Artesia Consulting

Cambridge Water

WRMP19 Household consumption forecast: Baseline forecast

Final

AR1243

December 2018

Report title:	**WRMP19 Household consumption forecast: Baseline forecast**
Report number:	**AR1243**
Date:	**December 2018**
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Executive Summary

The current Water Resources Planning Guideline identifies the need for water companies to use methods for supply and demand analysis that are appropriate to the level of planning concern in their water resources zones (WRZs).

In the 2014 Water Resources Management Plan (WRMP14) Cambridge Water was able to demonstrate a surplus in deployable output for the planning period out to 2039/40, and therefore available headroom, in the baseline supply demand balance for the next 25 years.

The demand forecast in WRMP14 was based on expected housing growth of 47,000 new properties to be built by 2040. The expected growth for WRMP19 is now approximately 43,000 new properties by 2045.

These changes between WRMP14 and the draft WRMP19 plan suggest that the 'problem characterisation' for the single water resource zone (WRZ) of Cambridge Water should be 'moderate'. A separate detailed problem characterisation exercise has been undertaken by the Company and this has confirmed this.

A baseline household consumption forecast has been produced for the Cambridge Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a moderate level of water resource planning concern.

The micro-component model has been developed using best available data from local and national datasets. The model is segmented by property type using unmetered, new build metered and free optant metered households. The model is based on per household consumption (PHC), and includes linear modelling of key micro-components against occupancy to reflect the variation of PHC by occupancy within each household type. The model forecasts are developed from historic industry and UKWIR micro-component datasets and Market Transformation Programme predictions (these are explained in the report).

The results of the micro-component forecast give a 7.88 Ml/day increase in household consumption for Dry Year Annual Average consumption, this is a 17.70% increase. This is largely driven by a 34% increase in the property forecast. Average PHC and PCC decrease throughout the forecast period, this is partly due to decreases in component demand due to market transformation, but mostly due to the shift from unmeasured to measured, properties. Average household PCC (mean of all household types) reduces from 141 to 133 l/person/day.

The model contains forecasts for Normal Year Annual Average, Dry Year Annual Average and Critical Period; with a breakdown of micro-components for each year of the forecast.

Contents

Tables

Figures

1 Context

Cambridge Water used a trend based forecast to predict household consumption in WRMP14. This predicted a change in PCC from the base year for unmeasured and measured properties; resulting in an average trend in PCC for all households from 140 l/person/day in the base year to 125 litres/person per day in 2040. The PCC forecasts were then apportioned across the micro-components based on micro-component percentages provided by South Staffordshire Water.

The problem characterisation for the company's single water resource zone has been confirmed as 'moderate' for WRMP19. An assessment of suitable household consumption forecasting methods was carried out based on a moderate medium level of concern. This took account of known data availability for the Cambridge WRZ, and indicated that micro-component modelling would be the preferred forecasting approach for this level of concern. A suitable alternative would be regression modelling, however, Cambridge Water does not have sufficient data and information on individual household consumption and property characteristics to enable regression modelling.

Therefore it has been decided to develop a new micro-component forecast for WRMP19.

Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g. showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). This study makes use of a national micro-component survey of 62 properties, alongside survey data which was collected at property level for the monitoring period.

The micro-component model is combined with property, population and occupancy forecasts in a unique way in that the micro-components vary with occupancy. Certain components have a valid relationship with occupancy, and others don't. This method is used to calculate base year OVF PHC values, which are then calibrated to the zonal normal year PHC values.

Forecasts of the property, population and occupancy are established by household segment via a model to allow for various assumptions and mathematical calculations as the company tends towards 100% meter penetration. Each household segment has a different base year OVF table / calculation, these are based on both measured differences between measured and unmeasured households, as well as assumptions made about devices within new properties and optant properties.

Micro-components are then forecast using a combination of longitudinal micro-component data and future market transformation programme derived micro-component values. These trends are applied to the normal year micro-component values. An additional occupancy specific trend is also added, to ensure that the varying occupancy within each of the household segments is captured.

Data from national studies was used to update previous micro-component estimates (from surveys, the Market Transformation (MTP) scenarios and other, older sources), and to consider upper and lower consumption forecasts.

Relevant data, existing survey results, and consumption data from metered customer billing records were all analysed and investigated, along with data collected in the 2016 UKWIR behaviour integration study, to estimate base year micro-component estimates.

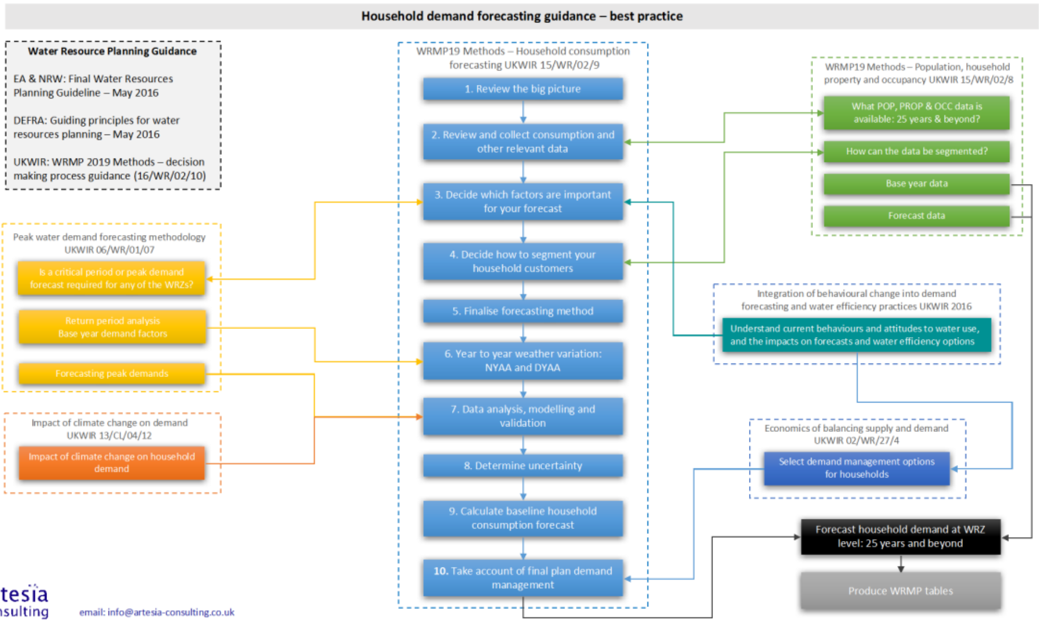
Household customers were segmented based on meter status (measured/unmeasured), with sub-divisions for meter type (existing metered, free meter optants, new property). Data was used to determine how to account for differences in consumption between segments and also the effect of meter switching.

Normal year and dry year adjustments were made to the base year consumption and the consumption forecast.

A scenario approach to modelling uncertainty was used, to reflect the various uncertainties in consumption forecasts.

Best practice guidelines (detailed in Figure 1) have been followed in deriving the baseline household demand forecast.

Figure 1 Best practice guidelines for household demand forecasting



2 Method selection

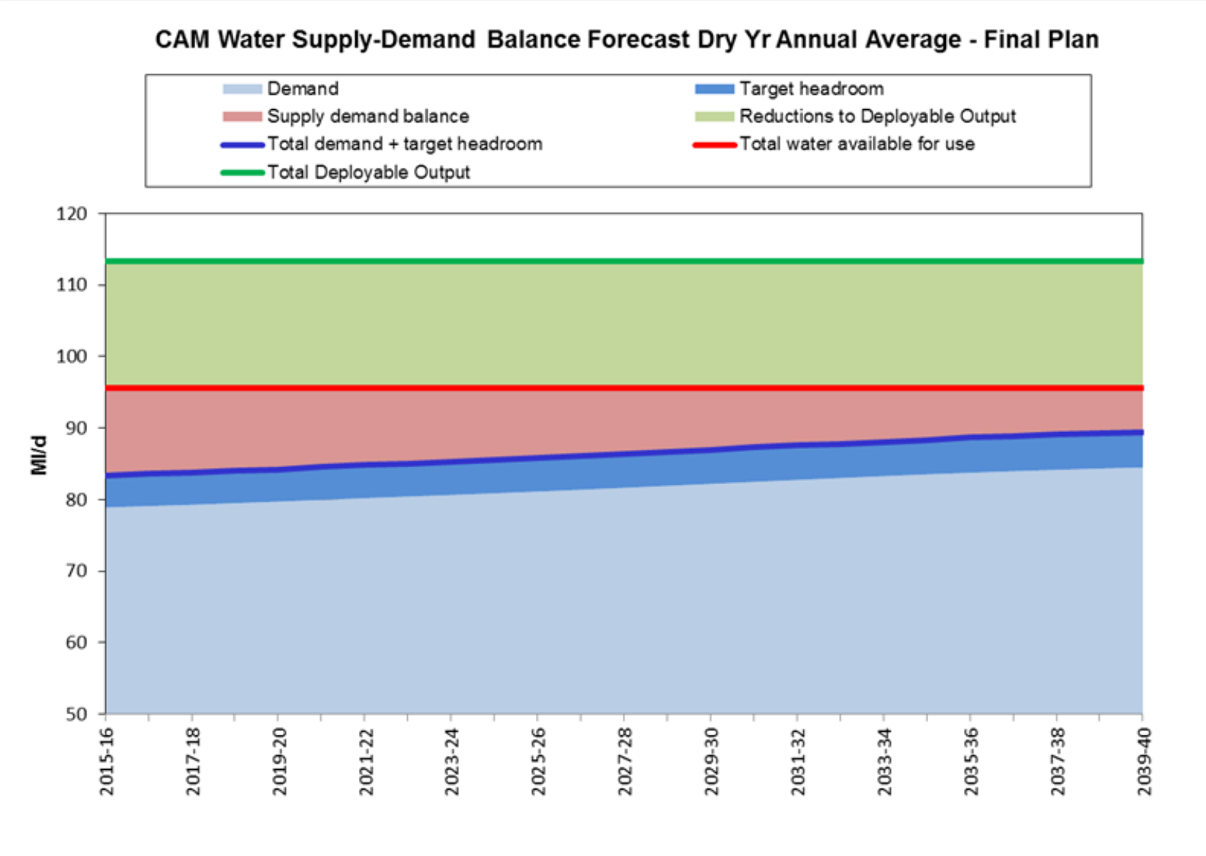
The current Water Resources Planning Guideline[1] identifies the need for water companies to use methods for supply and demand analysis that are appropriate to the level of planning concern in their water resources zones (WRZs).

In the 2014 Water Resources Management Plan (WRMP14) Cambridge Water was able to demonstrate a surplus in deployable output for the planning period out to 2039/40, and

[1] Water Resources Planning Guideline: Interim Update April 2017

therefore available headroom, in the baseline supply demand balance for the next 25 years. This is illustrated in Figure 2.

Figure 2 **WRMP14 Cambridge Water Supply-Demand Balance Dry year annual average - final plan**



The demand forecast in WRMP14 was based on expected housing growth of 47,000 new properties to be built by 2040. The expected growth for WRMP19 is now approximately 43,000 new properties by 2045. There are ongoing investigations into the sustainability of Cambridge Water abstractions, which means that the expectation is that there may be supply-demand deficits in the baseline forecast for WRMP19.

These changes between WRMP14 and the draft WRMP19 plan suggest that the 'problem characterisation' for the single water resource zone (WRZ) of Cambridge Water should be 'moderate'. A separate detailed problem characterisation exercise was undertaken by the Company, and has confirmed the 'moderate' status. This will be a factor in the choice of method for forecasting household consumption, as described below.

2.1 Approach

Guidance on the selection of appropriate household consumption forecasting methods were developed by UKWIR (UKWIR, 2016), along with guidance on the application of these methods.

The UKWIR guidance identifies nine criteria and a weighting and scoring framework, set out in a 'RAG Matrix'[2]. The guidance recommends that practitioners adapt the weightings and scores in this matrix to reflect their own situation, in order to identify the most appropriate methods for forecasting household consumption. In particular, the matrix should be amended to reflect the level of planning concern in a particular WRZ.

Cambridge Water has used the RAG matrix, with amendments to reflect the status of its single WRZ to shortlist preferred methods for household consumption forecasting. The assessment that has been undertaken is presented in the following sections.

2.2 RAG matrix and comments

Figure 3 illustrates the results of the RAG matrix.

Figure 3 Cambridge Water RAG Matrix for household consumption forecast method selection

Cambridge (Moderate)	Weighting	Regression models	Micro-component models	Macro-component models	Trend-based models	Variable flow methods
Acceptance by stakeholders	20	6	8	7	5	3
Explicit treatment of uncertainty	14	8	6	6	5	3
Underpinned by valid data	14	6	6	7	5	3
Transparency and clarity	10	6	8	7	4	4
Appropriate to level of risk	10	8	7	6	5	4
Logical and theoretical approach	4	8	8	8	6	4
Empirical validation	3	6	7	7	6	5
Explicit treatment of factors that explain HH consumption	2	6	7	7	6	4
Flexibility to cope with new scenarios	1	8	6	7	4	4
Weighted score		**526**	**551**	**526**	**388**	**267**
Rank		**2**	**1**	**2**	**4**	**5**

Table 2 provides comments on the justification for the scores presented in Figure 3.

2 Red Amber Green Matrix, used to highlight which methods score best to worst

Table 1 Justification for RAG Matrix scoring

Criteria	Comment
Acceptance by stakeholders	Based on current methods (using national data and forecasts to develop trend-based m-comp projections), the micro-comp approach should score more highly. Macro-comps should also score well given the context. Regression could be an option although data is likely to be an issue
Explicit treatment of uncertainty	Regression models do this best, so should score more highly.
Underpinned by valid data	The quality of data available e.g. from SODCON for PCC/PHC is not sufficient for regression models - so this is marked down. There are limited regional micro-component data, therefore the macro-component approach could be more appropriate, so is scored higher. Trend data is probably stronger at the macro level.
Transparency and clarity	Using macro or micro-components underpinned by trends based on observed and forecast (MTP) trends will provide the appropriate level of transparency and clarity for this WRZ, given the lack of data
Appropriate to level of risk	Methods should score relative to each other left to right across the matrix
Logical and theoretical approach	Given the level of concern and the data available, all most viable options score equally.
Empirical validation	Whilst the regression model should be better at this, the data won't allow it. The micro-component BY demand model can be calibrated against the BY reported PHC values; these also feed into the start of the macro forecast. The same approach can be tested on the model 5 years ago to see how it would turn out against the current PHC values to validate the forecast.
Explicit treatment of factors that explain HH consumption	Same comment re data availability and the regression - so marked down. The micro and macro models pick up the main technological trends and personal bathing trends without the data requirements of the regression model.
Flexibility to cope with new scenarios	Regression models do this best, so should score more highly, macro-comps is more flexible than micro-comps.

The weightings used in the matrix are based on industry standards, amended where appropriate to reflect the Cambridge Water position.

The scoring reflects the relevance of the methods to the Cambridge Water situation – particularly with regard to the level of planning concern in the WRZ and the availability of company-specific data, particularly for regression modelling.

Based on this, there are two viable candidate options – micro-components and/or macro-components, as there are insufficient company-specific data to proceed with regression modelling.

A micro-component forecast, has been selected, as per the RAG matrix. This will be based on recent national micro-component data to establish a base year model of consumption.

3 Review data availability

3.1 Base year data

The base year selected for the Draft model is 2017/18.

Base year figures have been extracted from Table 10 of the June returns. Cambridge Water has one water resource zone (WRZ). The base year per capita consumption excluding supply pipe leakage (PCC) for measured and unmeasured properties are 128.39 litres/head/day and 179.09 litres/head/day respectively.

Measured and unmeasured property and population figures are also extracted from the June returns. In the base year Cambridge Water has 92,580 measured properties and 36,401 unmeasured properties. Population within the measured households is 214,270, with a resulting occupancy of 2.31, the population of unmeasured properties is 100,790 with a resulting occupancy of 2.77.

The calculated per household consumption (PHC) values post MLE for measured households is 297.15 litres/property/day, unmeasured PHC is 495.87. This is calculated from the reported PCC figures combined with the reported occupancy figures.

3.2 Other data

Cambridge water supplied Artesia with some other data sources which are either used in the forecast, or for validation of the model. This data includes historic trends from the June Returns, the WRMP14 forecast, CACI forecast for population and properties, historic weather data, historic distribution input (DI) data , also survey data for micro-components from the SODCON domestic consumption monitor (DCM).

In addition to the data provided by Cambridge Water several national datasets are used to increase the understanding of historic, present and future micro-component consumption. Historic micro-components are extracted from the WRc CP187 report, current micro-components are extracted from UKWIR 16/WR/01/15 Integration of Behaviour Change and future projections are extracted from the Market Transformation Programme (MTP).

3.3 Measured micro-component data

By ‘measured’ we mean micro-component data that has been collected by measuring the different micro-components used within the household (as opposed from survey questions and assumptions). This allows ownership (O), volume per use (V) and frequency of use (F), to be calculated for each micro-component. There are two main sources of data for this:

- 2015-16 data collected using the Siloette system:

- a sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study[3] (this contains 62 households from around England and Wales),

- a sample of RV billed households, which does not have associated demographics (collated from other anonymous Siloette studies carried out by Artesia Consulting, from England and Wales).

- 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187[4]).

Both the Siloette and Identiflow systems measure the flow into a property and compute the individual micro-components through pattern recognition (although the detailed methodology of the two systems is different).

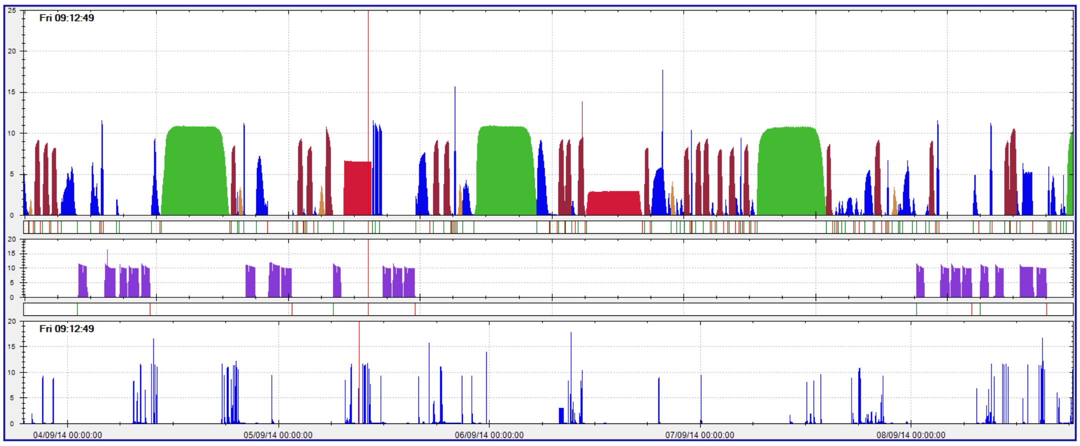
The Siloette system uses a Siloette logger that is connected to the pulsed output from a meter via a pulse unit, as illustrated in Figure 4.

Figure 4 Siloette logger installed in a boundary box

The logger records the flow through the meter at sub 1-second resolution. Once downloaded an algorithm is applied to the data to create a high-resolution flow trace of the flow into the property, as illustrated in Figure 5.

[3] Integration of behavioural change into demand forecasting and water efficiency practices, UKWIR 16/WR/01/15, 2016
[4] Increasing the Value of Domestic Water use Data for Demand Management, WRc, March 2005

Figure 5 Illustration of Siloette logger output



Each water-using event in the house has a flow-rate profile characterised by the time, duration and volume of water per use. Siloette takes the data from the logger and uses pattern-recognition software to disaggregate and quantify the individual micro-component events and provide information on time of event, flow rates and volumes. In Figure 5 the bottom trace shows the time-series of the flow profile, and the top row shows the resulting events that have been characterised, with each event type shown in a different colour (for example, baths are coloured green in Figure 5.)

The three sources of data described above are shown in Table 2 to Table 4.

Table 2 Micro-component summary data from 2015/16 metered billed households

2015/16 Metered billed households					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.26	7.83	56.83	23.92
Shower	0.92	62.36	0.86	49.54	20.85
Bath	0.43	104.60	0.24	10.61	4.47
Tap	1.00	5.66	11.61	65.72	27.66
Dish Washer	0.42	16.70	0.50	3.53	1.48
Washing Machine	0.95	54.19	0.55	28.44	11.97
Water Softener	0.02	52.06	0.97	0.98	0.41
External use	0.18	285.18	0.07	3.34	1.40
Plumbing Losses	0.22	37.20	1.55	12.86	5.41
Miscellaneous	0.95	1.63	3.74	5.78	2.43

Table 3 Micro-component summary for 2015/16 RV billed households

2016/16 RV billed households					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	7.58	8.86	67.15	22.53
Shower	0.94	54.82	0.94	48.69	16.34
Bath	0.54	113.65	0.36	22.35	7.50
Tap	1.00	4.56	17.91	81.62	27.39
Dish Washer	0.37	19.68	0.28	2.02	0.68
Washing Machine	0.94	56.36	0.66	34.59	11.60
Water Softener	0.09	112.02	0.24	2.41	0.81
External use	0.51	183.03	0.19	17.58	5.90
Plumbing Losses	0.30	75.84	0.65	14.76	4.95
Miscellaneous	0.93	1.56	4.75	6.85	2.30

Table 4 Micro-component summary for 2002/04 RV billed households

2002-2004 (from WRc CP187)					
Micro-component	"Weighted Ownership"	Volume per use (l)	Frequency of use (#/day)	Mean per household use (l/prop/day)	Percentage of PHC
Toilet	1.00	9.40	11.52	108.29	29.19
Shower	0.85	25.70	1.46	31.97	8.62
Bath	0.88	73.30	0.95	61.35	16.54
Tap	1.00	2.30	37.90	87.17	23.50
Dish Washer	0.37	21.30	0.71	5.60	1.51
Washing Machine	0.94	61.00	0.81	46.30	12.48
Water Softener	0.02	182.50	0.39	1.14	0.31
External use	0.65	46.70	0.89	27.10	7.30
Plumbing Losses					0.00
Miscellaneous	0.19	20.40	0.53	2.08	0.56

3.4 Market transformation data

Defra's Market Transformation Programme produced product summaries for various water using appliances in 2011[5]. These provide predictions of water use for appliances and devices in 2030 for three scenarios:

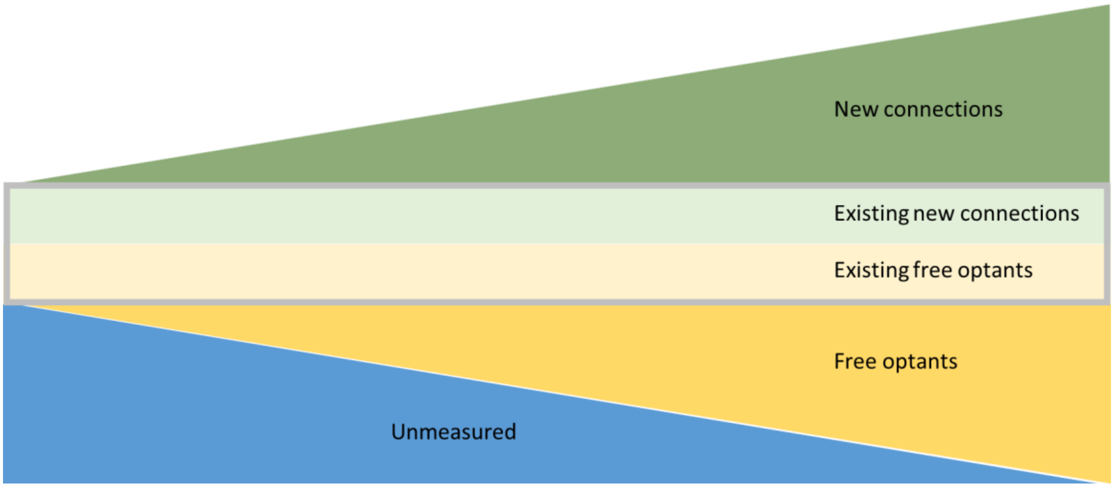
- Reference scenario (equivalent to baseline forecast)
- Policy scenario (assuming more effective implementation and accelerated take-up of more sustainable products)
- EBP or early best practice (which assumes a more positive impact than the policy scenario and an early take up of innovative water efficient products).

4 Property segmentation

Most companies report consumption figures for measured and unmeasured properties. To fully explore the complexity of different household segments and the difference in their consumption, behaviour and future trends Artesia calculates the forecast with the measured households split into existing properties, new properties, free optants as well as Compulsory/ Selective/other metering programme. Existing are in fact a combination of these, but will be termed existing and remain as a constant segment throughout the forecast from the base year value. An illustration of the breakdown of the measured and unmeasured households are shown in Figure 6. From base year the number of new properties increase based on property forecasts taken from CACI, and the switch between unmeasured to optant depends on the forecast optant rate. The optant forecast rate is calculated using a combination of the WRMP14 forecast and the historic reported optant numbers. Property and optant forecasts are both inputs into the segmentation model.

[5] http://efficient-products.ghkint.eu/cms/product-strategies/subsector/domestic-water-using-products.html#viewlist

Figure 6 **Illustration of property breakdown within the company, forecast from base year to the point of 100% meter penetration**

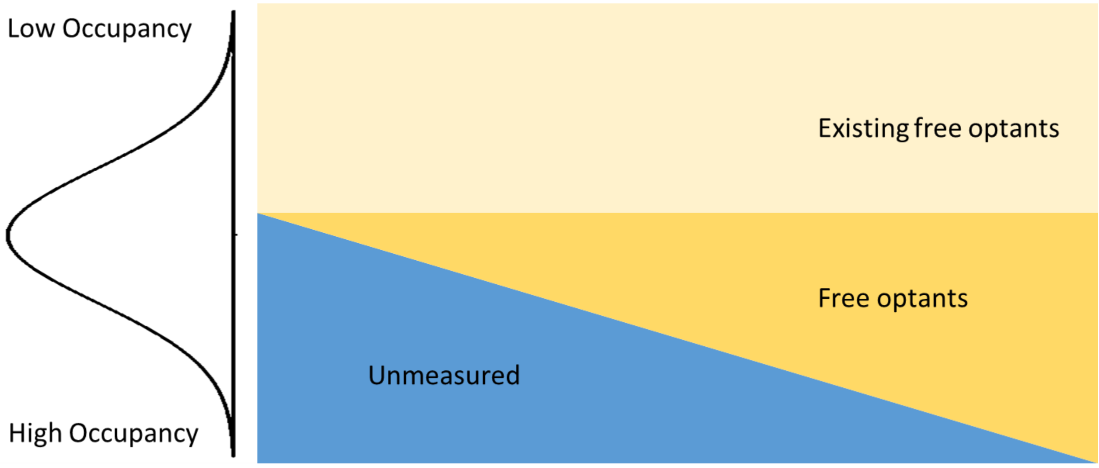


Some key assumptions made in the segmentation model;

- New households will always be metered
- Free optants move directly out of the unmeasured property segment.
- Voids are forecast to remain constant throughout the forecast period, in that there are no further voids added beyond the base year. Voids have not been included in the baseline forecast due to their negligible consumption.
- The point at which 100% meter penetration occurs is based on the meter optant forecast.
- Despite 100% penetration being unlikely in practice, the year in which this point is reach is needed for mathematical calculations in order to balance the population figures. In practice, this point is beyond the forecast period. The subtleties of final meter penetration rate may need further work in future forecasts.

Further to mapping properties into each of these segments, population must also be distributed.

Figure 7 Illustration of the change in occupancy as meter penetration tends towards 100%



In order to successfully distribute the population between the segments, certain assumptions and knowledge of the segments must be assessed. Occupancy is only reported for measured and unmeasured. Measured households generally have lower occupancy than unmeasured households. New properties are assumed to have company average occupancy (this assumes that occupants are moving into new properties from a range of existing properties, measured or unmeasured, either within or from outside the region, and hence have a company average occupancy). Occupancy of new properties and optant properties are inter-dependent, in that the sum of new and optant population within the existing measured households must equal the total for measured household population. Optants have a low occupancy, however this is highly dependent on meter penetration. Figure 7 demonstrates that as meter penetration increases, the occupancy of the unmeasured and optants increase until 100% meter penetration. Throughout the forecast the sum population for the optants plus unmeasured remains the same (this assumes that each year optants come from the unmeasured pool). Meanwhile the average occupancy of all the segments must follow the change in occupancy from the CACI property and population forecasts. These assumptions provide an estimate of the change in occupancy within the household segments over time; in reality there will be a complex movement of population within these segments, reflecting births, deaths, people moving into the region, people moving out of the region, and people moving within the region. Each year the segments are calibrated to take into account the company level occupancy changes throughout the forecast period. There is a slight decrease in company occupancy of the next 25 years, and this is attributed equally across all household segments.

To ensure the segmented households and populations sum to the company forecast various calibration steps and data validation checks are also included in the calculations.

5 Household consumption forecasts

5.1 Approach to micro-component forecasting

Micro-component models have been used for water demand forecasting in England and Wales from the late 1990s. They quantify the water used for specific activities (e.g.

showering, bathing, toilet flushing, dishwashing, garden watering, etc.) by combining values for ownership (O), volume per use (V) and frequency of use (F). For example, per-capita (PCC) or per household consumption (PHC) can be modelled as:

$$\text{PCC or PHC} = \sum_i (O_i \times V_i \times F_i) + pcr$$

Where

'O' is the proportion of household occupants or households using the appliance or activity for micro-component 'i',

'V' is the volume per use for 'i',

'F' is the frequency per use by household occupants or households for 'i',

pcr is per capita residual demand.

By applying this together with the population or property data, a water demand model can be formed. By forecasting changes in each of the variables (O, V, F or daily water use for each micro-component) over time, a water demand forecast can be created. Hence the micro-component forecast model requires estimates of changes in these variables, to reflect future changes in technology, policy, regulation, and behaviour.

This report describes how the inputs have been generated for:

- Base year micro-components from a micro-component occupancy model.
- Final planning year micro-components from an occupancy model. This allows a rate of change of micro-component daily water use to be derived due to the change in occupancy over the planning period.
- Technology, policy and behaviour trend values for micro-components (based on historic analysis of trends and future predictions from the Market Transformation Programme).

5.2 Basic inputs required

To build the micro-component forecast model, we need the following inputs:

- Base year household consumption broken down into micro-components.
- Reported base year household consumption (from water company annual return data).
- Rates of change in micro-components across the planning period.

5.3 Selection of the basic unit of consumption

Two commonly used methods of consumption forecasts are based on Per Capita Consumption (PCC) and Per Household Consumption (PHC). Linear modelling can use either approach.

In the case of PHC modelling, occupancy needs to be included as an explanatory variable, and PHC is composed of a consumption allotted to the house on the basis of its characteristics, and an additional consumption assigned to each occupant.

PCC modelling assigns a different consumption value per person on the basis of the characteristics of the property they inhabit.

In the former case, the model is property driven, which aligns with the data collection based on household meter reads.

The latter case introduces all the error associated with the household occupancy figure into the model at the very first step. If the model is based on PCC, the PCC is calculated from estimated occupancy (for which there is an error), so there is no part of the consumption modelling that is independent of occupancy error; all the error in population forecasting is propagated through the zonal forecast if it is based on PCC.

Modelling by PHC makes occupancy-driven household consumption components implicit in the model whereas PCC-driven modelling would need to incorporate a correction for changing occupancy rates in PCC forecasting.

For these reasons PHC is used as the basis for aggregating up to a zonal consumption forecast.

The Environment Agency require that the micro-components are reported in the WRMP tables in units of occupancy, i.e. per capita consumption; and the model converts the PHC micro-component values at the zonal level to PCC by dividing through by occupancy.

5.4 Micro-component occupancy model

Whilst we carry out the forecast model at household level, there is an influence on a selection of the micro-components from occupancy. Therefore, in calculating the base year and final year PHC values, we use a set of linear models that relate either daily use or frequency of use to occupancy in each year. The model is also used to provide the base and final year values for different metered property types: existing metered, optant metered, new property metered and selective metered.

The UKWIR 2015/16 micro-component data for measured billed households was used for the modelling because this dataset had a complete set of occupancy data for each household over the logging period. The total number of households in the sample was 62.

Figure 8 Each micro-component daily use plotted against occupancy

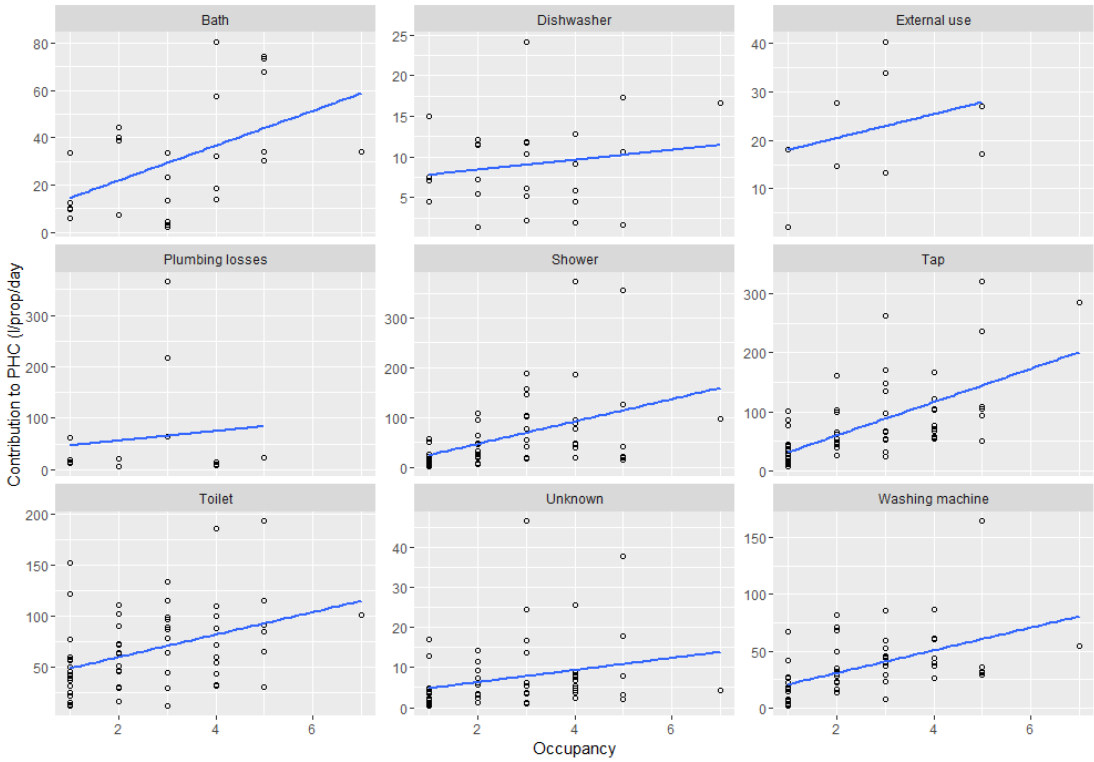


Figure 8 shows the average daily use (or contribution to per household consumption) for each of the following micro-components:

- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Dish washer use,
- Washing machine use,
- Water softener use,
- External use, and
- Miscellaneous use (including internal plumbing losses).

Each of the micro-components were investigated to determine whether the daily volume per use, frequency of use or ownership varied significantly with occupancy. The following micro-components showed relationships where occupancy was a significant factor:

- WC flushing,

- Shower use,
- Bath use,
- Tap use,
- Washing machine use.

For each of these micro-components (WC, Shower, Bath, WM and Taps) we developed a linear model using occupancy as the predictive factor.

Figure 9 shows the variation of WC flushing frequency per day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use against occupancy with the following equation:

*Frequency of use (uses/day) = 6.143 + 3.744 * ln(occupancy)* **Equation 1**

Figure 9 **Variation of WC flushing frequency (uses per day) with occupancy**

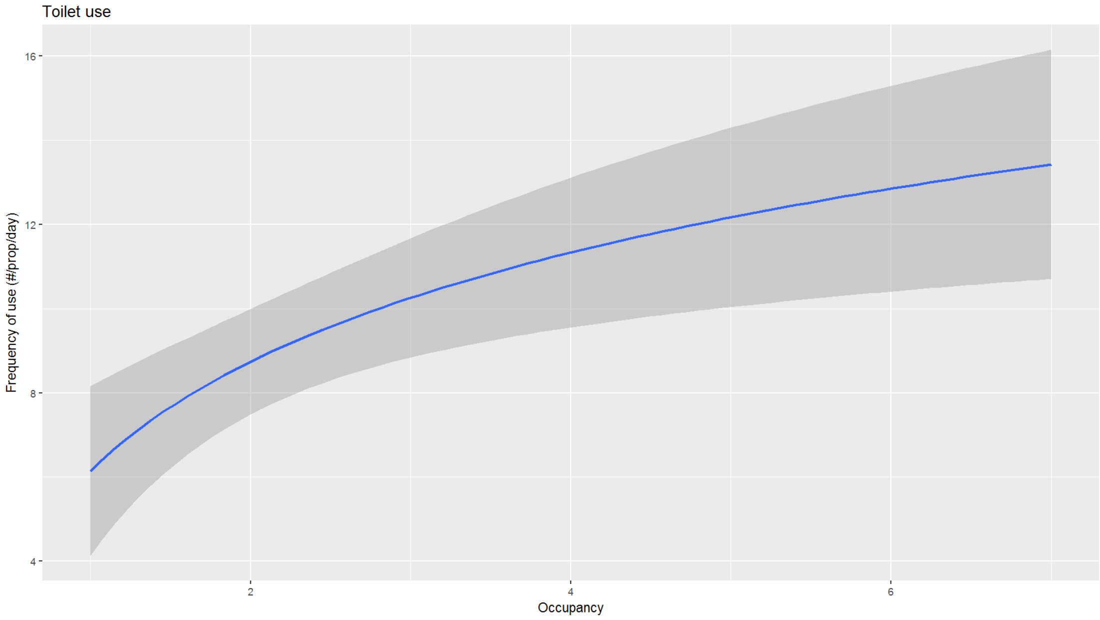


Figure 10 shows the variation of the water used for showering each day with occupancy, with the mean water use per day plotted against occupancy. Shower use was also explored in terms of frequency of use per day, but a more robust model could be built with volume used per day. This is probably because with increased occupancy there is increased variation in length of showering. The model is a log relationship of volume used per day against occupancy with the following equation:

*Shower volume used per day = 15. 47 + 57.47 * ln(occupancy)* **Equation 2**

Figure 10 Variation of shower volume used per day with occupancy

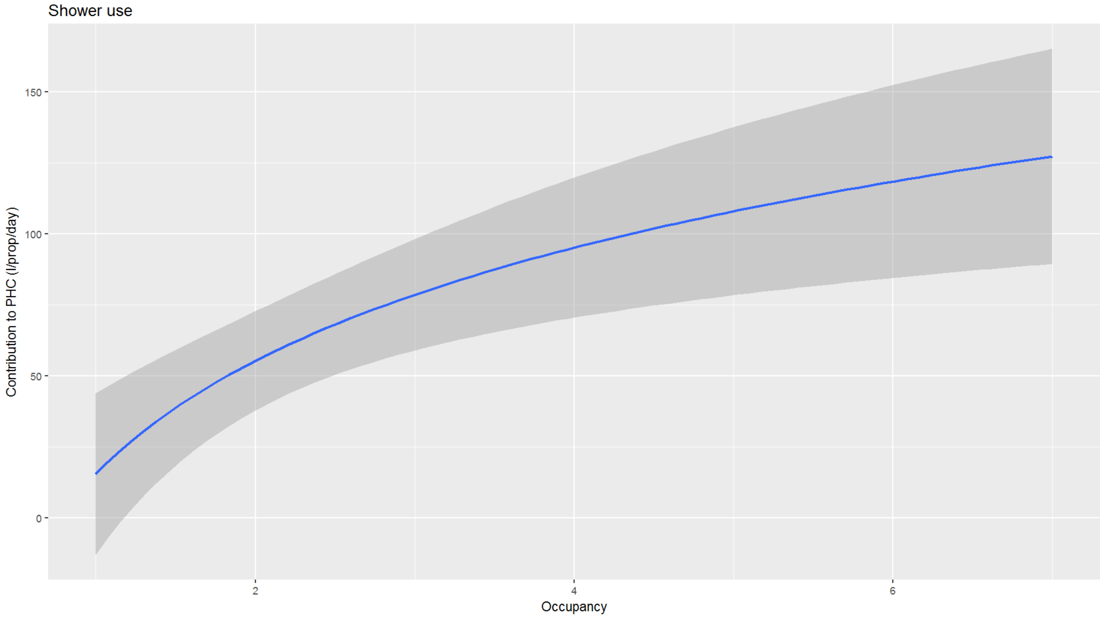


Figure 11 shows the variation of the water used for bath use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a linear relationship of volume used per day against occupancy with the following equation:

*Bath volume used per day = 7.181 + 7.378 * occupancy* ***Equation 3***

Figure 11 Variation of bath volume used per day with occupancy

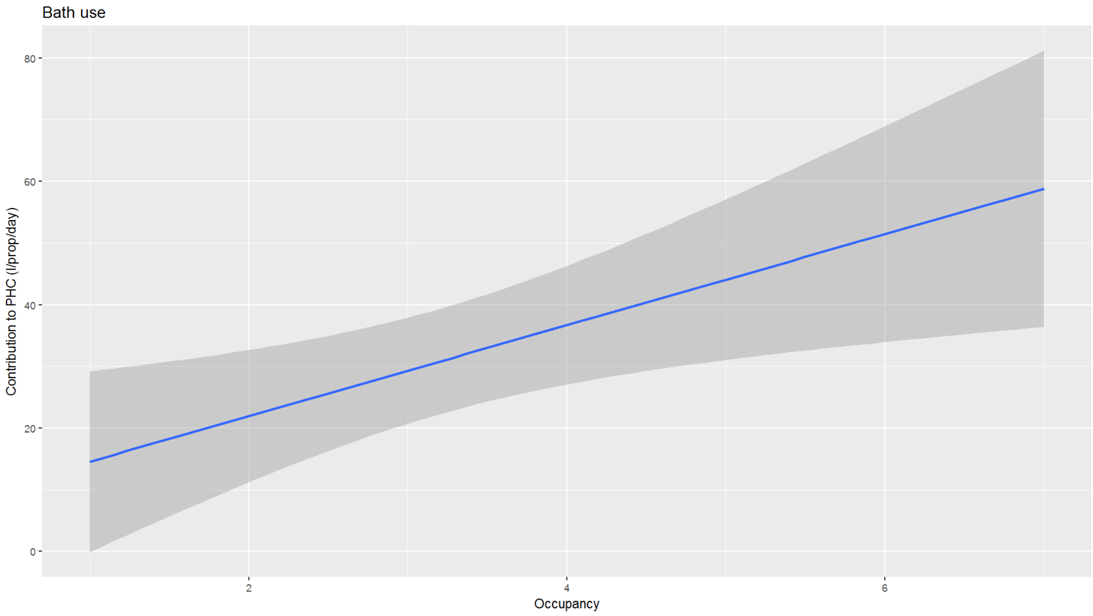


Figure 12 shows the variation of the water used for tap use each day with occupancy, with the mean water use per day plotted against occupancy. The model is a log relationship of volume used per day against occupancy with the following equation:

*Tap volume used per day = 27.92 + 62.89 * ln(occupancy)* **Equation 4**

Figure 12 Variation of tap volume used per day with occupancy

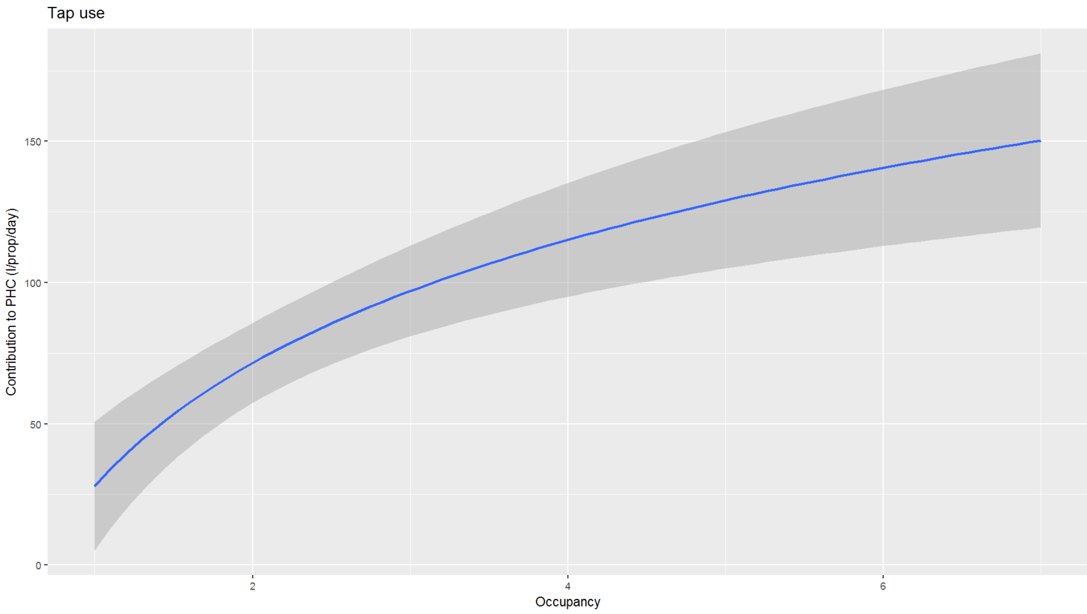
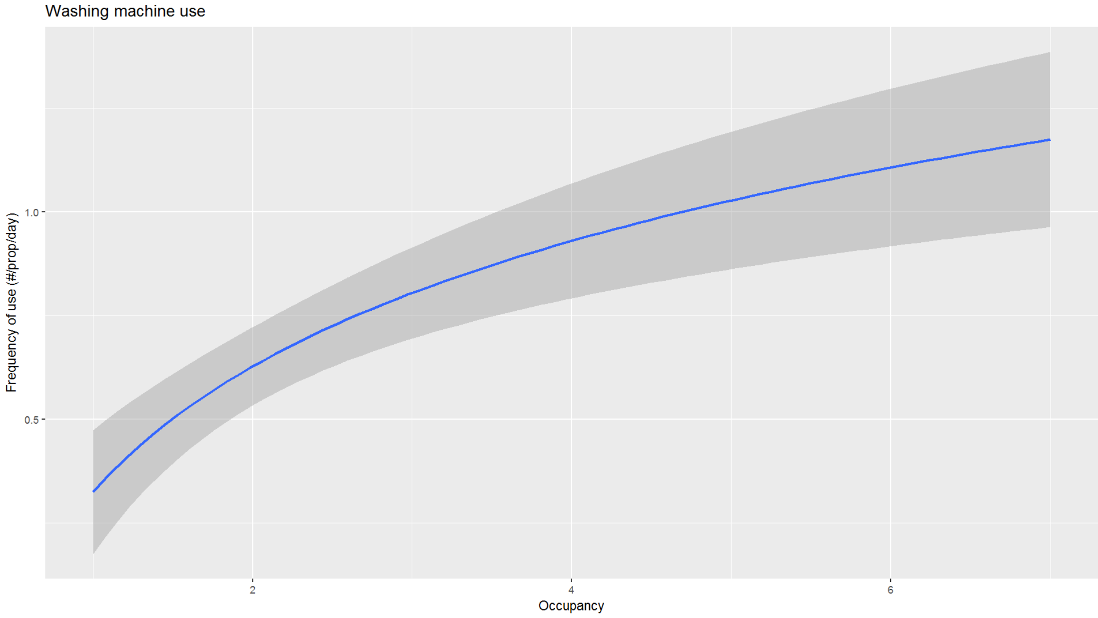


Figure 13 shows the variation of the water used for washing machine use each day with occupancy, with the mean frequency of use per day plotted against occupancy. The model is a log relationship of frequency of use per day against occupancy with the following equation:

*Frequency of use (uses/day) = 0.3242+ 0.43705 * ln(occupancy)* **Equation 5**

Figure 13 Variation of washing machine (frequency of use per day) with occupancy



For each property type the model variables shown in Table 5 are also changed depending on the meter status of the property.

Table 5 Micro-component variables that change with meter status

Property type	WC flush volume (mean l/flush)	Washing machine volume/use (mean l/use)	Dish washer volume/use (mean l/use)	Wastage / plumbing losses (frequency of occurrence)
RV billed household (HH)	7.58	54.19	16.7	1.5*1.55
Existing measured HH	7.26	54.19	16.7	1.55
Optant measured HH	6.0	54.19	16.7	0.5*1.55
New build measured HH	5.5	50.0	15.0	0.5*1.55
Selective metered HH	7.58	54.19	16.7	0.5*1.55

Combining all the relationships and variables, the micro-component occupancy model is defined in Table 6.

Table 6 Micro-component occupancy model parameters

Micro-component	Weighted Ownership 'O'	Volume per use 'V' (l/use)	Frequency of use 'F' (uses/day)	Daily use (l/prop/day)
WC flushing	1	See Table 5	See Equation 1	O*V*F
Shower use				See Equation 2
Bath use				See Equation 3
Tap use				See Equation 4
Dish washer	0.42	See Table 5	0.5	O*V*F
Washing machine	0.95	See Table 5	See Equation 5	O*V*F
Water softener	0.02	52.06	0.97	O*V*F
External use	0.18	285.18	0.07	O*V*F
Plumbing losses	0.22	37.2	See Table 5	O*V*F
Miscellaneous	0.95	1.63	3.74	O*V*F

The model can then be used to calculate the micro-component daily use (and hence the per household consumption 'PHC') for the following property types based on the occupancy assigned to each property type, in the base year and in the final year of the forecast:

- RV billed households
- Existing metered billed households
- Optant metered billed households
- New build metered households
- Selective (or compulsory) metered billed households.

Application of the occupancy model in the base year and final year are shown in Table 7 and Table 8 respectively. The base year in Table 7, which shows the occupancy, PHC derived from the micro-component occupancy model, and the calculated PCC. Also shown is the PHC and PCC calibrated to base year (normalised to NYAA).

Table 7 Micro-component occupancy model parameters – Base year (adjusted to NYAA)

Household types	Occupancy	PHC (modelled)	PCC (modelled)	Base year (NYAA) calibrated PHC	Base year calibrated PCC
RV billed HH	2.77	341.65	123.39	465.88	168.26
Existing metered billed HH	2.31	297.91	128.90	283.23	122.55
New build metered HH	2.44	281.74	115.51	267.86	109.82
Optant metered HH	2.33	281.12	120.78	267.27	114.83

Table 8 shows the modelled PHC and PCC figures based on the final year occupancies. These figures are without the forecast trends applied so is to demonstrate the impact of the changing occupancy over time of each of the household segments. RV billed occupancy increases with a resulting increase in PHC and decrease in PCC. The measured properties have a decreasing occupancy over the forecast period with a resulting reduction in PHC and small increase in PCC.

Table 8 Micro-component occupancy model parameters – Final year (NYAA)

Household types	Occupancy	PHC (OVF calculated)	PCC (OVF calculated)
RV billed HH	2.91	351.19	120.69
Existing metered billed HH	2.19	288.25	131.35
New build metered HH	2.16	260.35	120.31
Optant metered HH	2.28	277.26	121.67

Using the base year and final year PHC values, a rate of change in PHC due to occupancy change can be calculated for each household metered status. This is in addition to the technology and behaviour trends described in the following section.

5.5 Micro-component trend model – baseline scenario

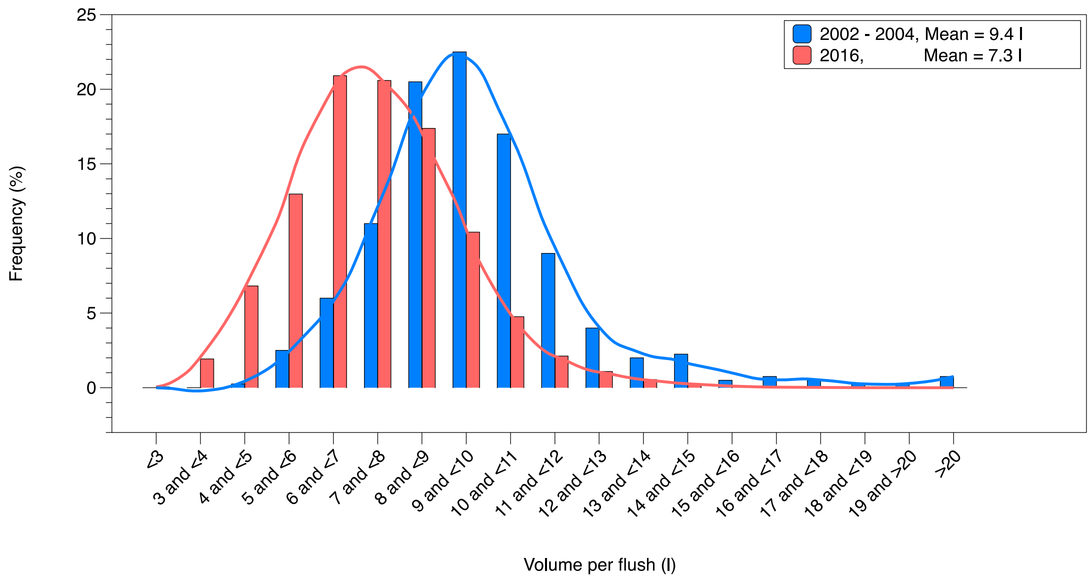
To investigate trends in individual micro-components due to technology change, policies and regulation, and behaviour change, we have used the data set from 2002/04 (Table 4) and the 2015/16 datasets (Table 2 and Table 3). For future projections of trends we have generally used the forecast water use values from Defra's Market Transformation Programme.

5.5.1 WC flushing

For the trend we assume that ownership and frequency of use for WC flushing remains constant, with the volume per use changing due to market transformation.

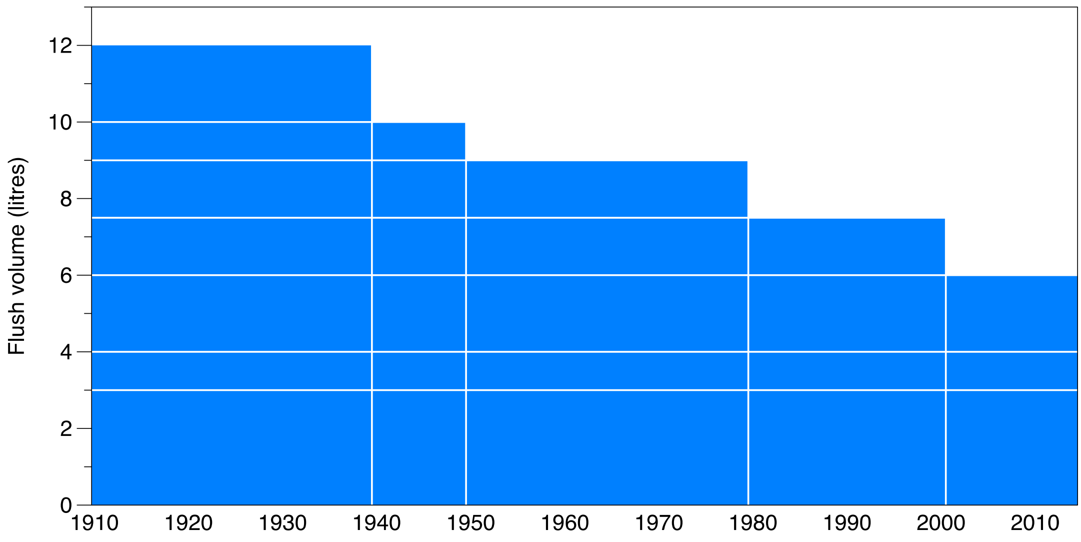
Using data from the WRc micro-component report CP187 and data from the UKWIR 2016 study, we can create a histogram of the volumes per flush from 2002/04 and 2015/16. These are shown in Figure 14**Error! Reference source not found.**. This shows that for 2002/04 the mean flush volume was 9.4 l/flush, with a range of flush volumes from 5 litres to > 15 litres. In 2015/16 the mean flush volume had reduced to around 7.3 litres with a range from 3 litres to about 13 litres per flush.

Figure 14 Histogram of WC flush volumes from 2002/04 and 2015/16



The reason for the reduction in flush volumes from 2002/04 to 2015/16 is due to the replacement of larger volume WC cisterns with smaller volume cisterns, due to market transformation based on regulatory policies. The schematic in Figure 15 shows the change in maximum flush volumes over time due to changes in regulation. From 12 litres in 1910 to 6 litre single flush or 6/4 or 6/3 litre dual flush in 2000 to date. The reason why we see larger flush volumes in the histogram is due to incorrect setting up of the fill height or over filling during the flush period.

Figure 15 Regulatory changes in flush volumes

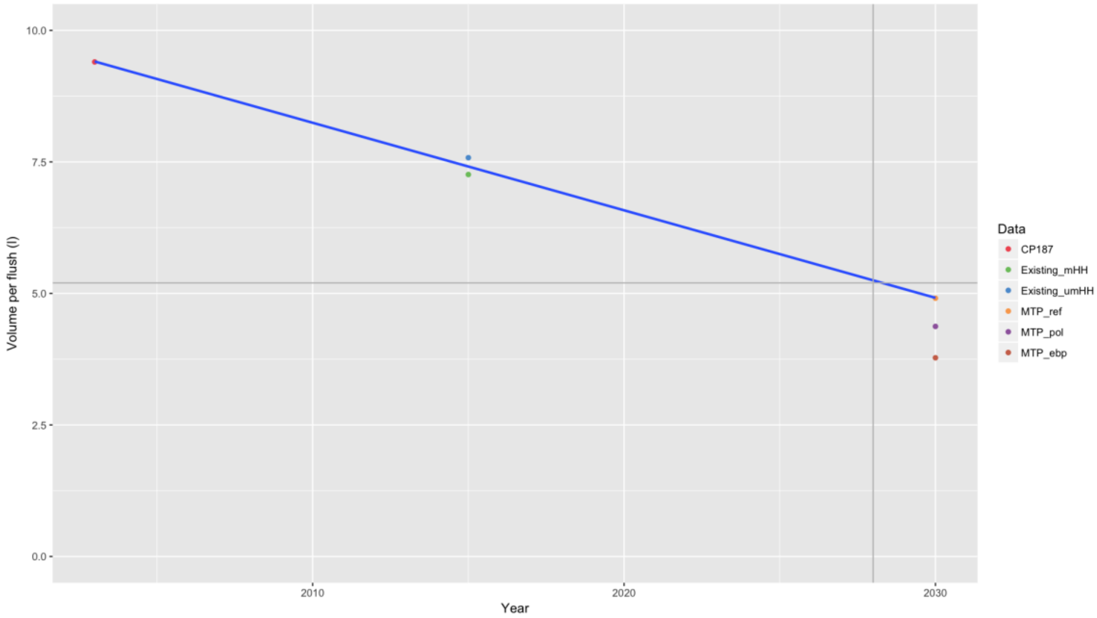


The latest MTP projections for WC flushing volumes[6] in 2030 for the reference scenario is 4.8 litres/flush. Figure 16 shows the mean 2002/04 (CP187), the 2015/16 flush volumes (Existing_mHH and Existing_umHH), and the flush volume from the MTP scenarios in 2030. The blue line shows the linear fit from the 2002/04, 2015/16 and MTP Reference scenarios.

If we assume that the market transformation continues at the current rate (a reasonable assumption for baseline forecasts, as there are no planned regulatory changes in WC flush volumes), then the flush volume in 2028 will be approximately 5.1 litres (shown by the intersect of the grey lines in **Error! Reference source not found.**). This provides some confidence in the MTP Reference scenario for WC flush volumes.

[6] Source: http://efficient-products.ghkint.eu/spm/download/document/id/954.pdf

Figure 16 Historic, current and future flush volumes

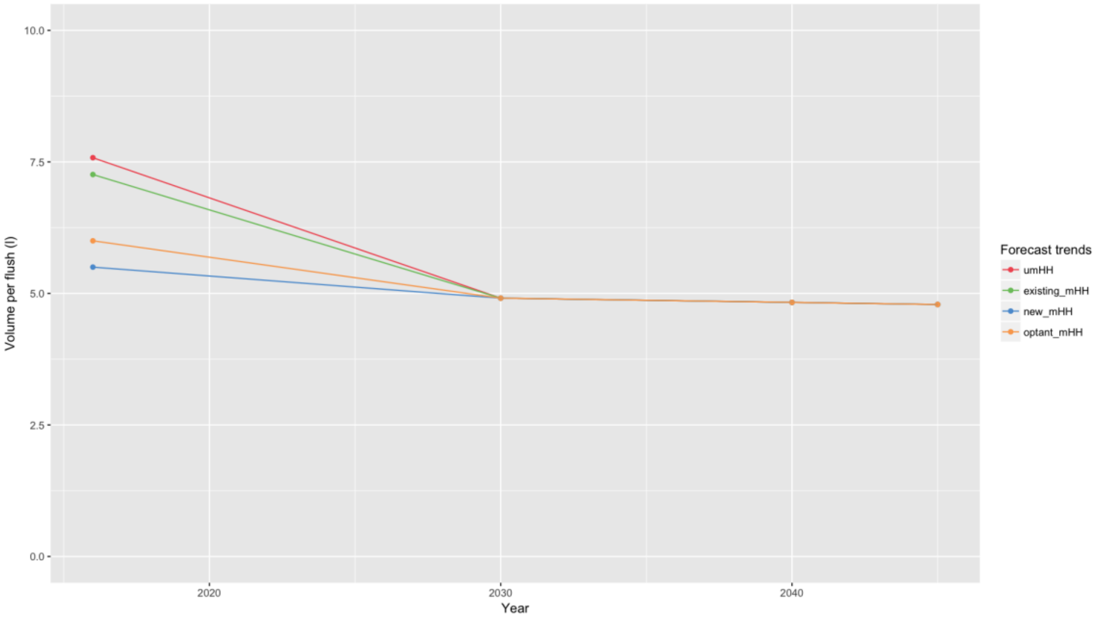


We have created future trends for WC volume per flush (see Figure 17) using:

- the base year volumes per flush in Table 5 for different property types,
- the 2030 projection for WC flush volume from the MTP reference scenario,
- an assumption that all property types will have achieved the MTP Reference scenario between the forecast base year and 2030 (for the baseline forecast assuming no change to current WC flush regulations)[7],
- and an assumption that the volume per use will then remain relatively constant until 2045.

[7] This is a reasonable assumption given the rate of change in average flush volumes observed from micro-component study data between 2002 and 2015, which indicates that approximately half the current stock of toilets are now low flush.

Figure 17 Trends for WC flush volumes



From these trends, annual rates of change have been produced for each of the property types. The rates of change are then incorporated into the model.

5.5.2 Showering

To investigate showering trends, we have used the overall daily water use (per household) from shower data. This is because shower use is a complex mix of behaviour (showering time), technology (shower flows), as well as frequency of use and occupancy.

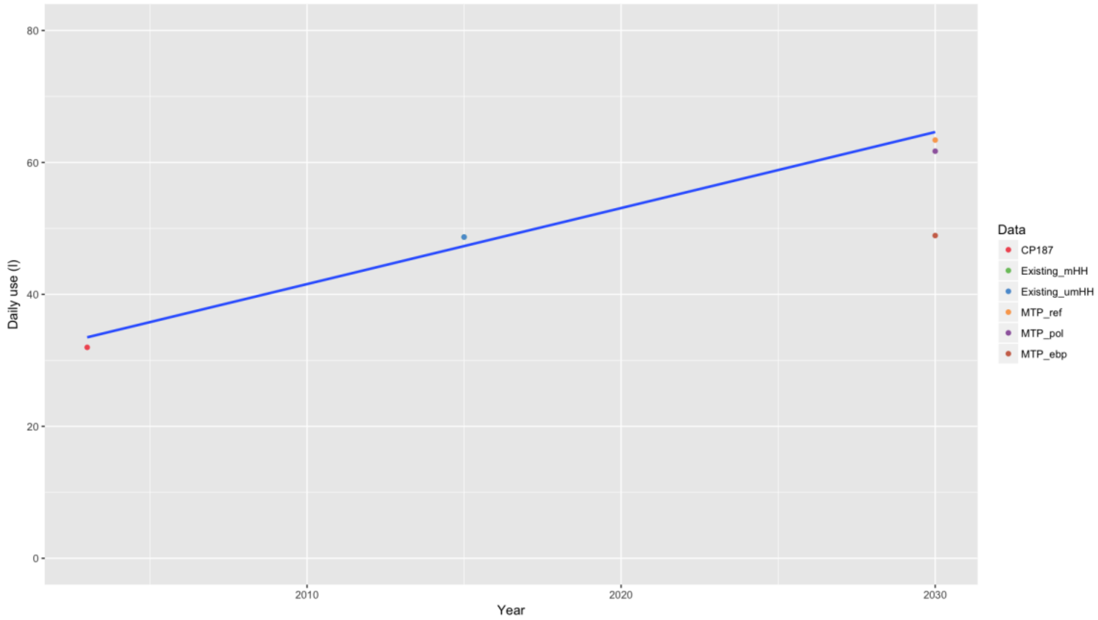
Figure 18 shows the following data points on daily shower volumes (l/day):

- 2003 from WRc CP187 report,
- 2016 from Table 2 (Existing_mHH) and Table 3 (Existing_umHH), both are approximately 49 l/day,
- 2030 from the MTP reference, policy and early best practice scenarios.

These data points assume an average occupancy for households in their specific years. The blue line shows a linear fit from the 2003, 2015/16 and MTP reference scenario. This shows a rising trend, which is consistent with the observations that shower use is increasing (in terms of ownership, frequency and flow rate).

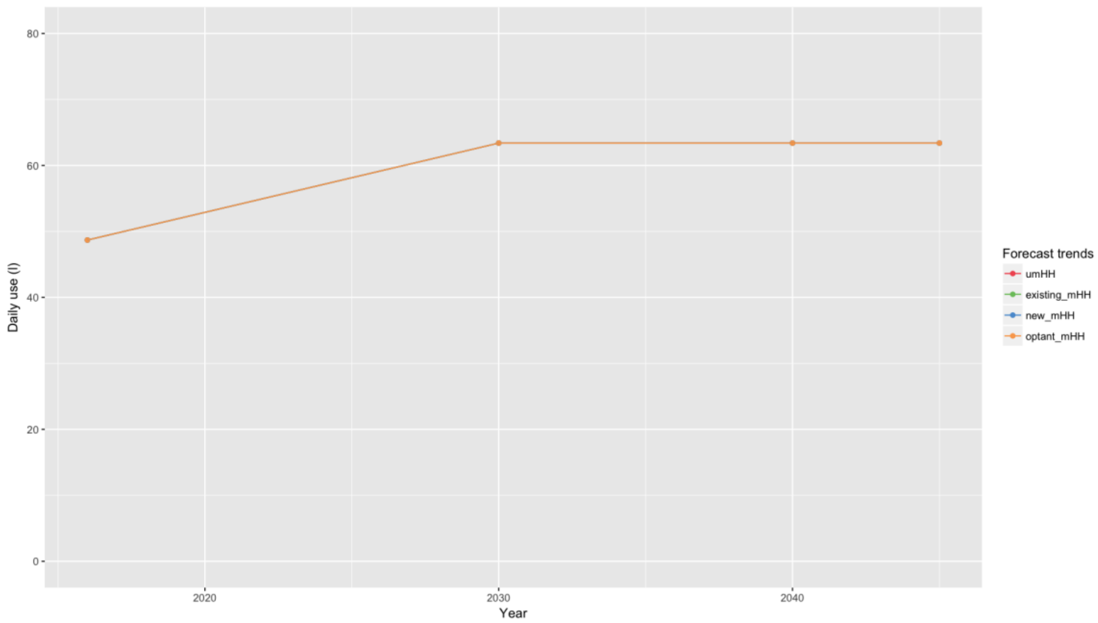
We have chosen not to fit trend line through the MTP Early Best Practice point as this assumes a very high proportion of water efficient showers being installed in new and existing households (which is not evident in current practice). This is used in the development of the lower PCC trend discussed in the alternative scenarios in Section **Error! Reference source not found.**.

Figure 18 Trend of daily volume of water used for showering



Using the trend line from Figure 18 and assuming that shower volumes per day plateau at the MTP reference scenario in 2030 and remain flat over the rest of the planning period, we have produced a predicted trend for shower use as shown in Figure 19. There is no evidence for different house types having different trends, so the same trend is used for all house types.

Figure 19 Future trend for daily volume of water used for showering



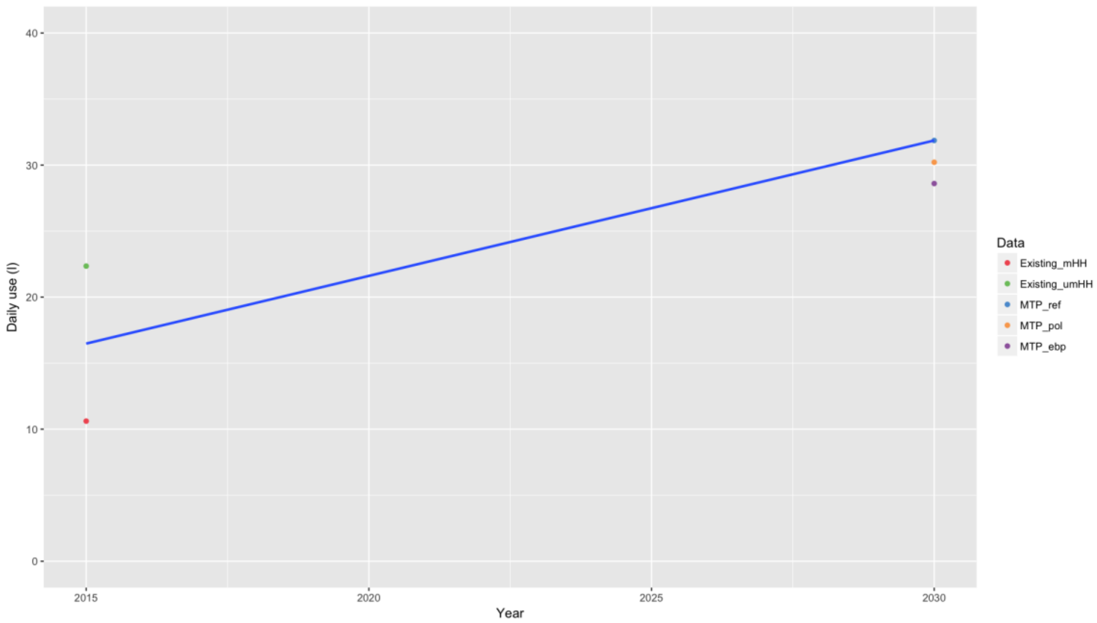
From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

5.5.3 Bath use

For bath use trends, we have used the overall household daily water use from baths. Like showering, bath use is mix of behaviour, frequency of use and volume per use. Figure 20 shows the evidence for daily volume of bath use from the following data points (l/day):

- 2016 from the bath use in Table 2 and Table 3,
- 2030 from the MTP reference, policy and early best practice scenarios.

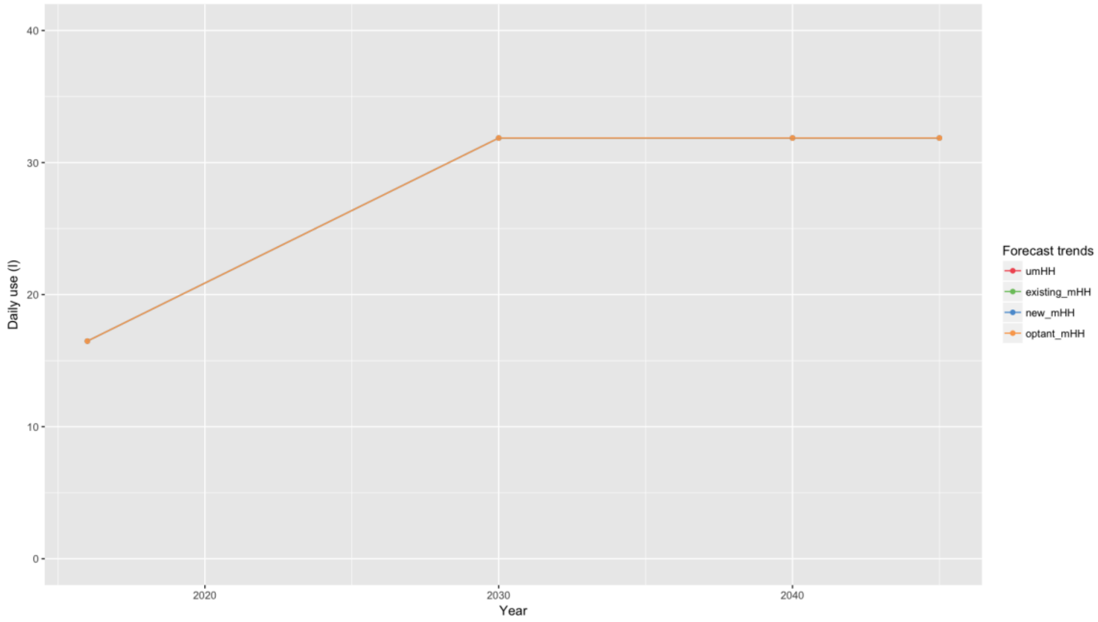
Figure 20 Trend of daily volume of water used for bath use



The blue line in Figure 20 is a linear fit of the 2016 and 2030 data. Using this trend, and assuming that bath use then levels off at 2030 to the end of the planning period, we have created the future trend shown in Figure 21. We have assumed that all household types show the same trend.

From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

Figure 21 Predicted trends of daily volume of water used for bath use



5.5.4 Washing machine use

For washing machine use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table 3.

This data was used to produce a linear trend over time shown in Figure 22 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

For the future trend in washing machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 50 l/use in 2016. The resulting future trends are shown in Figure 23. Rates of change are then computed from these trends and incorporated in the model.

Figure 22 Historic trend in washing machine volume per use

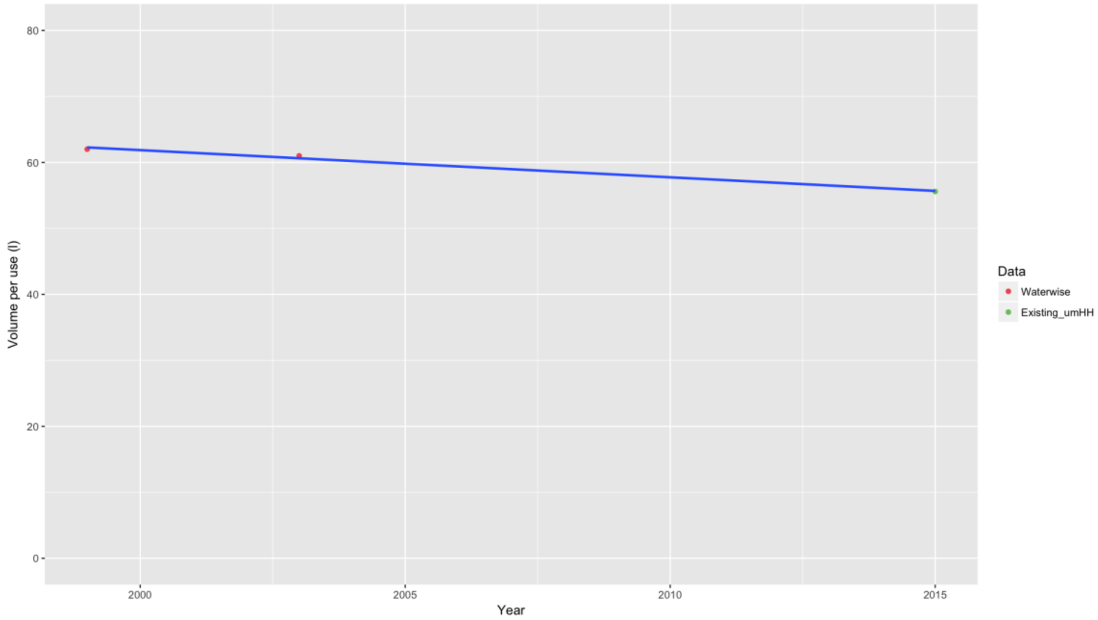
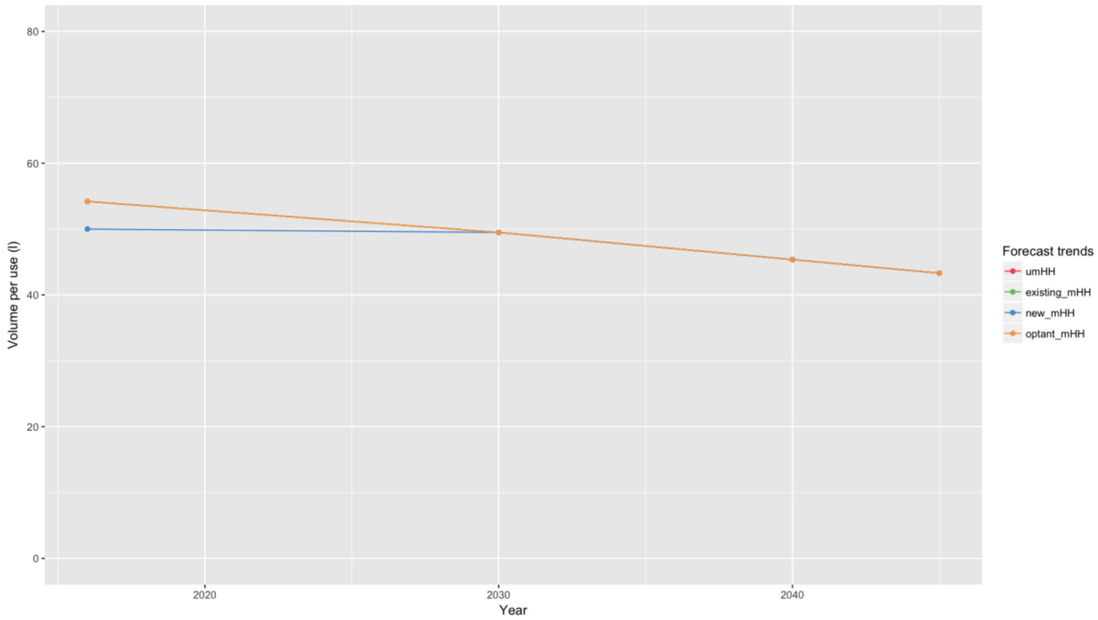


Figure 23 Future trend of washing machine volume per use



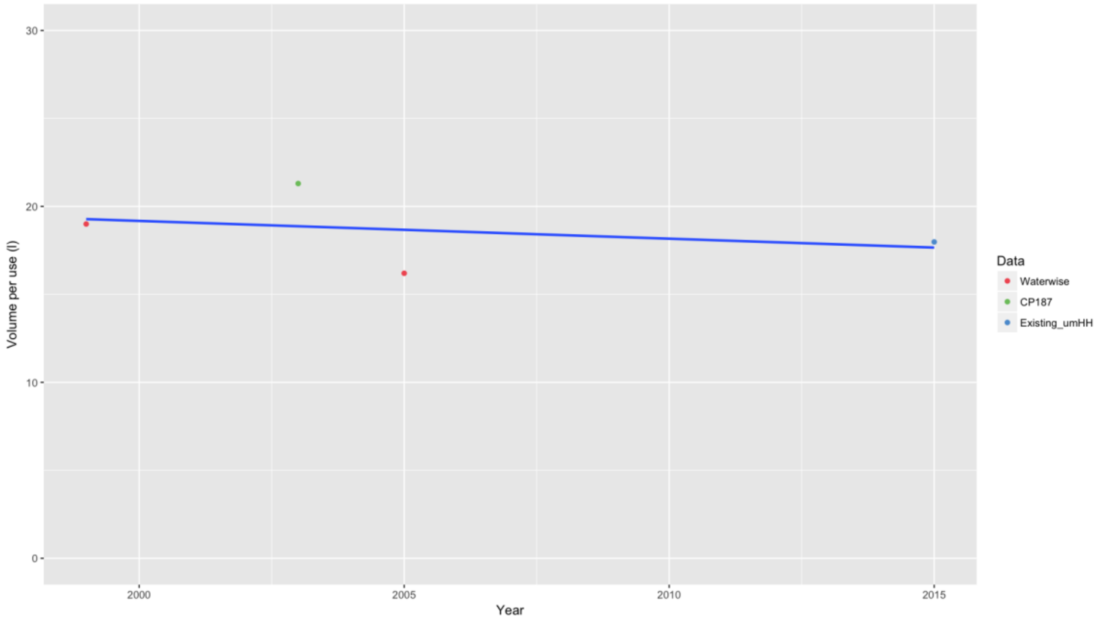
5.5.5 Dish washer use

For dishwasher use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table 3.

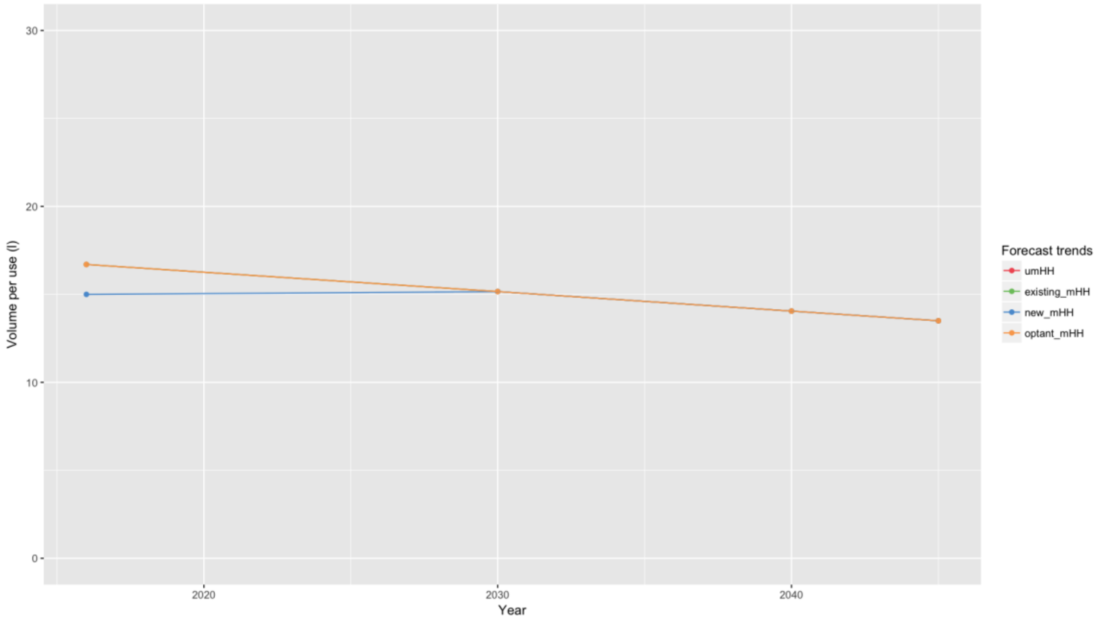
This data was used to produce a linear fit over time shown in Figure 24 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

Figure 24 Historic trend in dish washer volume per use



For the future trend in dish washer machine volume per use, we have extrapolated this trend to the end of the planning period (assuming continuous developments in technology). This trend is applied to all household types except new properties. These are assumed to have a starting point of 15 l/use in 2016. The resulting future trends are shown in Figure 25. Rates of change are then computed from these trends and incorporated in the model.

Figure 25 **Future trends of dish washer volume per use**



5.6 Micro-component trend model – alternative scenarios

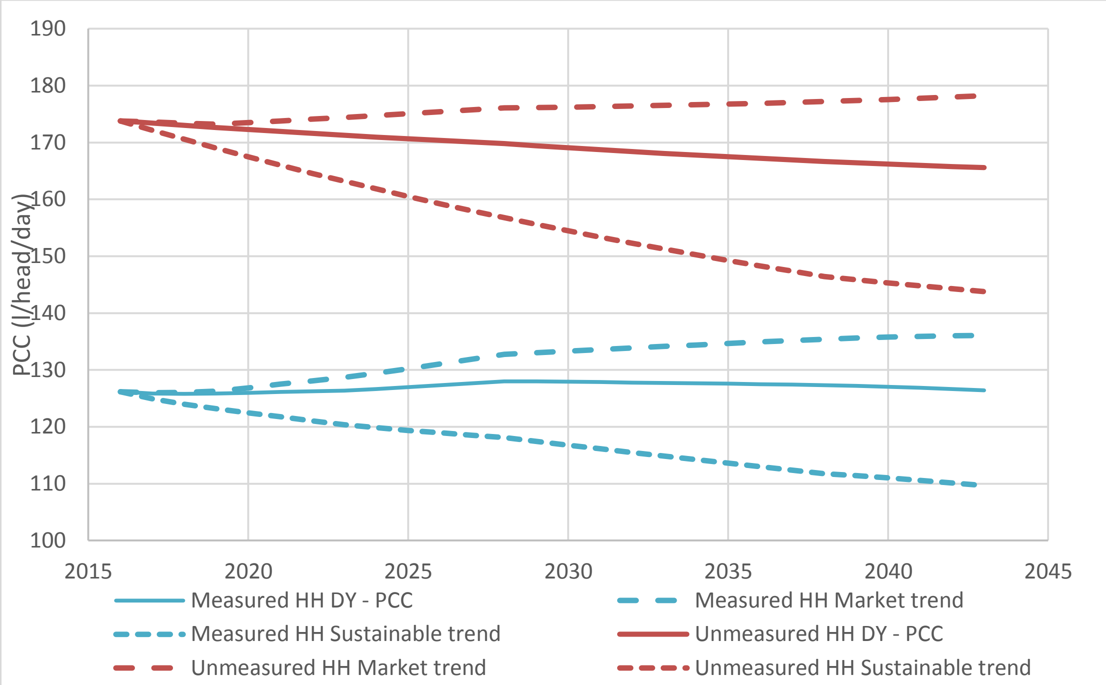
Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption.

Firstly, sustainable development, in this most extreme efficiency scenario, we have assumed that water saving is driven by both technological advancements and attitudinal changes. Sophisticated filtration technology would allow recirculation of shower water saving both energy and water. Waste water and washing functions are fulfilled by greywater recycling, aided by hydrophobic frictionless surfaces. Bathing is pretty much obsolete.

Secondly, market trend, this scenario assumes that the projected trend in micro-components does not continue beyond 2022. This would require a situation such as Brexit where UK building regulations may be decoupled from current standards and the logical decline in flush volumes is curtailed. The observed upward trend in showering continues to increase.

The variation in the trends are shown in Figure 26 for measured and unmeasured household PCC. These upper and lower scenarios are used to look at the possible impacts of different regulatory or market trends in water consuming products. We project the most likely estimate within the forecast, but these can be used to assess impacts if a water company is particularly critical in the water balance. The true uncertainties which should be used within the headroom analysis are shown later in the report in Figures 27 and 28. The results of headroom may be compared with the simpler scenario based projections to ensure both methods give an aligned projection.

Figure 26 **Variation in base line (DY) PCC trends**



5.7 Base Year Calibration

For each of the household segments, the OVF models are applied using the base year occupancy values. The OVF calculated PHC is then calibrated to the normal year annual average (NYAA) value. Further details of the NY calculations are described in section 6, however it is important to note that the NY factor is applied within the base year (BY) calibration to ensure that the rate of change over time for each component is not affected by annual variation that might by contained within the BY. The zonal reported measured and unmeasured BYAA are factored to NYAA. The zonal PHC values for the non-reported figures; existing measured, new properties measured, optant measured and selective/compulsory measured are calculated proportionally based on the NYAA measured value using the OVF calculated PHC in each segment.

5.8 Climate change

Climate change impacts on consumption have been calculated in accordance to UKWIR 13/CL/04/12 Impact of Climate Change on water demand. Median percentage climate change impacts on household demand at 2040, relative to 2012 are published for each river basin within the UK. Cambridge Water sits entirely within the Anglian basin. Therefore, the annual average forecasts have a 0.75% increase in consumption over that period. As the base year is now 2015/16 and the final forecast year is 2044/45 the percentage change is shifted along as there has been no further evidence since this report. However, as the forecast period with the base year set at 2015/16 is one year longer the final percentage is slightly larger than the figure printed in the guidance. If the forecast were to be run under a critical period scenario the percentage affected by climate increases from 0.75% to 2.05%.

When critical period is selected the appropriate climate change factor is applied in a linear fashion across the forecast period.

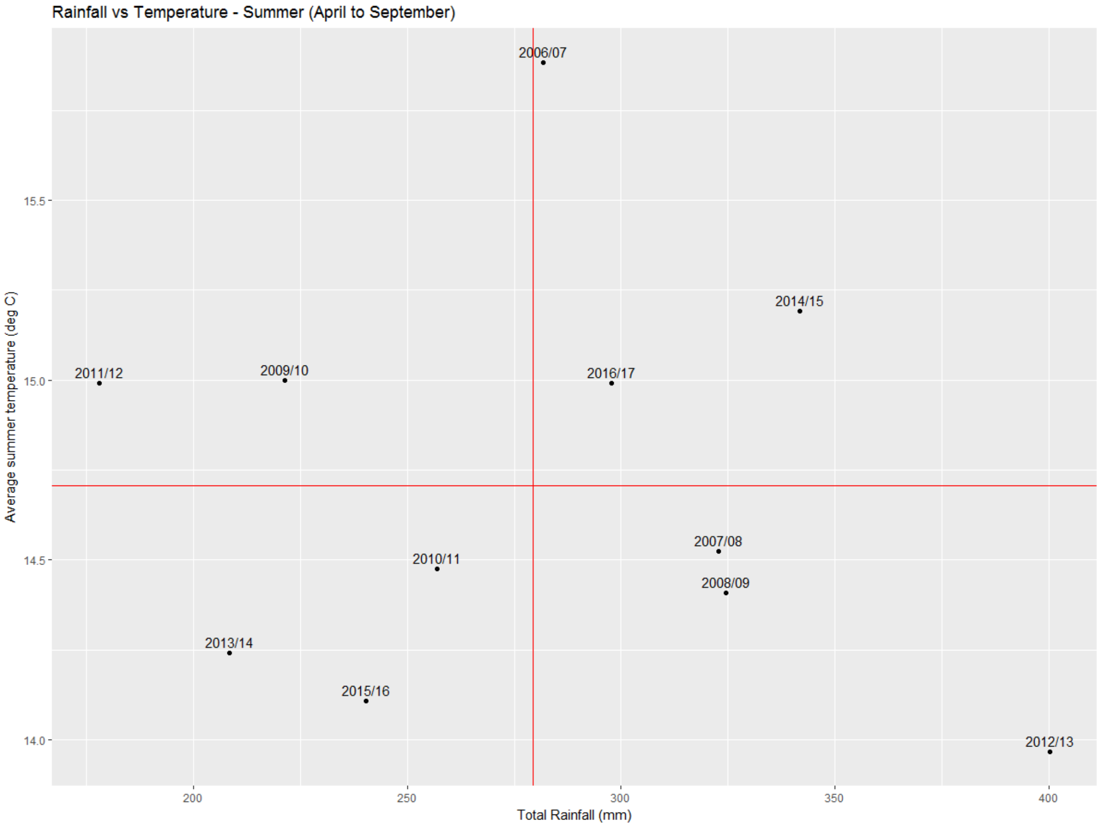
The model includes functionality to output forecasts with and without climate change factors. The additional demand from climate change is added to the external use micro-component only. The volume attributed to climate change is displayed in a separate row in the top section of the outputs.

6 Consumption uplifts for normal, dry year and critical period

The application of NYAA was touched on in section 5.7. In this section the full methodology and application is explained. The methodology for the NYAA and DYAA factors comes from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting.

Stage one is to assess the weather data, more specifically temperature and rainfall. Each factor is summarised for the summer months for each year. Total summer rainfall is plotted against mean summer temperature, with the mean of all years for the two factors plotted as ablines on the graph. This graph is shown in Figure. A judgement is made as to which is the hottest and driest year; 2006/07, 2011/12 and 2009/10 are all within (or very close to) the top left quadrant which suggests a hot dry summer. 2006/07 appears quite strong, as does 2011/12.

Figure 29 Quadrant plot for determining the dry year



Stage two is to analyse the PCC trends for measured and unmeasured, these are done separately to account for the difference in trend and also the potential difference in impact of the dry year.

Figure 27 Reported PCC trend - measured properties (dry year indicated in blue, base year indicated in yellow)

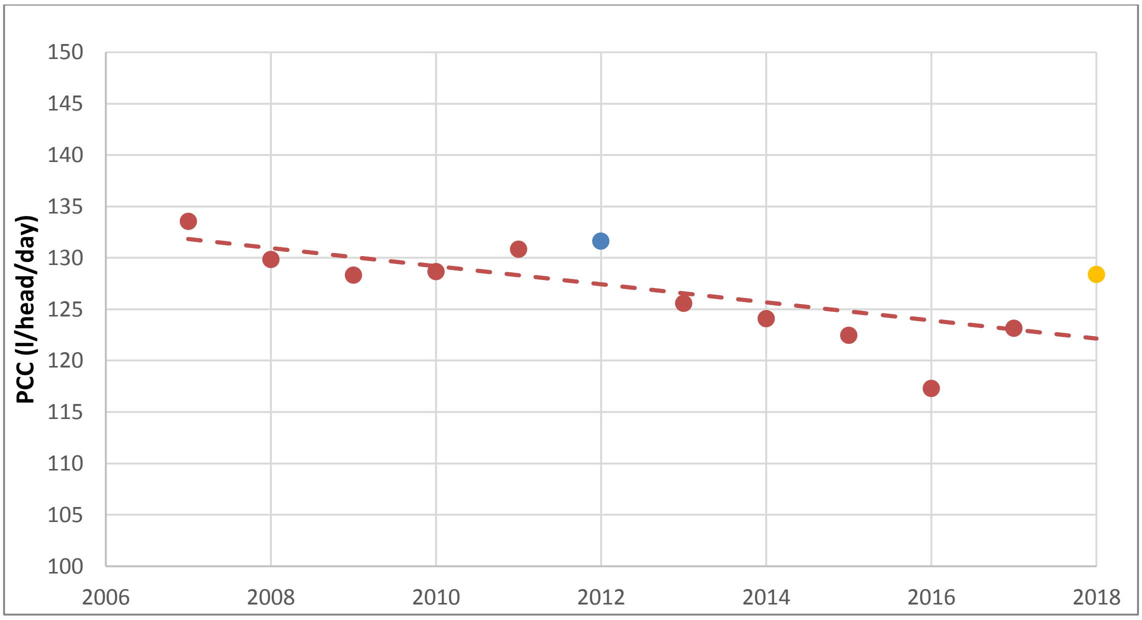
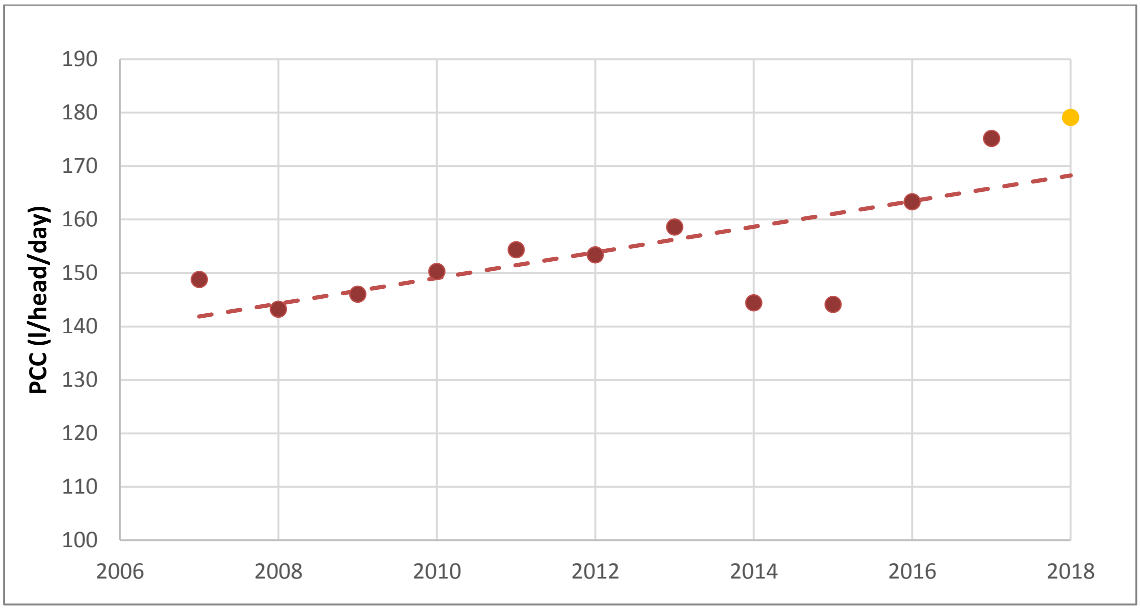


Figure 28 Reported PCC trend - unmeasured properties (base year in yellow)



The selection of the DY is done using the measured PCC values, shown in Figure 27. The reason for this is that measured values are deemed to be more accurate and less variable due to better quality data and less adjustments made with relation to supply pipe leakage. When assessing Figure 27, 2011/12 stands out as the year that responds the strongest out of the three possible dry year selections. In 2006/07 several companies enforced hosepipe bans especially in the South East of the UK. Whether or not Cambridge Water enforced the ban, media coverage of the ban has been shown to decrease consumption across many of the water companies. The dry year factor is calculated by removing the dry year, then calculating a trend line through the remaining points. The dry year factor is the reported figure divided by the modelled figure.

Normal year factor calculations are calculated in a similar way, using the same trend line which excludes the dry year point. The normal year factor is the modelled figure divided by the reported figure (yellow dot in Figure 27 and Figure 28). As stated previously, this is done separately for measured and unmeasured.

The dry year factor is calculated to be 1.033, measured normal year factor is 0.951 and the unmeasured normal year factor is 0.940. The WRMP14 forecast used a 1.035 dry year factor, which was using 95/96, no normal year adjustment factor was applied.

Critical period calculations are done in accordance to the methodology stated in UKWIR 06/WR/01/7. Distribution input (DI) is used due to the methodology requiring daily consumption figures. Despite DI including leakage it is the best source of data available. From the daily data a weekly rolling mean is calculated. For each (financial) year, the peak week and the annual average are calculated. A long term annual average is then calculated from all of the years in the time series, and the critical period peak week factor is the maximum peak week within one of the dry years (top left quadrant). The peak week was selected from 2006/07, with a result of 1.224. WRMP14 used a 1.25 critical period adjustment, the methodology was assessed and deemed out of line with the UKWIR peak week guidance, the updated figure is therefore a reflection of a minor change in methodology to use a long term annual average rather than a single annual average in the dry year.

Application of the NY factor is different to the DY and CP factors. The base year to normal year is applied before the calibration of the OVF calculated PHC, the reported figures are adjusted prior to this step so that the forecast is run from the normal year. Once the normal year forecasts are calculated the DY and CP factors are applied. These factors are independent of each other in that they are both applied to the NY forecast. Either option can be selected within the model. The baseline forecast for Cambridge is as a DYAA. CP can be selected as an alternative scenario.

A summary of the NYAA, DYAA and CP factors are summarised in Table 9.

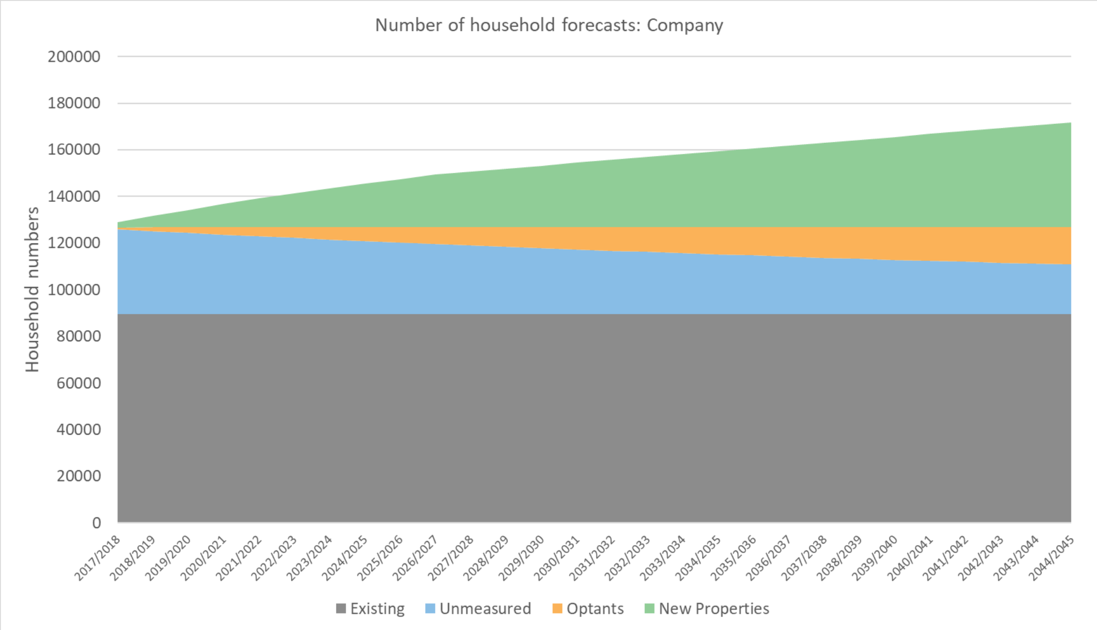
Table 9 Summary of factors applied in the household forecast

Factor	WRMP19	WRMP14
Normal to Dry year factor (all households)	3.3%	3.5%
Base to Normal year factor (measured households)	-4.9%	0
Base to Normal year factor (unmeasured households)	-6.0%	0
Normal to Critical period factor (all households)	22.4%	25%

7 Household consumption outputs

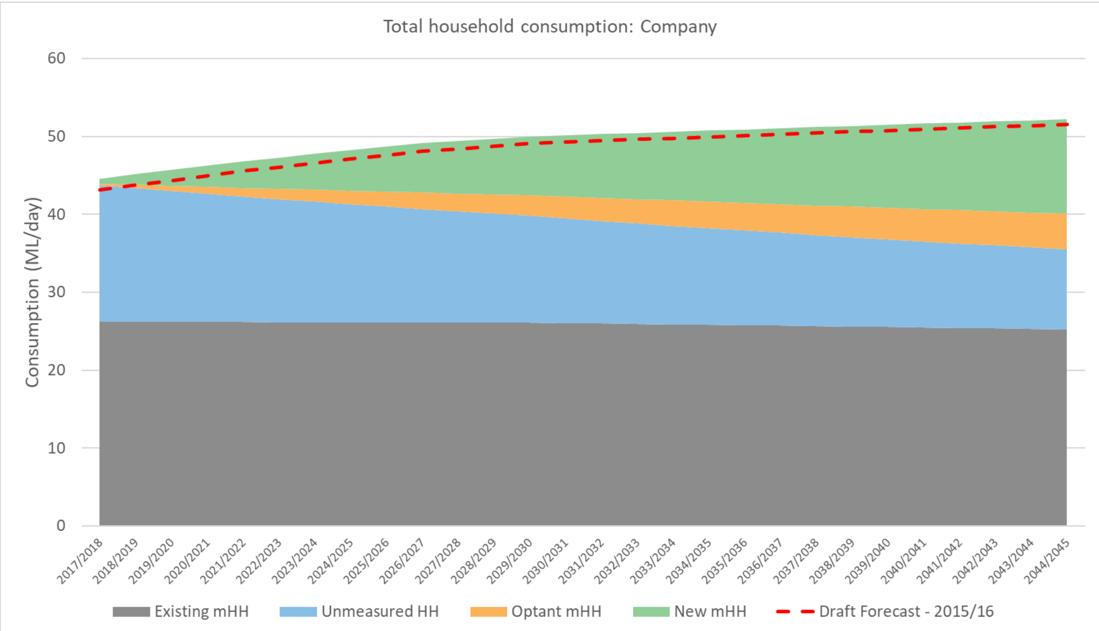
Graphical outputs for the central property forecast is shown in figures 31 and 32, and in tabular form within Table 10.

Figure 29 **Total number of households, split by household segment**



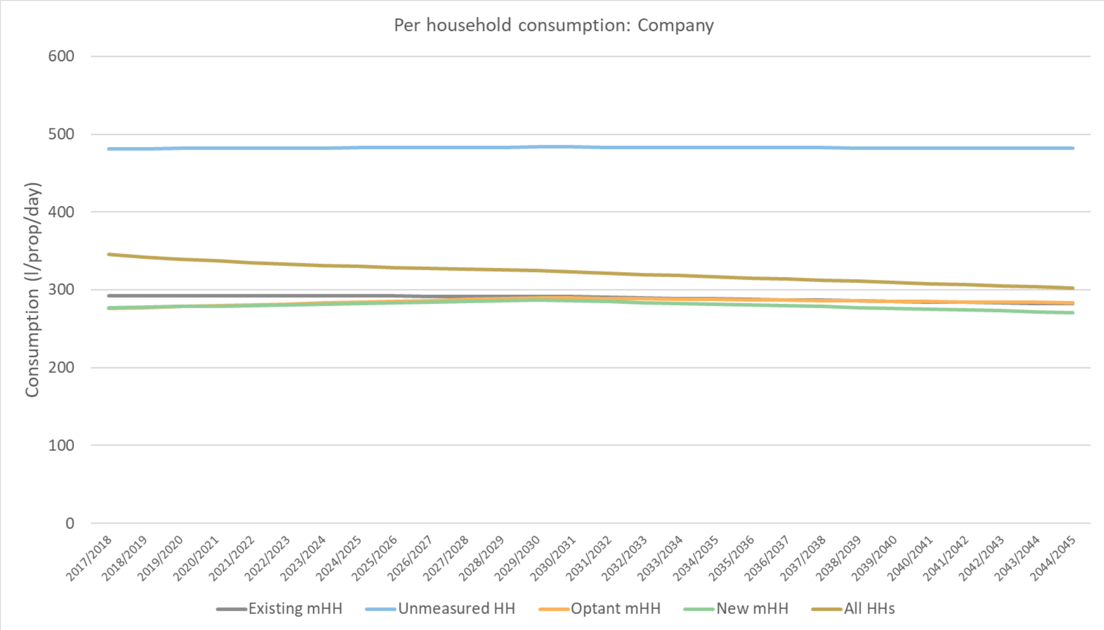
The total number of households, shown in Figure 29, increases from 128,981 to 172,537, so a 34% increase over the forecasting period.

Figure 30 **Total household consumption (Ml/d), split by household segment**



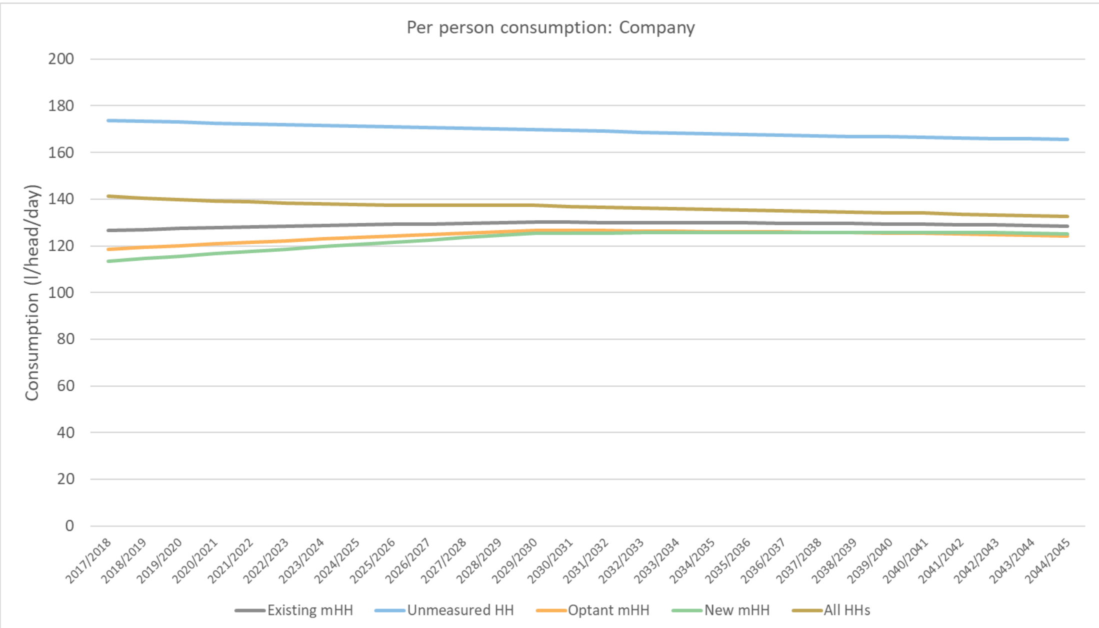
Total company household consumption increases from 44.55 Ml/day to 52.44 Ml/day, which is a 17.7% increase in demand over the forecast period, shown in Figure 30.

Figure 31 Company level PHC, split by household segment



PHC decreases over the forecasting period, this is shown in Figure 31. The total average PHC decreases from 345.42 l/property/day to just below 303.92 l/property/day. Each of the household segments have different trends, with the unmeasured households increasing slightly from 481.22 l/prop/day to 481.78. Each of the measured segments remain quite stable, with a slight rise and then fall dependent on the rate of change developed from measured and MTP figures. The overall decrease in PHC is a function of the unmeasured households converting to optant properties with a lower PHC.

Figure 32 Company level PCC, split by household segment



Company level PCC has a similar trend to PHC, with a slight decrease from 141.41 to 133.13 l/head/day. Unmeasured PCC shows a negative trend which is different compared to the PHC trend, this is due to the increase in occupancy within this segment, shown in Figure 33. The lower occupancy properties convert to optants, while the higher occupancy properties remain in the unmeasured segment. The measured segments show a rise until 2030, this is based on predicted increase in personal washing and then level off. The unmeasured properties have a similar trend in personal washing, but they have increased reductions due to whitegoods and WC flush volumes being at a higher starting point.

Figure 33 Company level occupancy, split by household segment

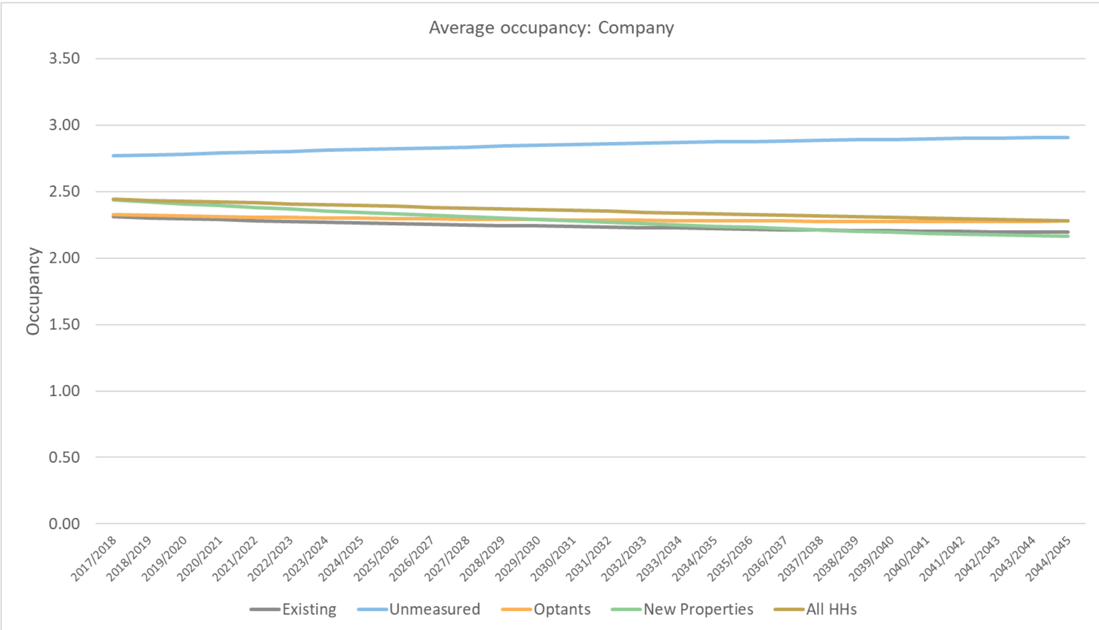


Figure 33 shows the trends in occupancy, the unmeasured rise is most notable, and as described before this is the impact of optant properties coming from the lower end of the occupancy distribution within the unmeasured households

Table 10 DYAA household consumption forecast – central property forecast

	AMP6			AMP7					AMP8	AMP9	AMP10	AMP11
Company Consumption (Ml/d)	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045
Total company	44.55	45.22	45.82	46.41	46.98	47.45	47.96	48.48	50.20	50.97	51.71	52.44
Measured	27.04	28.05	29.01	29.95	30.86	31.67	32.49	33.31	36.50	38.57	40.45	42.17
Unmeasured	17.52	17.17	16.81	16.46	16.11	15.78	15.47	15.17	13.70	12.40	11.26	10.26

Company PHC (l/prop/day)	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045
Company average	345.42	342.84	340.46	338.25	336.25	334.54	332.95	331.48	326.07	318.17	310.84	303.92
Measured	292.02	291.47	291.02	290.67	290.41	290.25	290.15	290.10	290.54	286.73	282.84	278.86
Unmeasured	481.22	481.41	481.60	481.79	481.99	482.18	482.38	482.57	483.54	482.95	482.37	481.78

Company PCC (l/head/day)	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045
Company average	141.41	140.75	140.17	139.66	139.23	138.91	138.62	138.38	137.92	136.29	134.85	133.13
Measured	126.18	126.20	126.27	126.39	126.55	126.78	127.00	127.25	128.84	128.48	128.04	127.07
Unmeasured	173.79	173.40	173.02	172.64	172.28	171.93	171.59	171.27	169.80	168.08	166.66	165.57

Measured PCC (l/head/day)	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045
WC (toilet) flushing	28.37	27.56	26.80	26.07	25.38	24.74	24.11	23.50	20.73	20.76	20.79	20.74
Personal washing	53.73	54.79	55.84	56.90	57.96	59.02	60.08	61.13	66.43	67.21	67.97	68.48
Clothes washing	15.68	15.60	15.53	15.47	15.41	15.35	15.30	15.25	15.01	14.58	14.12	13.60
Dishwashing	12.38	12.40	12.43	12.45	12.48	12.51	12.53	12.55	12.67	12.77	12.86	12.90
Miscellaneous (internal) use	14.61	14.40	14.19	13.97	13.76	13.56	13.35	13.14	12.13	11.12	10.07	8.93
External use	1.42	1.45	1.49	1.53	1.56	1.60	1.64	1.68	1.87	2.05	2.23	2.41
SUM	126.18	126.20	126.27	126.39	126.55	126.78	127.00	127.25	128.84	128.48	128.04	127.07

Unmeasured PCC (l/head/day)	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045
WC (toilet) flushing	38.37	37.26	36.15	35.05	33.96	32.87	31.79	30.72	25.45	25.02	24.63	24.29
Personal washing	74.11	74.96	75.82	76.67	77.52	78.38	79.23	80.09	84.37	83.62	83.02	82.57
Clothes washing	20.98	20.80	20.62	20.44	20.26	20.09	19.92	19.75	18.92	18.00	17.13	16.29
Dishwashing	16.67	16.61	16.56	16.50	16.45	16.40	16.35	16.30	16.07	15.87	15.69	15.55
Miscellaneous (internal) use	21.96	22.03	22.09	22.16	22.22	22.29	22.36	22.43	22.79	23.17	23.59	24.05
External use	1.70	1.74	1.78	1.82	1.87	1.91	1.95	1.99	2.20	2.40	2.60	2.80
SUM	173.79	173.40	173.02	172.64	172.28	171.93	171.59	171.27	169.80	168.08	166.66	165.57

The increase in company level household demand is largely due to the increase in the number of properties throughout the forecast period. PHC and PCC decline slightly which is largely based on the impact of increasing meter penetration. The PCC in the final year of this forecast is 133.13, with a total company household consumption of 52.44 Ml/day.

8 Conclusions & Recommendations

A baseline household consumption forecast has been produced for the Cambridge Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a moderate level of water resource planning concern.

The micro-component model has been developed using best available data from local and national datasets. The model is segmented by property type using unmetered, new build metered and free optant metered households. The model is based on per household consumption (PHC), and includes linear modelling of key micro-components against occupancy to reflect the variation of PHC by occupancy within each household type. The model forecasts are developed from historic micro-component datasets and Market Transformation Programme predictions.

The results of the micro-component forecast give a 7.88 Ml/day increase in household consumption for Dry Year Annual Average consumption, this is a 17.7% increase. This is largely driven by a 34% increase in the property forecast. Average PHC and PCC decrease throughout the forecast period, this is partly due to decreases in component demand due to market transformation, but mostly due to the shift from unmeasured to measured, properties. Average household PCC (mean of all household types) reduces from 141 to 133 l/person/day.

The model contains forecasts for Normal Year Annual Average, Dry Year Annual Average and Critical Period; with a breakdown of micro-components for each year of the forecast.