume of wastewater entering the sewerage system, there is unlikely to be any significant impact on load. NI Water carbon emissions for treating and pumping water and treating wastewater (Table 4) are from the most recent Annual Information Return (AIR12) and take account of electricity, other fuels, process emissions and credit for renewable electricity. Carbon emissions also arise from the use of other consumables, such as chemicals (i.e. from their production and transport), but these

Table 1 | Typical water use per household (supply pipe leakage excluded)

Appliance or activity	Water per appliance[a] %	Water per appliance[a] L/prop/day	Water requiring heating %	Water requiring heating L/prop/day
Toilet flushing	30	115.7	0	0
Personal washing (baths and taps)	21	81.0	75	60.8
Personal washing (showers)	12	46.3	100	46.3
Clothes washing	13	50.2	75	37.6
Washing up	8	30.9	75	23.1
Outdoor	7	27.0	0	0
Other	5	19.3	50	9.6
Drinking	4	15.4	0	0
Total	100	385.8		177.5

[a]The percentage of water per appliance is from Waterwise (undated), the volume is from Figure 1.

emissions are not currently reported by NI Water and are outside the scope of this paper.

The savings in the quantity of water treated and pumped are calculated from household savings, taking into account supply and distribution pipe losses and using the ratios in the overall water balance (Figure 1). The overall carbon savings to NI Water are affected by the uptake rate among households, which varies depending on a number of factors, including the method of distribution of water efficiency devices, e.g. by post or at events. A report by Waterwise (2011) considered retrofitting a whole town to convert toilets to dual flush and install water efficient showers and tap inserts. The report used an uptake rate of 10% for a worst case scenario, 20% for best case, and 15% as a best estimate. Assuming a rate of 15%, the 'quick fix' scenario would result in carbon savings to NI Water of 1,149 tCO_2e/yr, which is approximately 0.6% of the company's net operational emissions. Increasing uptake to 90% would save almost 6,900 tCO_2e/yr, which is 3.8% of current net operational emissions.

Carbon savings for households

The carbon savings from reduced hot water usage are calculated from (savings in quantity of hot water) × (heating demand for hot water) × (emission factor for heating water). Of the water efficiency measures considered in the 'quick fix' scenario, the shower timer, efficient shower head and tap insert result in hot water savings, estimated as 32 L/prop/day (Table 3).

The DECC (2012) Energy Consumption Survey reports on domestic heat use in Britain. In 2011, 18% of domestic energy consumption was for heating water. The survey also gives a breakdown of fuels used for heating water, but, due to differences in the domestic fuel mix between N Ireland and the rest of the UK, these data are not applicable

Table 2 | Water efficiency tools and estimated water savings achievable per property

Water efficiency tool	Estimated savings[a] L/prop/day	HH power savings	Savings in wastewater network
Cistern displacement devices	31.5	No	Equal to water savings
Shower timer	5	Yes	Equal to water savings
Tap insert	20	Some	Equal to water savings
Efficient shower head	29	Yes	Equal to water savings
Dual/variable flush device/conversion kit	25.4	No	Equal to water savings
Water efficient washing machines/dishwashers	20	Yes	Equal to water savings
Water butts	3	No	No
Trigger gun	2	No	No
Trickle/drip water system	1	No	No
Household water audits	10	Some	Some
Rainwater/grey water harvesting kit	100	No[b]	Some

[a]Estimated from Waterwise & Energy Saving Trust (2012), OFWAT (undated), and NI Water and supplier data.
[b]Likely increase in power use for pumping and/or treatment.

Table 3 | Water savings from 'quick fix' programme

Water efficiency tool	Estimated savings[a] L/prop/day	Savings from 'quick fix'[b] L/prop/day	Hot water savings from 'quick fix'[c] L/prop/day
Cistern displacement devices	31.5	7.9	0
Dual/variable flush conversion kit/ device	25.4	12.7	0
Shower timer	5	2.5	2.5
Efficient shower head	29	14.5	14.5
Tap insert	20	20	15
Trigger gun	2	2	0
Total		59.6	32

[a]Estimated water savings are from Table 2.
[b]It is assumed that cistern displacement devices are installed in 25% of lavatories and dual/variable flushes in 50%. The remaining 25% are assumed to already be low-flush. Half of showers are assumed to be electric (shower timer device installed) and half standard (efficient shower heads installed).
[c]The percentage of heated water in each device is from Table 1.

Table 4 | Carbon savings per household from reduced treatment and pumping

Stage	Water savings L/prop/ day	Water savings L/prop/ yr	Emissions[a] $kgCO_2e/Ml$	Emissions savings $kgCO_2e/prop/yr$
Water treated	88.0	32,110	258	8.3
Water pumped	88.0	32,110	77	2.5
Water delivered	69.2	25,242	–	–
Water consumed	59.6	21,745	–	–
Wastewater pumped	59.6	21,745	29.6	0.6
Total				11.4

[a]For water treatment and pumping, emissions per ML are for distribution input (DI). For wastewater, emissions per ML relate to the volume of wastewater treated.

to N Ireland. In Britain, 83% of homes have mains gas heating (Baker 2011) and gas is responsible for 84% of water heating (DECC 2012). In N Ireland, the penetration of gas is considerably lower: only around 15% of households have mains gas central heating (NIHE 2011). Although data on the fuels used for water heating in N Ireland are unavailable, the N Ireland House Condition Survey (NIHE 2011) provides details on the domestic heating fuel mix. The breakdown of fuels used for water heating was estimated from this data (Table 5).

The most recent report on domestic energy consumption in N Ireland gave average household consumption of 22,806 kWh/yr in 2005 (Utley & Shorrock 2008). This is higher than the UK value, which was around 17,000 kWh/yr in 2011 (DECC 2012). The domestic energy sector in N Ireland has more in common with that in the Republic of Ireland (ROI) than that in Britain (e.g. lower penetration of gas grid, high oil usage). In 2011, the average dwelling in the ROI consumed 19,875 kWh (Howley et al. 2012). Domestic energy use per dwelling in both Britain and the ROI has been on a downward trend over the past few years (DECC 2012; Howley et al. 2012), and the 2005 figure for N Ireland is likely to be on the high side. A value of 20,000 kWh/yr is chosen for use in this analysis. The percentage of domestic energy consumption for water heating in Britain is assumed, giving an annual demand of 3,600 kWh for water heating per household in N Ireland.

Hot water demand is estimated as 64,776 L/prop/yr (from Table 1), giving a heat demand of 0.06 kWh/L. With hot water savings of 32 L/prop/day, heat demand savings are 649 kWh/prop/yr and carbon savings from reduced hot water heating are 100 $kgCO_2e/prop/yr$. Adjusting for N Ireland occupancy and fuel emissions, this is of the same order of magnitude as the value reported by Waterwise (2011). Assuming 15% uptake among households, total carbon savings of 10,079 tCO_2e/yr could be achieved. While carbon from household water heating is not included in NI Water's emissions reporting, it is interesting to note that adding this to the carbon savings from reduced treatment and pumping gives total savings of 11,227 tCO_2e/yr, which is 6.2% of NI Water's net operational emissions.

Cost of water efficiency measures

Estimated costs to NI Water for bulk purchase of the water efficiency tools considered in the 'quick fix' scenario are presented in Table 6. Providing the water efficiency devices to 15% of the 672,816 households served by NI Water has a cost of around £1.6 million. Experience, however, suggests that not all distributed devices are installed, and the cost rises to £3.2 million if it is assumed that only half are installed. The costs in Table 6 are per device only. It is

Table 5 | Fuels used for water heating per household

Fuel	Heating fuel mix[a] %	Fuels for heating water[b] %	kWh/yr	Emission factor[c] $kgCO_2e/kWh$	Emissions $kgCO_2e/yr$	Emissions for water heating[d] $kgCO_2e/yr$
Non-central heating	1	–	–	–	–	–
Central heating	99	–	–	–	–	–
Gas	15.4	17.0	610	0.20435	124.69	21.14
Oil	68.2	69.8	2,511	0.29795	784.15	521.84
Solid fuel	4.4	–	–	–	–	–
• Coal	–	3.2	116	0.39361	45.70	1.47
• Peat	–	3.2	116	0.36515	42.39	1.37
Electric	4.1	6.2	221	0.58982	130.59	8.03
Dual	6.2	–	–	–	–	–
Other	0.7	0.7	25	0	–	–
Total	100	100	3,600	–	–	553.84
Emission factor for water heating						0.154 $kgCO_2e/kWh$

[a]From NIHE (2011).
[b]The domestic heating fuel mix was assumed to apply to hot water heating with the following assumptions: water heating in non-central heating homes is split evenly between electric and solid fuel; solid fuel is split evenly between coal and peat (similar to the split in the ROI (Howley *et al.* 2012)); water heating in households with dual systems is split evenly between gas, oil, solid fuel and electric. Domestic energy consumption is taken as 20,000 kWh/yr. The energy demand for heating water is assumed to be 18% of domestic energy consumption (DECC 2012).
[c]The emission factor for peat is the average of the emission factors for sod peat and peat briquettes from Howley *et al*. (2012). 'Other' fuel is assumed to be from renewables with an emission factor of zero. All other emission factors are Defra (2012).
[d]Emissions for water heating are calculated using the proportions of the different fuels in the water heating mix.
Numbers may not sum exactly due to rounding.

Table 6 | Cost of 'quick fix' scenario

Water efficiency device	Cost per device £	Number installed[a] Nr	Total cost £
Cistern displacement devices	1	25,231	25,231
Dual/variable flush conversion kit/device	10	50,461	504,612
Shower timer	1	50,461	50,461
Efficient shower head	10	50,461	504,612
Tap insert	0.50	201,845	100,922
Trigger gun	4	100,922	403,690
Total			1,589,528

[a]It is assumed that cistern displacement devices are installed in 25% of lavatories and dual/variable flushes in 50%. The remaining 25% are assumed to already be low-flush. Half of showers are assumed to be electric (shower timer device installed) and half standard (efficient shower heads installed).

assumed that devices in the 'quick fix' scenario could be installed and maintained by the homeowner. Costs associated with plumbing and maintenance are therefore assumed to be minimal and are neglected in this analysis. However, a more detailed analysis of costs should include an allowance for a visit to the home by a water/energy efficiency advisor. Research has shown that advice from such a specialist is very important in a water efficiency programme, as it helps to ensure the best use of water efficiency measures in a particular household (Waterwise & Energy Saving Trust 2012).

Cost savings for NI Water

A reduction in household water use results in cost savings to NI Water through reduced water treatment costs and reduced water and wastewater pumping costs. This analysis considers savings in electricity costs (the major energy spend), as well as savings from reduced carbon allowances requiring purchase under the Carbon Reduction Commitment (CRC). The cost paid by NI Water for electricity varies depending on the supplier and the specifics of a particular site, such as the time of day and the electricity load. On average, NI Water pays approximately £0.105/kWh for electricity (this is the total cost, including VAT and the Climate Change Levy). Under the CRC, NI Water must purchase allowances for each qualifying tCO_2e emitted by the company. The current cost of the CRC is £12/tCO_2e, but this will rise to £16/tCO_2e in 2014–2015 and will increase in line with the RPI (Retail Prices Index) from 2015–2016 onwards (HM Treasury 2012).

Electricity use in NI Water for water treatment and pumping was 629 kWh/Ml of DI in 2012, while the figure for wastewater pumping was 305 kWh/Ml of sewage treated. Using the assumed water savings from the 'quick fix' programme, cost savings from reduced electricity demand are £284,302/yr. Applying the current CRC price (£12/tCO_2e) to the emissions saved from reduced treatment and pumping gives cost savings of £13,785 in NI Water's CRC bill. Using a CRC price of £16/tCO_2e gives savings of around £18,400/yr, or about 1% of the 2012 CRC payment. The simple payback period to NI Water (without taking the cost of capital or possible rising energy prices into account) is about five years.

DISCUSSION

Water savings and metering

This paper considered a 'quick fix' scenario, which employed cistern displacement devices, dual/variable flush conversion kits/devices, shower timers, efficient shower heads, tap inserts and trigger guns to give total water savings of 59.6 L/prop/day, or 23.6 L/head/day in participating households. Assuming a 15% uptake, water savings among the total household population are 3.5 L/head/day. By comparison, the government's aim in England is to reduce average household water use by 20 L/head/day by 2030 (from 150 to 130 L/head/day) and, depending on new technological developments, this may be extended to 30 L/head/day (Defra 2008). The 'quick fix' scenario analysed in this paper may therefore be based on a low estimate of achievable water savings. That said, while water metering is in place in England, it is not used in N Ireland and there has to date been little political appetite for its introduction. Without water metering, there may not be such an incentive for change in domestic water consumption and a reduction of 20 L/head/day may be too optimistic for N Ireland.

Effectiveness of water saving devices

The quantities of water savings assumed for the devices in the 'quick fix' scenario were calculated from a range of sources from the literature and suppliers. The most up-to-date guidance on water savings in the UK was published in late 2012 by Waterwise and the Energy Saving Trust. This guidance contains a standardised set of values for the water savings from various devices (the primary sources of information were three UK-based studies that were based on both direct and indirect measurement).

The values used in the 'quick fix' scenario generally fall within the range given in the Waterwise/Energy Saving Trust report (after adjustment for N Ireland occupancy). The major exception is tap inserts. For the 'quick fix' scenario, savings of 20 L/prop/day were used (calculated assuming half of household taps are fitted with tap aerators, and assuming a reduction in water use of 50% on such taps (Waterwise & Energy Saving Trust 2012)). The value of 20 L/prop/day is similar to values quoted by OFWAT (undated), but is considerably higher than the range of 0 to 5 L/prop/day given in the Waterwise/Energy Saving Trust report. It should be noted, however, that the Waterwise/Energy Saving Trust report states that 'there is currently limited data available on actual savings' from tap aerators and that there have been significant problems with 'fitting and applicability' issues, leading to lower savings than previously assumed.

If the mid-range value in the Waterwise/Energy Saving Trust report (2.5 L/prop/day) is assumed for the 'quick fix' scenario, household water savings are reduced from 59.6 to 42.1 L/prop/day, and hot water savings from 32 to 18.9 L/prop/day. Savings in carbon emissions from reduced treatment and pumping fall from 0.6 to 0.45% of net operational emissions, while total carbon savings including those from reduced hot water usage in households decrease from 6.2 to 3.7% of net operational emissions.

The large uncertainties surrounding the effectiveness of certain water saving devices make it difficult to conduct a comprehensive assessment, and planners of water efficiency programmes need to be aware of these uncertainties. There can be huge variation in estimates, and specific NI Water field trials, along with more studies at industry level, are recommended to develop robust figures for the company.

Cost and heat savings

Only cost savings to NI Water were considered in this paper, and the simple payback period was calculated assuming that water efficiency devices were purchased by NI Water. However, reduced hot water use can bring significant cost savings to households and this should also be taken into account when assessing the cost benefits of water saving devices. Also of note is that fuel poverty is an increasing problem in N Ireland (NIHE 2011). Fuel poverty is defined as a household needing to spend over 10% of the household income on all fuel use to achieve a 'satisfactory standard of warmth' (NIHE 2011). At 44%, the number of households in fuel poverty in N Ireland is significantly higher than the 16% in England and the 33% in Scotland (NIHE 2011). The 'quick fix' scenario analysed in this paper reduced hot water heating demand by 18% and annual household energy usage by 3.2%. Further research is needed to analyse the cost benefits of reduced hot water use in N Ireland, particularly for households in fuel poverty.

Heat savings can also be achieved through reducing the quantity of water in a toilet flush. The heat loss from cold water in cisterns warming up and then being flushed away has been identified as significant in a number of reports, and the carbon emissions arising from this are reported to be of a similar magnitude to the emissions from water supply and wastewater treatment associated with toilet flushing (Environment Agency & Energy Saving Trust 2009). This is outside the scope of this paper, but should be included in a more detailed carbon analysis.

Reducing carbon emissions provides wider societal benefits, in that the effects of climate change may be lessened through a decrease in emissions. Previous advice has been to apply a 'cost of carbon' to quantify the wider impact of carbon emissions; however, the most recent guidance from UKWIR on project appraisals is to account for carbon in terms of tCO_2e, rather than in terms of cost (UKWIR 2012), and the cost of carbon is therefore not considered in this paper.

CONCLUSIONS

The analysis considered a 'quick fix' programme (cistern displacement devices, dual/variable flush conversion kits/devices, shower timers, efficient shower heads, tap inserts and trigger guns) to give average water savings of 59.6 L/prop/day. Carbon savings of 0.7% of current net operational emissions in NI Water are achievable from reduced water treatment and water/wastewater pumping, assuming uptake of water efficiency measures in 15% of households. Adding to this carbon savings from reduced demand for hot water in households gives total savings of over 11,200 tCO_2e/yr, which is equivalent to 6.2% of current net operational emissions. Reduced electricity demand for treatment and pumping, along with reduced carbon payments under the CRC, could deliver cost savings in the region of £300,000 to NI Water. However, this has to be weighed against the cost of the water efficiency devices, which is estimated as £1.6 million (although the actual cost would probably be more, as it is unlikely that all distributed devices would be installed). Whether or not NI Water should carry the cost of the devices is open to discussion, as the estimated 18% reduction in hot water heating demand would result in considerable cost savings to households. This could have a significant impact in N Ireland, where 44% of households are in fuel poverty. This paper has shown that there are clear carbon benefits to water efficiency, but the associated social and cost benefits, particularly to households, require more research. Further research, both company-specific and industry-wide, is also needed to obtain more accurate figures for the water savings achievable from water saving devices and measures.

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