Sustainable homes: a methodology for assessing influence on regional water demand
Ana Paula Micou, Gordon Mitchell and Adrian McDonald

ABSTRACT

Growth in population and households, and lifestyle changes are factors placing water resources under increasing stress in some parts of the UK. The Code for Sustainable Homes (CSH), a government regulation defining performance standards for new dwellings, is one measure that may act to counter rising domestic water demand. One goal of the CSH is to reduce potable water use per capita in each home through implementation of water conservation measures. This paper reports on work in progress that aims to understand the likely impact of the CSH on regional and national water demand. A spreadsheet model is being developed to assess domestic water demand under a range of CSH uptake scenarios, as well as a range of demographic, technical, economic and behavioural aspects of water consumption and conservation. The paper discusses the model development and presents some preliminary results for the Yorkshire region.

INTRODUCTION

Whilst flooding has regularly captured the news headlines in the UK in the last decade, it must not be forgotten that drought is another type of extreme event made more likely by climate change. (Indeed, as we write, drought orders have been implemented in the East of England as a whole since 1990.) Prolonged reductions in expected rainfall have the potential to seriously disrupt life, particularly in water stressed regions where demand already represents a high share of available supply. This risk of drought added to the growing demand for water acts to highlight the pressure on UK water resources.

In the UK water, companies supply water for four main purposes: public water supply, power generation, agriculture and other sectors of industry (McDonald et al. 2003). Public water supply involves domestic and commercial use, miscellaneous uses and leakage and this figure rose from 33.60% of the total abstractions in 1971 to 50.78% in 1991 (Herrington 1999). This increase was mostly due to the domestic demand of the public water supply, representing 37% in 1961 and 44% in 1991 (Herrington 1996). Figure 1 (DEFRA 2008) illustrates that the domestic sector now accounts for well over half of all water put into public supply.

Domestic demand continues to grow, a consequence of lifestyle changes that lead to increased use per capita, as well as a growing population and a decline in household size (in general the average household size has decreased from 2.9 persons per household in 1971 to 2.4 in 2008 (CASWEB 2011)), which fuels demand for new dwellings (the last government planned for 3 million new homes in England from 2006–2020).

Regarding domestic consumption per person, the average in England increased from 85 l per capita per day (l/c/d) in 1961 to 147 l/c/d in 1991 (Herrington 1996). Nowadays the average for England and Wales is 150 l/c/d, being stable since 2000 and in some regions even decreasing (EA 2007b).

Using water wisely is clearly important, and a range of conservation measures exist to reduce loss, consumption and waste. With its legacy of Victorian infrastructure, the UK loses up to a quarter of its supply through leakage, and major investment is being made in infrastructure.
renewal and innovative leakage repair, such as Yorkshire Water’s ‘platelet system’ (Yorkshire Water 2011), to reduce this loss. Using resources efficiently is also important and this approach means developing demand management strategies, particularly for the domestic sector.

Demand management instruments include unit pricing (via water metering), technology (e.g. water efficient appliances such as dual flush toilets and aerating taps, wastewater re-use, rainwater harvesting), asset management (e.g. pressure reduction), and education to bring about change in water use behaviours.

Legislation introduced in the UK in 2006 seeks to ensure that new dwellings are more environmentally sustainable. The Code for Sustainable Homes (CSH) sets performance targets for new housing, measuring overall sustainability on a 1–6 star rating scale (6 being the most demanding), addressing a range of categories covering resource use, pollution, health and well-being. One goal of the CSH is to reduce potable water use per capita through implementation of water conservation measures.

The structure of the Code and its quasi voluntary nature make understanding its effects difficult, due to the great number of ways in which it could be realized in practice. Therefore a model is being developed with which a wide range of scenarios can be explored. For example, we could have a scenario in which a great proportion of new houses are built to low CSH levels where standards are relatively undemanding (120 l/c/d), combined with a small proportion to the highest level (80 l/c/d), reflecting the reduced regulatory push. Conversely, we could have a situation in which demand for ‘green homes’ rises, and developers’ ability to respond to this demand improves, lowering the price of constructing sustainable homes, with many more high code level homes built, with lower water demand.

Furthermore, there are other factors not intrinsic to the CSH but directly related to it, which make the situation more difficult to predict. Demographic changes including household growth levels and household size tendencies will also affect the impact of the CSH on water demand. Lower building rates, as observed during the recession, and the increasing number of small households, particularly single occupancy households, might further reduce the effects of the CSH on overall per capita demand.

People’s behaviours will also affect the expected savings achieved by water demand management policies and the CSH in particular, also making effects difficult to predict. Aspects of behaviour involve either the willingness to retrofit with water saving devices or the acceptance of water saving measures by people moving into a CSH house. In the case of a CSH house, level 6 might be achieved through the implementation of a combination of water saving techniques like grey water recycling, low pressure taps and dual flush toilets. However, it cannot be assumed that these interventions will always remain in place and as effective as originally intended. Once householders are living in the house, there is nothing to stop them replacing these devices with conventional ones with a higher use of water should they feel uncomfortable. Also the way devices are actually used is another thing that is not well understood, as habits and preferences vary greatly.

The uncertainty surrounding CSH implementation means it is necessary to study a range of possible futures comprising aspects of the technology implied by the CSH, demography and construction trends, as well as behavioural aspects.

The main goals of the research are to understand the level of CSH uptake, at various performance standards, needed to achieve Government aspirations of 130 l/c/d overall, and as UK regions grow, to understand what impact the CSH might have on future regional household water demand.
This paper presents the methodology being developed to help assess the impact of the CSH on regional water demand in England over the next 25 years. The model structure is described along with a brief description of the constituent variables. Some preliminary results are presented and discussed.

THE CODE FOR SUSTAINABLE HOMES

The CSH is a regulation introduced by the Communities and Local Government Department (CLG) in December 2006, and became operational in April 2007. It is managed by BRE Global, the main licence holder. The CSH ‘measures the sustainability of a new home against nine categories of sustainable design, rating the ‘whole home’ as a complete package’ (CLG 2008a: 7). The categories are: energy and CO₂ emissions, water use, materials, surface water run-off, waste, pollution, health and well-being, management and ecology.

The main aim of the water category is ‘to reduce the consumption of potable water in the home from all sources, including borehole water, through the use of water efficient fittings, appliances and water recycling systems’ (CLG 2009a–c: 97), encouraging the harvesting of rainwater and reducing the amount of mains potable water used for external water use. The CSH allows for six levels of attainment in each category. Table 1 shows the maximum water consumption allowed to qualify for the various CSH attainment levels.

It is important to highlight some characteristics of the CSH that need to be addressed when assessing its effects:

- The CSH applies only to those houses built after 2007.

- CSH is not strictly mandatory, and developers have two options. Their developments can be tested against the CSH, in which case they get a certificate displaying the CSH level attained, or they can decide not to have the house assessed, in which case the house gets a ‘nil certificate’ to inform buyers that the house is not built against CSH requirements (CLG 2009a–c).

- The only case where the CSH is mandatory is for new publicly funded housing projects, like those from the Homes and Communities Agency. Such houses must currently be built to a minimum level 4 (Cyril Sweet 2007; CLG 2008b) but the minimum standard is expected to move to level 6 in 2013 (Cyril Sweet 2007).

The model

Figure 2 shows the conceptual model including the principal factors to be taken into account, and the relationships between them. The model treats existing dwellings (i.e. all dwellings already built in 2006) and planned dwellings (those to be built in or after 2007) as two separate entities, as policies on water efficiency for these are different. This paper examines more deeply the effects on water demand of new-built dwellings.

Figure 2 shows total consumption is the sum of consumption in existing houses and in new (to be constructed) houses:

\[
C = C_E + C_N
\]

(1)

where \(C\) = total consumption, \(C_E\) = consumption in existing houses, \(C_N\) = consumption in new houses.

Demand in new housing depends on two variables: the number of new properties that will be built and patterns of consumption in those households. This last variable will be different from the present consumption for two main reasons. First, the application level of the CSH: The CSH is not mandatory for all construction, and dwellings may be built to different code levels and water consumption standards; and second, an amendment to Part G of the Building Regulations (BR) sets to 125 l/c/d the maximum consumption of water for new dwellings (CLG 2008b). (Building Regulations set standards for design and construction

<table>
<thead>
<tr>
<th>CSH level</th>
<th>Maximum indoor water consumption (l/c/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>120</td>
</tr>
<tr>
<td>Level 2</td>
<td>120</td>
</tr>
<tr>
<td>Level 3</td>
<td>105</td>
</tr>
<tr>
<td>Level 4</td>
<td>105</td>
</tr>
<tr>
<td>Level 5</td>
<td>80</td>
</tr>
<tr>
<td>Level 6</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: Department of Communities and Local Government (CLG 2009a, b, c).
which apply to most new buildings and many alterations to existing buildings in England and Wales. Part G relates to sanitation, hot water and water efficiency.)

This situation means that even if houses are not built against the CSH, residents should not consume more than 125 l/c/d. This amount is still not sufficient to attain the least demanding CSH level, but does represent a lower per capita demand than commonly assumed for current dwellings (150 l/c/d). Hence the formula for new dwellings is:

\[
C_N = \%D_{N\text{CSH}1} \times 120 + \%D_{N\text{CSH}3} \times 105 + \%D_{N\text{PGBG}} \times 125
\]

where \(\%D_{N\text{CSH}}\) = proportion of new dwellings built to various CSH standards – the numbers represents attainment levels (1 = level 1–2; 2 = level 3–4; 3 = level 5–6), and \(\%D_{N\text{PGBG}}\) = proportion of new dwellings not built against the CSH, but against Part G of BR.

Consumption is also closely related to household size. As the latter falls, water consumption per household falls, but consumption per capita rises as economies of scale opportunities decline (Butler & Memon 2006; Environment Agency 2007a, b).

Each of the household size and dwelling types categories has been estimated for the future in 5-year intervals, using an annual growth rates model with data of the National Censuses of 1981, 1991 and 2001. This method has been used before by a research team at the School of Geography (University of Leeds) as part of the WAND project (Parsons et al. 2009). The same procedure is carried out for dwelling types (detached, semi-detached, terraced and flats).

Once the two sets of results are ready (household size and dwelling type) the projected counts are turned into proportions using Iterative Proportional Fitting (IPF). The IPF procedure is an iterative algorithm for estimating cell values of a contingency table such that the marginal totals remain fixed and the estimated table decomposes into an outer product (Stephan 1942). The result of this calculation gives total number of houses by category of household size and dwelling type (see Table 2).

Then, the corresponding proportion of households of each of those categories will be multiplied by the number

<table>
<thead>
<tr>
<th>Household size</th>
<th>Detached</th>
<th>Semi-detached</th>
<th>Terraced</th>
<th>Flats</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>27,060</td>
</tr>
<tr>
<td>Total</td>
<td>19,531</td>
<td>40,347</td>
<td>19,884</td>
<td>5,238</td>
<td>85,000</td>
</tr>
</tbody>
</table>

Figure 2 | Model structure.
of people in a household (1, 2, 3, 4 or 5.3 to represent households >5 persons) and by the water demand coefficients in order to obtain total consumption. The demand function for houses built to CSH level 3 with three occupants is thus:

$$C_N = (%D_N \times 105) \times (%\text{HO}_3 \times 3)$$

(3)

where %HO3 is the share of houses with three occupants; similar calculation across all CSH levels and household size categories lead to a total demand estimate.

The number of houses built against the CSH and its various attainment levels will vary over time, and depends on factors such as Government incentives, construction costs and further legislation (e.g. were the CSH to become mandatory for all new construction). The spread of CSH-compliant construction in the future is not only linked to water legislation, but relates also to Government goals on energy saving.

The reduction in water use and waste also means a reduction in energy use. Water management strategies, apart from reducing water consumption, are also effective at energy consumption reduction. Embodied energy (the energy that is present in a product virtually) in water supply is present in various stages of its life cycle. In a water supply network, leakage can be seen as water loss but also as a loss of energy used over the life cycle of the lost water – energy used in collection, treatment and distribution.

This situation applies at the household level too: a householder who saves water, probably also saves energy (which is a bigger motivation as energy costs much more), primarily because they use less hot water. That is, domestic water conservation may be driven more strongly by energy conservation initiatives addressing water heating, than by direct water conservation measures. Thus householders are likely to be more attracted by an energy efficient house than a water efficient one because of running costs.

The model addresses a 25-year horizon in 5-yearly steps, and is currently developed for the Yorkshire and Humber region of northern England, but is readily applicable to other parts of the country with the requisite input data. Demand estimates are made by Local Authority (LA) area (summed to regional total), and could be presented by water utility geographies with appropriate GIS based geoconversion.

The model is developed as a spreadsheet (Excel-based) application. Base inputs are matrices of dwelling projections by household size and dwelling type. The user is able to change the list of LAs so that appropriate matrices for other regions of England can be entered.

The model’s front end is a Visual Basic for Applications (VBA) form supported by a number of Excel macros recorded and coded using VBA subroutines and functions. The application (form) was made to be as simple yet flexible as possible so an inexperienced user should be able to use it with minimal training.

The model can be run for either existing or new houses alone or both together. Drop-down menus in the form make it easier to select previously run scenarios and any number of these can be saved as worksheets for future reference.

The final output of the model is a table with combined results of demographic and water consumption data for existing and new houses by LA area, and the entire region.

Model application

Baseline forecasts have been derived addressing different demographic projections, housing planning policies and assumptions about attainment of government water consumption targets. These baselines address:

- House construction projections informed by the Yorkshire and The Humber Regional Spatial Strategy (RSS) (GOYTH 2008).
- Household occupancy and dwelling type proportions – own projections based on historical census data. For these the growth rate of the whole region has been applied to each LA.
- Part G of the BR, mandatory for all new houses. This scenario assumes all new houses consume no more than 125 l/c/d.
- CSH uptake – baseline assumes new houses are not built to CSH standards.

Table 3 presents four test runs to illustrate the nature of the scenarios.
RESULTS AND DISCUSSION

All the test runs show increased demand except run 2 (R2) where a significant decrease is estimated (Figure 3). Run 1 (R1) (baseline values) experiences an increase in total consumption even though all new dwellings are more efficient than existing ones. The highest increase can be seen in R4 where the consumption rose 6% from 2006–2031.

An important decrease can be seen if all new dwellings achieve the highest CSH levels (R2). However, R2 is an extreme case which seems unlikely in practice, given the quasi-voluntary nature of the Code. Run 3 (R3), on the other hand, represents an arguably more realistic scenario where CSH uptake is as observed in 2010 (CLG 2010a, b) with constant application throughout the forecast period. This finding reveals that, with the current low levels of uptake, the CSH is unlikely to have much impact as a water conservation instrument.

So far, all the test runs develop housing at the rate implied by regional plans (the RSS). However, figures on completed house construction by LA area and the entire region show that on average less than half of the suggested targets are attained (CLG 2010b; GOYTH 2008). Thus run 4 (R4) uses the same percentage of CSH uptake as R3 but with only 50% of the building rates implied by the RSS. This situation results in an increase in demand relative to the baseline as fewer water efficient homes (compliant with Part G BR) are built.

These preliminary results show how the model responds to changes in demographic and housing inputs, and to assumptions about market penetration and attainment levels for the CSH.

R1 showed that even with construction at the rate assumed by the Regional Plans and the consumption target required by BR (125 l/c/d), regional water demand will still rise (due to an increasing proportion of low occupancy households).

The analysis also shows that the present 4% uptake of the CSH (most at level 3–4) if maintained in future will have little impact on demand. Moreover, if half of the houses proposed in the regional plans are built, demand will increase at even higher rates.

The only case where water demand falls is the extreme example where all planned houses are built against the higher CSH level, but even here, the decrease in demand is just 4% in 25 years, just reaching the aspirations of the Government (an average of 130 l/c/d) only by 2031.

It is difficult to presume that the R2 scenario will become realistic, unless implementation of the CSH becomes

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**Table 3** Details of each run

<table>
<thead>
<tr>
<th>Run</th>
<th>Scenario Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baseline See text</td>
</tr>
<tr>
<td>2</td>
<td>CSH – high attainment All new houses built to CSH level 5 (80 l/c/d)</td>
</tr>
<tr>
<td>3</td>
<td>CSH – observed penetration and attainment 4% of total dwellings completed this year obtained a CSH certificate, 97% of them built to level 3–4</td>
</tr>
<tr>
<td>4</td>
<td>New dwellings and CSH As run 3 but only 50% of planned construction achieved</td>
</tr>
</tbody>
</table>

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**Figure 3** Water consumption (l/c/d) for the four scenarios – 2006–2031.
mandatory for all new build. But even so, CSH levels 5 or 6 are ambitious and require systems such as grey water recycling or rain water harvesting, which are costly and not always welcome by the public. The most probable scenario for the future is a mix of dwellings achieving different CSH levels with many achieving none, and only developed to meet the 125 l/c/d target dictated by the BR.

The factors discussed above could be represented readily in the model but there are aspects that because of their nature are more challenging to model.

First, the CSH and BR assume that certain per capita consumption targets will be attained so long as the requisite infrastructure (fitting, etc.) are in place. Certification against these codes and regulations is based on evidence that such infrastructure is in place, not according to observed consumption, which could be substantively different depending upon individual users.

Second, the ‘Water Calculator’ (CLG 2009c), an online tool provided by government to allow developers to understand how their designs perform relative to CSH standards, may be rather inaccurate as it is based upon water appliance manufacturers’ consumption figures, which may be overly optimistic and do not address occupant behaviour.

Third, the extent to which CSH and BR homes remain compliant over time is unknown. As was mentioned in the introduction, occupiers may be dissatisfied with the experience offered by, say, aerating taps or shower heads, and replace them.

The last caveat has to do with the attainment of BR. The majority of new developments do attain the building standards but there is some evidence that as much as 30% of buildings fail some element of the standard. The issue is the strength of the regulator on monitoring; there is no evidence yet of whether developers are respecting Part G of the BR. To date, we must assume that developers are respecting Part G of the BR, but experience indicates that this situation may not be so.

Uncertainty for CSH study

In our study several sources of uncertainty for studying the effects of the CSH are recognized:

- uncertainty in the CSH itself
- uncertainty in scenarios design
- uncertainty in model design.

The introduction of the CSH evidently has the potential to mitigate against rising domestic water demand, but the structure of the Code and its quasi voluntary nature makes understanding these effects difficult. The great number of ways in which the Code might be realized in practice, and other factors not intrinsic to it but directly related to its application, make assessment yet more challenging.

The uncertainty surrounding the effects on future water consumption of demand strategies in general, and of the CSH implementation in particular, means it is necessary to study a range of possible futures comprising aspects such as the technology implied by the CSH, demographic characteristics and construction trends. Behaviour aspects are another source of uncertainty for our model: some users may love the green technologies, others may hate it. We do not know how the CSH will survive, and hence the degree to which assumed CSH water savings will be lost over time.

As we do not know which of the development scenarios is more likely, we would seek to involve stakeholders in scenario design (e.g. developer views on market for CSH homes; householder views on low water use fittings, etc.).

Other sources of uncertainty are related to the model design and input data: the demography part of the model is considered to be more confident as it is based on official published data and also the demographic aspects are not expected to have a radical change in the next 25 years. By contrast, the drivers related to water management policies are more uncertain for many reasons:

- **Baseline demand**: we do not have a good baseline of domestic demand against which to test CSH effects. This situation is due to a lack of adequate actual data, essentially a consequence of a water supply system in which the majority of users are not metered.
- **CSH application**: we consider many demand dependent factors in our model but note that there are certain factors intrinsic to the regulation which were not included, and which must be addressed via a scenarios approach with a high degree of uncertainty. These aspects are largely behavioural in nature, relating to householder choices and habits in relation to water use. These factors are potentially highly influential on demand.
Uncertainty also appears in the model relationships: for example the relation between household size and the consumption per capita in a CSH home does not reflect the economies of scale which are present as occupant numbers increase.

**CONCLUSIONS**

Although a work in progress, the model already appears to offer a useful basis for exploring the impacts of the CSH on water demand. Initial analyses suggest that whilst the CSH has the potential to mitigate future rises in demand, the likelihood of it doing so currently appears low, if the CSH remains voluntary for most new home construction.

To date, the model has only been used to explore a small number of test scenarios. Future work will address: (a) model enhancement to better address the behavioural aspects of demand and the CSH; (b) model enhancement to better address components on water efficiency for existing houses where the CSH is not currently applied (but could be, e.g. on change of ownership); (c) sensitivity testing to understand the relative importance of demand factors; and (d) developing scenarios that are thought to represent the most likely future trends in those factors (house building, CSH attainment, etc.). This aspect of the work would seek to involve stakeholders in scenario design (e.g. developer views on market for CSH homes; householder views on low water use fittings, etc.). It would also seek to assess spill-over effects of energy conservation measures (re: hot water) on water demand.

**REFERENCES**


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