Artesia Consulting

SES Water

WRMP19 Household consumption forecast: Baseline forecast

Final

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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).

The company-level supply-demand balance in the 2014 Water Resources Management Plan (WRMP14) had a surplus in available water resources until 2033/34. This was based on the transfer of surplus water from the East Surrey water resources zone (WRZ) to Sutton WRZ. In WRMP14 SES Water used a micro-component model to forecast household consumption.

SES Water has determined that problem characterisation for the company (now a single WRZ) should be 'low'.

A baseline household consumption forecast has been produced for the SES Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a low 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 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 property and population forecasts used in this model are taken from estimates provided by Experian as part of a separate project. We have checked the validity of these property and population forecasts and ensured their compliance with regulatory guidance.

The results of the micro-component forecast give a 36.96 Ml/day increase in household consumption for Dry Year Annual Average consumption, this is a 33.8% increase over the planning period to 2079/80. This is largely driven by a 69.6% 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 160 to 147 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.

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1 Context

SES Water used a micro-component forecast to predict household consumption in WRMP14. This predicted a relatively flat profile over the planning period, with an average decline of 0.097% per annum for measured households and an average decline of 0.151% per annum for unmeasured households, excluding climate change impacts. For both measured and unmeasured households there was a long-term reduction in consumption for toilet flushing, clothes washing, dish washing and external use, and a long-term increase in consumption for personal washing, mainly driven by an increase in the ownership and frequency of shower use.

The WRMP14 plan was for two water resources zones (WRZs). The company is now using a single WRZ.

The problem characterisation for the company's single water resource zone has been confirmed as 'low' for WRMP19. An assessment of suitable household consumption forecasting methods was carried out based on a low medium level of concern. This took account of known data availability for the SES 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, SES 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 an updated 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 study also uses micro-component survey data for about 8500 households collected from the company's on-line water efficiency calculator.

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 (OVF: ownership, volume, frequency, PHC: per household consumption) 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, change of occupier 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.

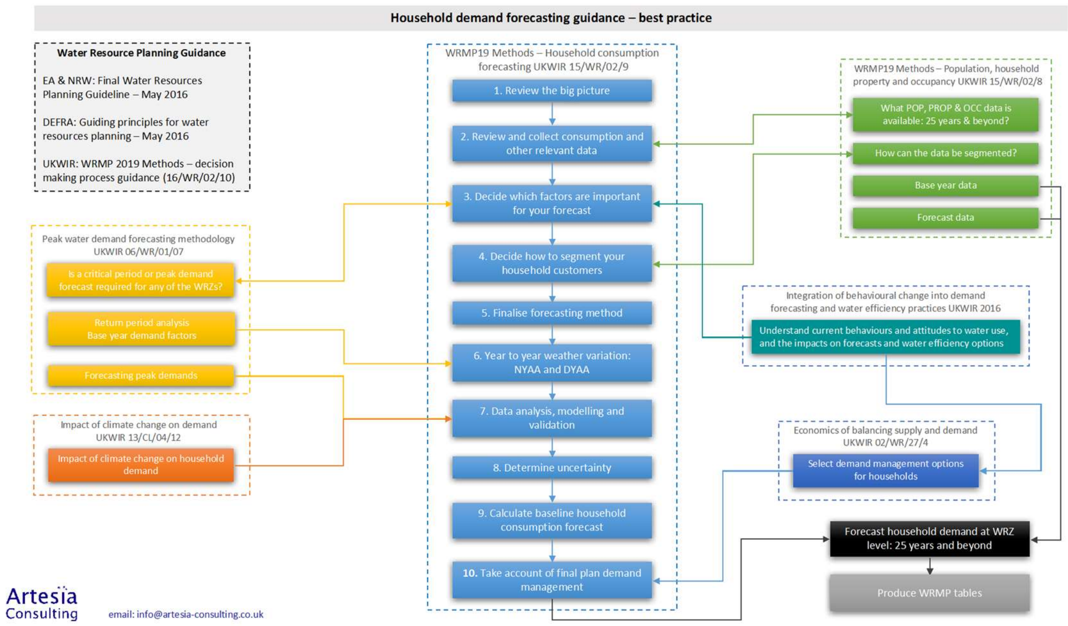
Household customers were segmented based on meter status (measured/unmeasured), with sub-divisions for meter type (existing metered, meter optants, new property, change of occupier). Data was used to determine how to account for differences in consumption between segments and also the effect of meter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

A separate detailed problem characterisation exercise was undertaken by the Company, and has confirmed an overall level of concern of 'low'. 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.

SES 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

Introduction

Figure 2 illustrates the results of the RAG matrix.

[1] Water Resources Planning Guideline: Interim Update April 2017
2 Red Amber Green Matrix, used to highlight which methods score best to worst

Figure 2 SES Water RAG Matrix for household consumption forecast method selection

Low concern zone	Weighting	Regression models	Micro-component models	Macro-comp-onents	Variable flow methods	Trend based models	Per capita methods	Use existing study data
Acceptance by stakeholders	10	7	6	8	6	6	4	2
Explicit treatment of uncertainty	5	8	6	6	5	4	2	2
Underpinned by valid data	6	5	6	6	4	4	2	2
Transparency and clarity	5	6	6	7	6	5	4	2
Appropriate to level of risk	7	6	8	8	7	6	3	2
Logical and theoretical approach	5	6	7	7	6	5	4	2
Empirical validation	2	7	6	7	4	4	2	2
Explicit treatment of factors that explain HH consumption	5	6	6	7	6	4	2	2
Flexibility to cope with new scenarios	5	7	6	8	5	4	4	2
Weighted score		**321**	**319**	**361**	**281**	**244**	**157**	**100**
Ranked		**2**	**3**	**1**	**4**	**5**	**6**	**7**

Table 1 provides comments on the justification for the scores presented in Figure 2.

Table 1 Justification for RAG Matrix scoring

Criteria	Comment
Acceptance by stakeholders	Based on existing micro-component model, the micro and macro component approaches should score more highly. The next highest alternate should be the Variable flow method, as this can use the BY PCC/PHC with a trend developed from the macro-component data. In effect, the macro-component approach is a micro-model of demand, with a trends developed through a macro-component approach.
Explicit treatment of uncertainty	Regression models do this best, so should score more highly.
Underpinned by valid data	The quality of data available from the control areas for PCC/PHC is probably not sufficient for regression models - so this is marked down. National micro-component data are available, there are no company-specific data. Given the low level of concern national data is appropriate. Trend data is probably stronger at the macro level. These should score more highly.
Transparency and clarity	The macro-component model for forecasting which is built on the existing micro BY demand model should satisfy this criterion.
Appropriate to level of risk	Low level of concern, so do not need to develop a completely new method. Micro-component model of demand should suffice with the data available, but to forecast each individual component may be difficult with the data available. Trends in micro-components are more readily available at the macro-component level, therefore this should score higher for the forecast.
Logical and theoretical approach	Given the level of concern and the data available, then the micro/macro approach is logical.
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 macro model picks up the main technological trends and personal bathing trends without the unnecessary complexity of the micro-component model.
Flexibility to cope with new scenarios	The macro-model for forecasting is most appropriate for this.

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

The scoring reflects the relevance of the methods to the SES 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 for this project. The available data makes this possible and is effectively more advanced than the macro-component method identified in 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 2015/16.

Base year figures have been extracted from Table 10 of the Annual Report data. SES Water has one water resource zone (WRZ). The base year per capita consumption excluding supply pipe leakage (PCC) for measured and unmeasured properties, post MLE (maximum likelihood estimation), are 140.65 litres/head/day and 157.11 litres/head/day respectively.

Measured and unmeasured property and population figures are also extracted from the June returns. In the base year SES Water has 128,020 measured properties and 135,431 unmeasured properties. Population within the measured households is 308,259, with a resulting occupancy of 2.41 the population of unmeasured properties is 366,032 with a resulting occupancy of 2.70. For the purpose of forecasting household consumption, the reported figures are adjusted to align with Experian figures to account for properties not captured in the customer numbers. Consequently, the population for measured household are set to 312,907 and unmeasured are set to 371,550, total population is 684,456 which has come from the econometric population forecast from Experian, this has been deemed to be the most likely forecast and sits between the plan and trend forecast. A most likely forecast was chosen over the plan forecast due to plan being quite low in comparison. The resulting measured occupancy is 2.44 and unmeasured occupancy is 2.74.

Note: For this forecast the property, population and occupancy analysis has been carried out as described above and in section 4. In the reporting year 2017/18, SES Water are planning to move about 2000 'shared flats' properties from the non-household cohort into the household cohort (currently consumption from these flats is included in the non-household forecast). When these properties are moved from non-household to household, both the household and non-household forecasts will need to be updated, but this cannot be done until the precise nature of these properties (in terms of meter type and occupancy) is determined.

The calculated per household consumption (PHC) values post MLE for measured households is 338.68 litres/property/day, unmeasured PHC is 424.61. This is calculated from the reported PCC figures combined with the reported occupancy figures.

3.2 Other data

SES 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, Experian forecast for population and properties, historic weather data, historic distribution input (DI) data, also micro-component survey data for about 8500 households from the company's on-line water efficiency calculator.

In addition to the data provided by SES 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).

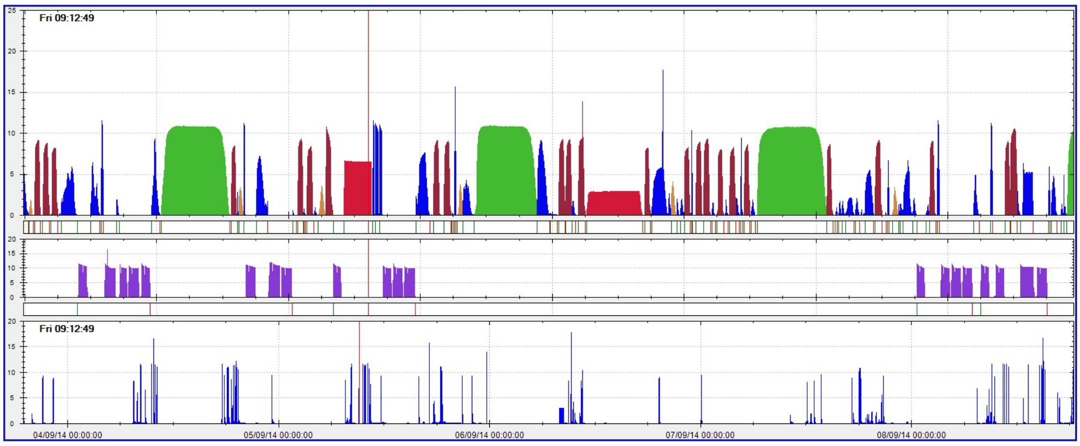
The Siloette system uses a Siloette logger that is connected to the pulsed output from a meter via a pulse unit, as illustrated in Figure 3.

[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 3 **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 4.

Figure 4 **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 4 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 4.)

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).

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

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, optants, as well as 'compulsory', 'selective', 'change of occupier', and 'other' metering programmes. 'Existing' metered households are in fact a combination of these different metered types, 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 5.

A forecast produced by Experian as part of a separate project[6] details the increase in number of properties. We have chosen to use the 'econometric' forecast from Experian, following consultation with SES Water. Guidance suggests the use of plan based properties and population. We deviate slightly from the guidance here due to the comparison of plan verses trend, here we see a lower projection for plan than trend, which is unusual. We in fact select the econometric trend as it sits between the plan and trend which we feel gives the most likely estimate. Using the lower plan based projections might leave the company at risk for water balance if the properties and population were in fact to follow either of the other trends provided by Experian. We have checked the validity of these property and population forecasts and ensured their compliance with regulatory guidance.

The Experian forecast only provides total property numbers. Therefore, as part of this work we have determined the switch from unmeasured to optant, which 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. Additionally the number of change of occupier metered properties are forecast, and are forecast in a similar way to optants, using historic reported figure and the WRMP14 forecasts. The change of occupier figures forecasted in WRMP14 forecast showed a steep decline likely due to the planned policy at the time. This has been discussed with SES, and it was decided to leave this in place as the current number of optants are following the WRMP14 forecasts. This will need to be revisited in the next WRMP. The figures used for the forecasts for free optants and change of occupier are shown in Table 5.

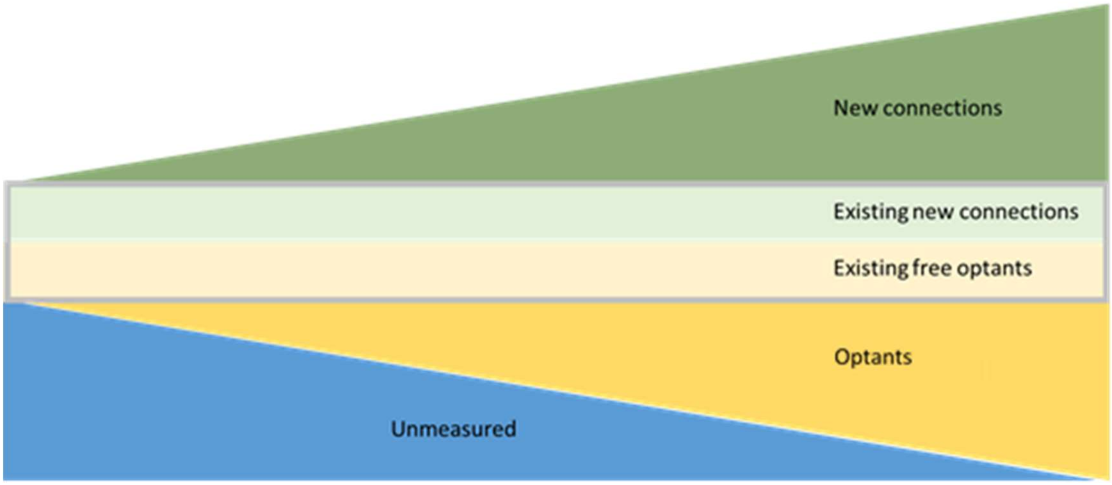
[6] Experian (2017) Population, Household, Property and Occupancy Forecasts for WRMP19.

Table 5 Change of occupier and optant forecasts total by AMP

	AMP5	AMP6	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13	AMP14	AMP15	AMP16	AMP17	AMP18
Optants (total per AMP '000)	11.802	19.729	18.087	13.391	9.914	7.341	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Change of occupier (total per AMP '000)	18.724	12.346	10.391	7.693	5.696	4.217	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
New connections (total per AMP '000)	7.394	9.804	12.628	13.894	14.734	15.845	16.270	14.805	14.388	14.388	14.388	14.388	14.388	14.388
Meter penetration (at end of AMP)	45.8%	59.7%	71.5%	79.9%	85.8%	90.0%	90.5%	90.9%	91.2%	91.5%	91.8%	92.1%	92.4%	92.6%

Property, optant and change of occupier forecasts are each inputs into the segmentation model.

Figure 5 Illustration of property breakdown within the company, forecast from base year to the point of 100% meter penetration

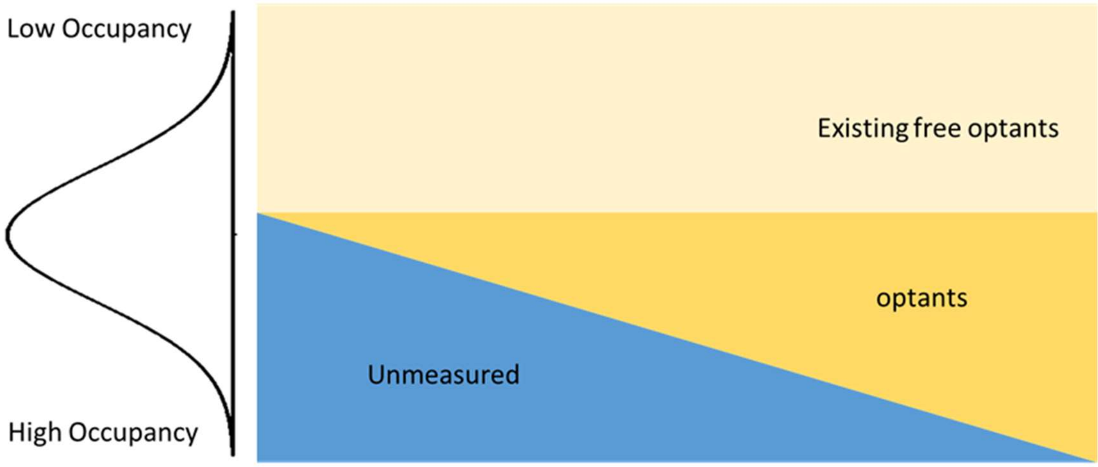


Some key assumptions made in the segmentation model:

- New households will always be metered.
- Optants and change of occupiers 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. Consumption in void properties is included in the demand category 'minor components' in 'water unbilled' (i.e. not in the household consumption component).
- The point at which 100% meter penetration occurs is based on the meter optant and change of occupier forecasts.
- 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 6 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. For SES the population figures are calibrated up to meet the Experian population, this occurs in the base year and throughout the forecast. 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 6 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). Change of occupier metering is not shown in Figure 6; the occupancy of change of occupier is assumed to be the same as the unmeasured properties, due to this process being random with respect to occupancy, with properties switched to being metered.

Meanwhile the average occupancy of all the segments must follow the change in occupancy from the Experian 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 over 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:

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

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 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, selective metered and change of occupier 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. In addition to this we use the SES Water micro-component survey data to tailor the occupancy models and OVF outputs for the update these figures to closer match the reported figures. The measured data is used as the primary source, with the survey data being used to validate and amend where necessary.

Figure 7 Each micro-component daily use plotted against occupancy

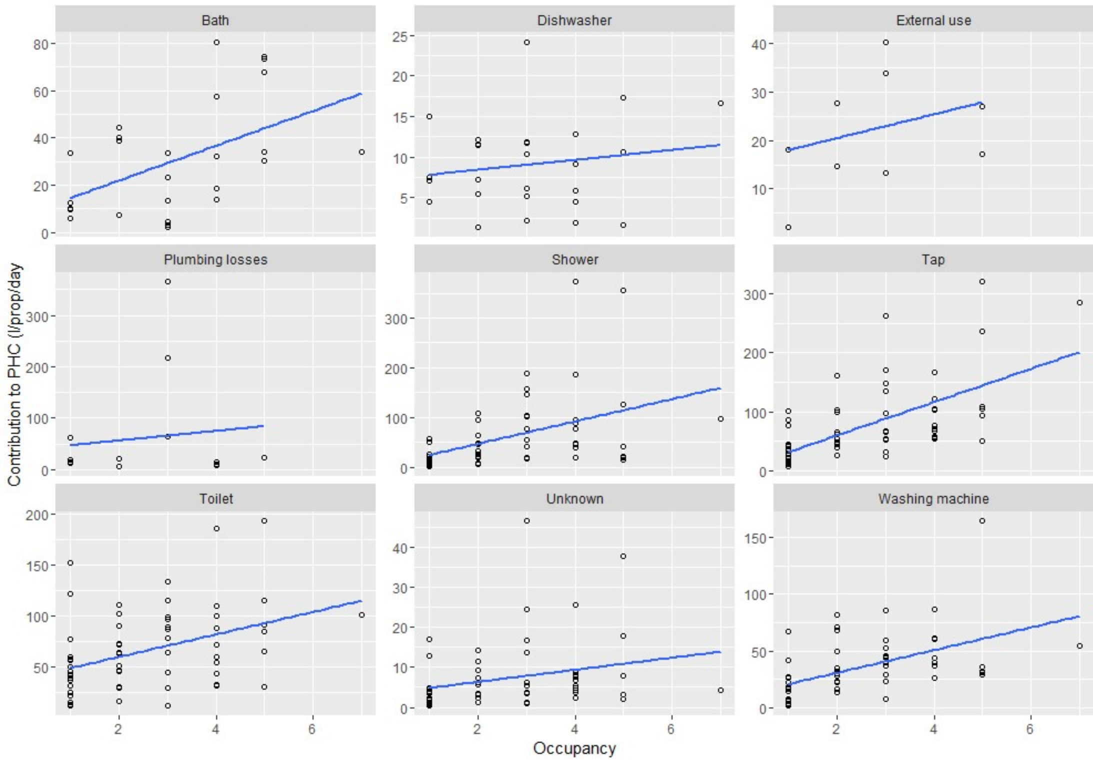


Figure 7 shows the average daily use (or contribution to per household consumption) for each of the following micro-components:

- 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:

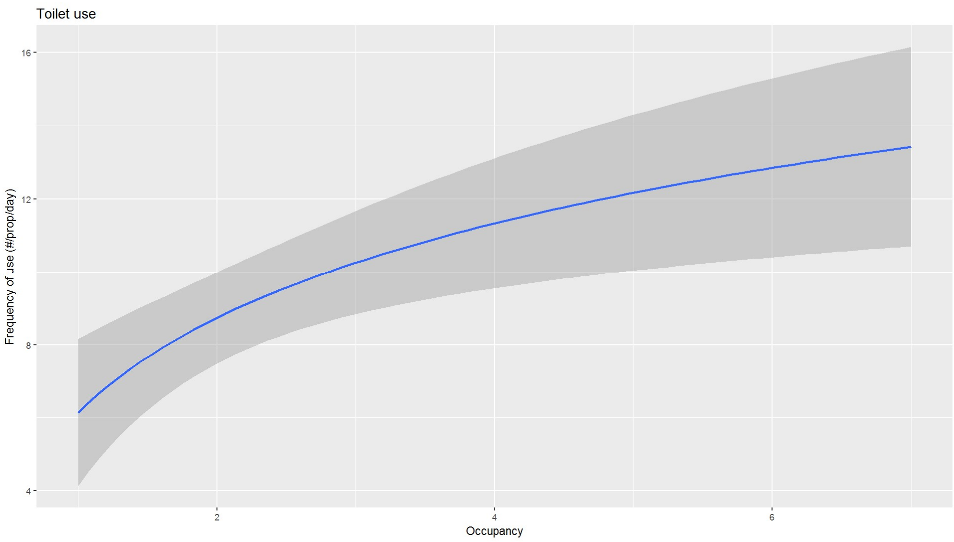
- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Washing machine use.

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

Figure 8 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 8 Variation of WC flushing frequency (uses per day) with occupancy



Specifically for SES Water the first update using the survey data was to incorporate the measured vs unmeasured split in the survey data. Due to the nature of the questions asked, only total PHC for toilets could be modelled, rather than frequency per use.

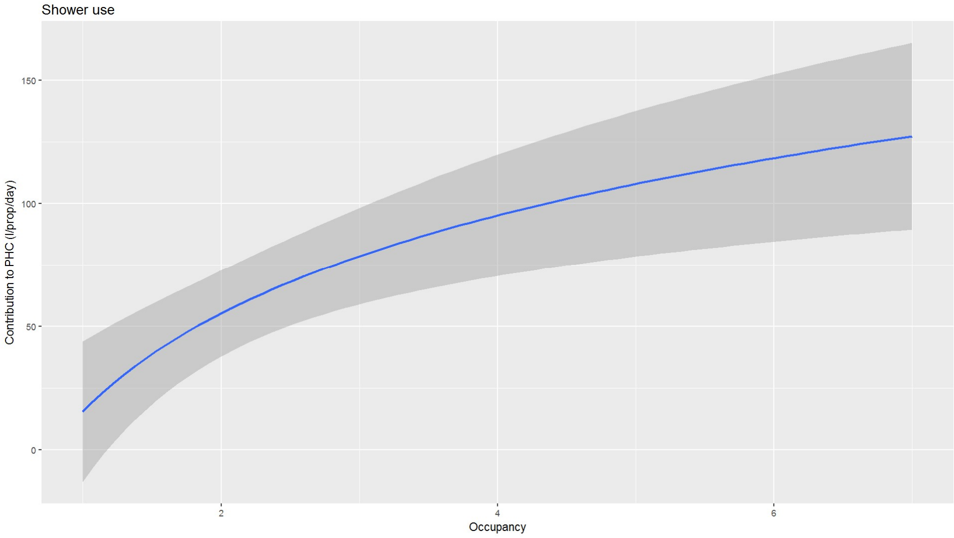
*SES Contribution to umPHC (l/prop/day) = 10.071 + 80.214 * ln(occupancy)* **Equation 1a**

*SES Contribution to mPHC (l/prop/day) = 19.305 + 67.269 * ln(occupancy)* **Equation 1b**

Figure 9 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 9 **Variation of shower volume used per day with occupancy**



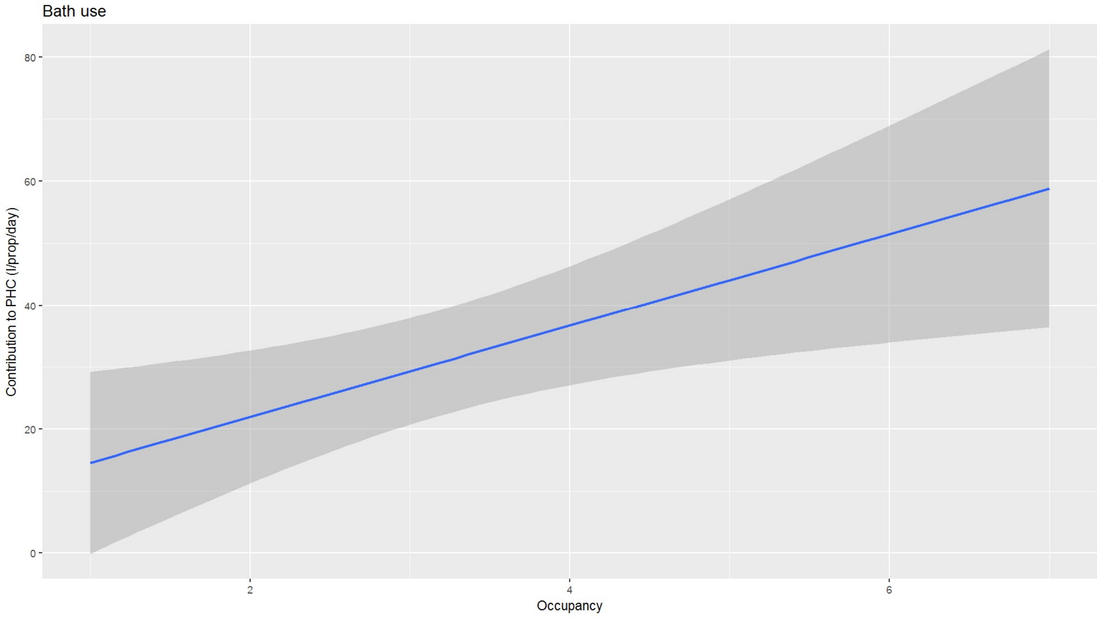
*SES Unmeasured Shower volume used per day = 29.93 +92.69 * ln(occupancy)* **Equation 2a**

*SES Measured Shower volume used per day = 29.10 + 86.99 * ln(occupancy)* **Equation 2b**

Figure 10 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 10 Variation of bath volume used per day with occupancy



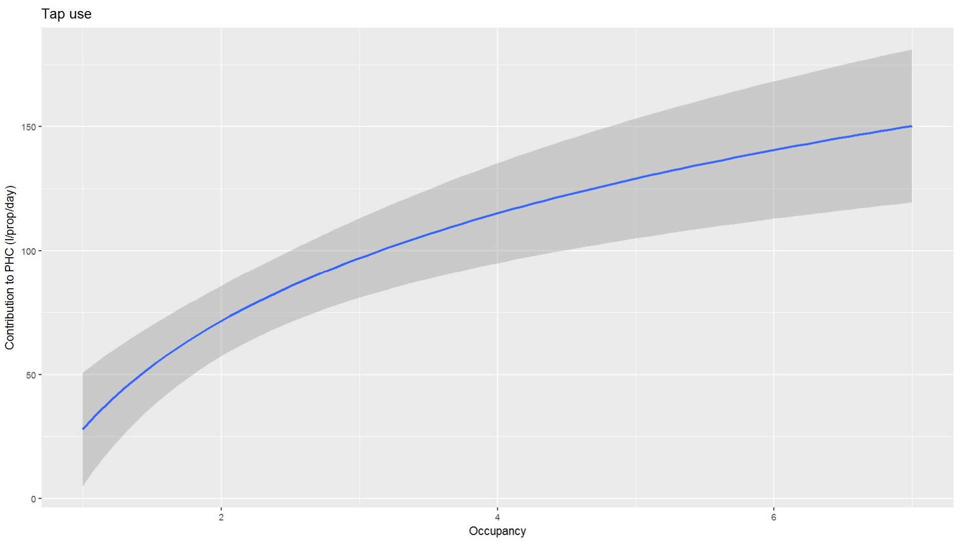
*SES unmeasured Bath volume used per day = 7.293 + 7.089 * occupancy* ***Equation 3a***

*SES measured Bath volume used per day = 6.077 + 9.185 * occupancy* ***Equation 3b***

Figure 11 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 11 Variation of tap volume used per day with occupancy



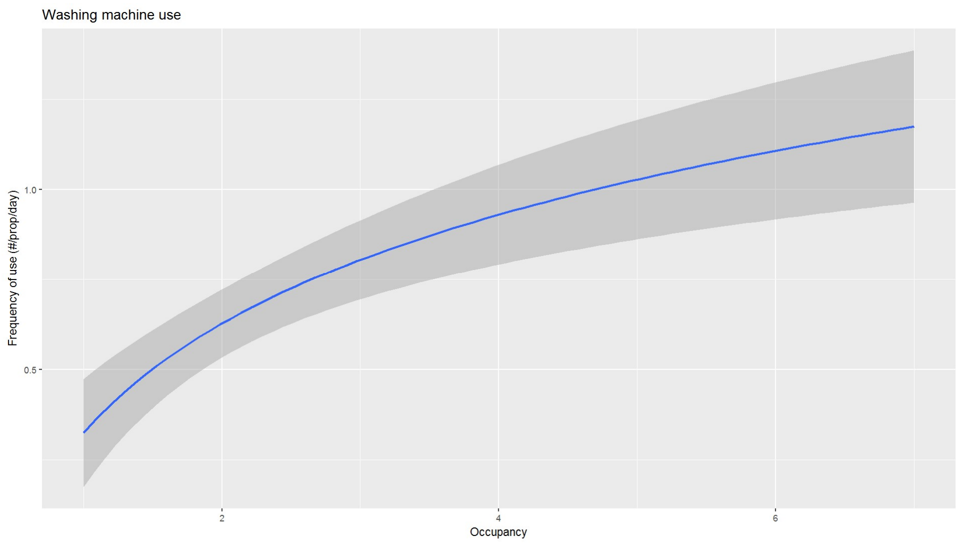
*SES unmeasured Tap volume used per day = 14.561 + 106.557 * ln(occupancy)* **Equation 4a**

*SES measured Tap volume used per day = 25.525 + 87.764 * ln(occupancy)* **Equation 4b**

Figure 12 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 12 Variation of washing machine (frequency of use per day) with occupancy



*SES Contribution to umPHC (l/prop/day) = 11.555 + 16.517 * ln(occupancy)* **Equation 5a**

*SES Contribution to mPHC (l/prop/day) = 14.949 + 5.179 * ln(occupancy)* **Equation 5b**

For each property type the model variables shown in Table 6 are also changed depending on the meter status of the property.

Wastage/plumbing losses frequency of occurrence value of 1.55 is taken from the UKWIR report[7]. The multiplying factors have been assumed considering the impact of metering on plumbing losses across property type.

Table 6 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

[7] UKWIR (2014) Understanding Customer Behaviour for Water Demand Forecasting

				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
Change of Occupier	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 7.

Table 7 **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 6	See Equation 1	If New/opt O*V*F, if umHH see Eq1a, if existHH average Eq 1b and O*V*F
Shower use				If New/opt See Equation 2, if umHH see Eq2a, if existHH average Eq 2b and Eq2.
Bath use				If New/opt See Equation 3, if umHH see Eq3a, if existHH average Eq 3b and Eq3.
Tap use				If New/opt See Equation 4, if umHH see Eq4a, if existHH average Eq 4b and Eq4.
Dish washer	0.42	See Table 6	0.5	O*V*F
Washing machine	0.95	See Table 6	See Equation 5	If New/opt O*V*F, if umHH see Eq5a, if existHH average Eq 5b and 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 6	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
- Change of occupier metered billed households.

Application of the occupancy model in the base year and final year are shown in Table 8 and Table 9 respectively. The base year in Table 8, 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 8 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	2.74	424.46	154.72	432.37	157.60
Existing metered billed HH	2.45	338.23	138.24	332.62	135.94
New build metered HH	2.60	291.90	112.24	316.07	121.53
Optant metered HH	2.04	255.89	125.50	277.08	135.89
Change of occupier metered HH	2.75	411.94	149.99	356.84	129.93

Table 9 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 9 Micro-component occupancy model parameters – Final year (NYAA)

Household types	Occupancy	PHC (OVF calculated)	PCC (OVF calculated)
RV billed HH	2.99	451.65	151.07
Existing metered billed HH	2.21	315.04	142.31
New build metered HH	2.01	246.38	122.38
Optant metered HH	1.91	244.18	127.85
Change of occupier metered HH	3.13	453.06	144.88

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

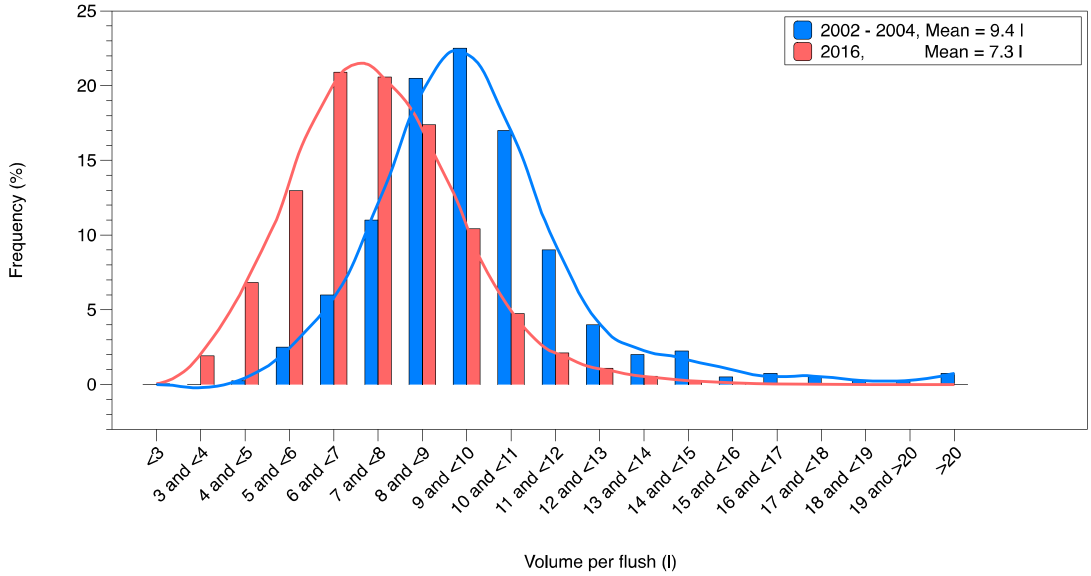
To investigate trends in individual micro-components due to technology change, policies and regulation, and behaviour change, we have used the data set from 2002/04 (Table 4) and the 2015/16 datasets (Table 2 and Table 3). For future projections of trends we have generally used the forecast water use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

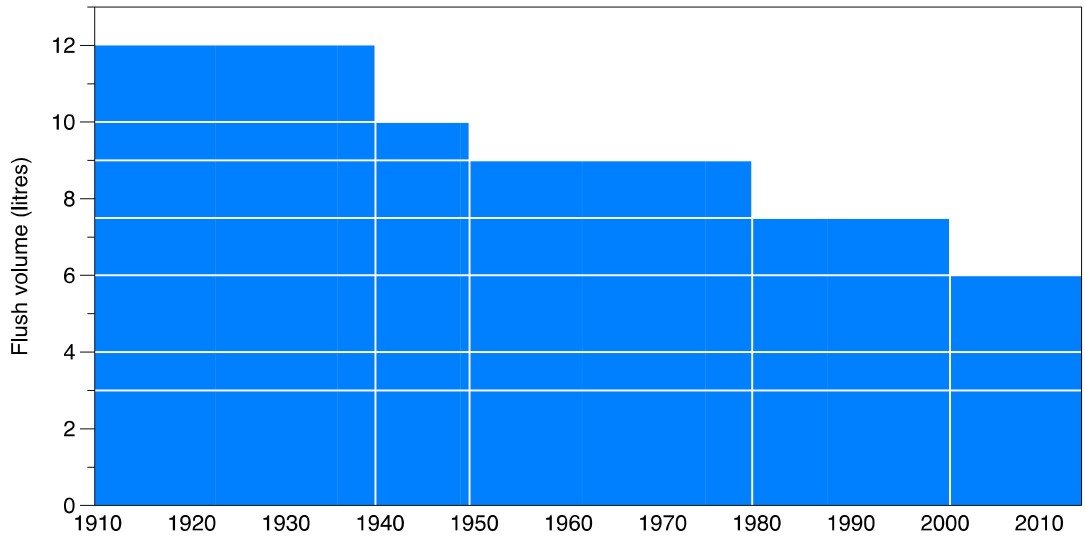
Using data from the WRc micro-component report CP187 and data from the UKWIR 2016 study, we can create a histogram of the volumes per flush from 2002/04 and 2015/16. These are shown in Figure 13. This shows that for 2002/04 the mean flush volume was 9.4 l/flush, with a range of flush volumes from 5 litres 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 13 **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 14 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.

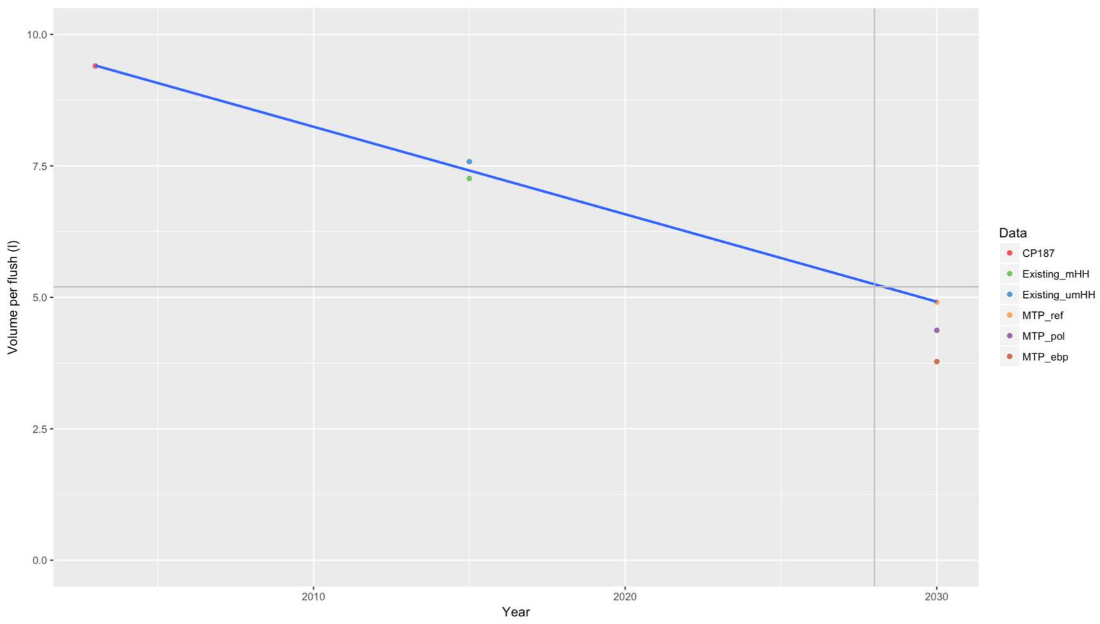
Figure 14 **Regulatory changes in flush volumes**



The latest MTP projections for WC flushing volumes[8] in 2030 for the reference scenario is 4.8 litres/flush. Figure 15 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 Figure 15). This provides some confidence in the MTP Reference scenario for WC flush volumes.

Figure 15 Historic, current and future flush volumes

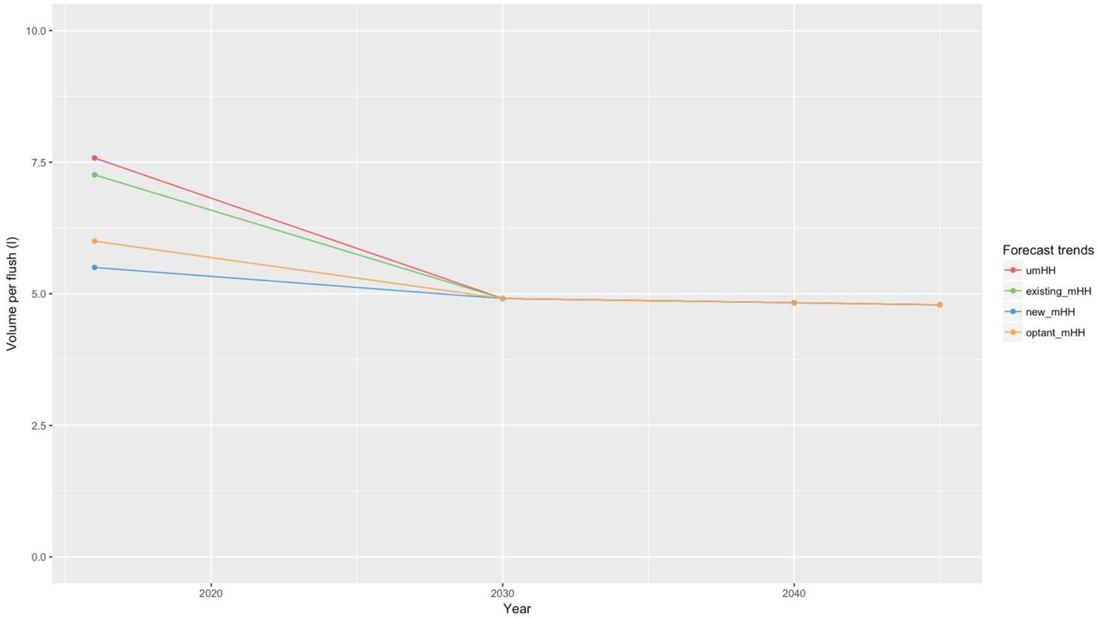


We have created future trends for WC volume per flush (see Figure 16) using:

- the base year volumes per flush in Table 6 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)[9],
- and an assumption that the volume per use will then remain relatively constant until 2045.

[8] Source: http://efficient-products.ghkint.eu/spm/download/document/id/954.pdf
[9] This is a reasonable assumption given the rate of change in actual data presented in Figure 14 and discussed elsewhere in this section.

Figure 16 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.

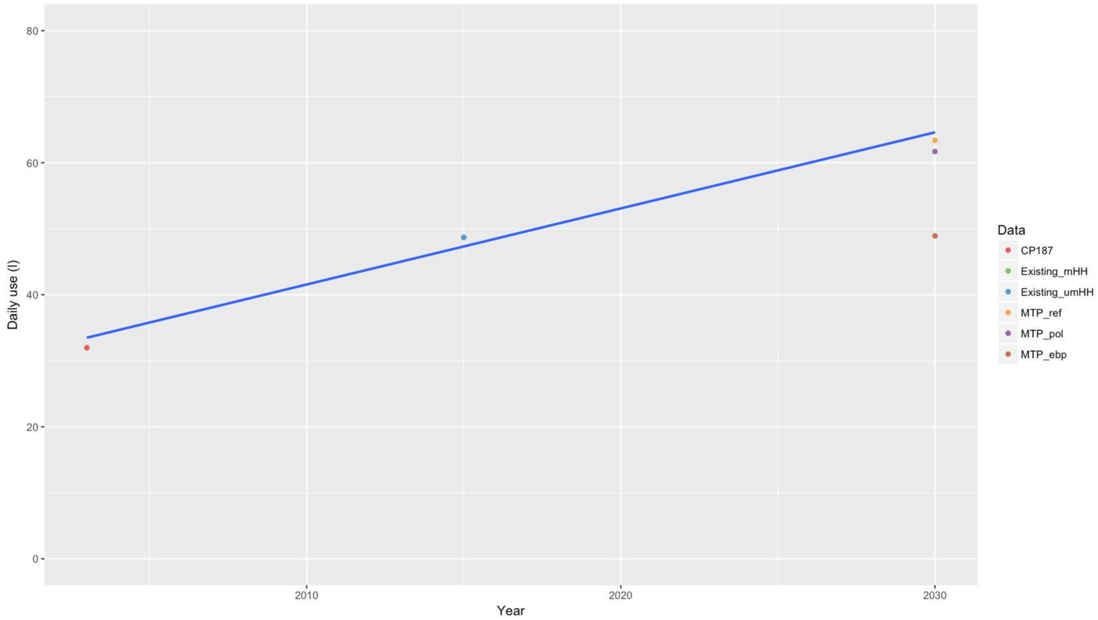
Figure 17 shows the following data points on daily shower volumes (l/day):

- 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).

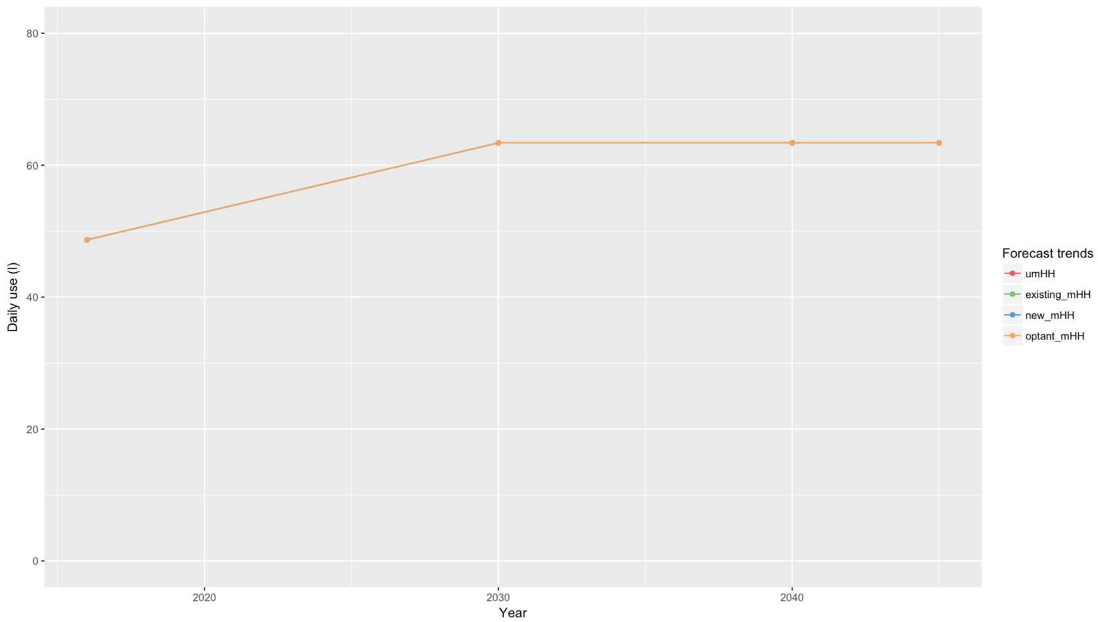
We have chosen not to fit trend line through the MTP Early Best Practice point as this assumes a very high proportion of water efficient showers being installed in new and existing households (which is not evident in current practice). This is used in the development of the lower PCC trend discussed in the alternative scenarios in Section 5.6.

Figure 17 Trend of daily volume of water used for showering



Using the trend line from Figure 17 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 18. There is no evidence for different house types having different trends, so the same trend is used for all house types. This is shown in the following figure.

Figure 18 Future trend for daily volume of water used for showering (unique trend for all house types)



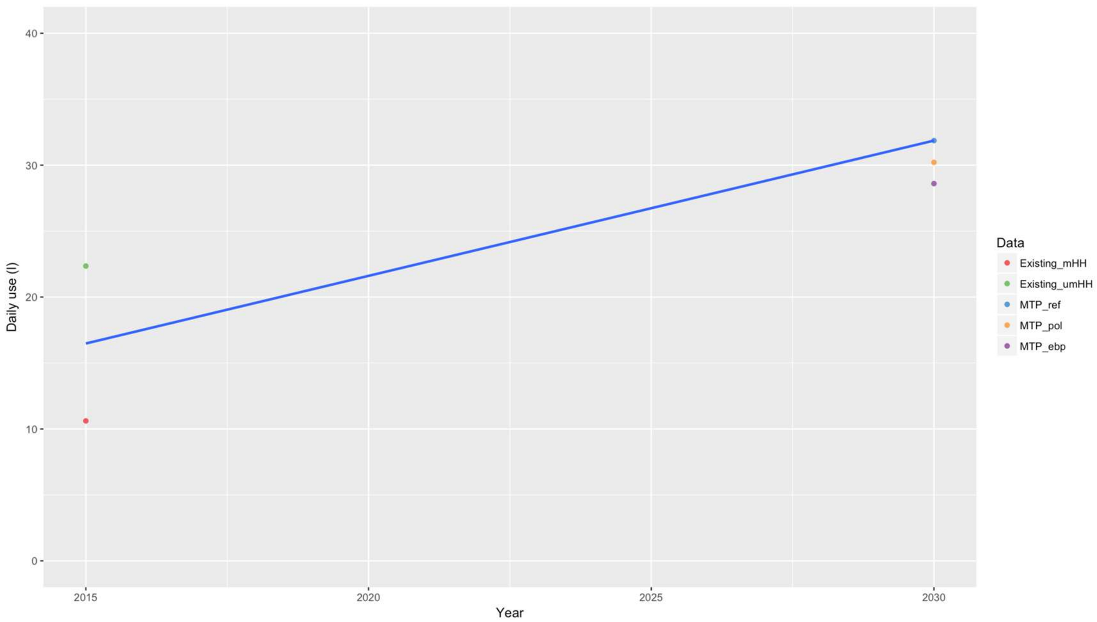
From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

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 19 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.

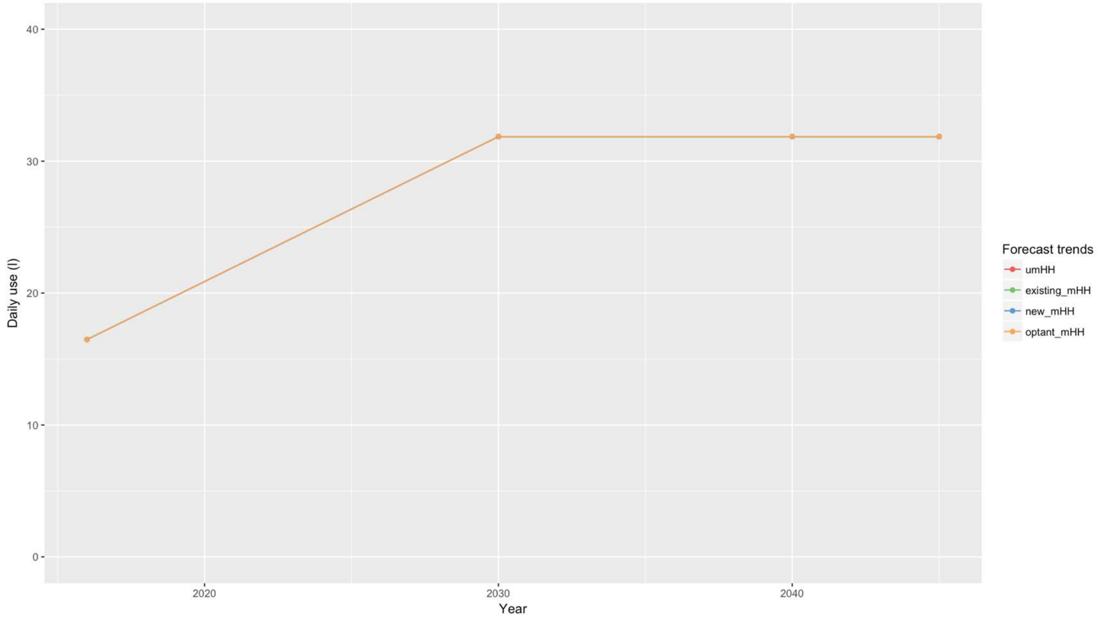
Figure 19 Trend of daily volume of water used for bath use



The blue line in Figure 19 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 20. 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 20 **Predicted trends of daily volume of water used for bath use (unique trend for all house types)**



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 21 (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 22. Rates of change are then computed from these trends and incorporated in the model.

Figure 21 Historic trend in washing machine volume per use

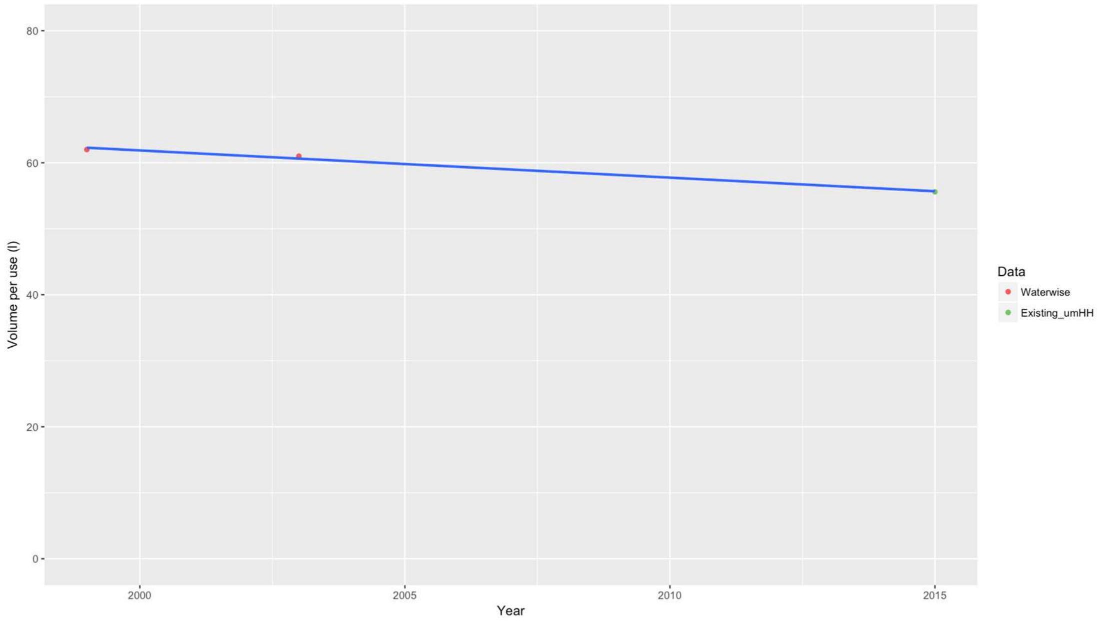
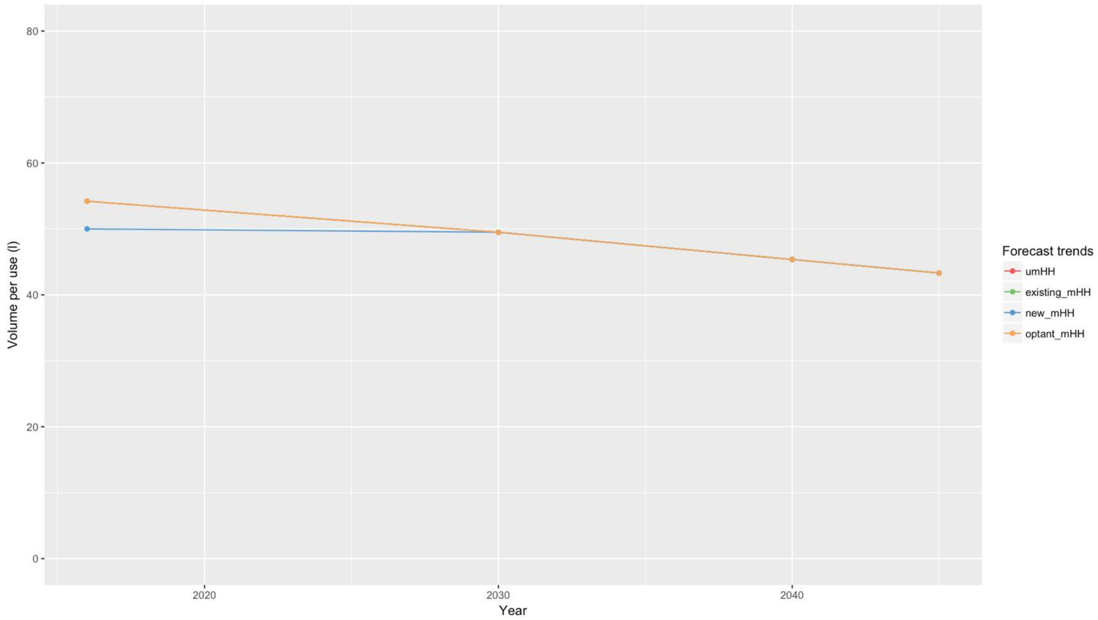


Figure 22 Future trend of washing machine volume per use



5.5.5 *Dish washer use*

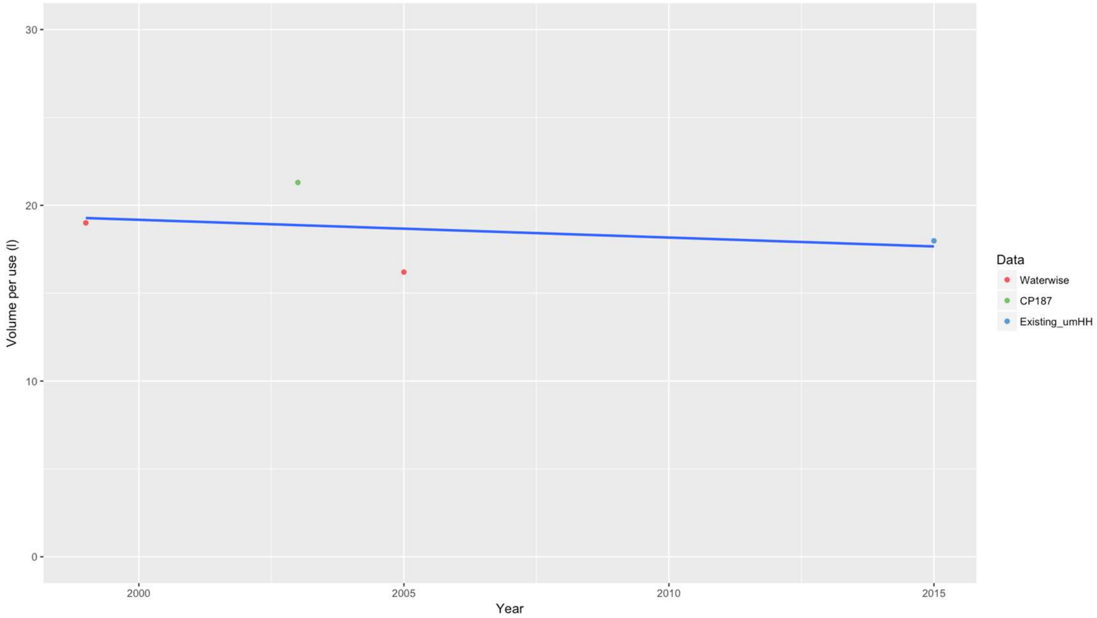
For dishwasher use, the following evidence has been used to derive an historic trend in volume per use:

- Waterwise data on washing machine volume per use from 1999 and 2003,

- Washing machine volume per use in 2016 from Table 3.

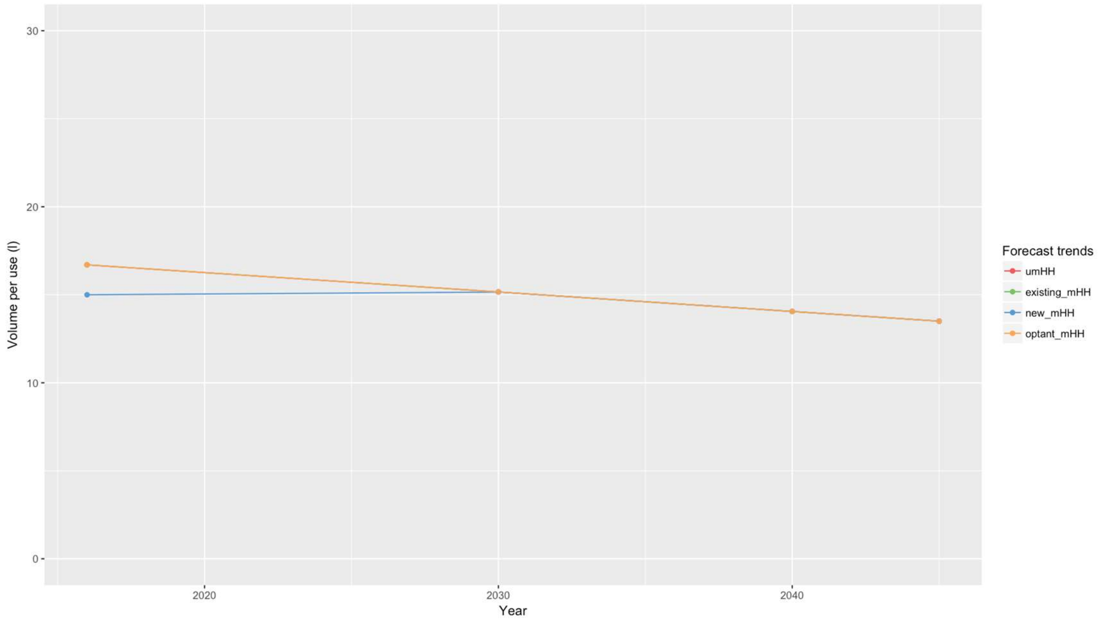
This data was used to produce a linear fit over time shown in Figure 23 (blue line). The volume per use has a trend over time to reflect the improvement in technologies to reduce energy and water use.

Figure 23 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 24. Rates of change are then computed from these trends and incorporated in the model.

Figure 24 Future trends of dish washer volume per use



5.5.6 *Micro-component rate of change by house type*

Based on the analysis detailed in the previous section, a series of trend have been developed by micro-component. These are summarised in the following table:

Table 10 Micro-component rate of change by property type

		AMP7 start	AMP8 start	AMP9 start	AMP10 start	AMP11 start	AMP12 start
micro-component	property type	2020/21	2025/26	2030/31	2035/36	2040/41	2045/46
WC flushing	Unmeasured (umHH)	-0.126	-0.144	-0.136	-0.008	-0.008	-0.008
	Existing measured (existing mHH)	-0.116	-0.131	-0.122	-0.008	-0.008	-0.008
	New measured (new mHH)	-0.038	-0.040	-0.035	-0.008	-0.008	-0.008
	Optant measured (optant mHH)	-0.065	-0.069	-0.061	-0.008	-0.008	-0.008
	Change of occupier measured (selective mHH)	-0.126	-0.144	-0.136	-0.008	-0.008	-0.008
Shower	Unmeasured (umHH)	0.077	0.071	0.053	0.000	0.000	0.000
	Existing measured (existing mHH)	0.090	0.083	0.061	0.000	0.000	0.000
	New measured (new mHH)	0.082	0.076	0.056	0.000	0.000	0.000
	Optant measured (optant mHH)	0.098	0.089	0.066	0.000	0.000	0.000

	Change of occupier measured (selective mHH)	0.077	0.071	0.053	0.000	0.000	0.000
Bath	Unmeasured (umHH)	0.190	0.160	0.110	0.000	0.000	0.000
	Existing measured (existing mHH)	0.216	0.178	0.121	0.000	0.000	0.000
	New measured (new mHH)	0.201	0.167	0.115	0.000	0.000	0.000
	Optant measured (optant mHH)	0.228	0.186	0.125	0.000	0.000	0.000
	Change of occupier measured (selective mHH)	0.190	0.160	0.110	0.000	0.000	0.000
Dish Washer	Unmeasured (umHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	Existing measured (existing mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	New measured (new mHH)	0.004	0.004	-0.004	-0.037	-0.038	-0.040
	Optant measured (optant mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
	Change of occupier measured (selective mHH)	-0.033	-0.034	-0.035	-0.037	-0.038	-0.040
Washing machine	Unmeasured (umHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	Existing measured (existing mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	New measured (new mHH)	-0.004	-0.004	-0.011	-0.042	-0.044	-0.046
	Optant measured (optant mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046
	Change of occupier measured (selective mHH)	-0.031	-0.032	-0.035	-0.042	-0.044	-0.046

After 45/46 rate of change is assumed to be zero for each micro-component.

5.6 Micro-component trend model – alternative scenarios

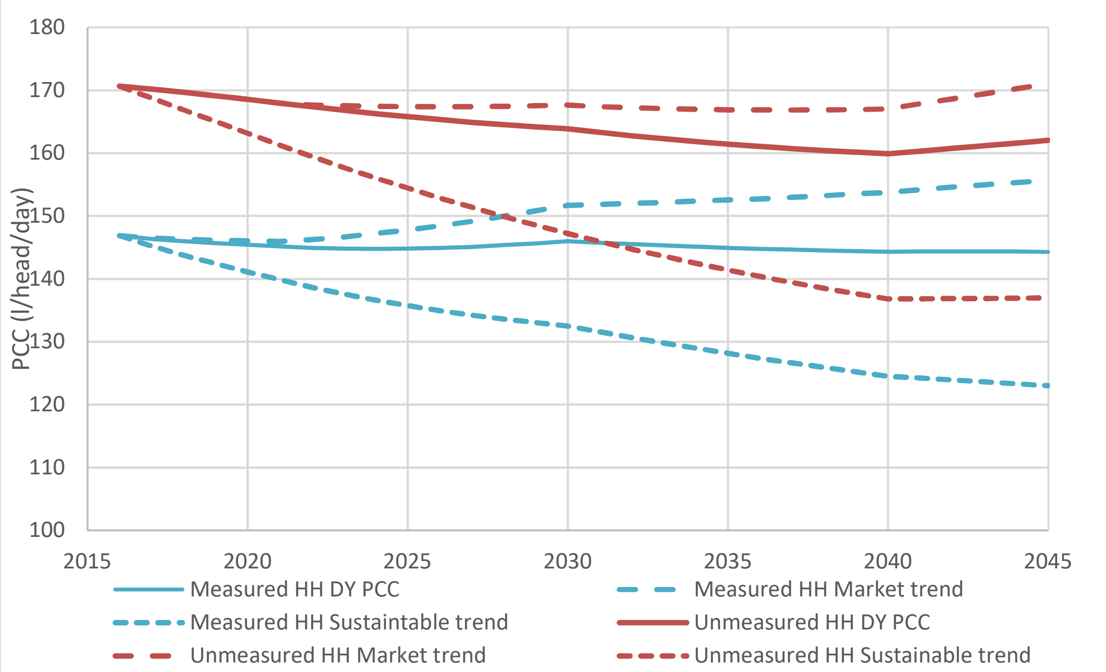
Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption.

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 is shown in Figure 25 for measured and unmeasured household PCC. These upper and lower scenarios may be used in the demand forecast uncertainty component of headroom.

Figure 25 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, selective/compulsory measured and change of occupier 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. SES Water sits entirely within the Thames basin. Therefore, the dry year annual average forecasts have a 0.88% increase in consumption over that period. As the base year is now 2015/16 and the final forecast year is 2079/80 the percentage change is shifted along and projected to the 2079/80 planning year as there has been no further evidence since this report. Therefore, as the forecast period is longer, the final percentage is larger than the figure printed in the guidance with a predicted impact in 2079/80 of 2.0 % for DYAA. If the forecast were to be run under a critical period scenario the percentage affected by climate increases to 5.5%. 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.

5.9 Trends, scenarios and uncertainty

Further work was carried out using a Monte Carlo approach, which has been applied at company (Ml/d) and at property level (PHC) split by measured and unmeasured to give an idea of the statistical variance and error calculations throughout the modelling procedure, these are shown in Figure 26 and Figure 27.

Population and property errors; for the population and properties we apply the UKWIR guideline[10] errors to a normal distribution (which we note is truncated at zero for the unmetered figures). The groups within the overall population and property figures are varied (where the figure is not fixed) and then normalised to sum to an overall population and property figure varied with the UKWIR errors. Note that the precise implementation requires a re-normalisation process at each time-step; as this process is somewhat complex we merely summarise the process here.

Modelling error has been derived from the standard statistical outputs from the micro-component linear modelling. It combines error within the predictor variables, modelling error and errors in the trends.

[10] UKWIR 15/WR/02/8 WRMP19 methods – population, household property and occupancy forecasting

Figure 26 Company level measured HH consumption Monte Carlo error distribution

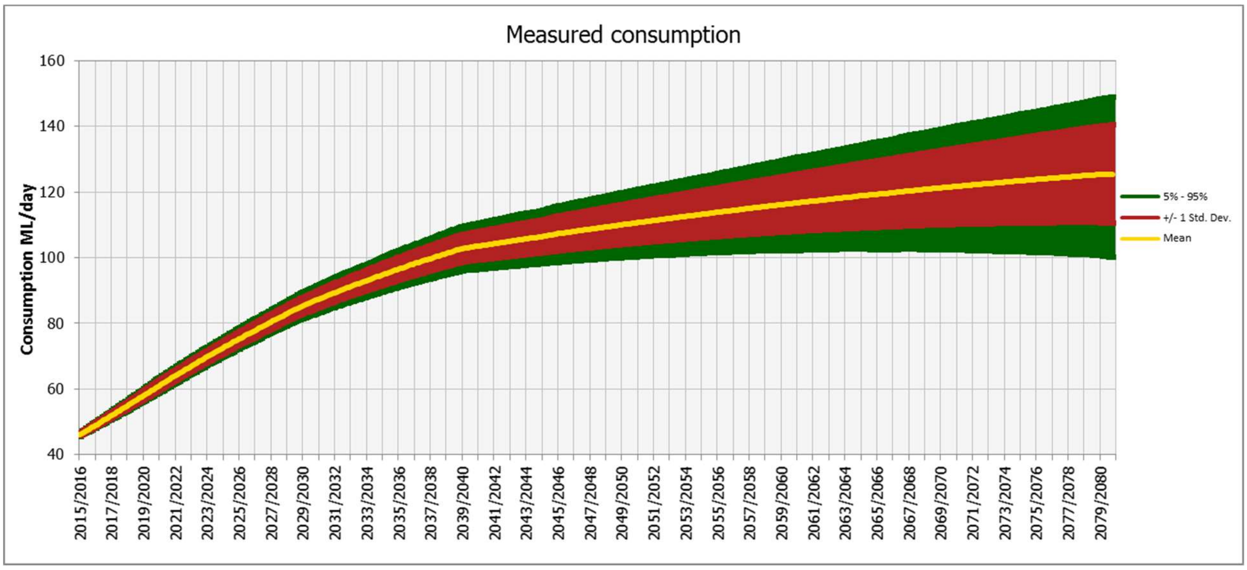
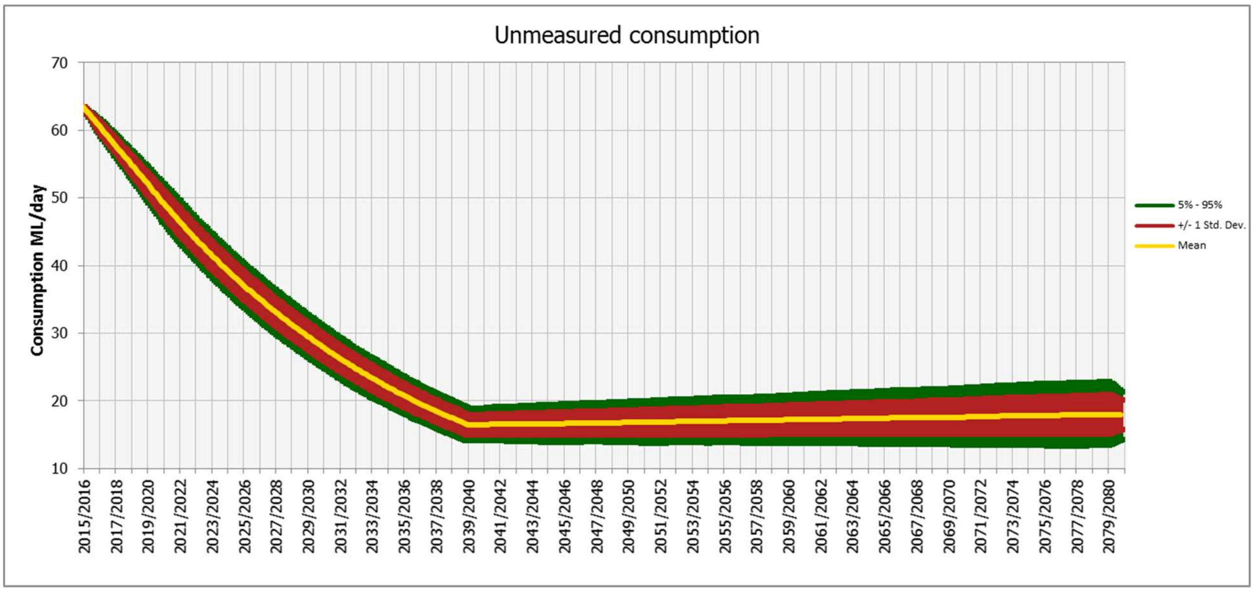


Figure 27 Company level unmeasured HH consumption Monte Carlo error distribution



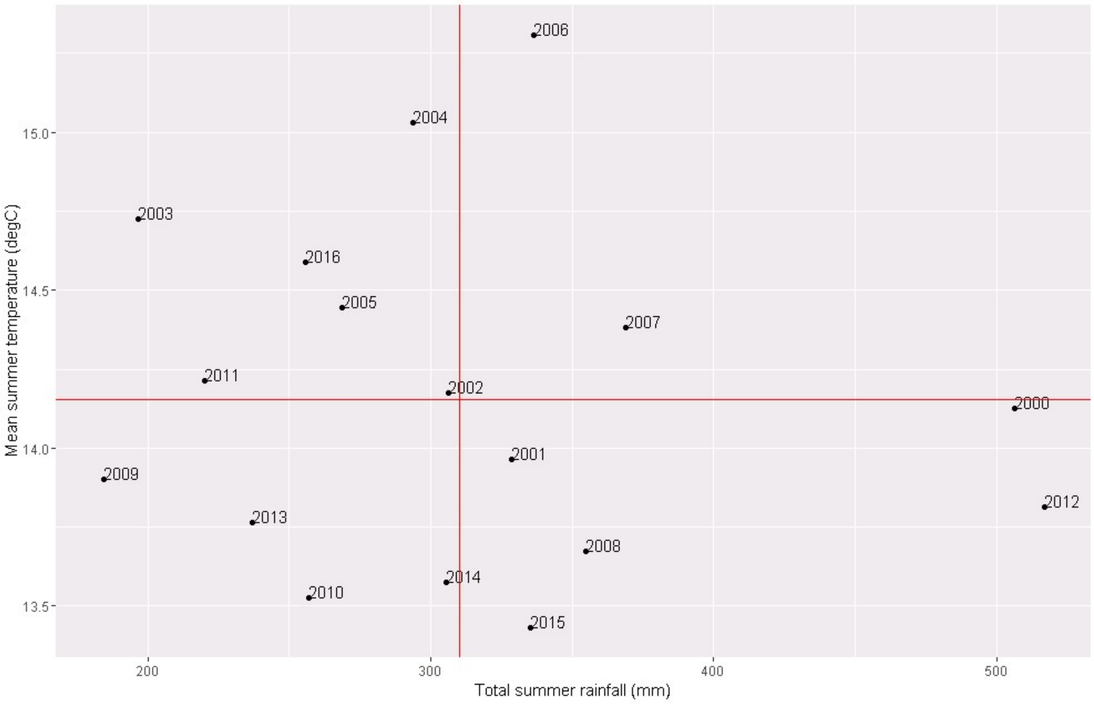
The results of this section are not used within the forecasting process, but are input into the headroom assessments. The graphs in Figure 26 and Figure 27 provide a graphical representation of the uncertainty surrounding the household consumption forecast.

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 summer 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 28. A judgement is made as to which is the hottest and driest year; 2003/04, 2004/05 and 2011/12 appear the strongest dry years in within the top left quadrant.

Figure 28: 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 29 **Reported PCC trend - measured properties (dry year indicated in red, base year indicated in yellow)**

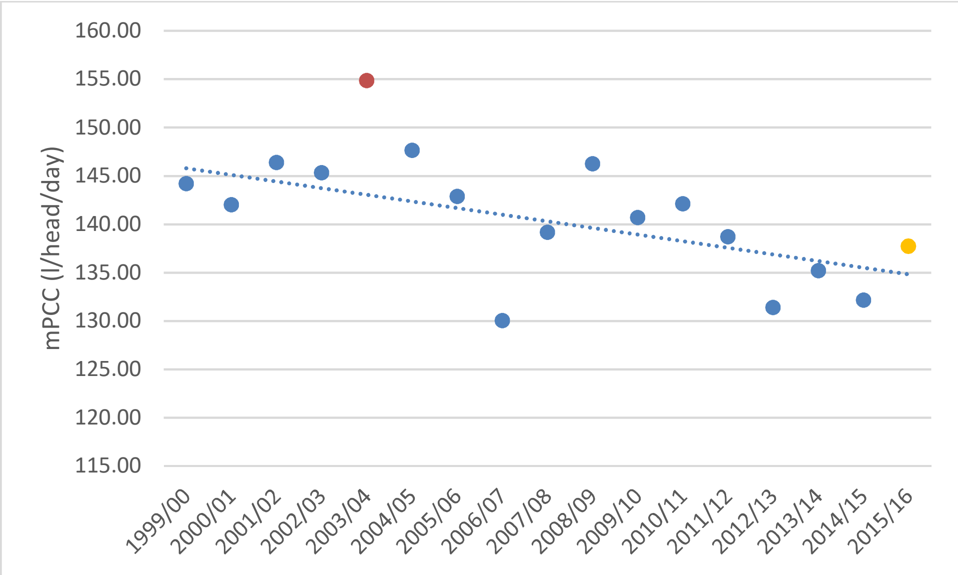
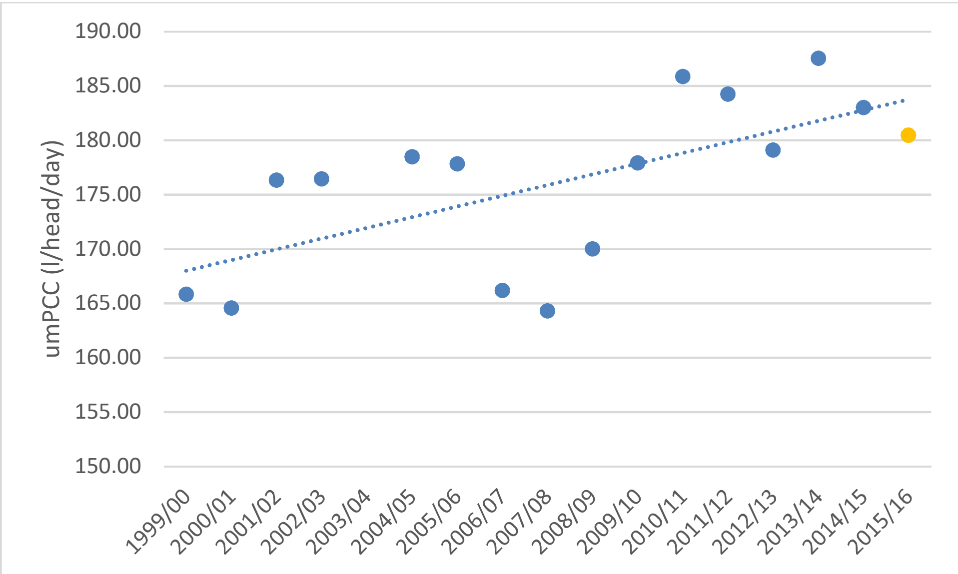


Figure 30 **Reported PCC trend - unmeasured properties (base year in yellow)**



The selection of the DY is done using the measured PCC values, shown in Figure 29. The reason for this is that measured values are deemed to be more accurate and less variable due to better quality data and fewer adjustments made with relation to supply pipe leakage. When assessing Figure 29, 2003/04 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 SES Water enforced the ban, media coverage of the ban has been shown to decrease consumption across many of the water companies, in fact 2006/07 does not appear strong in the quadrant plot either. 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 29 and Figure 30). As stated previously, this is done separately for measured and unmeasured.

The dry year factor is calculated to be 1.0827, measured normal year factor is 0.9790 and the unmeasured normal year factor is 1.0183. The WRMP14 forecast used a 1.10 dry year factor, which was using 03/04, 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 2003/04, with a result of 1.4949. WRMP14 used a 1.50 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 SES 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 11.

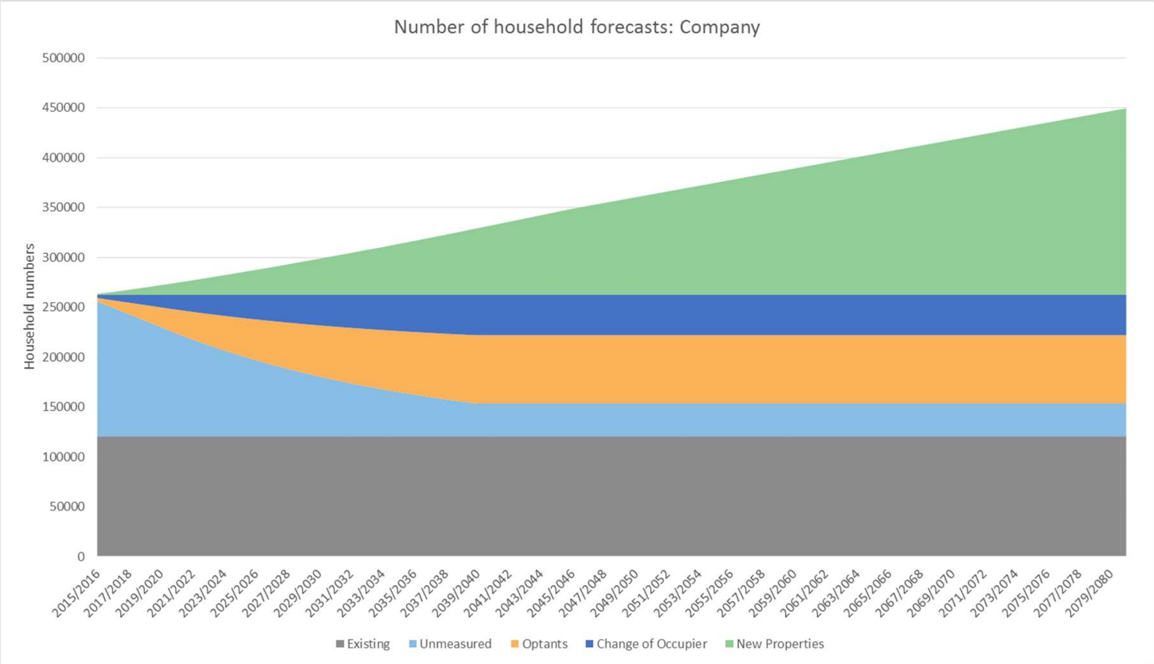
Table 11 Summary of factors applied in the household forecast

Factor	WRMP19	WRMP14
Normal to Dry year factor (all households)	8.3%	10%
Base to Normal year factor (measured households)	-2.1%	0
Base to Normal year factor (unmeasured households)	1.8%	0
Normal to Critical period factor (all households)	49.2%	50%

7 Household consumption outputs

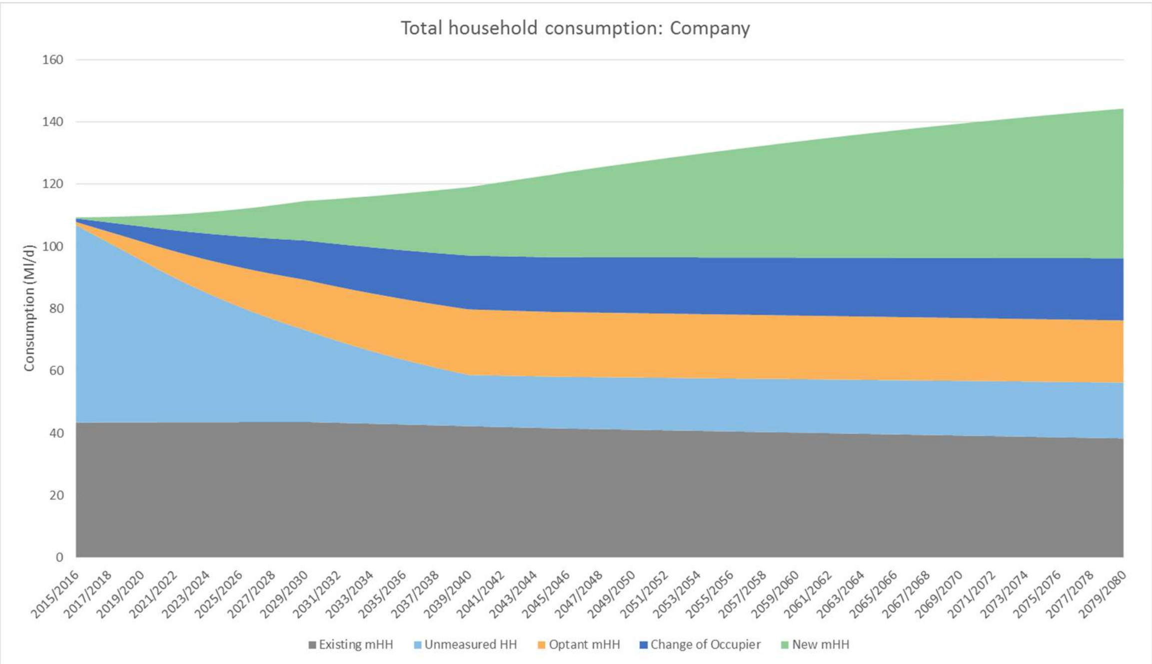
Graphical outputs for the central property forecast only (DYAA) are shown in figures 32 and 33. The central data is provided in tabular form in Table 13.

Figure 31 Total number of households, split by household segment



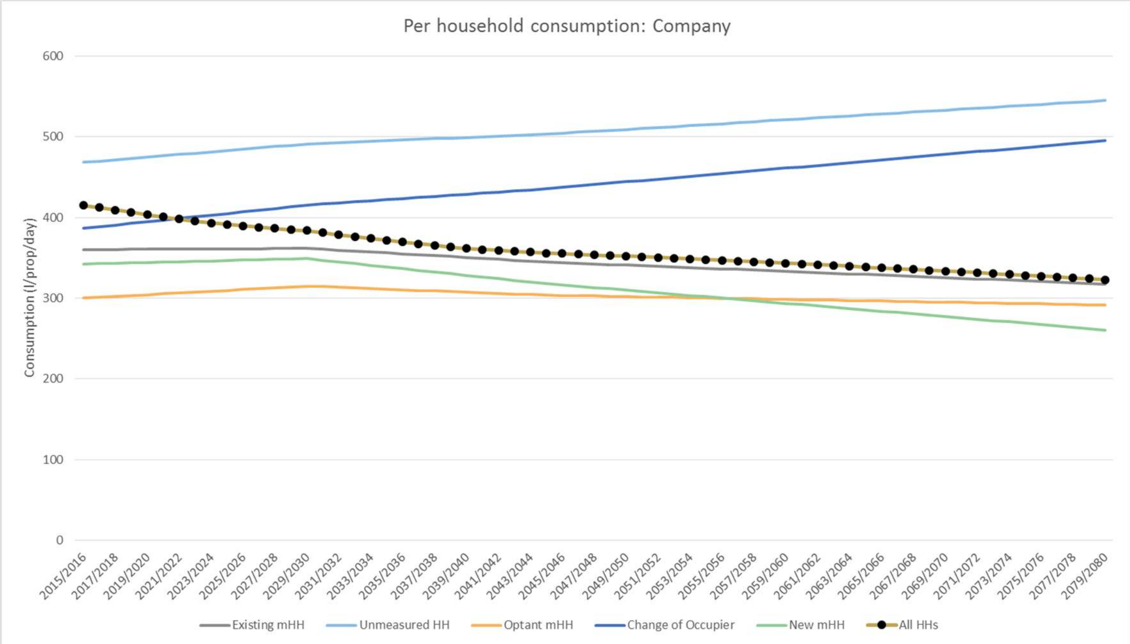
The total number of households, shown in Figure 31, increases from 263,451 to 446,691, so a 69.6% increase over the forecasting period.

Figure 32 Total household consumption (Ml/d), split by household segment



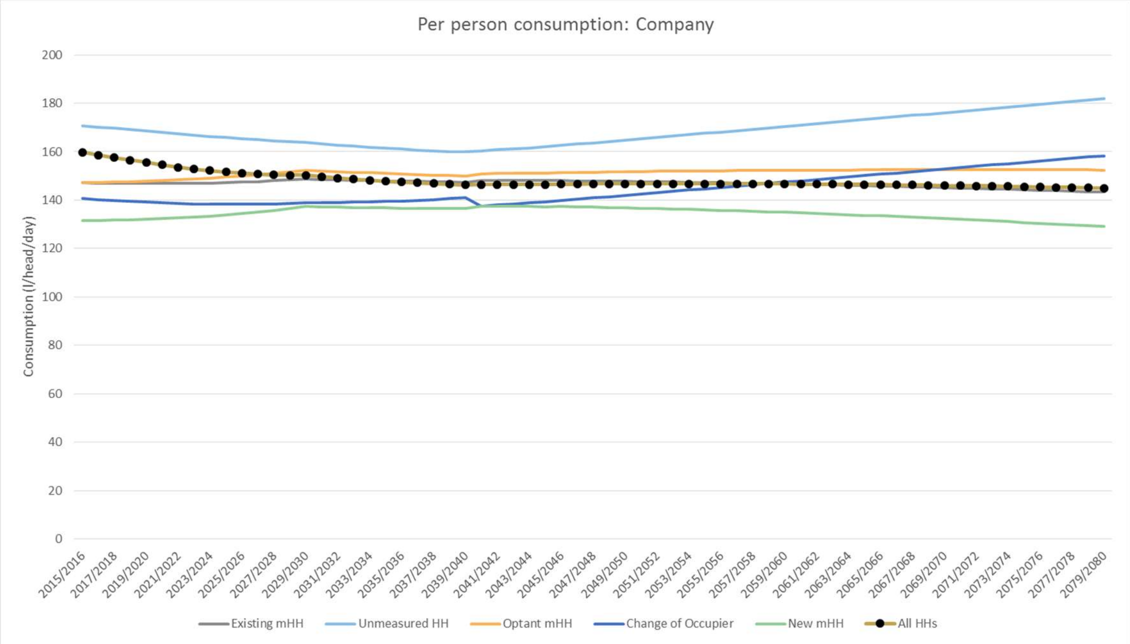
Total company household consumption increases from 109.36 Ml/day to 144.26 Ml/day, which is a 31.9% increase in demand over the forecast period, shown in Figure 32.

Figure 33 Company level PHC, split by household segment



Therefore, the PHC must decrease over the forecasting period, this is shown in Figure 33. The total average PHC decreases from 415.10 l/property/day to 322.95 l/property/day. Each of the household segments have different trends, with the unmeasured households increasing from 468.13 l/property/day to 544.76 l/property/day. 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 34 Company level PCC, split by household segment



Company level PCC has a similar trend to PHC, with a slight decrease from 159.77 to 144.93 l/head/day. Unmeasured PCC shows an increasing trend which is different compared to the PHC trend, this is due to the increase in occupancy within this segment, shown in Figure 35. 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 levels off. There is a small 'kink in change of occupier PCC around 2029/30: this is due to small change in assumed occupancy, as illustrated in Figure 35.

The unmeasured properties have a similar trend in personal washing, but they have increased reductions due to higher white goods and WC flush volumes at the start of the planning period.

Figure 35 Company level occupancy, split by household segment

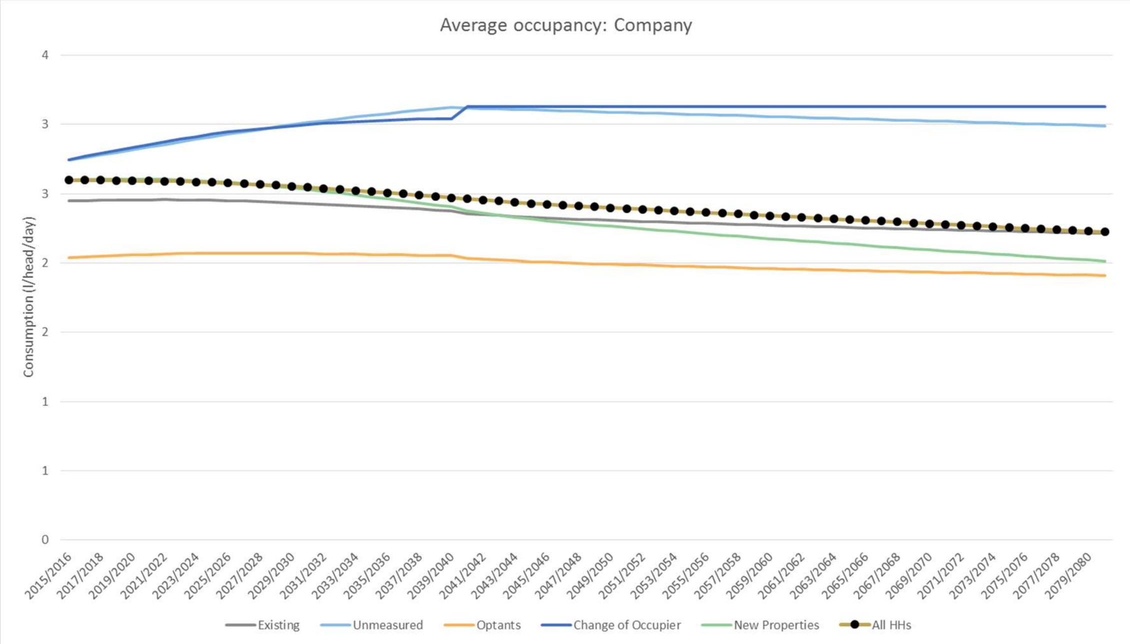


Figure 35 shows the trends in occupancy, the unmeasured rise is most notable, and as described before this is the impact of optant properties coming from the lower end of the occupancy distribution within the unmeasured households.

The Environment Agency (EA) requires micro-component models to report results following a particular classification, which is detailed below:

- WC (toilet) flushing
- Personal washing
- Clothes washing
- Dishwashing
- Miscellaneous (internal) use
- External use

In order to reconcile micro-component analysed by Artesia with the ones required by the EA WRMP tables, Artesia micro-components are redistributed. This is explicated by the following table.

Table 12 Redistribution of Artesia Micro-component to EA Micro-component

EA WRPG Micro-components		Micro-components	Multiplier	Tap use
WC (toilet) flushing	=	WC (Toilet flushing)	1	
Clothes washing	=	Washing Machine	1	
	+	Washer Drier	N/A	
	+	Internal Tap	0.02	Clothes washing
Personal washing	=	Showers	1	
	+	Power Showers	N/A	
	+	Baths	1	
	+	Internal Tap	0.03	Washing hands
	+	Internal Tap	0.45	Bathroom
Dishwashing	=	DISHWASHER	1	
	+	Hand Dishes	N/A	
	+	Internal Tap	0.32	Dishwashing
External use	=	Garden Hose	1	
	+	Garden Sprinkler	1	
	+	Watering Can	1	
Miscellaneous (internal) use	=	Internal Tap	0.08	Cleaning
	+	Internal Tap	0.07	Cooking
	+	Internal Tap	0.04	Drinking
	+	Wastage	1	

An overview of the final forecast for DYAA is shown in Table 13.

Table 13 DYAA household consumption forecast – central property forecast

	AMP6					AMP7					AMP8	AMP9	AMP10	AMP11	AMP15	AMP18
Company Consumption (Ml/d)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Total company	109.36	109.39	109.49	109.63	109.80	109.99	110.25	110.59	111.00	111.45	114.58	116.54	119.03	122.98	136.63	144.26
Measured	45.96	48.84	51.75	54.71	57.74	60.80	63.77	66.67	69.50	72.24	85.06	94.50	102.58	106.40	119.27	126.30
Unmeasured	63.40	60.55	57.74	54.91	52.06	49.19	46.48	43.92	41.50	39.21	29.52	22.04	16.45	16.58	17.36	17.96

Company PHC (l/prop/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Company average	415.10	412.10	409.18	406.28	403.40	400.56	397.95	395.54	393.32	391.30	383.58	371.80	361.48	355.90	338.60	322.95
Measured	358.99	357.67	356.66	355.88	355.31	354.91	354.69	354.62	354.66	354.81	356.51	351.41	346.18	340.38	321.86	305.28
Unmeasured	468.13	469.76	471.38	473.01	474.64	476.27	477.90	479.53	481.16	482.80	490.98	494.99	499.01	503.04	526.79	544.76

Company PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
Company average	159.77	158.64	157.58	156.56	155.55	154.54	153.61	152.81	152.15	151.57	150.21	147.80	146.28	146.45	146.43	144.93
Measured	146.88	146.36	145.98	145.68	145.42	145.16	144.92	144.81	144.80	144.83	145.99	144.95	144.30	144.29	143.20	140.85
Unmeasured	170.64	170.16	169.67	169.14	168.57	167.95	167.36	166.80	166.28	165.79	163.85	161.42	159.89	162.02	173.23	182.02

Measured PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
WC (toilet) flushing	32.08	31.07	30.09	29.19	28.32	27.48	26.67	25.91	25.19	24.49	21.35	21.16	21.02	20.95	20.75	20.38
Personal washing	68.91	69.64	70.44	71.23	72.02	72.79	73.56	74.37	75.22	76.08	80.75	80.29	80.08	80.26	78.88	77.13
Clothes washing	13.90	13.87	13.85	13.82	13.78	13.74	13.68	13.63	13.58	13.53	13.33	12.95	12.57	12.21	12.45	12.42
Dishwashing	14.53	14.47	14.42	14.37	14.32	14.27	14.22	14.17	14.13	14.09	13.98	13.91	13.88	13.89	13.75	13.50
Miscellaneous (internal) use	16.00	15.81	15.64	15.48	15.34	15.20	15.07	14.96	14.87	14.78	14.50	14.34	14.26	14.27	13.99	13.65
External use	1.46	1.50	1.55	1.59	1.64	1.68	1.72	1.77	1.81	1.85	2.08	2.29	2.50	2.70	3.39	3.76
SUM	146.88	146.36	145.98	145.68	145.42	145.16	144.92	144.81	144.80	144.83	145.99	144.95	144.30	144.29	143.20	140.85

Unmeasured PCC (l/head/day)	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	2023/2024	2024/2025	2029/2030	2034/2035	2039/2040	2044/2045	2064/65	2079/80
WC (toilet) flushing	36.59	35.53	34.46	33.40	32.34	31.28	30.24	29.20	28.19	27.18	22.35	21.89	21.55	21.70	23.03	24.06
Personal washing	83.91	84.73	85.54	86.31	87.06	87.77	88.48	89.21	89.94	90.68	94.54	93.35	92.67	94.11	99.90	104.36
Clothes washing	12.15	12.03	11.91	11.79	11.67	11.54	11.42	11.30	11.18	11.06	10.53	9.99	9.52	9.27	9.84	10.27
Dishwashing	17.02	16.95	16.87	16.78	16.69	16.60	16.51	16.43	16.35	16.27	15.93	15.68	15.53	15.72	16.69	17.43
Miscellaneous (internal) use	19.61	19.53	19.45	19.37	19.28	19.18	19.09	19.00	18.92	18.83	18.49	18.26	18.13	18.41	19.54	20.41
External use	1.34	1.39	1.44	1.49	1.53	1.58	1.63	1.67	1.72	1.77	2.00	2.25	2.50	2.81	4.24	5.47
SUM	170.64	170.16	169.67	169.14	168.57	167.95	167.36	166.80	166.28	165.79	163.85	161.42	159.89	162.02	173.23	182.02

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 144.93, with a total company household consumption of 144.26 Ml/day.

8 Conclusions & Recommendations

A baseline household consumption forecast has been produced for the SES Water Resource Zone using micro-component modelling and forecasting, which is suitable for a zone with a low 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, change of occupier metered and 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 36.67 Ml/day increase in household consumption for Dry Year Annual Average consumption, this is a 31.9% increase. This is largely driven by a 70% 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 160 to 145 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.