Technical Note

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Author:	Megan Shelton		
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1. Introduction

SES Water commissioned Atkins to update its existing household consumption forecast model (here after referred to as the model) to produce a demand forecast for the Water Resources South-East (WRSE) 2024 regional plan and the Company's own 2024 Water Resources Management Plan (WRMP24). The model was originally developed by Artesia Consulting for SES Water's 2019 Water Resources Management Plan (WRMP19). The model is based on micro-component modelling and forecasting. Further details about the model are provided in Section 2.

A non-household demand forecast model was also developed by Artesia Consulting in 2020 for the WRSE region. Further details about this model are provided in Section 3. Outputs from the non-household demand forecast model were incorporated into the model to allow the model to output non-household property and population forecast and non-household consumption forecasts.

Sections 4, 4.5 and 0 of this technical note outline the updates undertaken to the model between 2020 and 2023. Only a brief outline of the updates is provided in this technical note. Where necessary references have been made to reports which provide more detail of the updates undertaken. The specific reports which were produced when the updates were undertaken are provided as appendices.

Updates have initially been documented based on when they were undertaken. They have then been further sub-divided based on whether they relate to household or non-household.

The updates to the model include:

- Amending the model base year - this task was undertaken twice, first in 2020 where the model base year was amended to 2019/20 and again in 2023 when the model base year was amended to 2021/22).
- Updating population and property forecasts.
- Incorporating company policy/funded metering assumptions for Asset Management Plan (AMP) period 7.
- Updating external micro-component data.
- Incorporating the latest leakage, water taken unbilled and distribution System Operational Use estimates into the model.
- Review of climate change factors.
- Calculating and incorporating consumption uplift factors.
- Developing and incorporating a non-household demand forecast.
- Incorporating smart metering assumptions for households and non-households.
- Incorporating a template (Data Landing Platform (DLP) template) to enable outputs from the model to be reported to WRSE.

2. SES Water's household consumption forecast model

For its 2019 Water Resources Management Plan (WRMP19) SES Water commissioned Artesia Consulting to develop a household consumption forecast. This was produced using micro-component modelling and forecasting, which is suitable for a Water Resource Zone (WRZ) with a low level of water resource planning concern.

The model was developed using best available data from local and national datasets. The model is segmented by property type using unmeasured and measured, with measured households split into existing properties, new builds, optants as well as compulsory, selective, change of occupier and other metering programmes. The model is based on per household consumption and includes linear modelling of key micro-components against occupancy to reflect the variation of per household consumption by occupancy within each household type. The model forecasts are developed from historical industry and UKWIR micro-component datasets and Market Transformation programme predictions.

The property and population forecasts used in the model are taken from estimates provided by Experian.

The model produces forecasts for Normal Year Annual Average (NYAA), Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP); with a breakdown of micro-components for each year of the forecast.

Artesia's report 'WRMP19 Household consumption forecast: baseline forecast' describes in more detail how the model was developed. This report is included in Appendix A.

3. Non-household consumption model

Prior to developing a non-household demand forecast, WRSE commissioned Artesia Consulting to undertake a review of the current methods used by water companies for non-household demand forecasts and compare them to the Water Resources Planning Guideline. This review made a number of conclusions and recommendations from which WRSE developed a specification for the initial non-household demand forecast. The scope of this work was to develop a non-household demand forecasting model and produce a non-household demand forecast for the period 2025 to 2100 that is fully compliant with the Water Resource Planning Guideline. The key tasks carried out against this requirement were:

- Segmentation of customers and base year demand.
- Identification of explanatory factor for each customer segment.
- Assessment of the impact of climate change.
- Assessment of the impact of water efficiency.
- Assessment of demand by other sectors.

A non-household demand forecasting model was then developed for each sector which allowed demand to be forecast over the planning period. The model has been developed at the company and WRZ level and aggregated region level for each sector. It Includes multiple scenarios that have been generated to take account of uncertainties in various assessments. It also has been developed to be fully transparent and able to withstand scrutiny at a public inquiry. The outputs have been incorporated into a commonly used tool that allows companies to select the various outputs and scenarios at different levels.

Further details on how the model was developed and the outputs are documented in the Non-household demand forecasts 2020 to 2100 report in Appendix D.

4. 2020 model updates

In April 2020 SES Water commissioned Atkins to update the model (including both household and non household components) to enable SES Water to produce a demand forecast for the WRSE regional plan.

To be able to produce a demand forecast for the WRSE regional plan the following tasks were undertaken. These tasks were completed following the guidance provided in the demand forecast method statement which was produced by WRSE[1] and with reference to the then draft Water Resources Planning Guideline (WRPG)[2]. The WRPG has since been finalised[3].

A report was produced to document the model updates (Demand Forecast Updates for the WRSE Regional Plan) which is included in Appendix B.

The updates to the model included:

- Amending the model base year to 2019/20 and the baseline forecast to 2099/2100 (note that WRSE has since truncated the supply demand forecast to the end of the planning horizon at 2075).
- Incorporating base year population and property data and incorporating population and property forecasts produced by Edge Analytics.
- Incorporating company policy/funded metering (including the compulsory metering expected in Asset Management Plan (AMP) period 7) assumptions for AMP7

[1] Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4
[2] Environment Agency, 2020, Water Resources Planning Guideline, draft for consultation, version 6.8
[3] Environment Agency, March 2023, Water Resources Planning Guideline, Final for publishing, version 12

- Reviewing the approach to micro-components and updating where necessary according to latest available guidance and evidence base.
- Incorporating SES Water's leakage estimates, both for unmeasured supply pipe leakage and distribution losses
- Incorporating SES Water's current estimates of Water Taken Unbilled and Distribution System Operational Use.
- Reviewing the climate change factors and amending where necessary according to latest available guidance.
- Developing and incorporating NYAA, DYAA and DYCP (including 1 in 200 and 1 in 500 drought events) uplifts.
- Developing and incorporating a non-household forecast.
- Incorporating the DLP template to enable outputs from the model to be reported to WRSE.

The following sections briefly describe how these tasks were undertaken, including documenting the data used.

4.1. Household

4.1.1. Re-base to 2019/20

The model was re-based to 2019/20 from 2015/16. Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. The model was also extended to 2099/00 (previously the model only forecast to 2080/81).

To re-base the model data was extracted from:

- SES Water's 2019/20 Annual Review.
- Population forecast supplied by Edge Analytics.
- SES Water's WRMP19 Tables.
- Hidden and transient population supplied by Edge Analytics.

In the model base year household properties are split between measured households and unmeasured household. This split was determined by data extracted from SES Water's 2019/20 Annual Review. Measured properties are further sub-divided in the model into the following categories: new properties; properties opting for a meter in-year (optants); and properties metered on change of occupancy.

The number of properties in each of these categories was determined using the following data sources:

- SES Water's 2019/20 Annual Review.
- SES Water's WRMP19 Tables.

Table 4-5 in the Demand Forecast Updates for the WRSE Regional Plan report in Appendix B explains how the number of properties in each of these groups was determined for the base year.

Edge Analytics (as part of the WRSE collaborative study on population) provided data on hidden and transient population for SES Water for the base year (2019/20). The mid-level estimate for irregular migrants, short-term residents and second addresses (not visitors) was incorporated into the model.

4.1.2. Population and property forecasts

Property and population forecasts for SES Water were supplied by Edge Analytics. Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led forecasts, to account for the considerable uncertainty in the projections. From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty. WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on. Guidance was provided in a WRSE Method Statement[4]. Further details on the forecasts used in the model are provided in sections 4.1.2.1 and 4.1.2.2.

[4] Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4.

4.1.2.1. Baseline forecast

For the baseline forecast, the Housing-Plan-P scenario was selected. This scenario was developed using two approaches: a ‘top-down’ approach and a ‘bottom-up’ approach. WRSE adopted the ‘bottom-up’ approach as it is considered to more accurately represent the locations of new growth across Water Resource Zones (WRZs).

To determine the proportion of properties in the optants and change of occupier categories, metering data was taken from the SES Water’s WRMP19 Tables.

The following assumptions were applied to the model when determining the proportion of properties in the optants and change of occupier categories:

- For the baseline forecast after AMP7 (2025/26 onwards) there is no metering on change of occupancy. This assumption is based on the WRPG which states *‘your baseline customer demand should take account of customer demand without any further water efficiency or metering intervention from yourselves…’*:
- The number of change of occupier properties for each year of the baseline forecast has been calculated by adding together the number of properties metered on change of occupier (row 45.4 from SES Water’s WRMP19 Tables) and the number of properties compulsory metered (row 45.3 from SES Water’s WRMP19 Tables).
- For optant metering the baseline forecast only included optant metering beyond AMP7 (2024/25) which was not encouraged by SES Water. Optant metering data for the baseline has been taken from the SES Water’s WRMP19 Tables (row 45.2) and includes optant metering until 2029/30.

As previously mentioned, Edge Analytics provided data on hidden and transient population with the SES Water area for the base year (2019/20). As no year-on-year forecasts were available for this segment of population the base year figures were used throughout the planning period.

Table 4-1 presents the sources of data used to determine base year population and property numbers and also baseline forecasts.

Table 4-1 - Population and property baseline forecast

Category	Source
Base year population	Edge Analytics (Housing-Plan-P)
Base year property numbers	SES Water 2019/20 Annual Review
Baseline forecast population	Edge Analytics (Housing-Plan-P)
Baseline forecast property numbers	Edge Analytics data (Housing-Plan-P) calibrated to the SES Water 2019/20 Annual Review data

As the model calibrates the Edge Analytic property data to SES Water’s 2019/20 Annual Review property data, the model deviates from the occupancy rates provided by Edge Analytics, although the rate of change in properties and therefore occupancy rates over the planning period remains consistent with the Edge Analytics forecast. The calibration is required to ensure there is consistency between SES Water’s customer database and the Edge Analytics data.

4.1.2.2. Growth forecasts

Table 4-2 provides a list of the scenarios WRSE decided should be included in the model and the growth forecasts which match these scenarios.

Table 4-2 - Selected growth forecasts for SES Water

Scenario	Selected growth forecast for SES Water
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

The household population estimates comprise both people living in households and people living in communal establishments (population 'not in households'), e.g. care homes, long-stay hospitals, students in halls of residence. Even though the property types for these customers may be classed as non-household, the water use is largely domestic, so they are counted as household customers for the purposes of the demand forecast.

4.1.3. Consumption

The model generates household consumption through micro-component modelling. Further details on how the model does this is provided in the following report: WRMP19 Household consumption forecast: baseline forecast – Appendix A. The micro-component modelling results generated by the model are calibrated to base year household consumption data extracted from SES Water's 2019/20 Post-Maximum Likelihood Estimation (MLE) Water Balance.

Following a high-level review of the micro-component Ownership (O), Volume per use (V) and Frequency of use (F) values included in the model it was apparent external use was lower than expected. With external use representing such a low proportion of household water use it was found that external use was not high enough to apply the assumed Temporary Use Bans (TUBs) savings, which were assumed in the company's then Draft Drought Plan 2021[5] to equate to approximately 3.2 % of DYAA demand (Distribution Input (DI) minus leakage) and approximately 5.4% of DYCP demand (DI minus leakage).

The micro-component data sources presented in Section 3.3 of the WRMP19 Household consumption forecast: baseline forecast report (Appendix A) which were not used in the model were reviewed and sensitivity testing undertaken using the various external use values. Table 4-3 lists the data sources presented in Section 3.3 of the WRMP19 Household consumption forecast: baseline forecast report (Appendix A). The external use values used in the model come from Table 2.

Table 4-3 - Micro-component data sources presented in Appendix E2 of SEs Water's Final WRMP19

Data source	Description
Table 2	Micro-component summary data from 2015/16 metered billed households. A sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study (this contains 62 households from around England and Wales).
Table 3	2015/16 RV billed households. 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).
Table 4	Micro-component summary for 2002/04 RV billed households. 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187).

It should be noted that altering the external use OVF values did not impact the overall per capita consumption (PCC) because the model offsets the increase in the external use micro-component by applying an equal percentage decrease across all the other micro-components.

[5] SES Water, March 2021, Draft Drought Plan, for public consultation. Since finalised and published in 2022.

The sensitivity analysis concluded that only the Table 4 external use micro-component OVF values ensure that TUBs savings could be purely attributed to reductions in external use, i.e. the savings are less than the external use values in both the base year and the final year of the planning period. The final year of the planning period would also work using Table 3 OVF values, but not the base year. SES Water decided to use this data because it is more recent than the Table 4 OVF values. Table 4-4 provides the original and revised external use OVF values use in the model.

Table 4-4 - External use OVF values

	Ownership	Volume (litres)	Frequency of use per day	O*V*F
Original model values	0.18	285.18	0.07	3.34
Revised model value	0.51	183.03	0.19	17.74

4.1.4. Incorporating company policy/funded metering assumptions

SES Water has an Outcome Delivery Incentive (ODI) linked to household PCC. By the end of AMP7, SES Water has a target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA (derived from the overall PCC target of 138.0 litres per head per day, weighted for 1 dry year occurring every 10 years). This target is achieved through metering savings and water efficiency savings.

Metering savings included in the model were updated to match the assumptions stated in SES Water's 2019 Business Plan, which was 14.5% for metering on change of occupier and 2.5% for optant smart metering.

Following the application of the metering savings, the residual of the AMP7 target was achieved through applying water efficiency savings to taps and external use. These micro-components were selected because they are two areas where water efficiency savings can easily be made in the home. For example: turning the tap off whilst brushing your teeth and using collected rainwater or re-using paddling pool water to water the garden.

A saving of 1.45% was applied to taps and a saving of 3.5% was applied to external use. These savings were applied from 2020/21 to the end of AMP7 (2024/25) and were applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into PCC by dividing by the total population.

4.2. Non-household

As previously mentioned in Section 3, Artesia Consulting produced a non-household demand forecast for SES Water. The household demand forecast model was adapted to include this non-household demand forecast using data extracted from SES Water's 2019/20 Annual Review and the non-household demand forecast model produced by Artesia Consulting.

4.2.1. Population and properties

4.2.1.1. Base year

Base year non-household population and property data were extracted from SES Water's 2019/20 Annual Review. Data were provided for measured and unmeasured non-households.

4.2.1.2. Baseline forecast

To calculate the population and property baseline forecast, the non-household consumption data supplied by Artesia (see Section 4.2.2) was used along with the base year population and property values to calculate a measured per property consumption (PPC) and PCC. The PCC value was used to calculate the number of properties for each year of the forecast using the following formula:

Previous year's number of properties + (consumption for given year – previous year's consumption) / base year PPC

This approach assumed that the increase in non-household consumption through the planning period is a result of the more non-household properties and not the existing non-household properties using more water.

The PCC value was used to calculate the population for each year of the forecast using the following formula:

Previous year's population + (consumption for given year – previous year's consumption) / base year PCC

The assumption that 90% of non-household properties would be measured by the end of AMP7 (2024/25), as planned for in SES Water's PR19 Business Plan, was also applied to the model.

Further details of the values used and outputs are presented in Section 8.1.2 of the Demand Forecast Updates for the WRSE Regional Plan in Appendix B.

4.2.2. Consumption

As previously mentioned in Section 3, Artesia Consulting produced a consumption forecast for SES Water for measured and unmeasured non-households. Three scenario forecasts (Lower, Central and Upper) as well as a baseline forecast were produced. Exact details on how this consumption data was included in the model is provided in the Demand Forecast Updates for the WRSE Regional Plan report in Appendix B.

It was decided that the baseline forecast should be used from 2019/20 to 2024/25 and from 2025/26 the central forecast should be used. The reason for using the baseline forecast and the central forecast was because in the central forecast there was an unexplained dip in the measured non-household consumption after the base year, which corrects itself by 2025/26.

4.3. Other demand components

Various other components of the model were updated. The following sections provided details of the components which were updated.

4.3.1. Leakage

Base year leakage figures were extracted from SES Water's 2019/20 WRMP Annual Review.

According to the WRPG, total leakage should remain constant "from 2025/26 […] from the start of your plan to the end of the planning period". Therefore, in the model leakage remains constant from the first year of AMP8 (2025/26). Leakage values for the start of AMP8 were extracted from SES Water's Final WRMP19 and these values remain constant through to 2099/00. Between the base year (2019/20) and the start of AMP8 (2025/26) SES Water's 2019/20 Annual Review leakage values have been linearly interpolated. The leakage values used in the model are presented in Table 4-5.

Table 4-5 - Leakage values

Component	2019/20 (Base year)	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26
	Ml/d						
Measured Non-household - USPL	0.18	0.19	0.20	0.21	0.22	0.22	0.23
Unmeasured Non-household - USPL	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Measured household - USPL	3.41	3.60	3.78	3.97	4.15	4.34	4.52
Unmeasured household - USPL	4.35	3.77	3.18	2.60	2.01	1.43	0.84
Void Properties – USPL	0.41	0.36	0.32	0.27	0.22	0.18	0.13
Distribution Losses	15.52	15.27	15.01	14.76	14.51	14.25	14.00
Total leakage	23.94	23.25	22.56	21.86	21.17	20.48	19.79

4.3.2. Water taken unbilled

Water taken unbilled was extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.01 Ml/d has been used for the base year and this remained constant throughout the baseline forecast.

4.3.3. Distribution System Operational Use

Distribution System Operational Use has been extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.73 Ml/d has been used for the base year and this remains constant throughout the baseline forecast.

4.3.4. Climate change

The climate change factors used in the model were those detailed in Artesia's 2017 report[6] which states:

"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 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 0.88% to 2.40%. When critical period is selected the appropriate climate change factor is applied in a linear fashion across the forecast period."

These factors were reviewed with reference to the following guidance, which are referred to in the draft WRPG:

- UKWIR (2009) Assessment of the Significance to Water Resource Management Plans of the UK Climate Projections 2009,
- UKWIR (2013) Impact of Climate Change on Water Demand.

The review showed that no changes were required to the climate change factors used in the model.

4.4. Consumption uplift factors

The model includes varies consumption uplift factors, these were revised following latest guidance and incorporated into the model. The following sections outline the factors which were revised, and the methodology used for these revisions. The final revised factors are presented in Table 4-6.

4.4.1. Normal and dry year factors

Using the methodology from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting[7] the consumption uplift factors for Normal Year Annual Average (NYAA) and Dry Year Annual Average (DYAA) were re-calculated. Further details of the stages of the re-calculations are provided in section 10.1 of the Demand Forecast Updates for the WRSE Regional Plan report in Appendix B. The revised DYAA and NYAA factors incorporated into the model are presented in Table 4-6.

4.4.2. Critical period factor

Using the methodology stated in the UWKIR report Peak Water Demand Forecasting Methodology[8] which is the guidance the WRPG states should be followed, a revised critical period factor has been calculated. Further details of the stages of the re-calculations are provided in section 10.1 of the Demand Forecast Updates for the WRSE Regional Plan report in Appendix B. The revised critical period factor incorporated into the model is presented in Table 4-6.

[6] Artesia, 2017. WRMP19 Household consumption forecast: Baseline forecast Final.
[7] UKWIR, 2016, WRMP19 Methods – Household Consumption Forecasting
[8] UKWIR, 2006, Peak Water Demand Forecasting Methodology

4.4.3. 1 in 200 and 1 in 500 drought event factors

The peak week factors for 1 in 200 and 1 in 500 drought events were generated by Artesia Consulting and provided in the WRSE Dynamic demand analysis, Phase 2 report (reference: AR1408)[9]. The WRSE Dynamic demand analysis, Phase 2 explored different peak metrics using two data sets: Series 2 DI data and Series 3 DI data. It was agreed that the peak week metrics generated using the Series 3 data set should be used in the demand forecast.

The 1 in 200 and 1 in 500 drought event factors incorporated into the model are presented in Table 4-6.

Table 4-6 - Summary of factors applied in the household forecast

Factor	Value
NYAA (measured)	0.9943
NYAA (unmeasured)	1.0429
DYAA	1.0849
DYCP	1.4735
1 in 200	1.260*
1 in 500	1.290*

*Series 3

4.5. WRSE outputs

WRSE provided SES Water with the Data Landing Platform (DLP) template. The model was used to populate the BL Demand worksheet in the DLP template. The BL Demand worksheet included a list of demand components. These components needed to be populated for a number of run scenarios and growth forecasts.

To populate the demand components of the DLP template an additional worksheet was added to the model (called 'WRSE outputs'). This worksheet included the 24 components from the BL Demand worksheet and covered the planning period (2019/20 to 2099/00). For every year of the planning period each component was linked to the corresponding output cell(s) of the model, which are in the 'Scenario selection & outputs' worksheet of the model. The calculated distribution input was originally calculated by adding the various demand components together with the consumption attributed to climate change although it was subsequently (June 2023) realised that the latter was already accounted for in the other components and so was removed from the DI calculation in the latest models used for WRSE investment model runs (SES Water MC HHCF Model v4.19.1.1 onwards). The WRSE outputs worksheet automatically populated with the output data from the model.

Switches were included in the model to allow the user to select the required model run in order to populate the various run scenarios and growth forecasts required in the DLP template.

For each run scenario and growth forecast the data in the 'WRSE outputs' worksheet needed to be manually copied in the corresponding rows of the 'BL Demand' worksheet in the DLP template which would be submitted.

[9] Artesia, February 2021, WRSE Dynamic demand analysis, Phase 2

5. 2022 model updates

In April 2022 a new version of the DLP template was issued which included additional components on smart meter installations and the number of household properties. This meant additional data on smart meter installations needed to be incorporated into the model and amendments were required to the 'WRSE outputs' worksheet to capture these new components.

There was also a request from SES Water to update the population and property forecast scenarios and incorporate new consumption uplift factors. The following sections describe the updates made to the model.

5.1. Smart meters

The following components were added to the model:

- Total household smart Meters.
- Automated Meter Infrastructure (AMI) - upgrades from basic or AMR meters (household).
- Basic (non-automated) meter installations (non-household).
- Automated Meter Reading (AMR) - installations (non-household).
- Automated Meter Infrastructure (AMI) - installations (non-household).

These components were calculated in a new worksheet in the model called 'WRSE output calc'. The 'WRSE outputs' worksheet was also updated in the model to include these new components.

The following sections describe the assumptions and data used to calculate these components. The components have been separated into household and non-household.

5.1.1. Household

SES Water requested application of the following assumptions when calculating the household smart meter components:

- There will be no smart meters installed until 2023/24.
- In 2023/24 2% of total measured properties will have smart meter installed.
- In 2024/25 5% of total measured properties will have a smart meter installed.
- From 2025/26 all new build properties, meter optants, compulsory metering properties will have a smart meter installed.
- From 2025/26 all meter exchanges will be smart (AMI).
- Meter exchanges will be based on basic meters having a 12-year life span (i.e. basic meters are exchanged 12 years after installation).
- From 2025/26 1/12 of the remaining households with a basic meter will be exchanged annually until all basic meters are upgraded to AMI.

Table 5-1 shows how each household component was calculated, including the data sources used and assumptions applied.

Table 5-1 - Household smart meter components

Component	Year(s)	Calculation description
Total household smart Meters (cumulative including existing)	2023/24	Assume 2% of total household measured properties (excluding voids) have a smart meter. Calculated using total measured household - properties (excluding voids) from the 'Scenario selection & outputs' worksheet.
	2024/25	Assume 5% of total measured properties (excluding voids) have a smart meter.

Component	Year(s)	Calculation description
		Calculated using total measured household - properties (excluding voids) from the 'Scenario selection & outputs' worksheet.
	2025/26 onwards	Assume all new build properties, meter optants, compulsory metering properties, metering on change of occupancy properties, selective metering properties and other changes to existing metering properties will have a smart meter installed. The cumulative smart meter installations since the start of the planning periods (excluding upgrades) are calculated. This is then added to the meter upgrades to give the total household smart meters (cumulative including existing). Calculated using total measured household - properties (excluding voids), New build properties – properties, Meter optants – properties, Compulsory metering – properties, Metering on change of occupancy – properties, Selective metering – properties and Other changes to existing metering – properties from the 'Scenario selection & outputs' worksheet.
Automated Meter Infrastructure (AMI) – upgrades from basic or AMR meters (household).	2019/20 to 2024/25	Assume no upgrades to AMI (smart meter).
	2025/24 to 2036/37	The number of existing measured properties remains constant throughout the planning period. The smart meter installations in 2023/24 and 2024/25 and the number new build properties, optant properties and compulsory metering properties in 2025/26 have been subtracted from the existing measured properties values to give the number of existing measured properties with a basic meter in 2025/26. This has then split evenly across the next 12 years. Calculated using total measured household - properties (excluding voids), New build properties – properties, Meter optants – properties, Compulsory metering – properties, Metering on change of occupancy – properties, Selective metering – properties and Other changes to existing metering – properties from the 'Scenario selection & outputs' worksheet.
	2037/38 onwards	All existing metered properties will have a smart meter installed by 2036-37 so upgrades are zero from this date onwards.

5.1.2. Non-household

SES Water requested application of the following assumptions when calculating the non-household smart meter components:

- From 2025/26 all meter installations are AMI.
- From 2019/20 to 2024/25 assume 80% of meter installations are basic and 20% are AMR.

Table 5-2 shows how each household component was calculated, including the data sources used and assumptions applied.

Table 5-2 - Non-household smart meters

Comment	Years	Description
Basic (non-automated) meter installations (non-household)	2019/20	Assume zero as no previous year data to calculate the number of new non-household properties.
	2020/21 to 2024/25	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume 80% of the new non-household properties will have a basic meter installed. Calculated using Measured non-households – properties in the 'Scenario selection & outputs' worksheet.
	2025/26 onwards	All meter installations will be AMI (smart) so zero basic meter installations.
Automated Meter Reading (AMR) - installations (non-household)	2019/20	Assume zero has no previous year data to calculate the number of new non-household properties.
	2020/21 to 2024/25	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume 20% of the new non-household properties will have a basic meter installed. Calculated using Measured non-households – properties in the 'Scenario selection & outputs' worksheet.
	2025/26 onwards	All meter installations will be AMI (smart) so zero basic meter installations.
Automated Meter Infrastructure (AMI) - installations (non-household)	2019-20 to 2024/25	All meter installation during this period will be basic or AMR so there will be zero AMI installations.
	2025-26 on wards	The number of new non-household properties each year has been calculated. If the number of new non-households is negative, then it has been assumed to be zero. Assume all new non-household properties will have an AMI installation. Calculated using Measured non-households – properties in the 'Scenario selection & outputs' worksheet.

5.2. Household properties

The following components were included in the new DLP template:

- New build properties – properties
- Meter optants – properties
- Compulsory metering – properties
- Metering on change of occupancy – properties

- Selective metering - properties
- Other changes to existing metering - properties

These components are already calculated in the model and outputs presented in the ‘Scenario selection & outputs’ worksheet. The ‘WRSE outputs’ worksheet was updated to include these new components and the components were linked to the relevant cells in the ‘Scenario selection & outputs’ worksheet.

5.3. Population and property forecasts

As well as the growth forecasts already included in the model (see section 4.1.2.2) two additional growth forecasts were incorporated into the model. These forecasts were taken from the data supplied by Edge Analytics for the 2020 model updates.

The following two growth forecasts were incorporated into the model:

- ONS18-Central Projection (referred to as ‘Principle’ projection (ONS18-P) in Edge Analytic data spreadsheet).
- Housing-Plan-P with OxCam

Table 5-3 provides a list of the revised scenarios included in the model and the growth forecasts which match these scenarios.

Table 5-3 - Selected growth forecasts for SES Water

Scenario	Selected growth forecast for SES Water
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H
Ofwat Common Reference Scenario	ONS-18-P
OxCam 1a, 1b, 2a and 2b	Housing-Plan-P with OxCam

5.4. Consumption uplift factors

SES Water requested that 1 in 200 Annual Average (AA) and 1 in 500 AA consumption uplift factors were incorporated into the model. These uplift factors were provided by Artesia Consulting. The uplift factors used were generated using the Series 3 data set. Section 4.4.3 provides further information on the Series 3 data set. Table 5-4 shows the factors which were incorporated into the model. These factors were incorporated into the model in the ‘Base year’ worksheet where the existing uplift factors are included. The model was updated so these new factors can be selected in the ‘Scenario selection & outputs’ worksheet in the same way the existing consumption uplift factors can be selected.

Table 5-4 - Uplift factors

Factor	Value
1 in 200 Annual Average	1.024
1 in 500 Annual Average	1.028

6. 2023 model updates

In February 2023 SES Water requested the following updates to the model:

- Re-base to 2021/22.
- Incorporate revised household population and property forecasts supplied by Edge Analytics.
- Revise the 'Scenarios selection and outputs' worksheet to align to the latest WRMP table formats.

Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. However, only data relating to households was updated. No updates to non-household data were included in this update. These updates are documented in Section 6.1.

Several further amendments to the model were requested in April/May 2023 to provide an alternative, more realistic meter penetration scenario. These were amendments to the following:

- Water efficiency savings.
- Meter penetration.
- Smart meter installations.
- When metering savings are effective.

These amendments all related to household components of the model. No amendments were made to the non-household components of the model. Section 6.2 provides further details of these amendments.

6.1. February model updates

The model was re-based to 2021/22 from 2019/20 and new population and property forecasts incorporated into the model. Re-basing the model included a review of all model components to update year profiles, re-direct relevant formulas and insert updated data. The following sections described the data used and any assumption applied when re-basing the model and incorporating new population and property forecasts.

6.1.1. Re-base 2021/22

To re-base the model data was extracted from:

- SES Water's 2021/22 Annual Review
- SES Water's 2020/21 Annual Review
- Population forecast supplied by Edge Analytics
- SES Water's draft WRMP24 Tables.
- SES Water's 2021/22 Post-Maximum Likelihood Estimation (MLE) Water Balance.

How this data is applied in the model has previously briefly been discussed in section 4.1.1 and is also documented in the following the Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Appendix C. It should be noted that hidden and transient population data was not updated.

The number of measured properties in each of the following categories: new properties; properties opting for a meter in-year (optants); and properties metered on change of occupancy was determined using SES Water's draft WRMP24 Tables.

The model generates household consumption through micro-component modelling. Further details on how the model does this is provided in the following report: WRMP19 Household consumption forecast: baseline forecast – Appendix A. The micro-component modelling results generated by the model are calibrated to base year household consumption data extracted from SES Water's 2021/22 Post-Maximum Likelihood Estimation (MLE) Water Balance.

6.1.2. Population and property forecasts

Updated property and population growth forecasts for SES Water were supplied by Edge Analytics. These forecasts were published in February 2023.

Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led forecasts, to account for the considerable uncertainty in the projections. From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty. WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on. Further details on the forecasts used in the model are provided in sections 6.1.3 and 6.1.4

6.1.3. Baseline forecast

For the baseline forecast the same scenario as selected for the 2020 model update was selected (Housing-Plan-P). The description of this scenario is as follows:

A Housing-led scenario, with population growth underpinned by each local authority's Local Plan housing growth trajectory. Following the final year of data, projected housing growth in non-London areas returns to the average of ONS-14 & ONS-16 long-term annual growth average by 2050. For London Boroughs, housing growth returns to the GLA Central scenario long-term annual average by 2050.

The scenario was updated using the February 2023 forecast supplied by Edge Analytics.

6.1.4. Growth scenarios

The following growth scenarios forecasts were incorporated into the model and replaced the previous growth forecast incorporated into the model in 2020.

- OxCam-1a-r-P
- ONS-18-Rebased-L
- Housing-Need-H
- ONS-18-Rebased-P
- OxCam 1a-P

6.1.5. Incorporating company policy/funded metering assumptions

As explained in Section 4.1.4, SES Water has an ODI linked to household PCC. The target PCC is achieved through metering savings and water efficiency savings. With the model rebased to 2021/22 it was necessary to amend the water efficiency savings to achieve the target PCC. The revised water efficiency savings applied in the model are presented in Table 6-1. The table shows the original savings applied in 2020 and the revised savings.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25) and have been applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

Table 6-1 - Water efficiency savings

	Water efficiency saving (%)		
	Taps	External use	Shower
Original saving	1.5	3.5	0
Revised saving	6.5	10.5	3.5

6.2. April/May model updates

6.2.1. Incorporating company policy/funded metering assumptions

As outlined in section 4.1.4, SES Water has an ODI linked to household PCC. The target PCC is achieved through metering savings and water efficiency savings. The water efficiency savings were amended in 2023 (see section 6.1.5). However, SES Water requested that the water efficiency savings originally included in the model should be re-instated. Therefore, the water efficiency savings included in the model are as follows:

- A saving of 1.45% was applied to taps.

- A saving of 3.5% was applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25) and have been applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

6.2.2. Metering

6.2.2.1. Meter penetration

SES Water's universal metering programme was at 72% for households in 2022/23 and is predicted to reach 85% by 2024/25. SES Water requested this predicted metering percentage is reflected in the model. In additional to there being 85% meter penetration by 2024/25, SES Water also requested that two thirds of this should occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.

To achieve these meter penetration percentages in the model the optant properties and properties metered on change of occupancy (which includes compulsory metering) were adjusted so that the total number of the total number of properties across the plan remained consistent but the required metering penetration targets were achieved. The forecast for new connections was not amended as this is linked to the property forecast from Edge Analytics.

For properties opting for a meter the resultant projection suggests a peak in 2024/25 which could possibly be a result of media campaigns, followed by a drop to a background decreasing level.

For properties metered on change of occupancy the resultant projection suggests a big push on compulsory metering by SES Water in 2024/25 followed by a sharp reduction prior to stopping the policy.

The Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Appendix C provides further details of the resultant property projections for each category of properties.

6.2.2.2. Smart meters

As previously mentioned in Section 0 the model was updated to include data on the number of smart meters installed.

SES Water requested the following assumption was included in the model:

- 20,000 smart meters will be installed in the last year of AMP7 (2024/25).

Previous assumptions on the installation of smart meters on household properties were removed and replaced with 8.037% of total measured properties being smart metered in 2024/25 under the baseline forecast. Under alternative forecast scenarios the exact figure of smart meters is not always 20,000.

6.2.2.3. Metering delay

SES Water identified they have a year's delay between a meter being installed to metered rates being effective (following initial billing for about 10,000 household properties. SES Water is aiming to reduce this, but requested this delay is reflected in the model as it will impact consumption. However, following consideration and further discussions with SES Water it is was agreed that the savings achieved through metering, for all household properties, are likely to occur over a number of years. There is likely to be an immediate change to consumption (a reduction) due to an awareness that the customer is being charged for what they use and then a possible further reduction in consumption after seeing their first metered bill a year later. There could even potentially be further reductions with subsequent bills. As SES Water does not have any specific data on when exactly metering savings are achieved it was decided the clearest and readily auditable method would be to incorporate into the model a 1-year delay in the impact of metering for all household properties. As well as taking into account that the full impact of metering on consumption is likely to spread across installation date and receipt of the first few bills this approach also takes into account the fact that not all meters are installed at the start of the year.

Further details on how the updates were incorporated into the model are provided in The Demand Forecast – 2021-22 rebase update for WRSE Technical Note in Appendix C.

7. Summary

SES commissioned Atkins to implement various updates to its household consumption forecast model between 2020 and 2023 to allow it to produce a demand forecast for the WRSE regional plan and WRMP24.

The main updates to the model included:

- Re-basing the model, initially to 2019/20 and then to 2021/22.
- Updating population and property forecasts with data produced by Edge Analytics.
- Incorporating SES Water's AMP7 metering and water efficiency strategies.
- Updating external micro-component data.
- Calculating consumption uplift factors and incorporating these and drought event uplift factors produced by Artesia Consulting into the model.
- Incorporating non-household consumption data into the model and developing a non-household property and population forecast which was incorporated into the model.
- Updating other components of baseline demand within the model such as water taken unbilled and leakage.
- Incorporating smart metering assumptions for households and non-households.

To allow outputs of the model to be shared with WRSE, the DLP template was incorporated into the model as an additional worksheet which automatically populated with the output data from the model.

Three versions of the model have been created. These versions include different combinations of demand management savings and different climate change factors for DYAA and DYCP. The latest versions of the model are:

- SES Water MC HHCF Model v4.19.1.1.
- SES Water MC HHCF Model v4.20.2.
- SES Water MC HHCF Model v4.20.3.

A brief explanation about each version of the model is provided in the following sections.

7.1. SES Water MC HHCF Model v4.19.1.1

This version of the model includes baseline demand management with DYAA linearly interpolated/extrapolated climate change factor of 0 in 2012 to 0.88 in 2040 applied to by DYAA and DYCP scenarios in 2040.

In this version of the model water efficiency savings have been applied, which means by the end of AMP7 SES Water meets its target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA. The water efficiency savings included in this version of the model are:

- A saving of 6.5% applied to taps.
- A savings of 10.5% applied to external use.
- A saving of 3.5% applied to showers.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4 and 6.1.5.

7.2. SES Water MC HHCF Model v4.20.2

This version of the model is an alternative demand forecast (i.e. alternative profile of demand savings) with DYAA linearly interpolated/extrapolated climate change factor of 0 in 2012 to 0.88 in 2040 applied to by DYAA and DYCP scenarios.

In this version of the model the water efficiency savings applied to allow SES Water to meet its target PCC have been converted back to the water efficiency savings originally included in the model when it was updated in 2020. The water efficiency savings included in this version of the mode are:

- A saving of 1.45% applied to taps.
- A saving of 3.5% applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4, 6.1.5 and 6.2.1.

SES Water's latest metering assumptions have also been applied in this version of the model. These include:

- SES Water's latest metering penetration prediction. SES Water predict its universal metering programme will reach 85% by 2024/25 and two thirds of this will occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.
- An assumption that 20,000 smart meters will be installed in the last year of AMP7 (2024/25).
- Incorporating a 1-year delay in the impact of metering for all household properties.

Further information on these metering assumptions can be found in section 6.2.2.

7.3. SES Water MC HHCF Model v4.20.3

This version of the model is an alternative demand forecast with climate change formula corrected so it applies the larger 2.4 climate change factor to the DYCP scenario in 2040 rather than the DYAA factor that is applied to both in v4.19.1.1 and v4.20.

In this version of the model the water efficiency savings applied to allow SES Water to meet its target PCC have been converted back to the water efficiency savings originally included in the model when it was updated in 2020. The water efficiency savings included in this version of the mode are:

- A saving of 1.45% applied to taps.
- A saving of 3.5% applied to external use.

These savings have been applied from 2021/22 to the end of AMP7 (2024/25). Further information on these water efficiency savings can be found in sections 4.1.4, 6.1.5 and 6.2.1.

SES Water's latest metering assumptions have also been applied in this version of the model. These include:

- SES Water's latest metering penetration prediction. SES Water predict its universal metering programme will reach 85% by 2024/25 and two thirds of this will occur in 2024/25 i.e. meter penetration in 2023/24 should be approximately 76.3%.
- An assumption that 20,000 smart meters will be installed in the last year of AMP7 (2024/25).
- Incorporating a 1-year delay in the impact of metering for all household properties.

Further information on these metering assumptions can be found in section 6.2.2.

Appendix A.

A.1. WRMP19 Household consumption forecast: Baseline forecast

Artesia Consulting

SES Water

WRMP19 Household consumption forecast: Baseline forecast

Final

AR1176

September 2017

Report title:	**WRMP19 Household consumption forecast: Baseline forecast**
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Client:	**SES Water**
Author(s):	**Sarah Rogerson, Dene Marshallsay, Rob Lawson**

Any enquiries relating to this report should be referred to the authors at the following address:

Artesia Consulting Ltd, Unit 2 Badminton Court, Yate, Station Road, Bristol, BS37 5HZ.

Telephone: + 44 (0) 1454 320091

Website: www.artesia-consulting.co.uk

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.

Contents

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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.

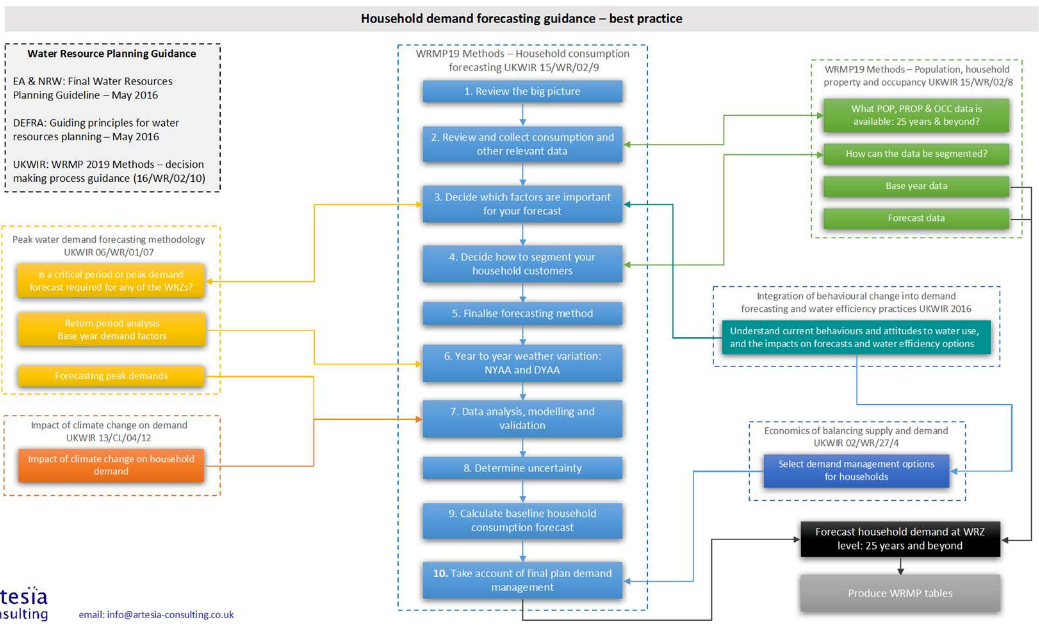
Household customers were segmented based on meter status (measured/unmeasured), with sub-divisions for meter type (existing metered, meter optants, new property, change of occupier). Data was used to determine how to account for differences in consumption between segments and also the effect of meter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

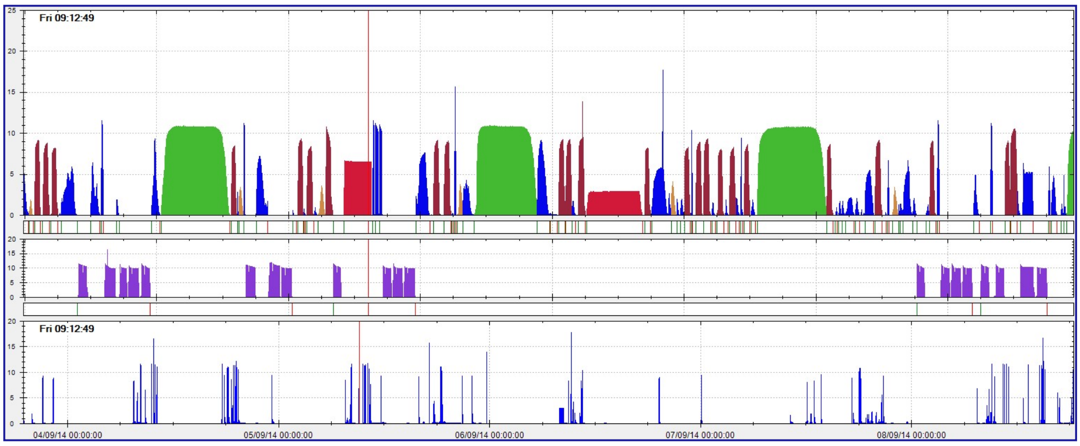
The Siloette system uses a Siloette logger that is connected to the pulsed output from a meter via a pulse unit, as illustrated in Figure 3.

[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.

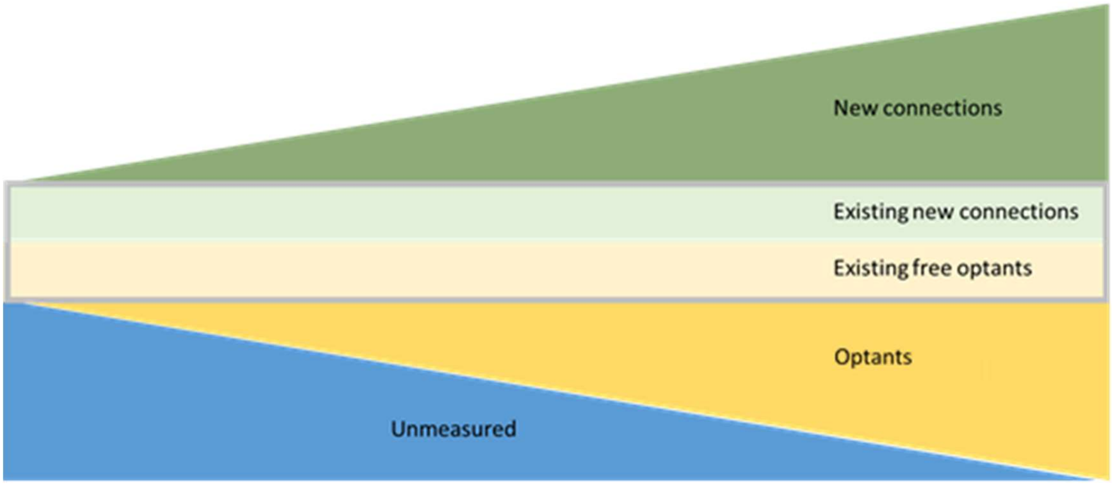
[6] Experian (2017) Population, Household, Property and Occupancy Forecasts for WRMP19. January 2017

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**

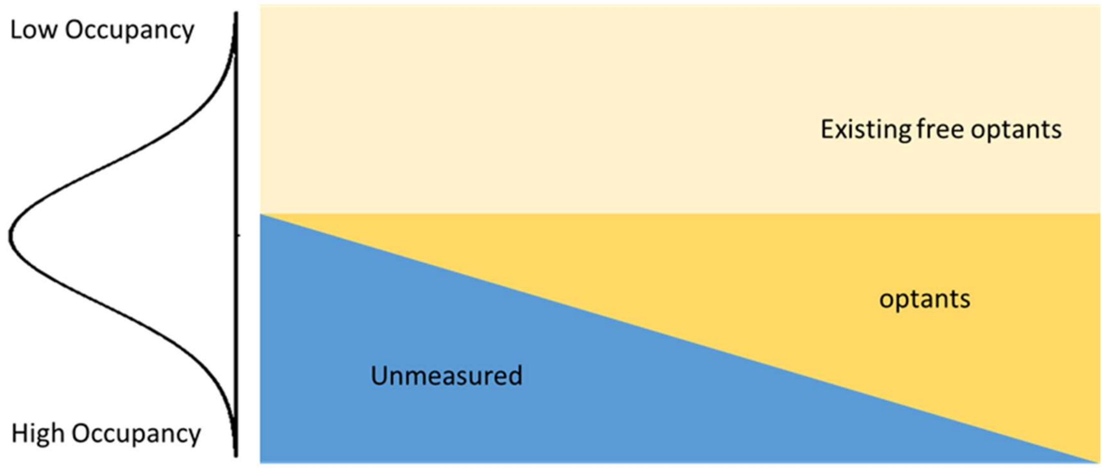


Some key assumptions made in the segmentation model:

- 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:

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

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 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

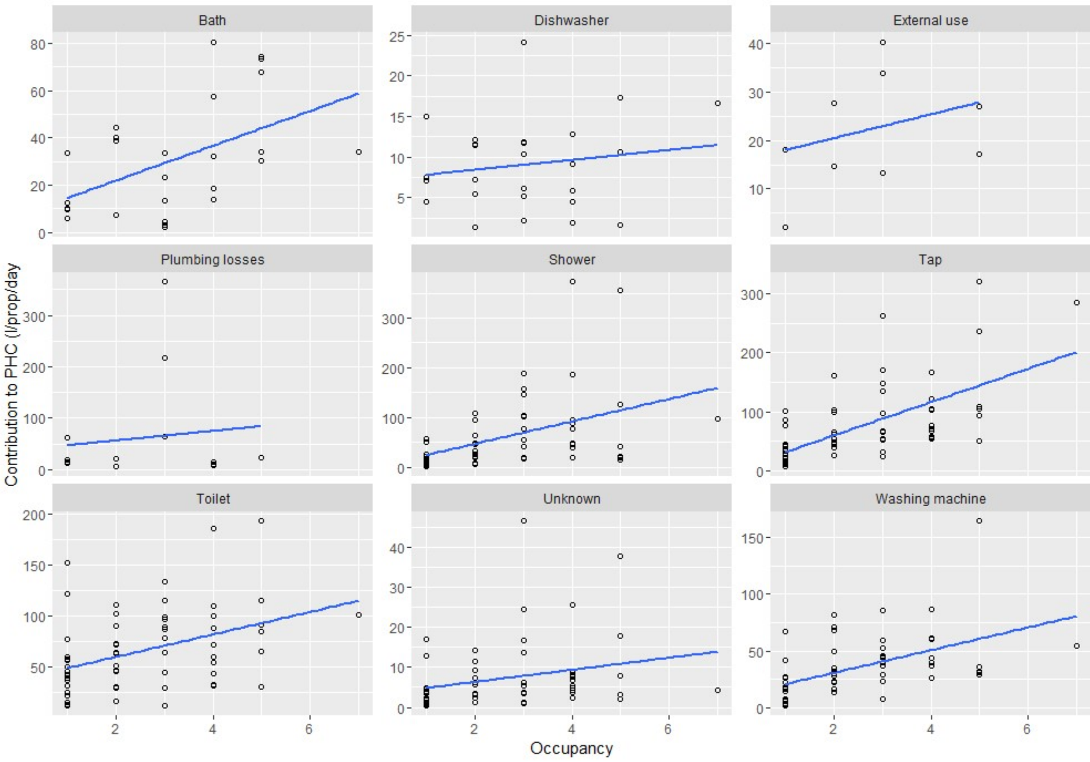


Figure 7 shows the average daily use (or contribution to per household consumption) for each of the following micro-components:

- 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:

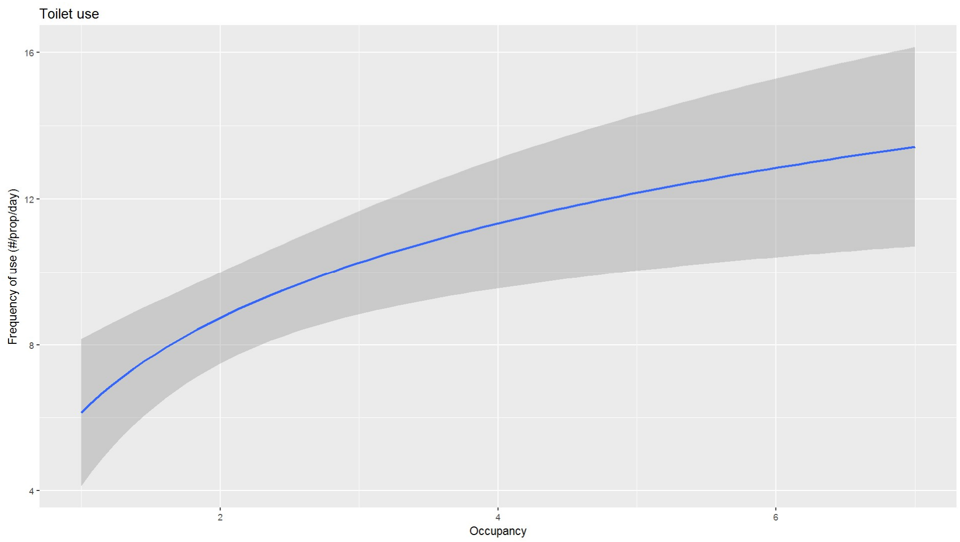
- WC flushing,
- Shower use,
- Bath use,
- Tap use,
- Washing machine use.

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.

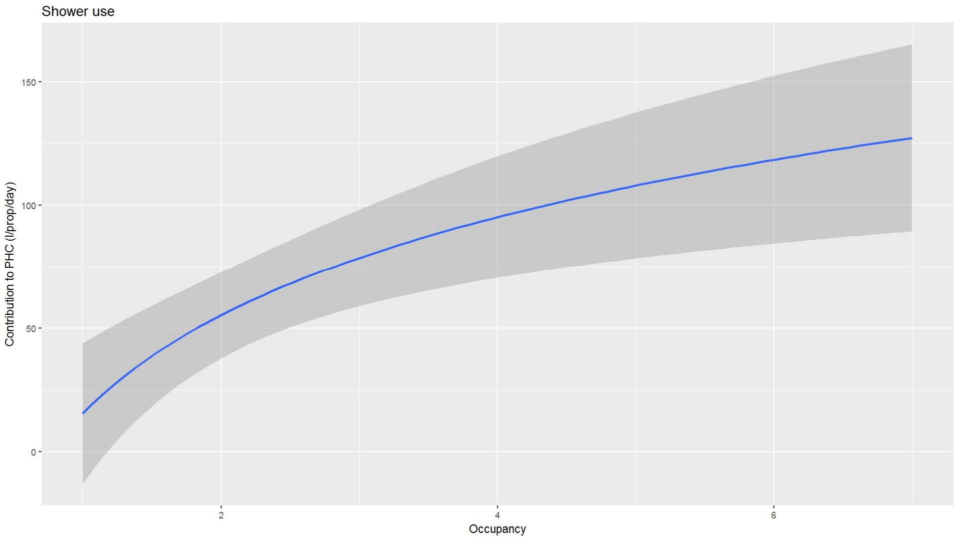
*SES Contribution to umPHC (l/prop/day) = 10.071 + 80.214 * ln(occupancy)* **Equation 1a**

*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**



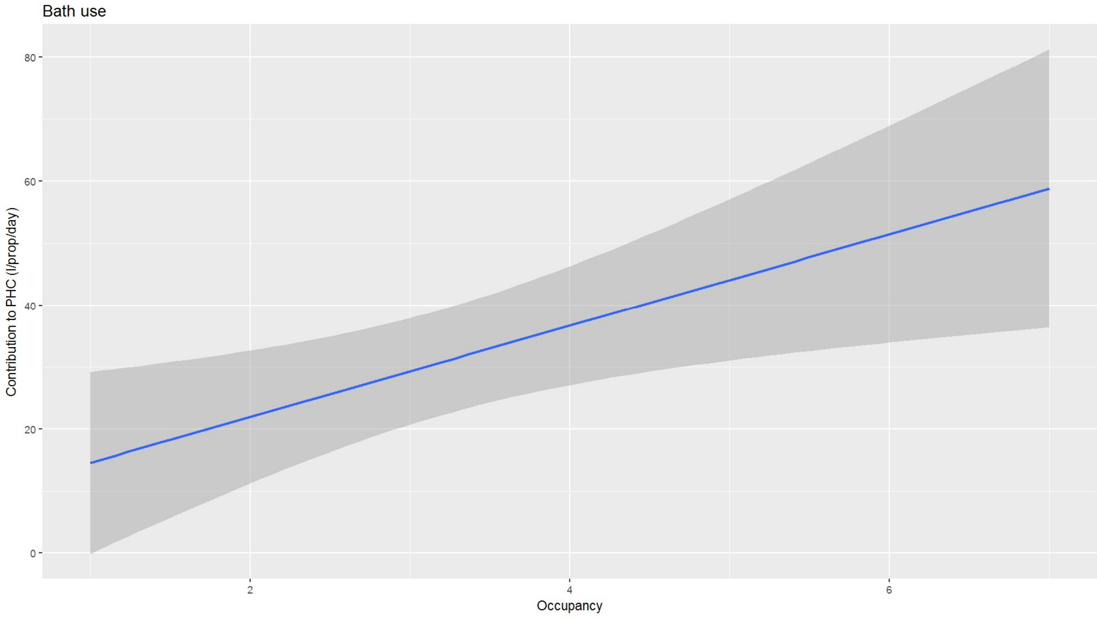
*SES Unmeasured Shower volume used per day = 29.93 +92.69 * ln(occupancy)* **Equation 2a**

*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



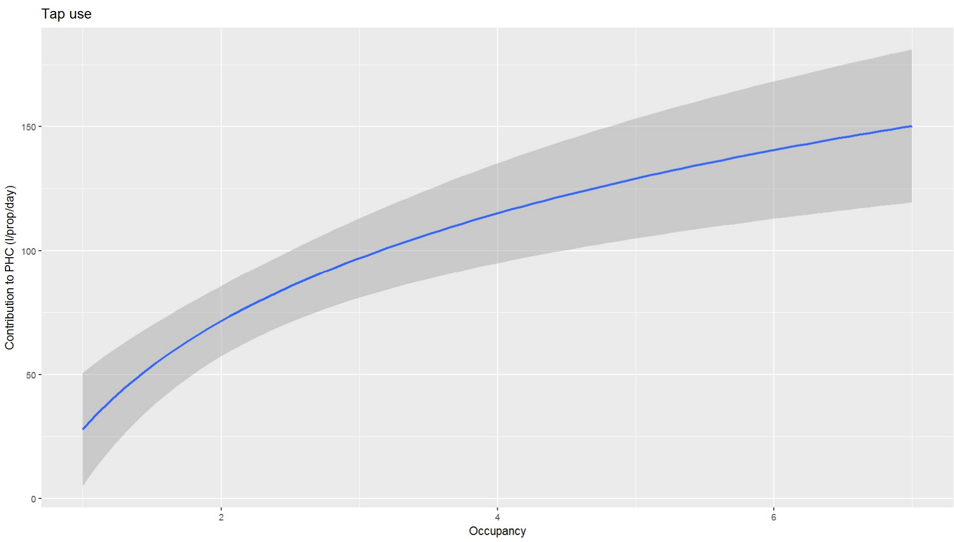
*SES unmeasured Bath volume used per day = 7.293 + 7.089 * occupancy* ***Equation 3a***

*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



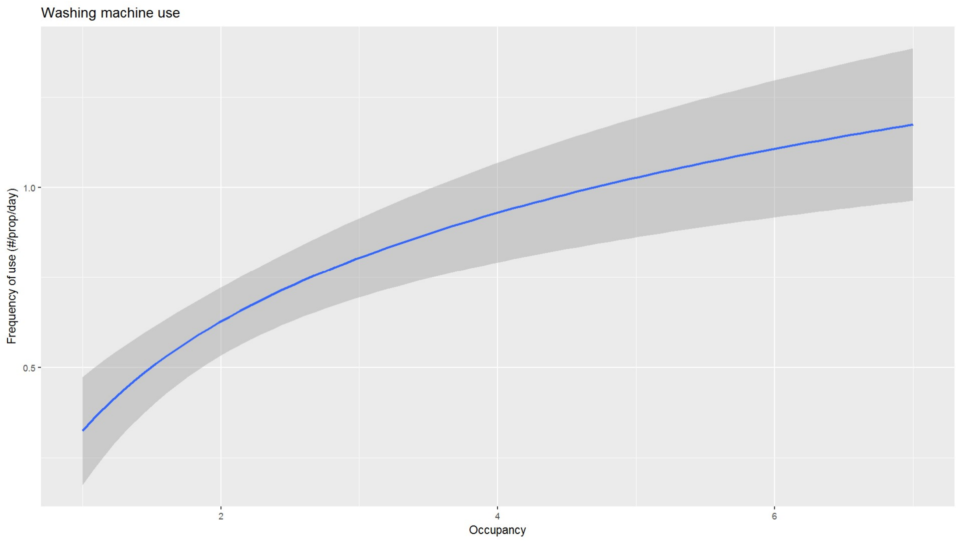
*SES unmeasured Tap volume used per day = 14.561 + 106.557 * ln(occupancy)* **Equation 4a**

*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

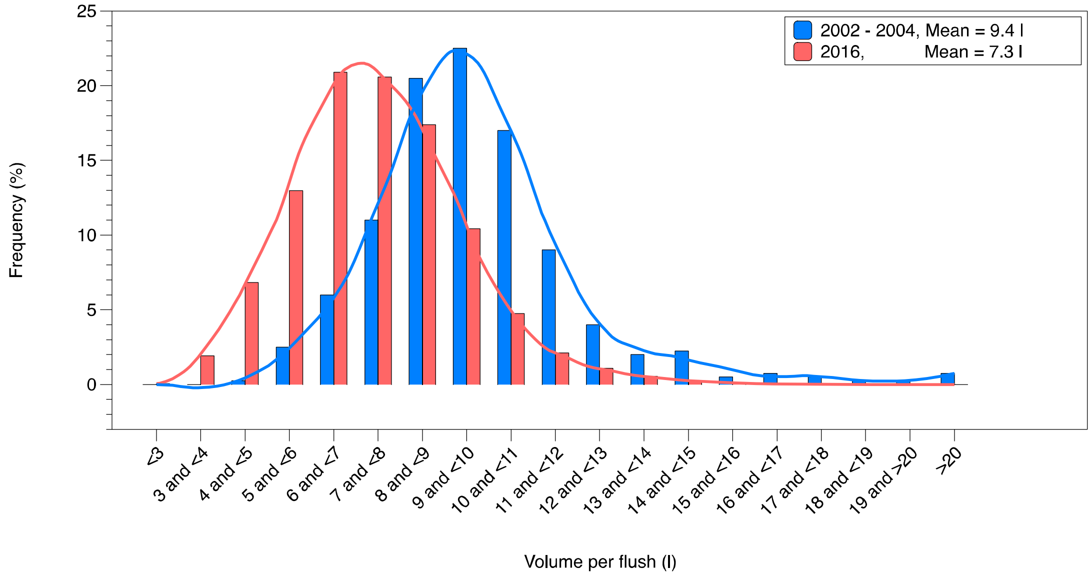
To investigate trends in individual micro-components due to technology change, policies and regulation, and behaviour change, we have used the data set from 2002/04 (Table 4) and the 2015/16 datasets (Table 2 and Table 3). For future projections of trends we have generally used the forecast water use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

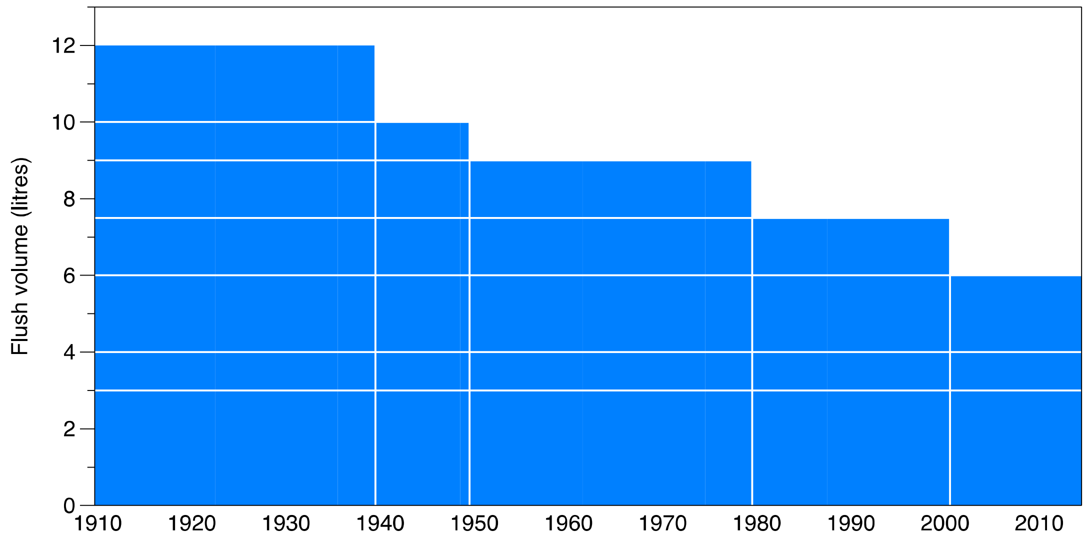
Using data from the WRc micro-component report CP187 and data from the UKWIR 2016 study, we can create a histogram of the volumes per flush from 2002/04 and 2015/16. These are shown in Figure 13. This shows that for 2002/04 the mean flush volume was 9.4 l/flush, with a range of flush volumes from 5 litres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

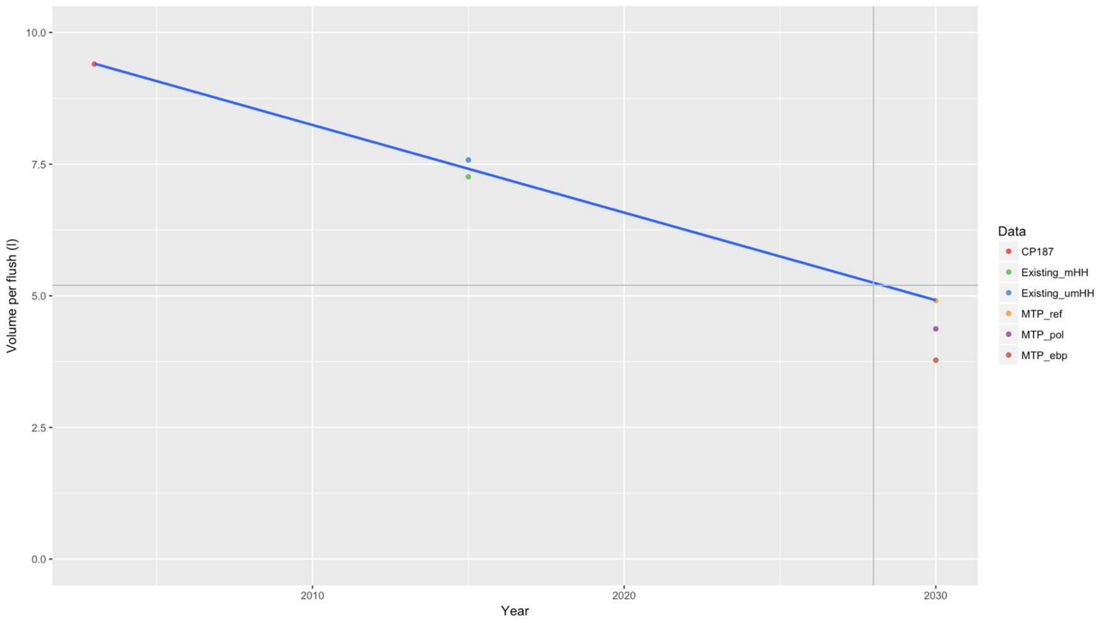
Figure 14 Regulatory changes in flush volumes



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

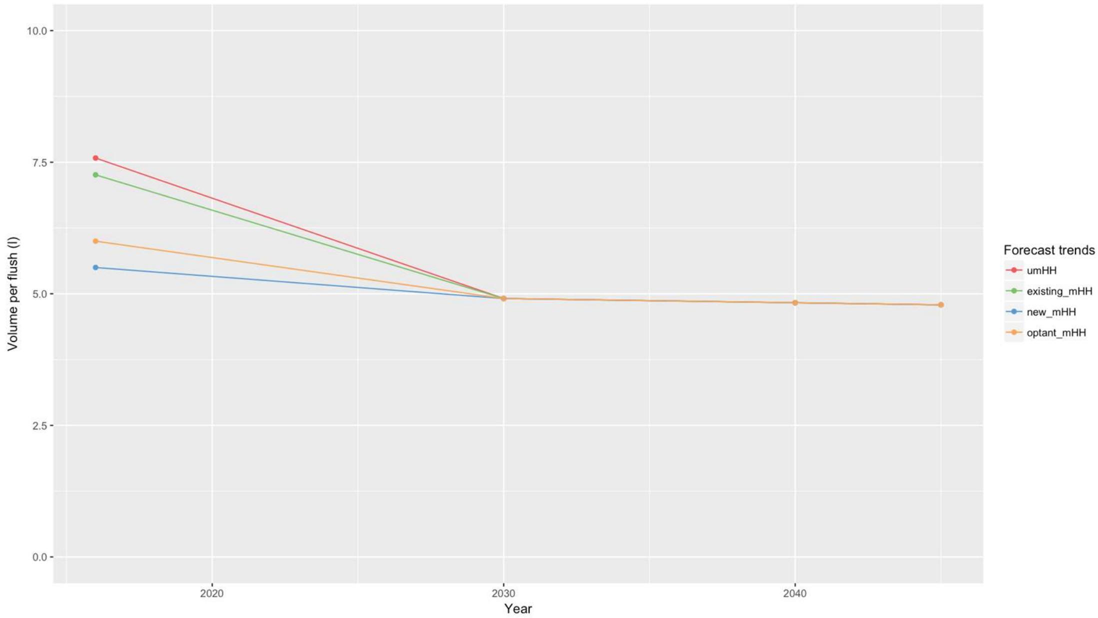


We have created future trends for WC volume per flush (see Figure 16) using:

- 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.

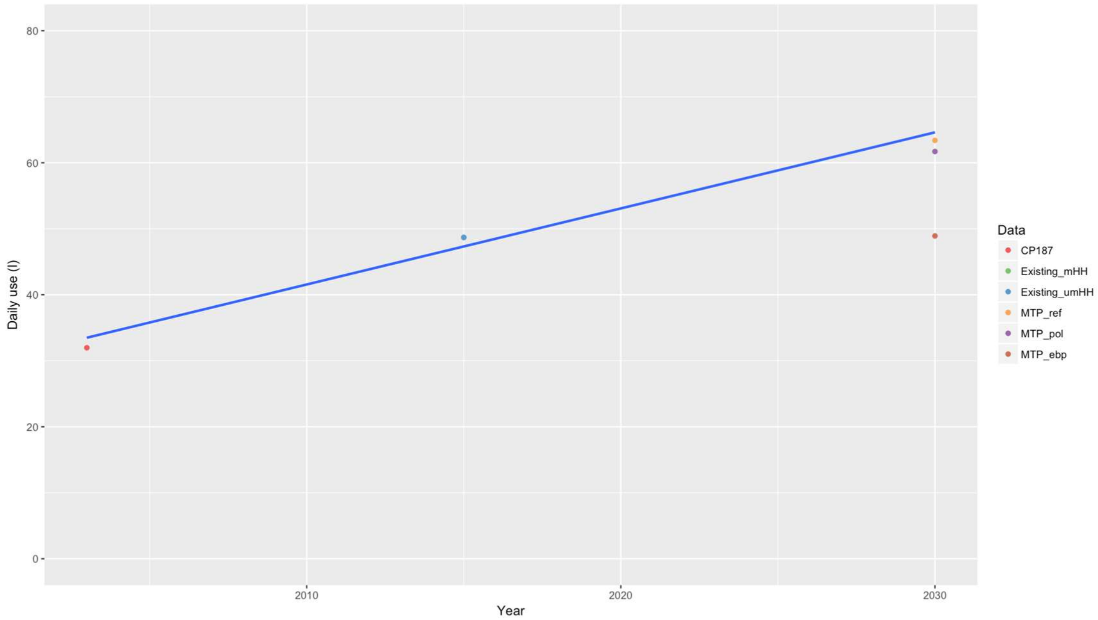
Figure 17 shows the following data points on daily shower volumes (l/day):

- 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).

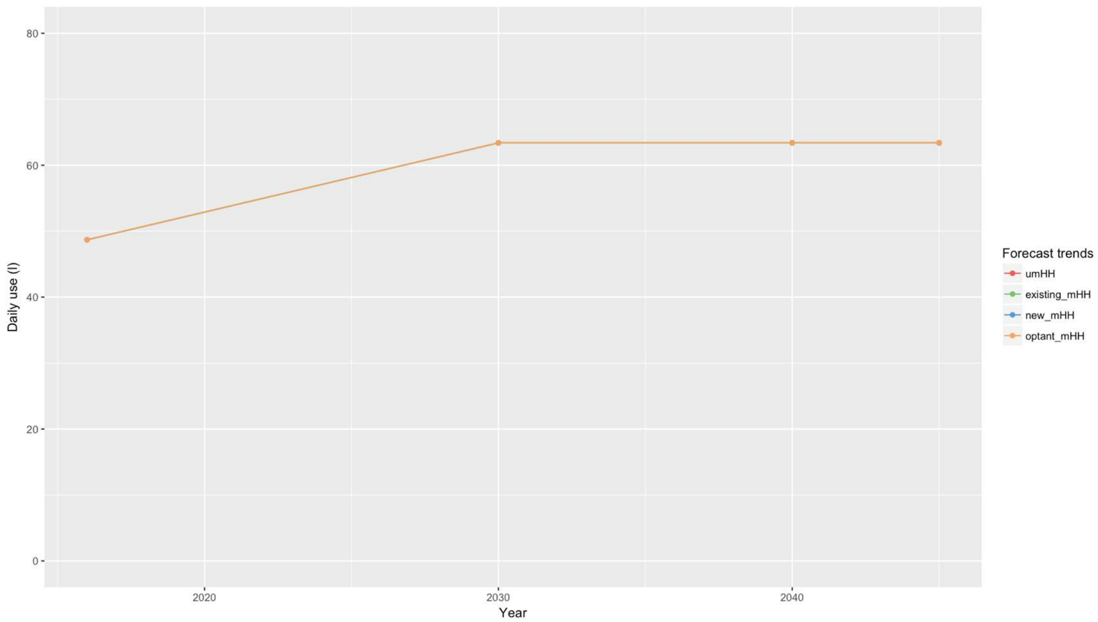
We have chosen not to fit trend line through the MTP Early Best Practice point as this assumes a very high proportion of water efficient showers being installed in new and existing households (which is not evident in current practice). This is used in the development of the lower PCC trend discussed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



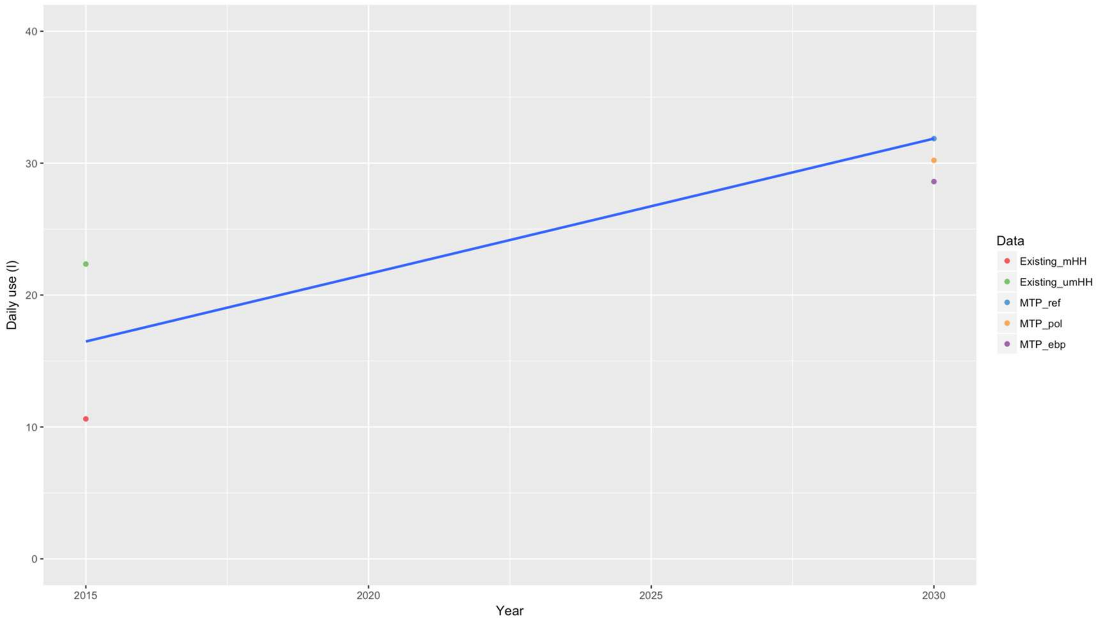
From this trend, annual rates of change have been produced. These are used for each of the property types. The rates of change are then incorporated in the model.

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.

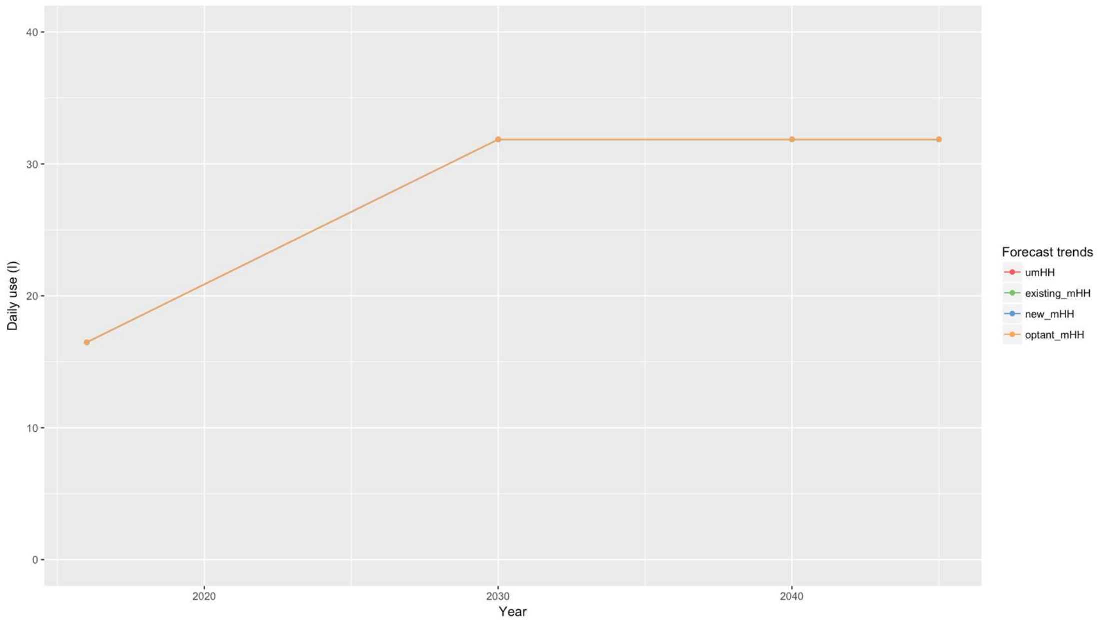
Figure 19 Trend of daily volume of water used for bath use



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

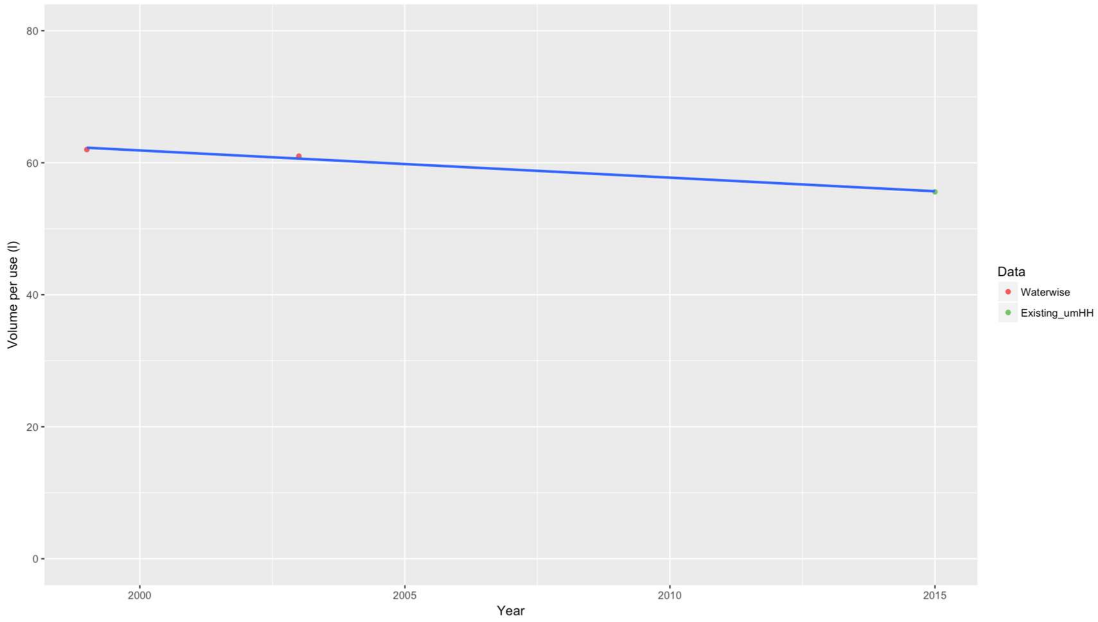
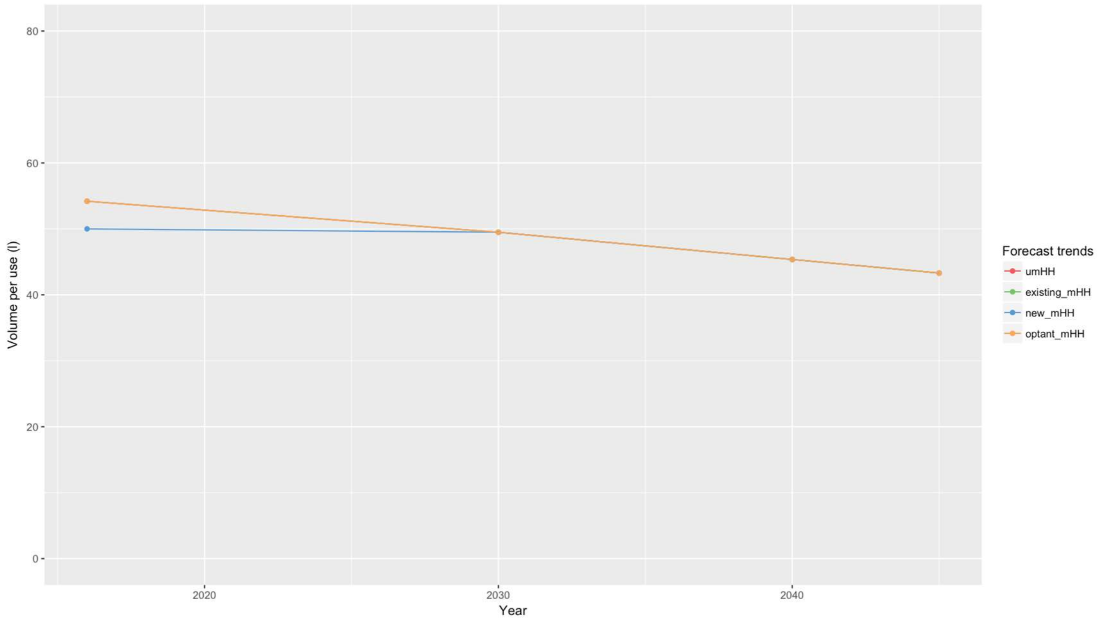


Figure 22 Future trend of washing machine volume per use



5.5.5 Dish washer use

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

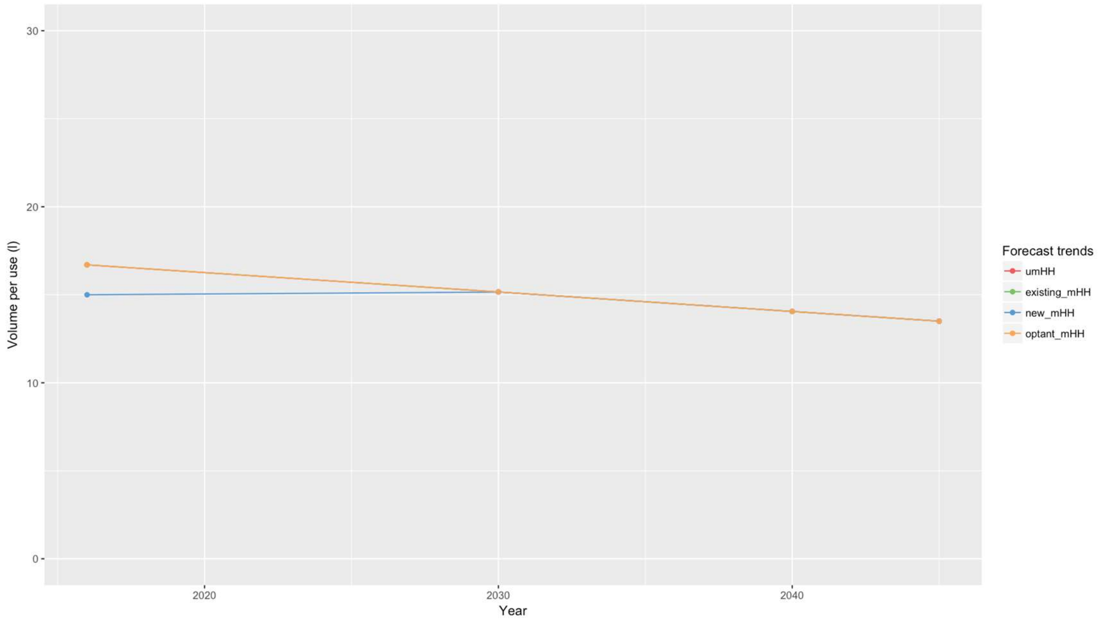
- Waterwise data on washing machine volume per use from 1999 and 2003,
- Washing machine volume per use in 2016 from Table 3.

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

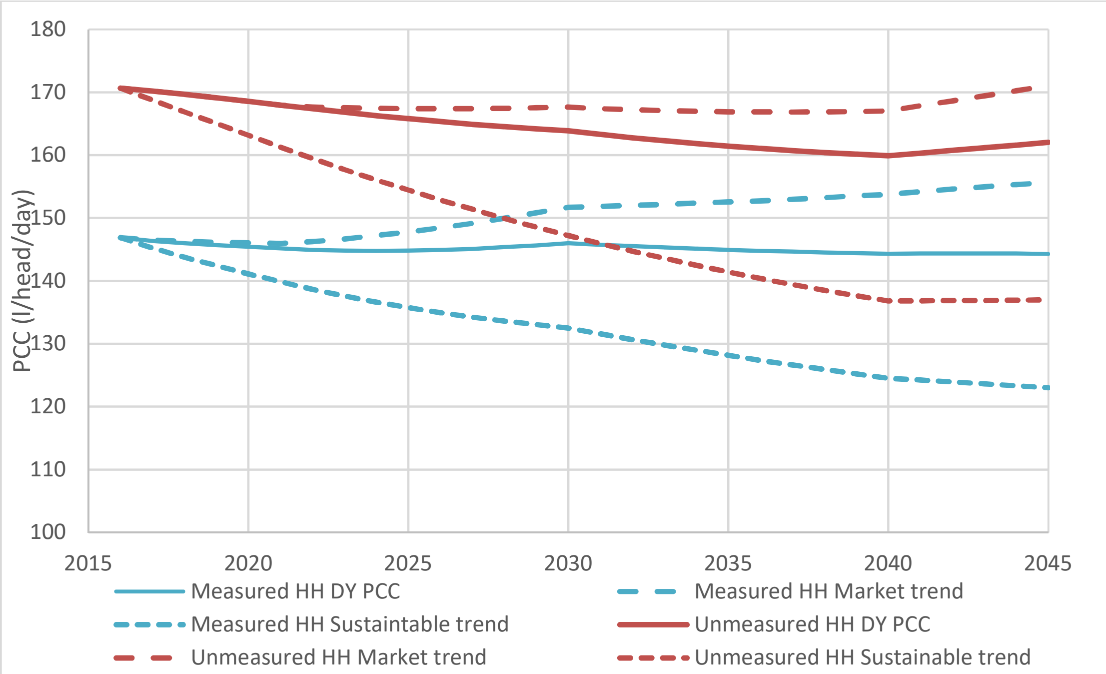
Two scenarios based on micro-component trends are added to account for variations within the future predicted rate of change in consumption.

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

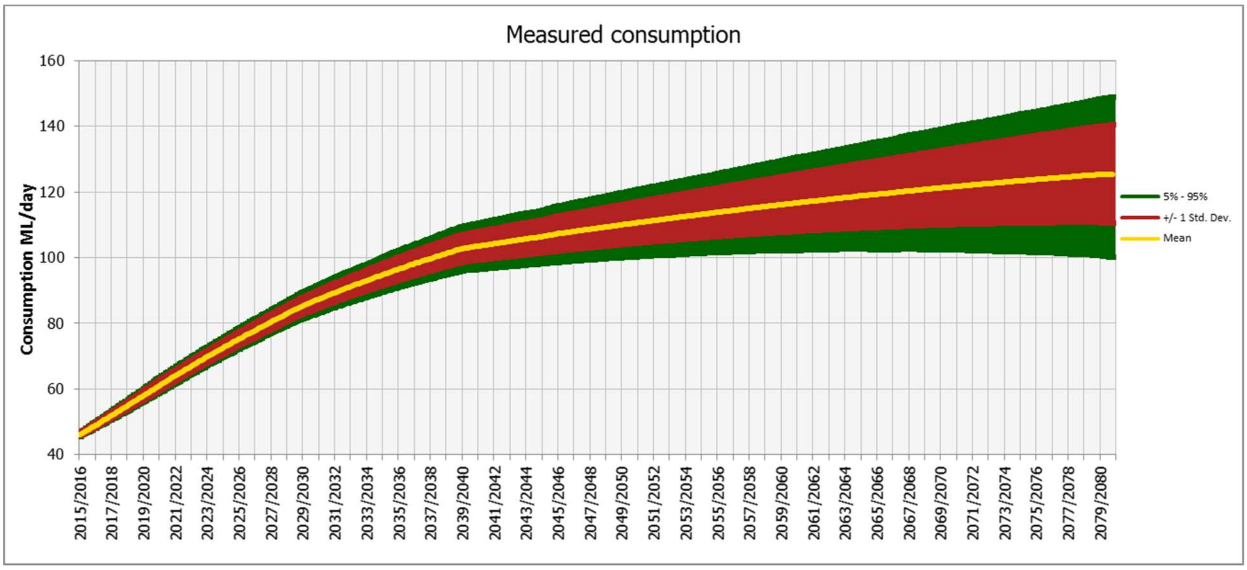
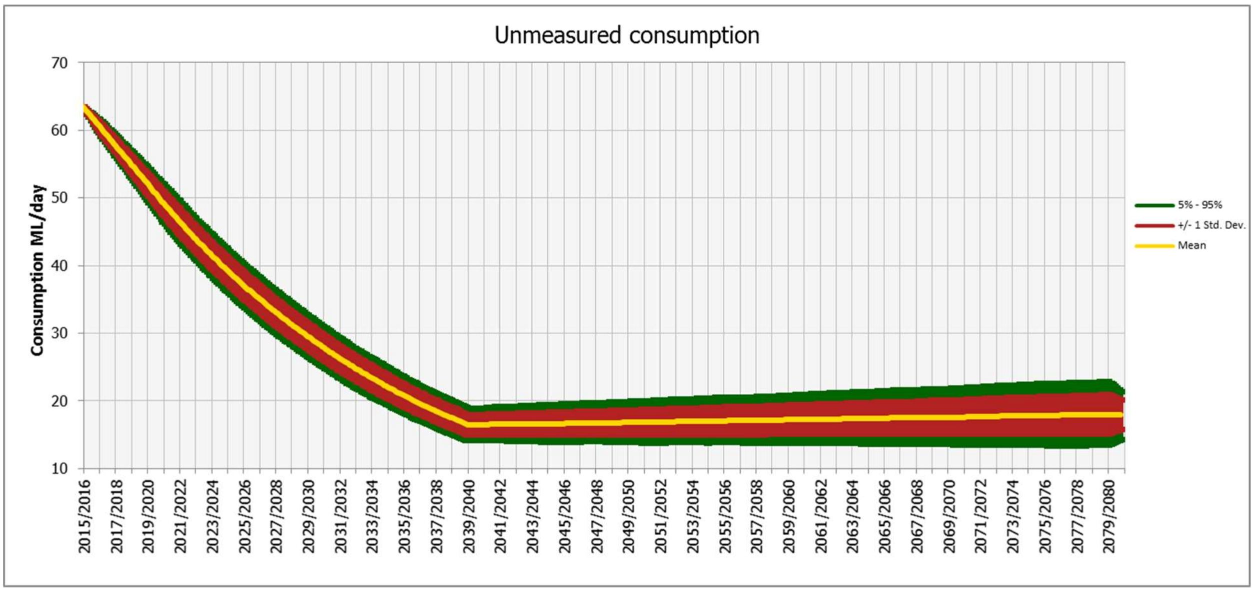


Figure 27 Company level unmeasured HH consumption Monte Carlo error distribution



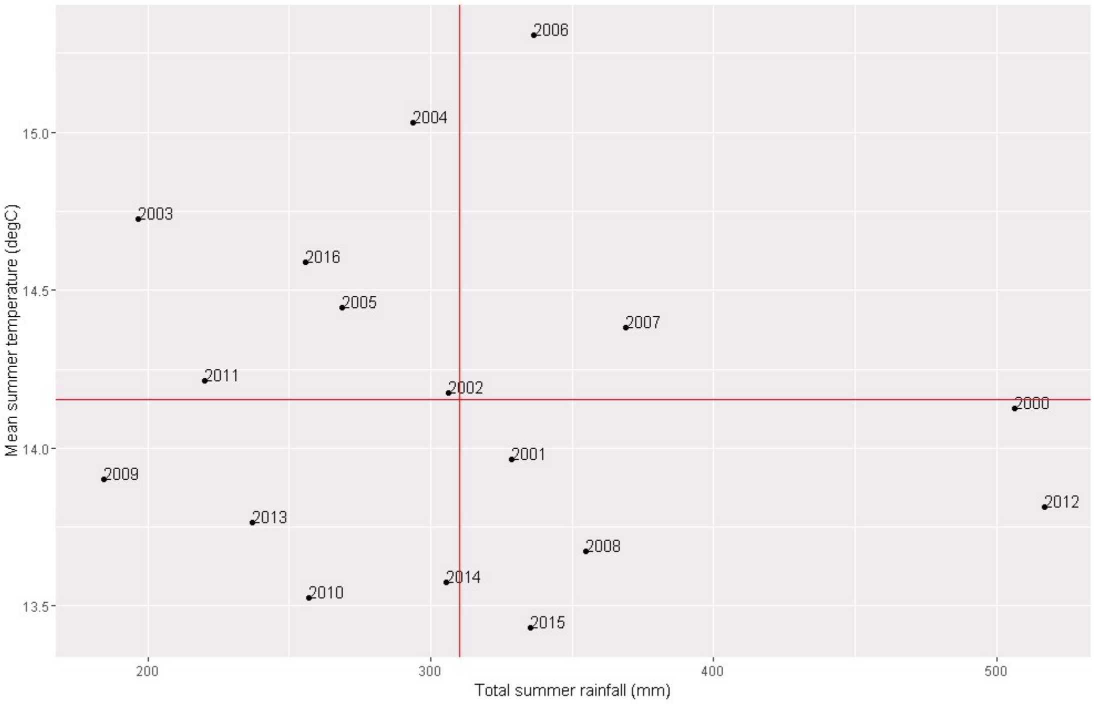
The results of this section are not used within the forecasting process, but are input into the headroom assessments. The graphs in Figure 26 and Figure 27 provide a graphical representation of the uncertainty surrounding the household consumption forecast.

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)**

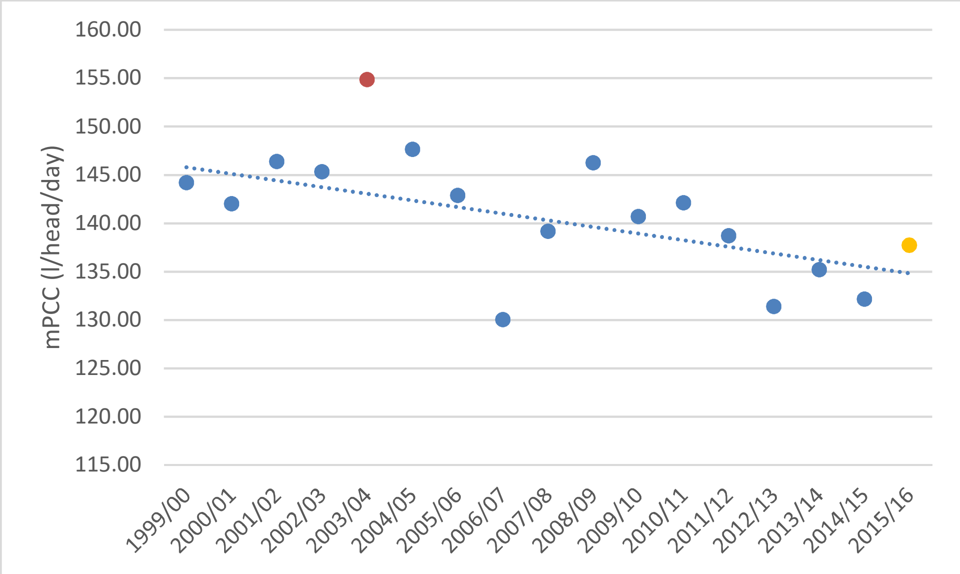
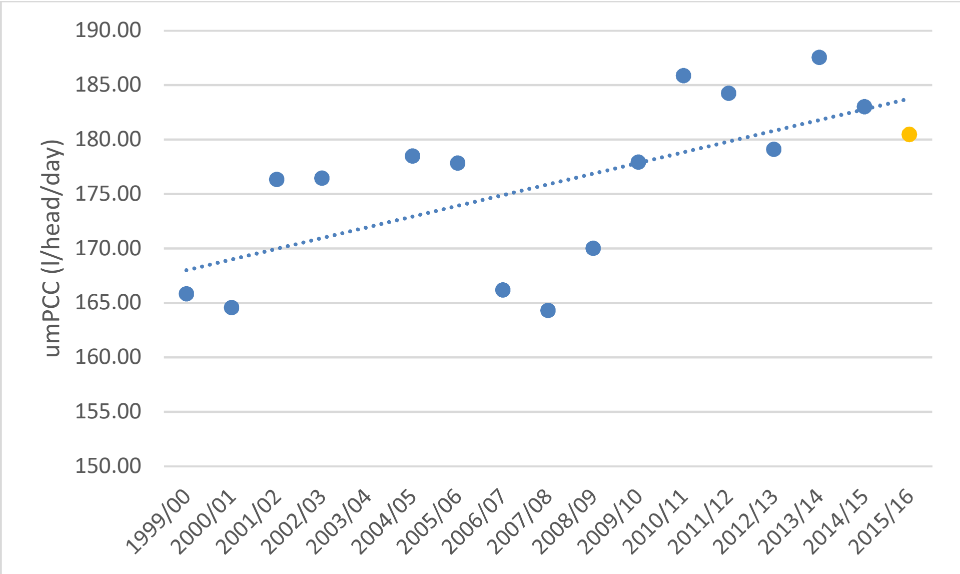


Figure 30 **Reported PCC trend - unmeasured properties (base year in yellow)**



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.

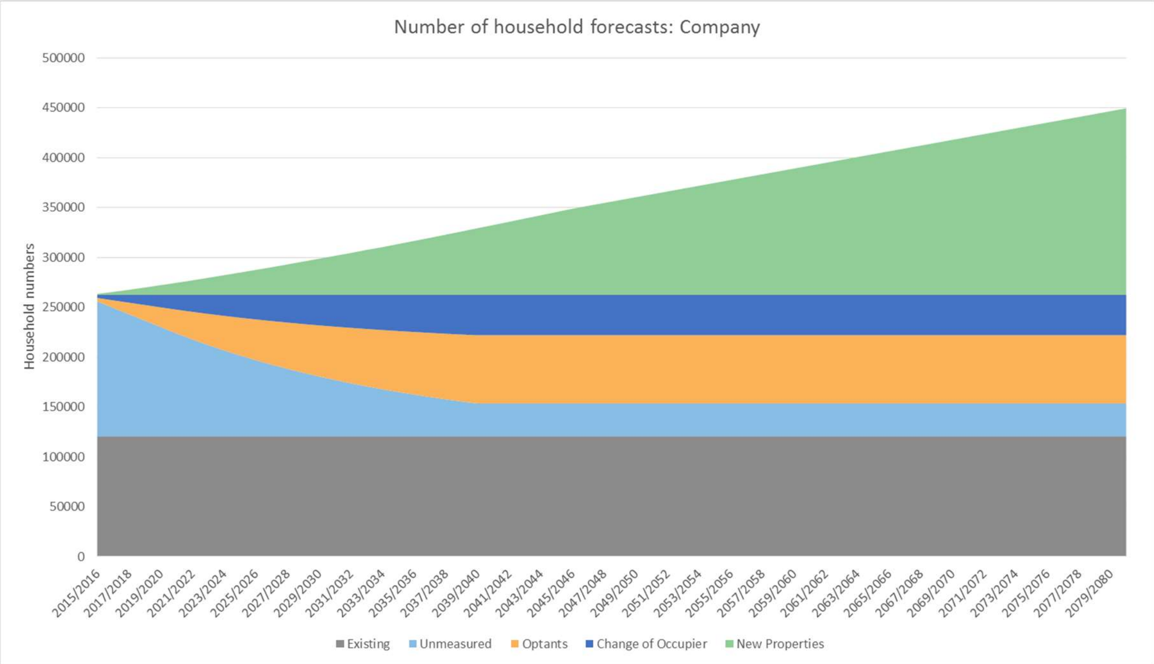
Table 11 Summary of factors applied in the household forecast

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

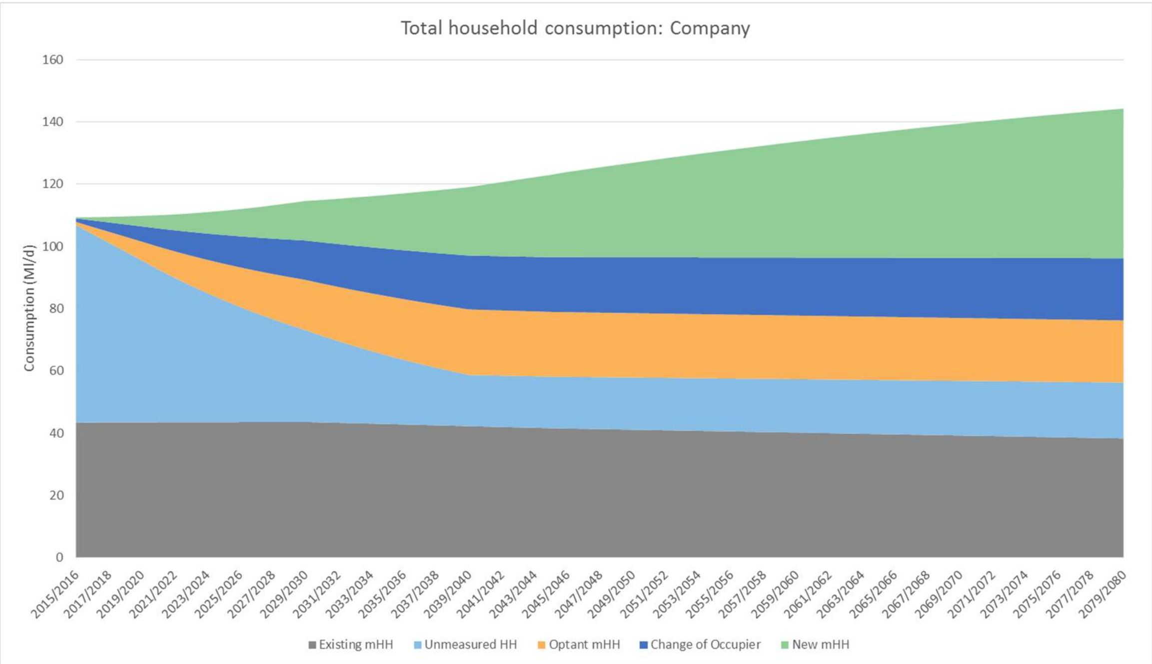
Graphical outputs for the central property forecast only (DYAA) are shown in figures 32 and 33. The central data is provided in tabular form in Table 13.

Figure 31 Total number of households, split by household segment



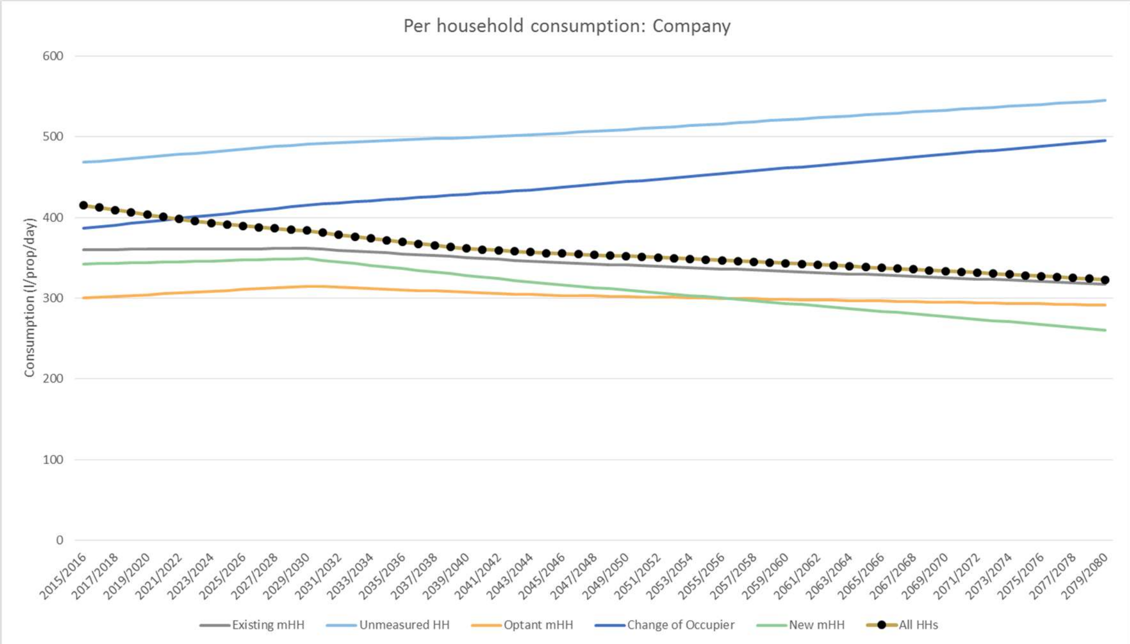
The total number of households, shown in Figure 31, increases from 263,451 to 446,691, so a 69.6% increase over the forecasting period.

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



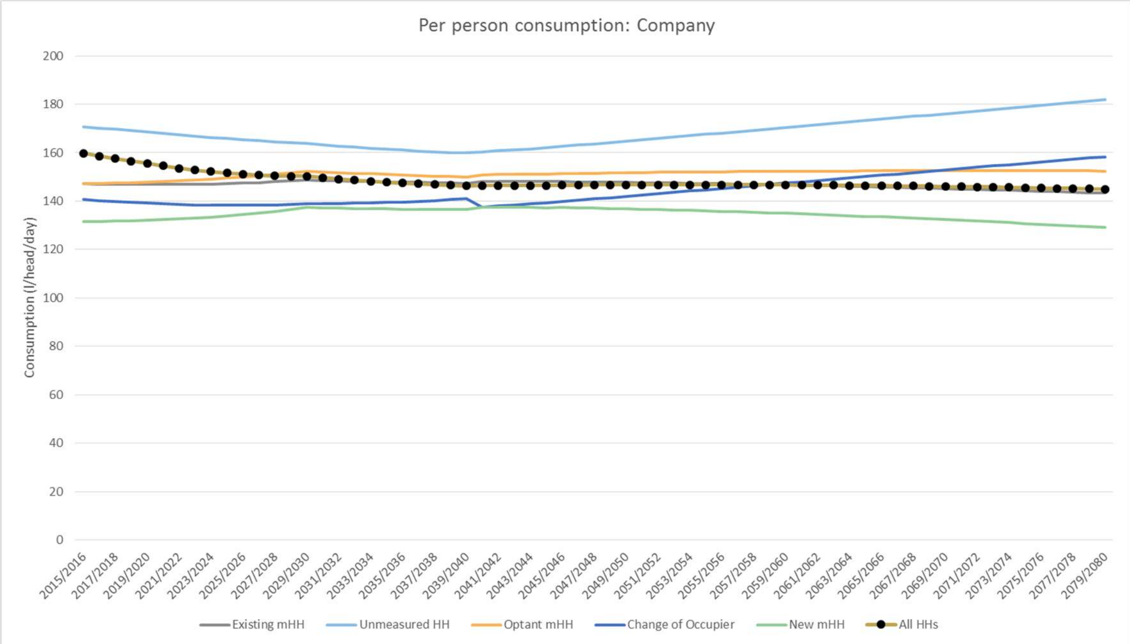
Total company household consumption increases from 109.36 Ml/day to 144.26 Ml/day, which is a 31.9% increase in demand over the forecast period, shown in Figure 32.

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

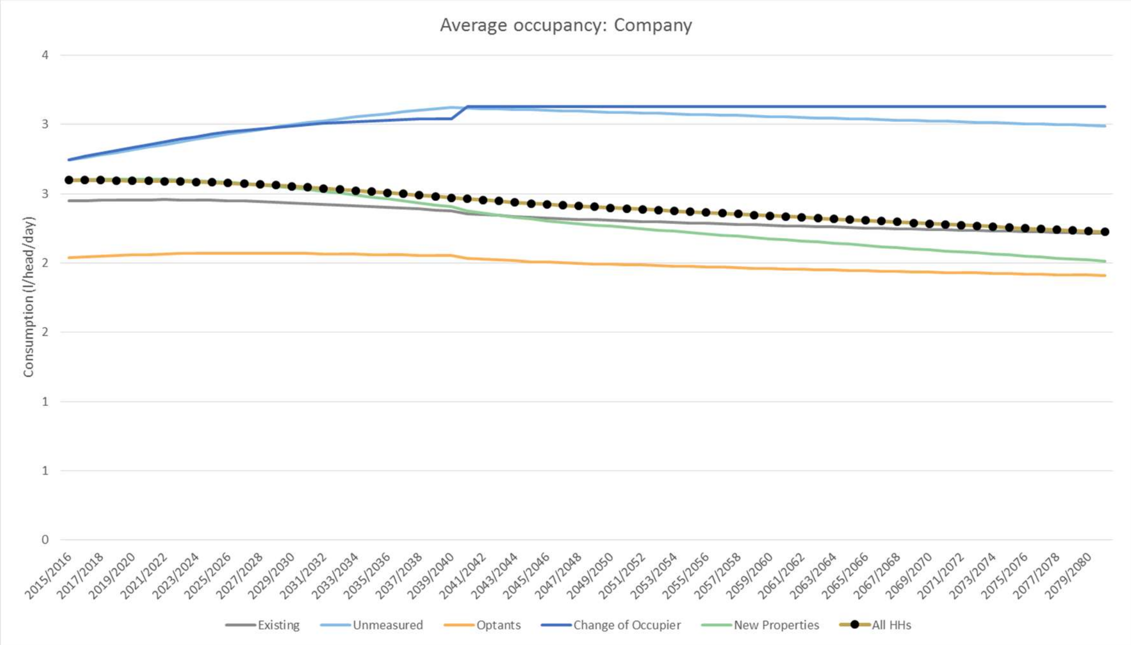


Figure 35 shows the trends in occupancy, the unmeasured rise is most notable, and as described before this is the impact of optant properties coming from the lower end of the occupancy distribution within the unmeasured households.

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.

Appendix B.

B.1. Demand Forecast Updates for the WRSE Regional Plan report

ATKINS

Member of the SNC-Lavalin Group

SES Water - Water Resources Support

Demand Forecast Updates for the WRSE Regional Plan

SES Water

October 2022

5197934/DG/070

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Contents

Tables

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1. Introduction

For the 2019 Water Resources Management Plan (WRMP19) SES Water commissioned Artesia Consulting to develop a household consumption forecast. Artesia Consulting produced a household consumption forecast by using micro-component modelling and forecasting. Further details of this modelling and forecasting are provided in Section 2.

In April 2020 SES Water commissioned Atkins to update their household consumption forecast model (herein referred to as the model) developed by Artesia Consulting to enable SES Water to produce a demand forecast for the Water Resources South East (WRSE) regional plan.

To be able to produce a demand forecast for the WRSE regional plan the following tasks needed to be undertaken. These tasks were completed following the guidance provided in the demand forecast method statement which was produced by WRSE[1] and with reference to the then draft Water Resources Planning Guideline (WRPG)[2]. The WRPG has since been finalised[3].

- Amend the model base year to 2019/20 and the baseline forecast to 2099/2100.
- Incorporate base year population and property data and incorporate population and property forecasts produced by Edge Analytics into the model.
- Incorporate company policy/funded metering (including the compulsory metering expected in Asset Management Plan (AMP) period 7) assumptions for AMP7 into the model (noting that from 2025/26 onwards, the WRPG states that baseline demand should not include any further water efficiency or metering interventions from companies).
- Review the approach to micro-components included in the model and update where necessary according to latest available guidance and evidence base.
- Incorporate SES Water's leakage estimates into the model, both for unmeasured supply pipe leakage and distribution losses (noting that from 2025/26 onwards, the WRPG states that leakage should remain static).
- Incorporate into the model SES Water's current estimates of Water Taken Unbilled and Distribution System Operational Use.
- Review the climate change factors included in the model and amend where necessary according to latest available guidance.
- Develop and incorporate Normal Year Annual Average (NYAA), Dry Year Annual Average (DYAA) and Dry Year Critical Period (DYCP) (including 1 in 200 and 1 in 500 drought events) uplifts into the model.
- Develop and incorporate a non-household forecast into the model.

This report describes how these tasks were undertaken, including documenting the data used.

[1] Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4
[2] Environment Agency, 2020, Water Resources Planning Guideline, draft for consultation, version 6.8
[3] Environment Agency, February 2021, Water Resources Planning Guideline, for publishing, version 9

2. Background to SES Water's household consumption model

The WRMP19 model developed for SES Water used micro-component modelling and forecasting, which is suitable for a Water Resource Zone (WRZ) with a low level of water resource planning concern.

The model was developed using best available data from local and national datasets. The model is segmented by property type using unmeasured and measured, with measured households split into existing properties, new builds, optants as well as compulsory, selective, change of occupier and other meting programmes. The model is based on per household consumption and includes linear modelling of key micro-components against occupancy to reflect the variation of per household consumption by occupancy within each household type. The model forecasts are developed from historic industry and UKWIR micro-component datasets and Market Transformation programme predictions.

The property and population forecasts used in the model are taken from estimates provided by Experian.

The model produces forecasts for NYAA, DYAA and DYCP; with a breakdown of micro-components for each year of the forecast.

Further details of how the model was developed can be found in Appendix E2 of SES Water's Final WRMP19[4].

3. Review of model

Atkins undertook a review of version 4.4 of the model which was provided to Atkins by SES Water on 19th May 2020. The aim of the review was to enable Atkins to understand how the model functioned and highlight the input data required for the model to be updated.

The following sections (sections 4 to 11) explain the model updates undertaken, including the data used.

4. Household population and properties

The model required revised population and property forecasts. This involved updating the base year and baseline forecast population and property data. The base year and baseline forecast population and property data came from two sources:

- SES Water 2019/20 Annual Review
- Edge Analytics.

Table 4-1 shows how these sources of data were used in the model. Section 4.1 and 4.2 describe these data sources in more detail.

Table 4-1 - Population and property baseline forecast

Category	Source
Base year population	Edge Analytics (Housing-Plan-P)
Base year property numbers	SES Water 2019/20 Annual Review
Baseline forecast population	Edge Analytics (Housing-Plan-P)
Baseline forecast property numbers	Edge Analytics data (Housing-Plan-P) calibrated to the SES Water 2019/20 Annual Review data

[4] SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

As the model calibrates the Edge Analytic property data to SES Water's 2019/20 Annual Review property data, the model therefore deviates from the occupancy rates provided by Edge Analytics, although the rate of change in properties and therefore occupancy rates over the planning period remains consistent with the Edge Analytics forecast. The calibration is required to ensure there is consistency between SES Water's customer database and the Edge Analytics data.

4.1. Annual Review data

Base year 2019/20 population and property figures were extracted from SES Water's 2019/20 Annual Review and are presented in Table 4-2.

Table 4-2 - Base year 2019/20 household population and property numbers data

	Properties	Population
Measured	162,355	419,998
Unmeasured	108,685	307,037
Total	**271,040**	**727,035**

4.2. Edge Analytics data

Property and population forecasts for SES Water were supplied by Edge Analytics. Edge Analytics used the latest available Local Plan and Office for National Statistics (ONS) trend-based data, as well as other sources including the Greater London Authority (GLA). Forecasts were produced for a wide range of scenarios, by using a combination of trend, housing-led (incorporating housing need, housing requirements and actual planned scenarios) and employment-led forecasts, to account for the considerable uncertainty in the projections.

From the range of scenarios, there was the need to adopt one as a baseline growth forecast, supported by a selected number of additional growth projections that allows SES Water to account for uncertainty.

WRSE agreed on consistent property and population growth scenarios for companies across the region to base their demand forecasts on and provided guidance in a WRSE Method Statement[5]. Using the guidance provided in the WRSE Method Statement the relevant property and population forecasts were extracted for use in SES Water's demand forecast. Table 4-3 provides a list of the scenarios WRSE decided should be included in the model and the growth forecasts which match these scenarios.

For the baseline forecast the Housing-Plan-P scenario was selected. The Housing-Plan-P scenario was developed using two approaches: a 'top-down' approach and a 'bottom-up' approach. WRSE adopted the 'bottom-up' approach as it is considered to more accurately represent the locations of new growth across Water Resource Zones (WRZs).

Table 4-3 - Selected growth forecasts for SES Water

Scenario	Selected growth forecast for SES Water
Baseline	Housing-Plan-P (bottom-up)
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

The household population estimates comprise both people living in households and people living in communal establishments (population 'not in households'), e.g. care homes, long-stay hospitals, students in halls of residence. Even though the property types for these customers may be classed as non-household, the water use is largely domestic, so they are counted as household customers for the purposes of the demand forecast.

[5] Water Resources South East, November 2020, Method Statement: Demand Forecast Version 4.

Year-on-year projections of household population were provided for the above scenarios.

To allow the desired growth forecast to be used in the model a switch was added to the model, which allows the user to select the desired population and property forecast. The switch works by the user manually typing in the name of the population and property scenario they wish to run through the model. This scenario is then selected by the model.

4.3. Hidden and transient population

Edge Analytics (again as part of the WRSE collaborative study on population) provided data on the hidden and transient population within the SES Water area. The data used in the demand forecast was the mid-level estimate for irregular migrants, short-term residents and second addresses (not visitors). The base year figures provided by SES Water are shown in Table 4-4. Year-on-year forecasts were not available for this segment of population so these figures remained constant throughout the baseline forecast.

Table 4-4 - Hidden and transient populations

Hidden and transient population types	Population
Irregular migrants	8,801
Short-term residents	1,453
Second addresses	726
Visitors	0
Total	**10,980**

4.4. Property types

Within the model household properties are split into those which are measured and those which are unmeasured. Measured households are further sub-divided into the following categories:

- Existing
- New properties
- Optants
- Change of occupier.

The data required to determine the number of properties in each category for the base year and baseline forecast are explained in Section 4.4.1 and 4.4.2.

4.4.1. Base year 2019/20

Base year household properties are split between measured households and unmeasured households. This split was determined by the data extracted from SES Water's 2019/20 Annual Review (see Section 4.1).

For the base year the number of new properties, the number of properties opting for a meter in-year (optants) and the number of properties metered on change of occupancy is required. Table 4-5 presents the base year properties in each of these categories and a brief explanation of how they have been determined.

Table 4-5 - Property types

Property type	Explanation	Number of properties in the base year 2019/20
Unmeasured properties	The number of unmeasured properties has been extracted from SES Water's 2019/20 Annual Review.	108,685
Existing measured properties	The number of existing measured properties has been calculated by subtracting the number of new properties, optants and change of occupier properties (method for calculating these properties types is provided in the rows below) from the total number of measured properties which was extracted from SES Water's 2019/20 Annual Review.	153,335
New properties (or new connections)	The annual number of new connections for 2019/20 has been calculated from SES Water's 2019/20 Annual Review. The total number of measured and unmeasured properties in a given year is subtracted from the previous year's total number of measured and unmeasured household properties to give the difference which is the annual number new connections.	2,620
Optants	The number of optant properties has been calculated from data included SES Water's 2019 Water Resources Planning Tables (row 45.2). The number of optant properties in 2019/20 has been used.	4,065
Change of occupier	The number of change of occupier properties has been calculated from data included SES Water's 2019 Water Resources Planning Tables. The number of properties metered on change of occupier (row 45.4) and the number of compulsory metered properties (row 45.3) in 2019/20 have been added together.	2,335
	Total number of household properties	**271,040**

4.4.2. Baseline forecast

To determine the proportion of properties in the optants and change of occupier categories, metering data was taken from the SES Water's 2019 Water Resources Planning Tables.

For the baseline forecast after AMP7 (2025/26 onwards) there is no metering on change of occupancy. This assumption is based on the WRPG which states *'your baseline customer demand should take account of customer demand without any further water efficiency or metering intervention from yourselves…*':

The number of change of occupier properties for each year of the baseline forecast has been calculated by adding together the number of properties metered on change of occupier (row 45.4 from SES Water's 2019 Water Resources Planning Tables) and the number of properties compulsory metered (row 45.3 from SES Water's 2019 Water Resources Planning Tables).

For optant metering the baseline forecast only included optant metering beyond AMP7 (2024/25) which was not encouraged by SES Water. Optant metering data for the baseline has been taken from the SES Water's 2019 Water Resources Planning Tables (row 45.2) and includes optant metering until 2029/30.

Table 4-6 presents the metering data included in the baseline forecast.

Table 4-6 - Baseline forecast metering data

Year	Change of occupancy and compulsory metering	Optants
2020/21	12,881	4,065
2021/22	12,745	3,828
2022/23	12,617	3,604
2023/24	12,496	3,394
2024/25	12,382	3,196
2024/26	0	2,006
2026/27	0	1,889
2027/28	0	1,779
2028/29	0	1,675
2029/30	0	1,577

5. Household occupancy rates

Occupancy rates for each property type are calculated by dividing the population by the number of properties. As discussed in section 4.1and 4.2 the population data is supplied by Edge Analytics. Property data is also supplied by Edge Analytics, but this is calibrated to the property data from SES Water's 2019/20 Annual Review. These occupancy rates are used in the model to convert per household consumption (PHC) to per person consumption (PCC).

5.1. Base year occupancy rates

Table 5-1 provides an explanation on how occupancy rate has been derived for the base year.

Table 5-1 - Base year occupancy rates

Property type	Explanation	Occupancy rate in the base year 2019/20
Measured	The population data provided by Edge Analytics is split between measured and unmeasured households based on the proportion of the population reported to be living in measured and unmeasured households in SES Water's 2019/20 Annual Review. The population is then divided by the number of properties, which has been calculated by calibrating the property data provided by Edge Analytics to the property data in SES Water's 2019/20 Annual Review, to give an occupancy rate.	2.58
Unmeasured		2.82
Existing measured	The occupancy rate of existing properties is calculated by dividing the final (following calibration) existing population by the number of existing properties.	2.59
New properties (or new connections)	The occupancy rate of the new connection properties is assumed to be the mean of measured and unmeasured occupancy.	2.68
Optants	Calculated by dividing the optant population by the number of optant properties. The number of optant properties is calculated by taking the total measured properties minus the new connections population, minus the change in occupier properties. Population is calculated by taking the total measured population minus the new connections population, minus the change in occupier population	2.32
Change of occupier	The occupancy rate for change of occupier is assumed to be the same as the unmeasured occupancy rate.	2.82

5.2. Baseline forecast occupancy rates

In the baseline forecast in order to successfully distribute the population between the property types, certain assumptions and knowledge of the property types must be assessed. As previously mentioned in Table 4-1 SES Water has used the Edge Analytics population data for the purposes of the WRMP24, which is considered to be the best available data on population and therefore superseding the company's Annual Review 2019/20 population numbers. This occurs in the base year and throughout the baseline 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 property population and optant population within the existing measured households must equal the total measured household population. Optants generally have a low occupancy, however this is highly dependent on meter penetration. As meter penetration increases, the occupancy rates of unmeasured and optant properties increase until 100% meter penetration is reached, because those lower occupancy households for whom opting to have a meter installed is more likely to be economically beneficial would likely have opted already.

Meanwhile the average occupancy of all the property types must follow the year-on-year trend in occupancy from the Edge Analytics property and population data. These assumptions provide an estimate of the change in occupancy within the household types over time; in reality, there will be a complex movement of population within these property types, reflecting births, deaths, people moving into the region, people moving out of the region, and people moving within the region.

In order to achieve the desired occupancy rate for each property type and for the average occupancy of all the property types to follow the year-on-year trend in occupancy from the Edge Analytics data the existing measured property type is used as a balancing item in the model.

6. Household consumption

The model generates household consumption through micro-component modelling. The model is based on PHC, which makes the occupancy-driven household consumption component implicit in the model. The PHC values for each property type are converted to a total consumption per property by multiplying by the total number of properties. The total consumption per property values are then converted to a PCC by dividing by the population for the property type.

The results from this modelling are calibrated to base year household consumption data extracted from SES Water's 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance. The process involved in reviewing the micro-component modelling and any amendments to the data included in the model are described in Section 6.1. The input data required for calibrating the base year micro-component modelling results is presented in Section 6.2.SES Water's household consumption forecast also takes account of its PR19 Outcome Delivery Incentive (ODI) targets linked to household PCC. This target is explained in Section 6.3 and how the target is included in the model is documented.

6.1. Micro-component modelling and forecasting

In the model the relationship between some micro-components (WC flushing, shower use, bath use, tap use and washing machine use) and occupancy has been used to calculate base year ownership, volume per use and frequency of use (OVF) per household consumption values. According to Appendix E2 of SES Water's Final WRMP19, OVF values from an UKWIR study undertaken in 2016[6] formed the basis for this modelling. For those micro-components which did not have a relationship with occupancy, the OVF values from the UKWIR 2015/16 micro-component dataset were used for calculating base year water usage. This dataset was used because it had a complete set of occupancy data for each household over the monitoring period which was required for the linear modelling.

A review of the WRMP19 micro-component modelling and forecasting approach was undertaken which included:

- Reviewing the split of household water consumption between the various micro-components based on professional judgement and any relevant data collected during the literature review.
- A literature review to determine if any new data on micro-component water usage was available.
- Analysing micro-component data collected by SES Water's 'Get Water Fit' initiative.

The findings of the review are documented in Sections 6.1.1 to 6.1.3.

6.1.1. Split of household consumption between micro-components

From an initial high-level review of the micro-component OVF values included in the model is was apparent external use was lower than expected. Table 6-1 shows the OVF values used to calculate household measured and unmeasured external use. Further analysis of the split between micro-components which was reported in SES Water's Final WRMP19 shows that external water use only makes up 1% of micro-component water usage (see

[6] UKWIR, 2016, 16/WR/01/15, Integration of behavioural change into demand forecasting and water efficiency practices

Table 6-2).

Table 6-1 - External use OVF values

Micro-component	Ownership	Volume (litres)	Frequency of use per day	O*V*F
External use	0.18	285.18	0.07	3.34

Table 6-2 - Percentage of water usage per micro-component for SES Water's WRMP19

Micro-component	WRMP19	
	Measured	Unmeasured
Toilet flushing	21.8%	21.4%
Personal washing	46.9%	49.2%
Clothes washing	9.5%	7.1%
Dish washing	9.9%	10.0%
Miscellaneous internal use	10.9%	11.5%
External use	1.0%	0.8%

Figure 6-1 which is taken from the Energy Saving Trust's report 'At home with water'[7] suggests that external water usage should be approximately 2% of household consumption. This has been determined by adding garden usage and car usage (assumed to be car washing) together. It was concluded that potentially the model underestimates the proportion of water used externally.

Figure 6-1 shows the percentage of water usage for dish washing (by hand and by a dishwasher) is 5%, which is 5% lower than SES Water's WRMP19 data in

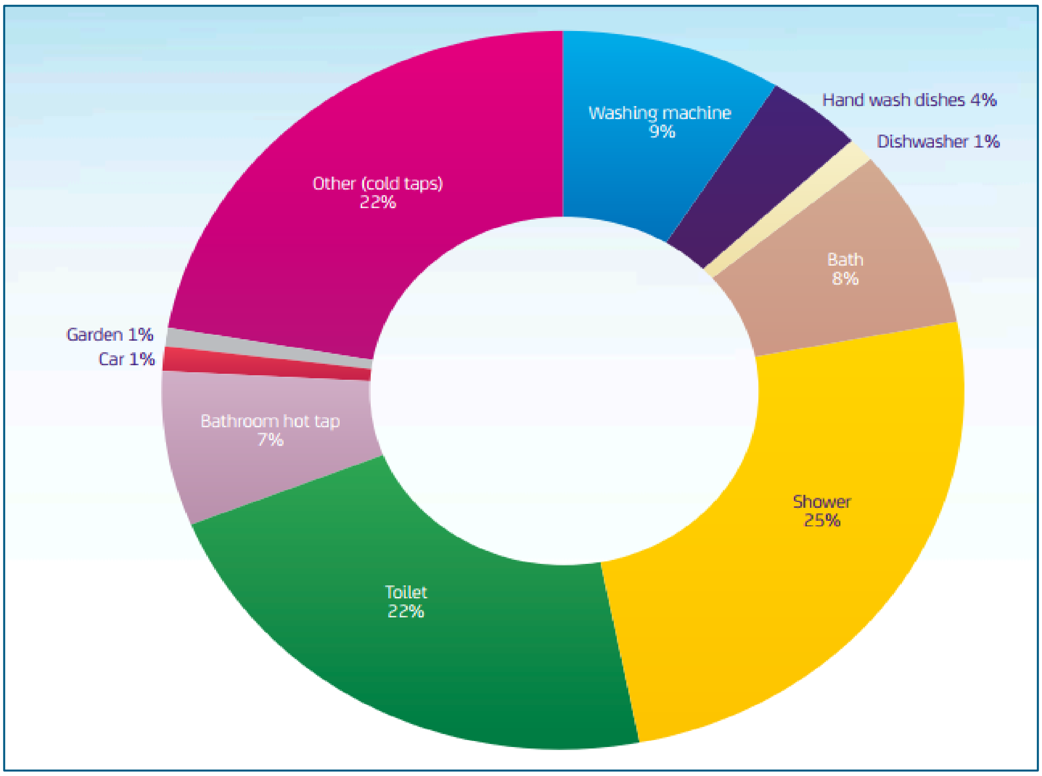
[7] Energy Saving Trust, July 2013, At home with water

Table 6-2. However, determining the activities that water from a kitchen tap is used for (e.g. washing dishes, hand washing, preparing food etc) can be hard to establish.

For the majority of the remaining micro-components listed in

Table 6-2 the percentages shown were considered reasonable and roughly correspond to the data presented by the Energy Saving Trust in Figure 6-1.

Figure 6-1 - Household water consumption



Source: Energy Saving Trust, At home with water, July 2013.

6.1.1.1. External use adjustments

Temporary Use Bans (TUBs), one of the mechanisms by which companies can encourage customers to save water during a drought, target external uses of water. With external use representing such a low proportion of household water use in SES Water's WRMP19 model, it was found that external use was not high enough to apply the assumed TUBs savings, which are assumed in the company's Draft Drought Plan 2021[8] to equate to approximately 3.2 % of DYAA demand (Distribution Input (DI) minus leakage) and approximately 5.4% of DYCP demand (DI minus leakage).

Appendix E2 of SES Water's Final WRMP19[9] presents three tables of micro-component data, including the data used in the model. A description of the data in each table is provided in Table 6-3. The actual data is provided in Figure 6-2, which was used when the model was developed. External use represents 1.4% of household water consumption. The percentage of external use in the other two tables is higher at 5.9% and 7.3% of per household consumption.

Sensitivity testing was undertaken using the external use values from Tables 3 and 4 from Figure 6-2 in turn. The external use OVF values in the model were replaced with the OVF values from Table 3 and Table 4 to see what impact they each had on external use. It should be noted that altering the external use OVF values will not impact the overall PCC because the model offsets the increase in the external use micro-component by applying an equal percentage decrease across all the other micro-components. The sensitivity analysis concluded that only the Table 4 external use micro-component OVF values ensure that TUBs savings could be purely attributed to reductions in external use, i.e. the savings are less than the external use values in both the base year and the final year of the planning period. The final year of the planning period would also work using Table 3 OVF values, but not the base year.

SES Water decided to adopt the Table 3 OVF values and the necessary updates were applied to the model. Even though the Table 3 external use micro-component OVF values means that TUBs savings cannot be

[8] SES Water, March 2021, Draft Drought Plan, for public consultation
[9] SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

purely attributed to reductions in external use in the base year, SES Water decided to use this data because it is more recent than the Table 4 OVF values.

Table 6-3 – Micro-component data sources presented in Appendix E2 of SES Water's Final WRMP19

Data source	Description
Table 2	Micro-component summary data from 2015/16 metered billed households. A sample of measured billed households, which has associated occupancies and demographic information on the households, collated during an UKWIR Study (this contains 62 households from around England and Wales).
Table 3	2015/16 RV billed households. 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).
Table 4	Micro-component summary for 2002/04 RV billed households. 2002 – 2004 O, V, and F data collected using the Identiflow system (a sample of RV billed households, reporting in WRc Report CP187).

Figure 6-2 - WRMP19 micro-component data

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

6.1.2. Literature review

A literature review was undertaken to establish whether any new data on micro-component water usage was available, which could then potentially be used to update the model.

The review showed that no new data on micro-component water usage was available and the model used the latest data which was collated during an UKWIR study[10]. However, the review identified the potential impact the COVID-19 pandemic could be having on water demand. The 'lockdown' response to the pandemic has disrupted the normality of everyday lives which has had a knock-on effect on water use practices and therefore water use in the home. With working from home being part of lockdown, people have spent more time at home than normal and therefore used more water in the home. The frequency of use of certain indoor micro-component has increased according to a survey conducted in May 2020[11]. In addition, indoor micro-components in the home are generally less water efficient than those in offices. Therefore, the volume of water used per use may be greater than using the same micro-component in an office. During lockdown people spent more time than normal in their gardens. Water UK (2020) reported that UK water companies saw the highest ever demand for water. It is likely that the surge in demand was caused by a combination of increased external water use for watering gardens and filling up paddling pools due to the warm weather, and people spending more time at home than normal. Also, an increased ownership of hot tubs was seen during lockdown which will have contributed to external water use. Although regardless of the COVID-19 pandemic hot tub ownership was increasing prior to the pandemic beginning.

The potential impact the COVID-19 pandemic has had on demand for water has not been included in the model update as lockdown started at the end of March 2020 and therefore the majority of the impacts would have not occurred in the base year (2019/20).

6.1.3. 'Get Water Fit' initiative

SES Water are running an initiative to encourage their customers to use water wisely. This initiative is called 'Get Water Fit'. The data collected through this initiative included information such as whether the household has a dishwasher and washing machine and how many times it is used per week, the type of shower, how many times it is used per week and the duration of the shower. It also collected information on household occupancy. This type of information could potentially be used to inform the micro-component OVF values.

SES Water provided Atkins with the July 2020 and August 2020 'Get Water Fit' datasets. The combined datasets included approximately 100 measured households and 100 unmeasured households. Initial analysis of this data provided the ownership and frequency values for a range of micro-components for measured and unmeasured households (Table 6-4). Further ownership values for additional micro-components (represented as a percentage) are presented in Table 6-5.

Table 6-4 - Ownership and frequency values from the Get Water Fit data

Micro-component	Ownership		Frequency of use per day	
	Measured	Unmeasured	Measured	Unmeasured
Shower	1.53	1.35	2.11	2.07
Toilet	2.19	1.87	*	*
Basin	2.14	1.81	*	*
Bath	1.03	0.96	0.44	0.47
Kitchen utility tap	1.42	1.29	*	*
Kettle	*	*	3.38	3.18
Wash dishes by hand	See Table 6-5	See Table 6-5	2.05	1.72
Dishwasher	See Table 6-5	See Table 6-5	0.67	0.52

[10] UKWIR, 2016, UKWIR 16/WR/01/15 Integration of behavioural change into demand forecasting and water efficiency practices.
[11] FINISH, 2020, The Great British Rain Paradox

Washing machine	See Table 6-5	See Table 6-5	0.79	0.79

*No data available to calculate ownership or frequency of use per day values.

Table 6-5 - Ownership values (represented as percentages) from Get Water Fit data

Micro-component	Ownership %			
	Measured		Unmeasured	
	Yes	No	Yes	No
Wash dishes by hand	49	51	55	45
Dishwasher	75	25	64	36
Washing machine	98	2	98	2

Using assumptions on the volume of water used for showers from the Energy Saving Trust (13 litres per minute for a power shower and 5 litres per minute for an electric shower) the average volume of water used per person per day has been calculated (see Table 6-6). This calculation is based on the average duration of a shower for measured households being 7.9 minutes and for unmeasured households 8.26 minutes. The duration of a shower data has been collated from the 'Get Water Fit' datasets.

Table 6-6 - Average water use for showering

	Multi jet (Power)		Electric	
	Measured	Unmeasured	Measured	Unmeasured
Average water use (litres per person per day)	120.78	118.86	46.45	45.71

The data being collected by the 'Get Water Fit' initiative provides the ownership and frequency of use information required for calculating micro-component water usage. As demonstrated above it can be combined with appliance water usage data other studies to develop the volume per use values which is also required to calculate micro-component water usage.

However, currently, with only 200 sample households, the dataset is small and therefore not considered sufficiently robust to base SES Water's micro-component demand forecast on.

6.1.4. Summary

It was concluded that even though potentially new trends in micro-component water usage were highlighted in the literature review, because the model includes linear modelling of micro-components against occupancy it would not be straight forward for Atkins to amend the micro-component trends as the exact calculations behind the linear modelling were not available in the model.

The review also highlighted that external use represented a very low proportion of household water consumption which would have implications if TUBs savings were applied. As external use did not have a relationship with occupancy the OVF values used to calculate base year external use water usage came directly from the UKWIR 2015/16 micro-component dataset. It was therefore decided to alter the OVF values for external use as documented in Section 6.1.1.1.

Figure 6-3 to Figure 6-8 present a summary of the micro-component PCC for the measured and unmeasured households for various consumption uplift factors.

Figure 6-3 - Measured micro-component consumption NYAA

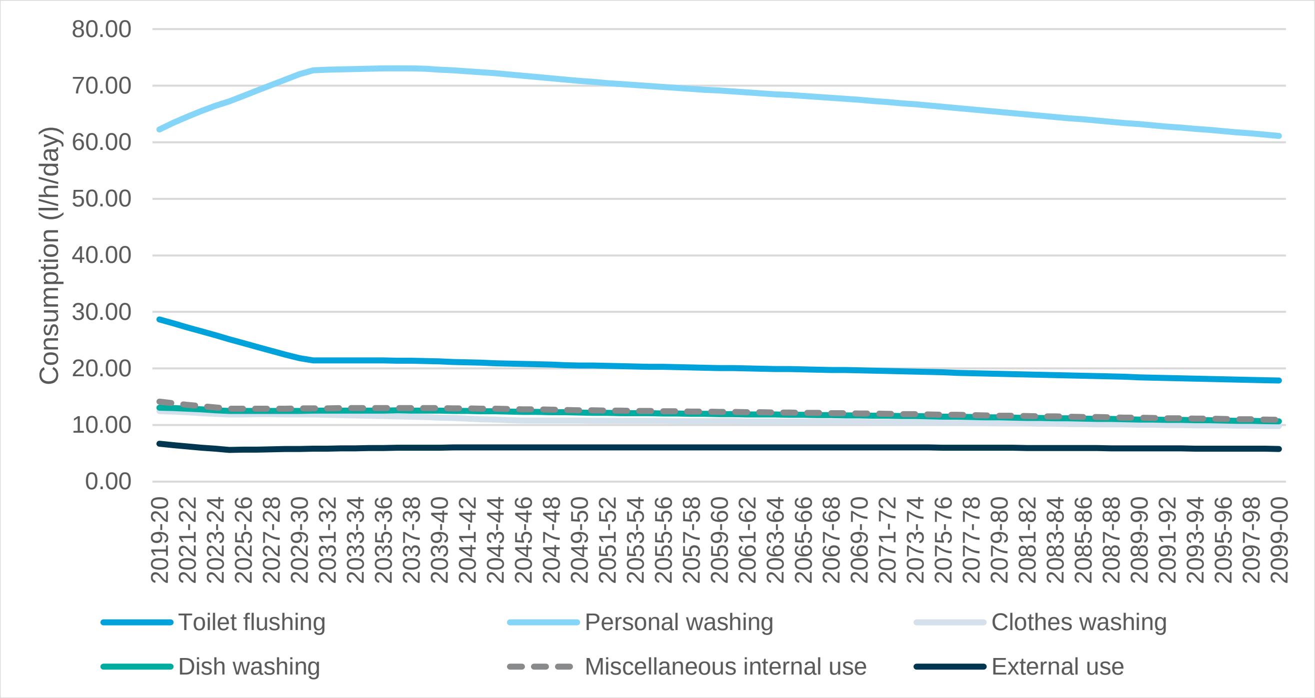


Figure 6-4 - Unmeasured micro-component consumption NYAA

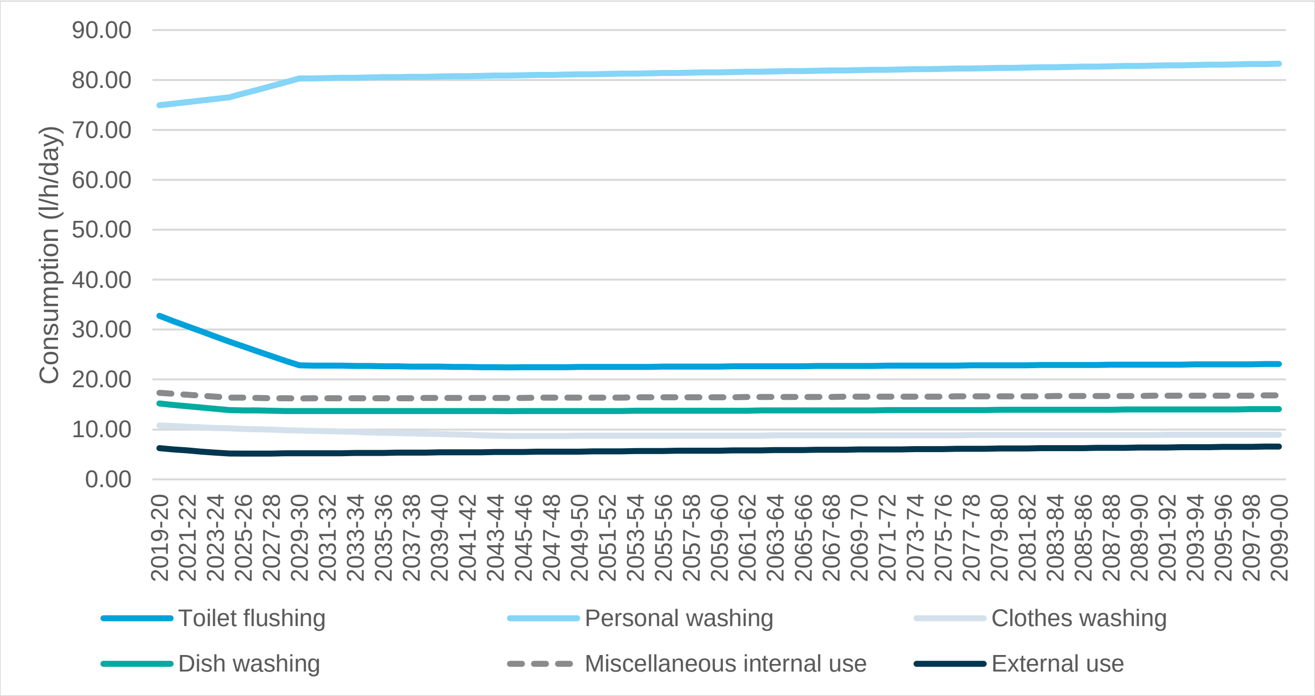


Figure 6-5 - Measured micro-component consumption DYAA

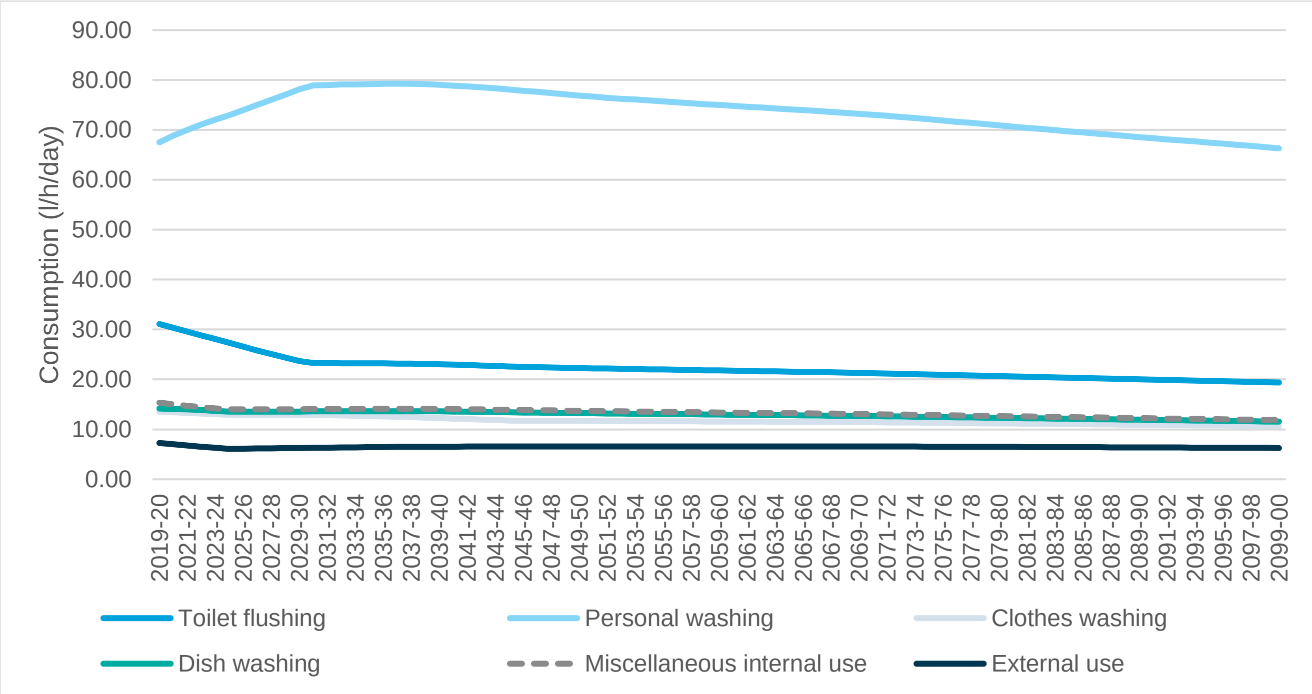


Figure 6-6 - Unmeasured micro-component consumption DYAA

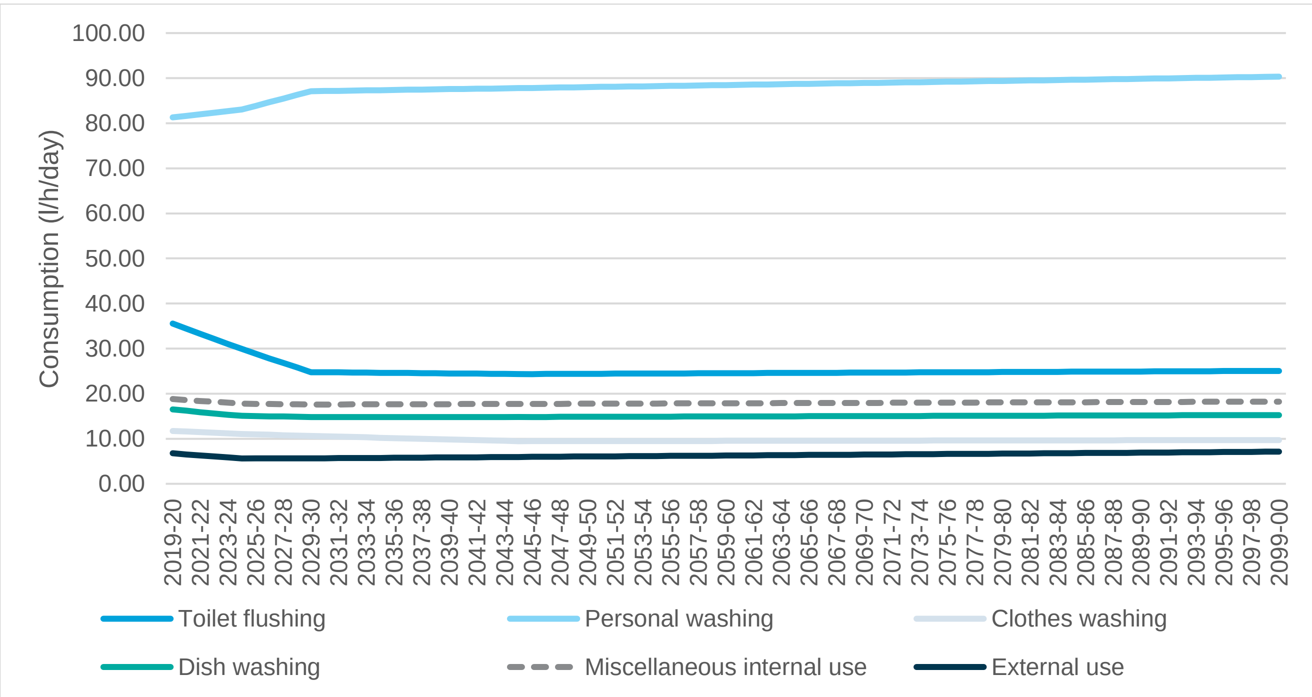


Figure 6-7 - Measured micro-component consumption DYCP

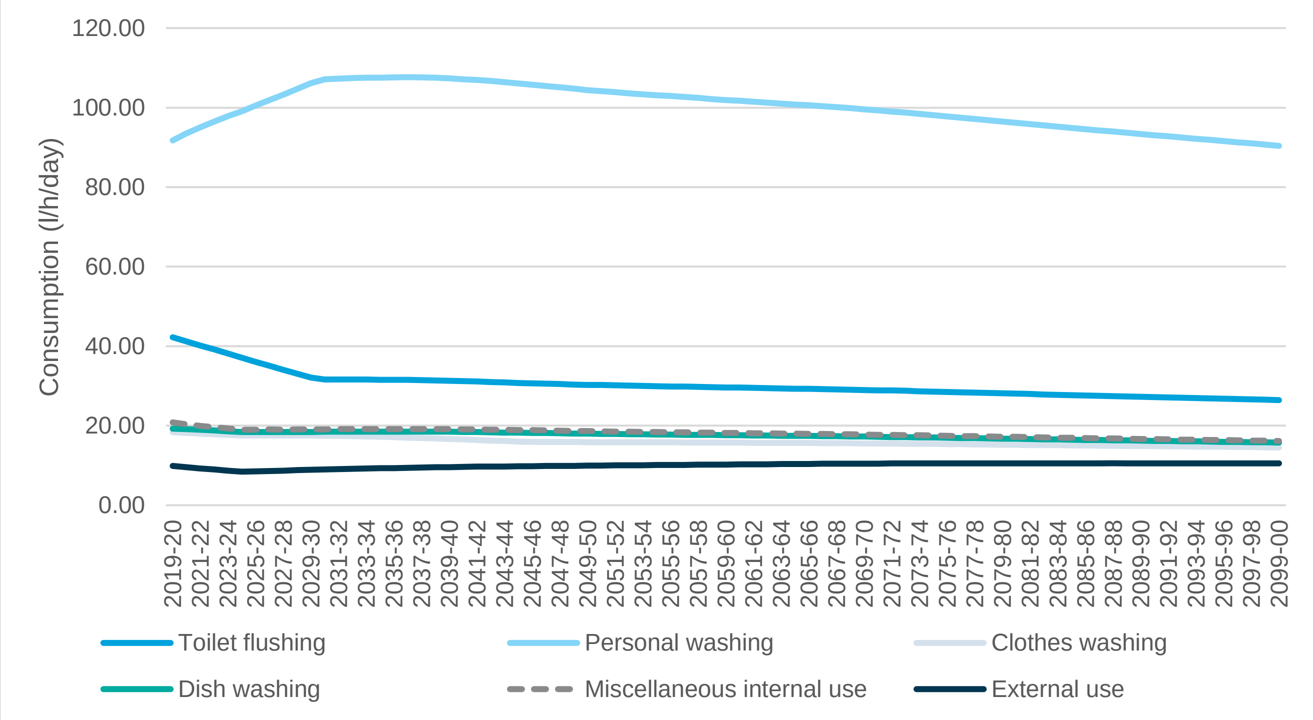
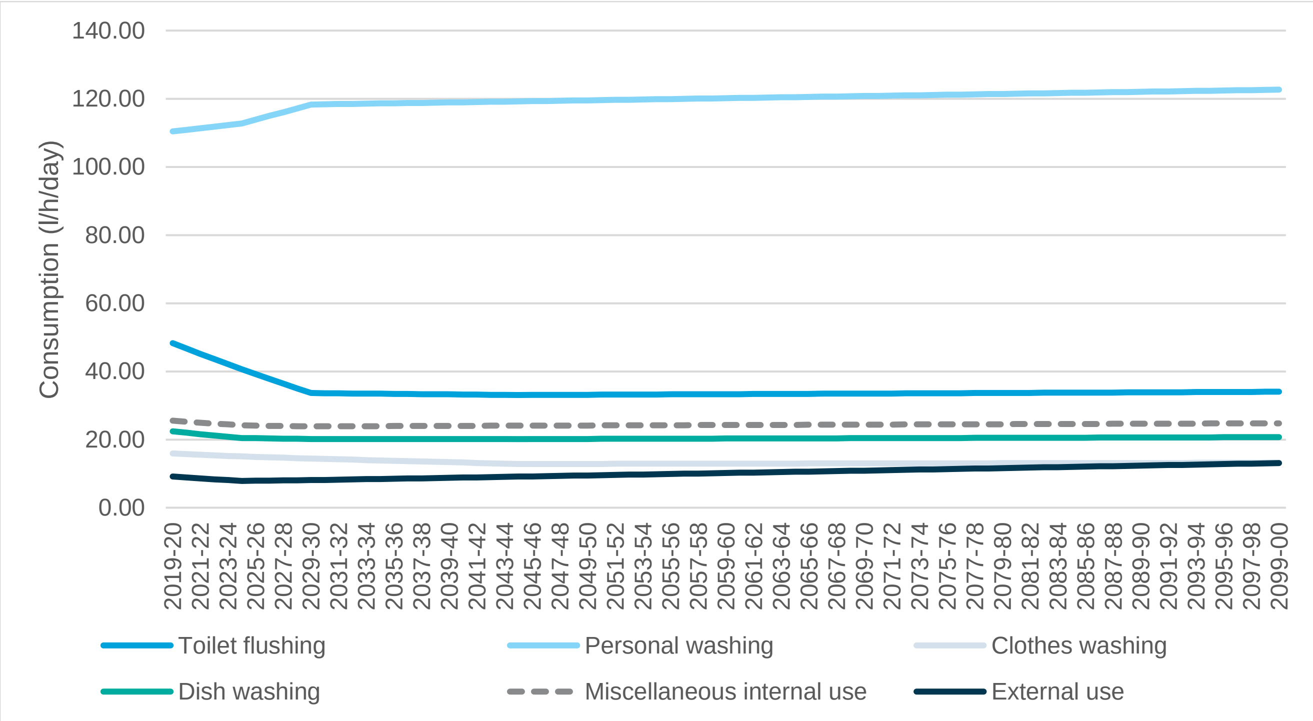


Figure 6-8 - Unmeasured micro-component consumption DYCP



6.2. Base year household consumption calibration

Base year household consumption data (pre-Maximum Likelihood Estimation (MLE) and post-MLE) in Ml/d has been extracted from SES Water's 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance data. Using the base year property and population data from the 2019/20 Annual Review the consumption data has been converted into a consumption per property per day both measured and unmeasured households. The Post MLE per property consumption data is then used to calibrate the consumption data generated by the model.

Table 6-7 presents the base year household consumption data from SES Water's 2019/20 Pre-MLE Water Balance and Post-MLE Water Balance and the per property consumption calculated using this data and SES Water's 2019/20 Annual Review property and population data.

Table 6-7 - Base year 2019/20 household consumption

	Pre-MLE	Post-MLE
Measured households (Ml/d)	57.25	57.92
Unmeasured household (Ml/d)	44.29	46.25
Measured household (Litres/property/day)	352.64	356.78
Unmeasured household (Litres/property/day)	407.50	425.51

6.3. Outcome Delivery Incentive

SES Water have an ODI linked to household PCC. By the end of AMP7 SES Water have a target PCC of 136.8 litres per head per day for NYAA and 148.5 litres per head per day for DYAA (derived from the overall PCC target of 138.0 litres per head per day, weighted for 1 dry year occurring every 10 years). This target is achieved through metering savings and water efficiency savings. The following sections describe the metering savings and water efficiency savings applied in the model to achieve this target.

6.3.1. Metering savings

Metering savings included in the model were updated to match the assumptions stated in SES Water's 2019 Business Plan. The metering savings assumed for WRMP19 and the WRSE regional plan submission in 2020/21 are presented in Table 6-8.

Table 6-8 - Metering savings

Type of metering	Saving assumed for WRMP19	Saving assumed for WRSE submission
Metering on change of occupier	20.0%	14.5%
Optant smart metering	n/a	2.5%

6.3.2. Water efficiency savings

After updating the metering savings assumptions, the residual of the AMP7 target was achieved through applying water efficiency savings to the following micro-components:

- Taps
- External use.

These micro-components were selected because they are two areas where water efficiency savings can easily be made in the home. For example: turning the tap off whilst brushing your teeth and using collected rainwater or re-using paddling pool water to water the garden.

A saving of 1.45% was applied to taps and a saving of 3.5% was applied to external use. These savings were applied from 2020/21 to the end of AMP7 (2024/25). The savings are applied to per household consumption which are then converted into total consumption by multiplying by the total number of properties and then into per capita consumption by dividing by the total population.

With reference to section 6.1.1.1 (External use adjustments) it should be noted that the water efficiency savings outlined in this section had been applied to external use when the sensitivity testing was undertaken to determine if the TUBs savings could be purely attributed to reductions in external use.

7. Non-household consumption

WRSE commissioned Artesia to carry out a region-wide assessment of non-household and non-public water supply demand. The aim was to produce a Central (baseline) forecast for each WRZ, alongside an Upper and Lower forecast to account for uncertainty, using a methodology which is relatively consistent across the companies as well as adhering to the planning guidelines.

A forecast for measured and unmeasured non-households was produced. Three scenario forecasts (Lower, Central and Upper) as well as a baseline forecast were produced. A new worksheet called *Non HH forecast* was added to the model to incorporate this data. The new worksheet was linked to the existing outputs worksheet in the model (*Scenario selection & outputs*) and also includes a facility to select which non-household scenario forecast the user wants to include in the model.

Through discussions with SES Water it was decided to use the baseline forecast from 2019/20 to 2024/25 and from 2025/26 the central forecast was used. The reason for using the baseline forecast and the central forecast was because in the central forecast there was an unexplained dip in the measured non-household consumption after the base year, which corrects itself by 2025/26.

8. Non-household population and properties

8.1. Property and population forecast

The model required a revised population and property forecast for non-households. This involved updating the base year and baseline forecast non-household property and population data. The base year non-household population and property data was obtained from SES Water's 2019/20 Annual Review. The baseline non-household population and property forecasts were calculated using the base year data and the non-household consumption forecast supplied by Artesia. Further details of the base year values included in the model and how the baseline forecast was calculated is included in Sections 8.1.1 and 8.1.2.

8.1.1. Base year

Base year population and property figures were extracted from SES Water's 2019/20 Annual Review. Table 8-1 presents the household population and property data from SES Water's 2019/20 Annual Review.

Table 8-1 - Base year non-household population and property data

	Properties (000s)	Population (000s)
Measured	7.75	7.69
Unmeasured	1.15	0.75
Total	8.91	8.42

8.1.2. Baseline forecast

To calculate the population and property baseline forecast the non-household consumption data supplied by Artesia was used along with the base year population and property values to calculate a measured per property consumption (PPC) and PCC. The outputs of these calculations are presented in Table 8-2.

Table 8-2 – Base year non-household PPC and PCC

Component	Base year (Ml/d)
Non household measured PPC	3.01
Non household measured PCC	3.04
Non household unmeasured PPC	1.76
Non household unmeasured PCC	2.79

The PPC value was used to calculate the number of properties for each year of the forecast using the following formula:

Previous year's number of properties + (consumption for given year – previous year's consumption) / base year PPC

By using this approach, it was assumed that the increase in non-household consumption through the planning period is a result of more non-household properties and not the existing non-household properties using more water.

The PCC value was used to calculate the population for each year of the forecast using the following formula:

Previous year's population + (consumption for given year – previous year's consumption) / base year PCC

As mentioned in Section 7 the baseline and central consumptions forecasts were used in the model. When calculating PPC and PCC the baseline or central consumption forecast was used as stated in Section 6.1.

The assumption that 90% of non-household properties would be measured by the end of AMP7 (2024/25), as planned for in SES Water's PR19 Business Plan, was also applied to the model. The resultant property forecast is presented in Figure 8-1 and the population forecast in Figure 8-2.

Figure 8-1 - Non-household property forecast

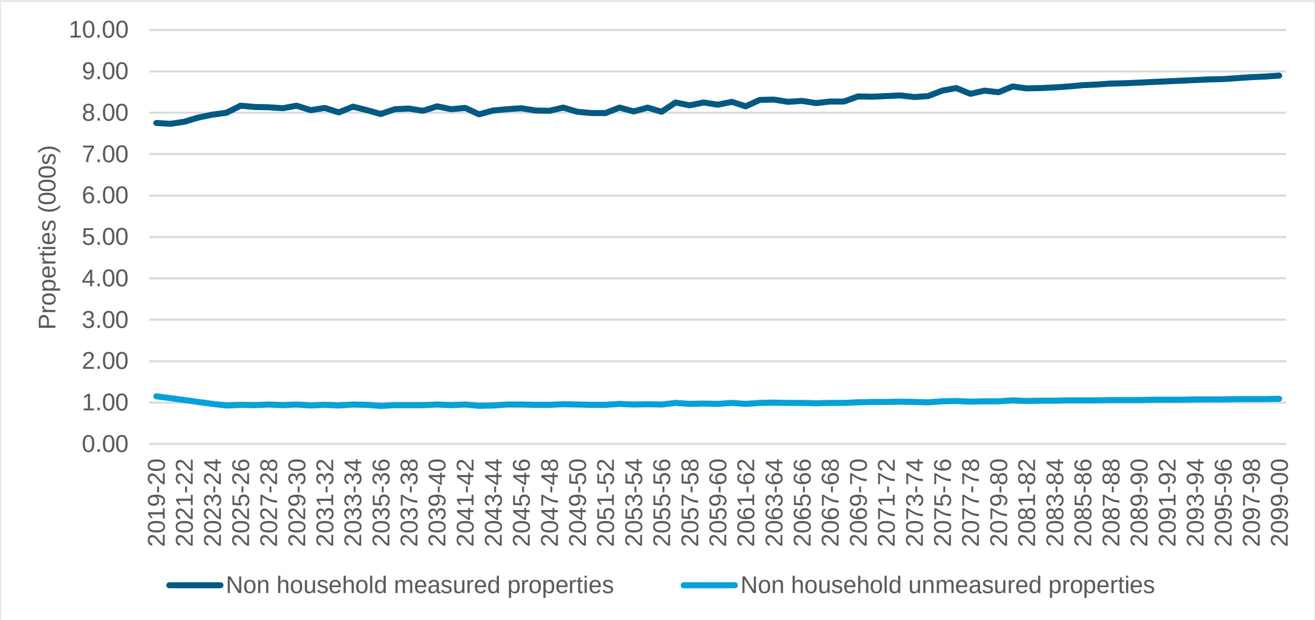
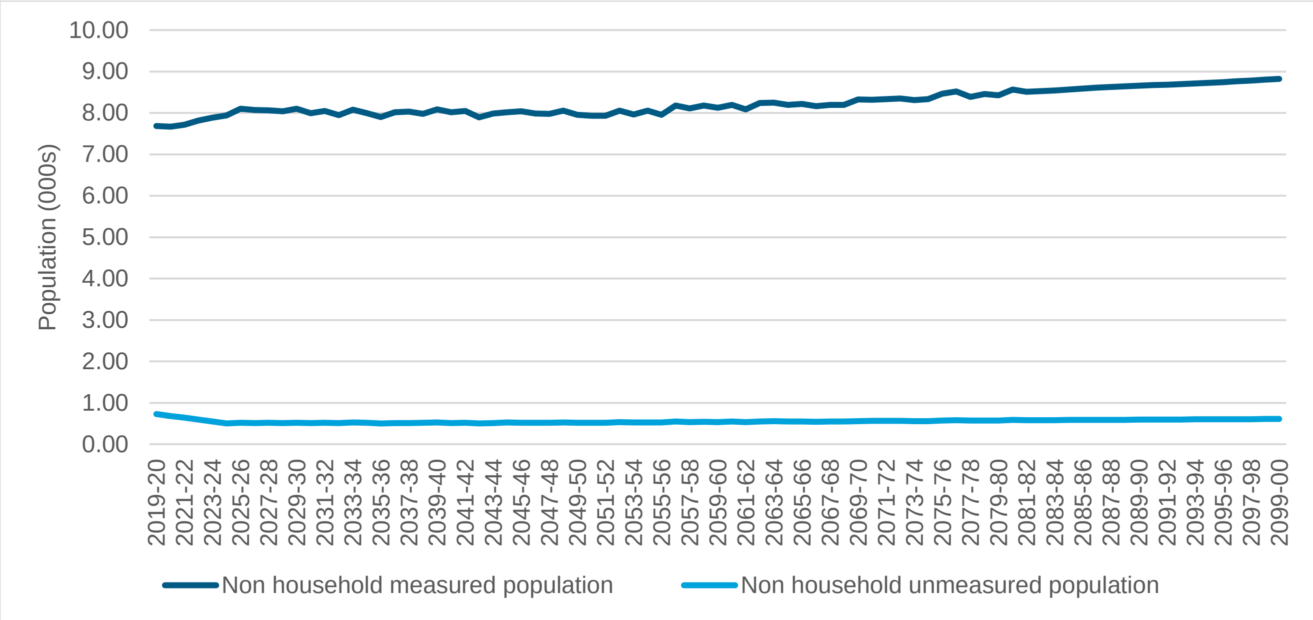


Figure 8-2 - Non-household population forecast



9. Other demand components

9.1. Leakage

Base year leakage figures have been extracted from SES Water's 2019/20 WRMP Annual Review. Table 9-1 presents the base year leakage data included in the model.

According to the WRPG, total leakage should remain constant *"from 2025/26 […] from the start of your plan to the end of the planning period"*. In the model leakage remains constant from the first year of AMP8 (2025/26). Leakage values for the start of AMP8 were extracted from SES Water's Final WRMP19 and these values remain constant through to 2099/00. Between the base year (2019/20) and the start of AMP8 (2025/26) SES Water's 2019/20 Annual Review leakage values have been linearly interpolated as presented in Table 9-1.

Table 9-1 – Leakage values

Component	2019/20 (Base year)	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26
	Ml/d						
Measured Non-household - USPL	0.18	0.19	0.20	0.21	0.22	0.22	0.23
Unmeasured Non-household - USPL	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Measured household - USPL	3.41	3.60	3.78	3.97	4.15	4.34	4.52
Unmeasured household - USPL	4.35	3.77	3.18	2.60	2.01	1.43	0.84
Void Properties – USPL	0.41	0.36	0.32	0.27	0.22	0.18	0.13
Distribution Losses	15.52	15.27	15.01	14.76	14.51	14.25	14.00
Total leakage	23.94	23.25	22.56	21.86	21.17	20.48	19.79

9.2. Water taken unbilled

Water taken unbilled has been extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.01Ml/d has been used for the base year and this remains constant throughout the baseline forecast.

9.3. Distribution System Operational Use

Distribution System Operational Use has been extracted from SES Water's 2019/20 WRMP Annual Review. A figure of 2.73Ml/d has been used for the base year and this remains constant throughout the baseline forecast.

9.4. Climate change

The climate change factors used in the model were reviewed with reference to the following guidance, which are referred to in the draft WRPG:

- UKWIR (2009) Assessment of the Significance to Water Resource Management Plans of the UK Climate Projections 2009,
- UKWIR (2013) Impact of Climate Change on Water Demand.

The review showed that no changes were required to the climate change factors used in the model.

When the model is run under the NYAA or DYAA scenarios the percentage of consumption driven by climate change is 0.6% by 2074/75 and 1.6% under the DYCP scenario.

10. Consumption uplifts factors

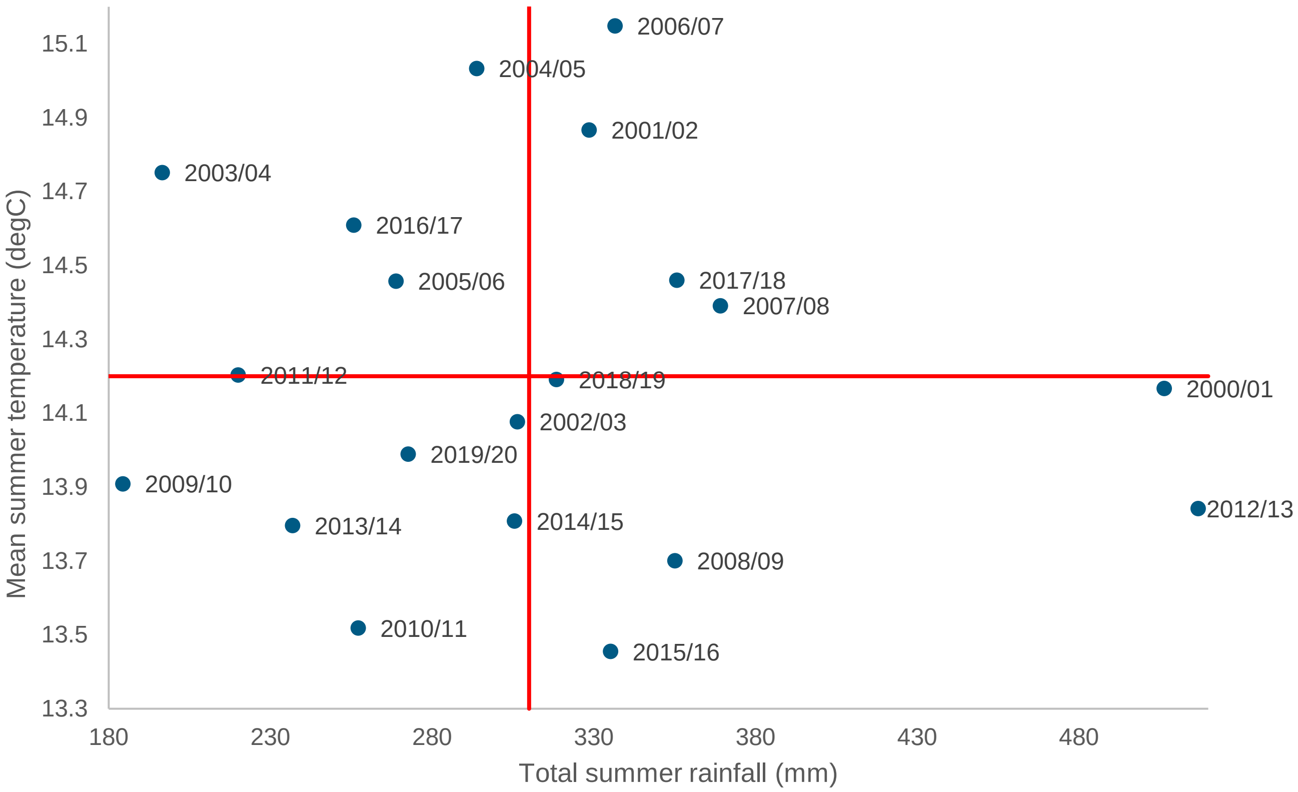
10.1. Normal and dry year factors

Consumption uplift factors for NYAA and DYAA have been re-calculated using the methodology from the UKWIR guidance report number 15/WR/02/9 – household consumption forecasting[12]. This is the same methodology used when the model was developed for WRMP19 and which is documented in Appendix E2 of SES Water's Final WRMP19[13]. The WRPG states this UKWIR guidance should be followed to develop consumption uplift factors for WRMP24.

The first stage is to assess the weather data, more specifically summer temperature and rainfall. Each factor was summarised for the summer months for each year (April, May, June, July, August and September). To help select the hottest and driest year a rainfall-temperature-quadrant plot was produced (Figure 10-1) with the axes representing long-term average weather. A judgement was made as to which is the hottest and driest year. 2003/04, 2004/05, 2005/06 2016/17, sit within the top left quadrant showing they are the strongest dry years.

[12] UKWIR, 2016, WRMP19 Methods – Household Consumption Forecasting
[13] SES Water, September 2017, WRMP19 Household consumption forecast: baseline forecast

Figure 10-1 – Quadrant plot for determining the dry year



The next stage was to analyse the PCC trends for measured and unmeasured. These were done separately to account for the difference in trends and the potential difference in impact of the dry year.

Figure 10-2 - Reported PCC trend - measured properties

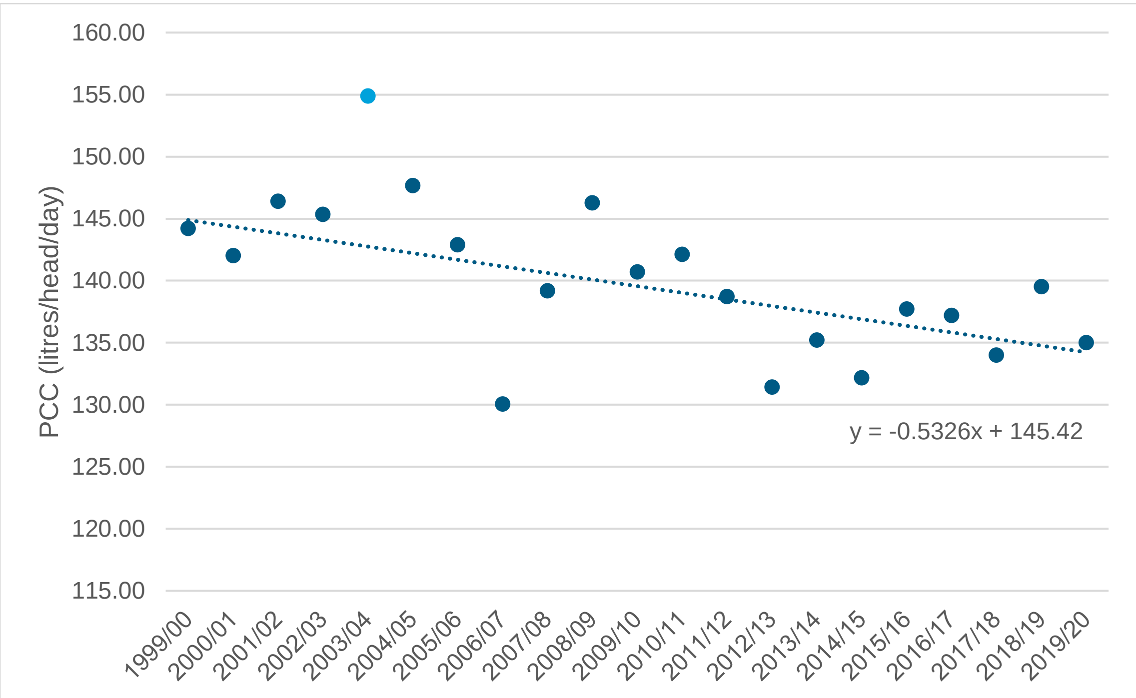


Figure 10-3 – Reported PCC trend – unmeasured properties

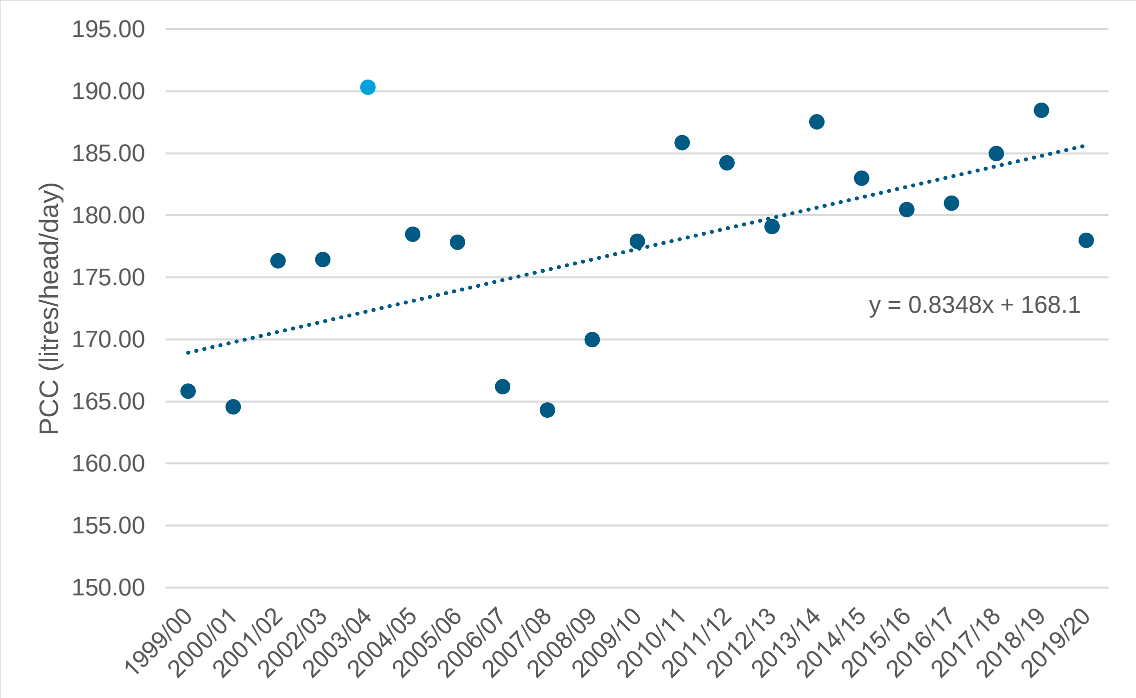


Figure 10-2 (measured reported PCC trend) was used to select the dry year. The reason for using the measured reported PCC values was because they were deemed to be more accurate and less variable due to better quality data and fewer adjustments made with the relation to supply pipe leakage. In Figure 10-2 2003/04 stands out as the year that responds the strongest out of the possible dry year selections.

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.

The normal year factor is 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 (2019/20 PCC value). This is done separately for measured and unmeasured.

The dry year factor is calculated to be 1.085, the measured normal year factor is 0.994 and the unmeasured normal year factor is 1.043. The normal year factors are applied to the per property consumption data, which has been generated using the post-MLE consumption and the property data from SES Water's 2019/2020 Annual Review. These normalised per property consumption values are then used to calibrate the per property consumption values, generated for each property type, by the model.

10.2. Critical period factor

Critical period calculations have been done in accordance to the methodology stated in the UWKIR report Peak Water Demand Forecasting Methodology[14] which is the guidance the WRPG states should be followed. 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 was 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 1.4735.

A summary of the NYAA, DYAA and DYCP factors are provided in Table 10-1.

[14] UKWIR, 2006, Peak Water Demand Forecasting Methodology

Table 10-1 - Summary of factors applied in the household forecast

Factor	WRSE submission
NYAA (measured)	0.9943
NYAA (unmeasured	1.0429
DYAA	1.0849
DYCP	1.4735

10.3. 1 in 200 and 1 in 500 drought event factors

The peak week factors for 1 in 200 and 1 in 500 drought events were generated by Artesia and provided in the WRSE Dynamic demand analysis, Phase 2 report (reference: AR1408)[15]. These factors were incorporated into the household consumption forecast model in the same way as the DYAA and DYCP factors. These factors are applied to the NYAA forecast and can be selected within the model the same way as NYAA, DYAA or DYCP

Table 10-2 – 1 in 200 and 1 in 500 drought event factors

SES Water	Series 3	
WRZ	1 in 200	1 in 500
SES Water	1.26	1.29

11. WRSE outputs

WRSE provided SES Water with the Data Landing Platform (DLP) template. The model was used to populate the BL Demand worksheet in the DLP template. The BL Demand worksheet included a list of demand components. These components needed to be populated for a number of run scenarios and growth forecasts. Table 11-1 shows the growth forecasts which were required to populate the DLP template. For each of the six growth forecasts the following scenarios were required: NYAA, DYAA, DYCP, 1 in 200 annual average (A), 1 in 200 critical period (P), 1 in 500A and 1 in 500P. The same uplift factors (as shown in Table 10-2) were used to populate the A and P 1 in 200 and 1 in 500 run scenarios.

Table 11-1 - Growth forecasts for DLP template

Scenario	Selected growth forecast for SES Water
Baseline	Housing-Plan-P (bottom-up)
Maximum growth projection	ONS-14-H
Median growth projection	Housing-Need-L
Minimum growth projection	ONS-18-Low-L
Completions-5Y-P projection	Completions-5Y-P
Housing-Need-H projection	Housing-Need-H

To populate the demand components of the DLP template an additional worksheet was added to the model (called WRSE outputs). This worksheet included the 24 components from the *BL Demand* worksheet and covered the planning period (2019/20 to 2099/00). For every year of the planning period each component was linked to the corresponding output cell(s) of the model, which are in the *Scenario selection & outputs* worksheet of the model. The distribution input component included the percentage of consumption driven by climate change. The WRSE outputs worksheet automatically populated with the output data from the model.

[15] Artesia, February 2021, WRSE Dynamic demand analysis, Phase 2

Switches were included in the model to allow the user to select the required model run in order to populate the various run scenarios and growth forecasts required in the DLP template. Table 11-2 describes the switches included in the model.

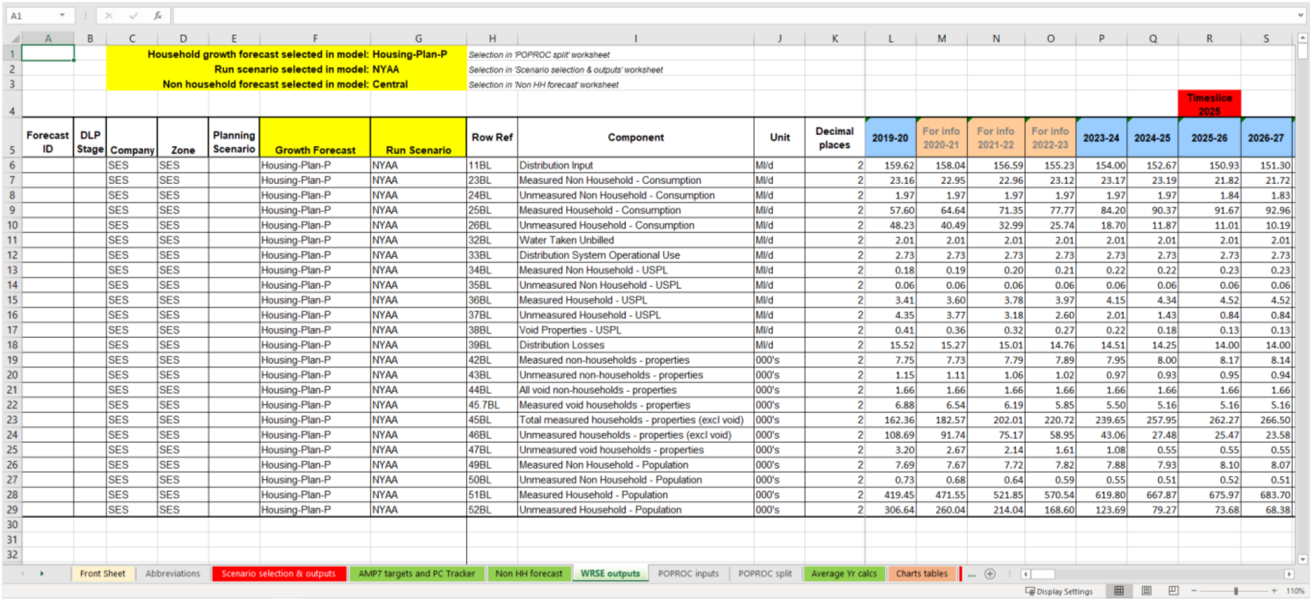
Table 11-2 - Model switches

	Switch details
Household growth forecast	Switch added to the POPROC split worksheet. The user is required to manually type in the name of the population and property scenario they wish to run through the model.
Run Scenario	A drop-down menu in the Scenario selection & outputs worksheet allows the user to select the run scenario. The following options are available: NYAA, DYAA, DYCP, 1 in 200 and 1 in 500.
Non household forecast	A switch had been added to the Non HH forecast worksheet. The user is required to manually type in the number scenario they wish to run through the model. The scenarios have been numbered as follows: central = 1, lower = 2, upper = 3 and baseline = 4.

The WRSE outputs worksheet includes a summary of the selected parameters chosen for the model run. This allows the user to easily identify the parameters which have been used to run the model and populate the DLP template. An example of the *WRSE outputs* worksheet is shown in Figure 11-1.

For each run scenario and growth forecast the data in the *WRSE outputs* worksheet needed to be manually copied in the corresponding rows of the *BL Demand* worksheet in the DLP template which would be submitted.

Figure 11-1 - WRSE outputs worksheet



Household growth forecast selected in model: Housing-Plan-P — *Selection in 'POPROC split' worksheet*
Run scenario selected in model: NYAA — *Selection in 'Scenario selection & outputs' worksheet*
Non household forecast selected in model: Central — *Selection in 'Non HH forecast' worksheet*

Forecast ID	DLP Stage	Company	Zone	Planning Scenario	Growth Forecast	Run Scenario	Row Ref	Component	Unit	Decimal places	2019-20	For info 2020-21	For info 2021-22	For info 2022-23	2023-24	2024-25	2025-26 (Timeslice 2025)	2026-27
		SES	SES		Housing-Plan-P	NYAA	11BL	Distribution Input	Ml/d	2	159.62	158.04	156.59	155.23	154.00	152.67	150.93	151.30
		SES	SES		Housing-Plan-P	NYAA	23BL	Measured Non Household - Consumption	Ml/d	2	23.16	22.95	22.96	23.12	23.17	23.19	21.82	21.72
		SES	SES		Housing-Plan-P	NYAA	24BL	Unmeasured Non Household - Consumption	Ml/d	2	1.97	1.97	1.97	1.97	1.97	1.97	1.84	1.83
		SES	SES		Housing-Plan-P	NYAA	25BL	Measured Household - Consumption	Ml/d	2	57.60	64.64	71.35	77.77	84.20	90.37	91.67	92.96
		SES	SES		Housing-Plan-P	NYAA	26BL	Unmeasured Household - Consumption	Ml/d	2	48.23	40.49	32.99	25.74	18.70	11.87	11.01	10.19
		SES	SES		Housing-Plan-P	NYAA	32BL	Water Taken Unbilled	Ml/d	2	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01
		SES	SES		Housing-Plan-P	NYAA	33BL	Distribution System Operational Use	Ml/d	2	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
		SES	SES		Housing-Plan-P	NYAA	34BL	Measured Non Household - USPL	Ml/d	2	0.18	0.19	0.20	0.21	0.22	0.22	0.23	0.23
		SES	SES		Housing-Plan-P	NYAA	35BL	Unmeasured Non Household - USPL	Ml/d	2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		SES	SES		Housing-Plan-P	NYAA	36BL	Measured Household - USPL	Ml/d	2	3.41	3.60	3.78	3.97	4.15	4.34	4.52	4.52
		SES	SES		Housing-Plan-P	NYAA	37BL	Unmeasured Household - USPL	Ml/d	2	4.35	3.77	3.18	2.60	2.01	1.43	0.84	0.84
		SES	SES		Housing-Plan-P	NYAA	38BL	Void Properties - USPL	Ml/d	2	0.41	0.36	0.32	0.27	0.22	0.18	0.13	0.13
		SES	SES		Housing-Plan-P	NYAA	39BL	Distribution Losses	Ml/d	2	15.52	15.27	15.01	14.76	14.51	14.25	14.00	14.00
		SES	SES		Housing-Plan-P	NYAA	42BL	Measured non-households - properties	000's	2	7.75	7.73	7.79	7.89	7.95	8.00	8.17	8.14
		SES	SES		Housing-Plan-P	NYAA	43BL	Unmeasured non-households - properties	000's	2	1.15	1.11	1.06	1.02	0.97	0.93	0.95	0.94
		SES	SES		Housing-Plan-P	NYAA	44BL	All void non-households - properties	000's	2	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
		SES	SES		Housing-Plan-P	NYAA	45.7BL	Measured void households - properties	000's	2	6.88	6.54	6.19	5.85	5.50	5.16	5.16	5.16
		SES	SES		Housing-Plan-P	NYAA	45BL	Total measured households - properties (excl void)	000's	2	162.36	182.57	202.01	220.72	239.65	257.95	262.27	266.50
		SES	SES		Housing-Plan-P	NYAA	46BL	Unmeasured households - properties (excl void)	000's	2	108.69	91.74	75.17	58.95	43.06	27.48	25.47	23.58
		SES	SES		Housing-Plan-P	NYAA	47BL	Unmeasured void households - properties	000's	2	3.20	2.67	2.14	1.61	1.08	0.55	0.55	0.55
		SES	SES		Housing-Plan-P	NYAA	49BL	Measured Non Household - Population	000's	2	7.69	7.67	7.72	7.82	7.88	7.93	8.10	8.07
		SES	SES		Housing-Plan-P	NYAA	50BL	Unmeasured Non Household - Population	000's	2	0.73	0.68	0.64	0.59	0.55	0.51	0.52	0.51
		SES	SES		Housing-Plan-P	NYAA	51BL	Measured Household - Population	000's	2	419.45	471.55	521.85	570.54	619.80	667.87	675.97	683.70
		SES	SES		Housing-Plan-P	NYAA	52BL	Unmeasured Household - Population	000's	2	306.64	260.04	214.04	168.60	123.69	79.27	73.68	68.38

12. Summary

SES Water commissioned Atkins to update their household consumption forecast model to allow them to produce a demand forecast for the WRSE regional plan.

The updates included:

- Incorporating new household population and property data, including SES Water's AMP7 metering and water efficiency strategies.
- Reviewing the micro-component modelling and forecasting approach, which resulted in external water usage OVF values being adjusted to ensure TUBs savings could be applied appropriately.
- Incorporating non-household consumption data into the model and developing a non-household property and population forecast which was also incorporated into the model.
- Calculating consumption uplift factors and incorporating these into the model.
- Updating other components of baseline demand within the model such as water taken unbilled and leakage.

Following these updates, the baseline demand components of the DLP template were populated and submitted for the WRSE regional plan.

For the WRMP24, SES Water will be incorporating the effects of COVID-19 in its assessment of baseline demand. This will be undertaken in a future iteration of the model. Also, as the 'Get Water fit' initiative continues and the dataset grows, the data should continue to be analysed and used to inform the micro-component modelling.

Megan Shelton
Atkins Limited
Western House (Block C)
Peterborough Business Park
Lynch Wood
Peterborough
PE2 6FZ

Tel: +44 (0)1733 366900
Fax: +44 (0)1733 366999
Megan.Shelton@atkinsglobal.com

Appendix C.

C.1. Demand Forecast – 2021-22 rebase for WRSE

ATKINS
Member of the SNC-Lavalin Group

Technical Note

Project:	Water Resources Support		
Subject:	Demand Forecast - 2021-22 rebase update for WRSE		
Author:	Lauren Petch		
Date:	10/03/2023	Project No.:	5197934
Distribution:	Carla Higgs, SES Water (carla.higgs@seswater.co.uk); Grace Wood-Lofthouse, SES Water (grace.wood-lofthouse@seswater.co.uk)		

Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1	First draft	LP	MS	MS	SW	10/03/2023

1. Introduction

This technical note outlines work carried out by Atkins in February and March 2023 to rebase SES Water's demand forecast to 2021-22 data and refers to v4.19 of the model[1]. This builds on previous work carried out by Atkins, Task WR-6, (see technical note: Summary of Water Resources and Drought Plan support services provided by Atkins to SES Water on 26 Jan 2023) to review and update the demand forecast model for the WRSE Regional Plan[2].

Section 2 of this note details all the updates carried out to each part of the spreadsheet model. A more detailed explanation of what is included in the model and how it works can be found in our previous report[2].

1.1. Data

For this work the following new or updated datasets were provided by SES Water and utilised as described in Table 2-1:

- SES Water dWRMP22 Tables final November 2022.xlsx
- 20230215_MLE_AR22Extract.xlsx
- 20230215_Population_properties_AR22Extract.xlsx

[1] SES Water MC HHCP Model v4.19.xlsx
[2] Demand Forecast Updates for the WRSE Regional Plan, Atkins 2022, ref: 5197934/DG/070

- WRSE VICUS Forecasts – February 2023.xlsx
- 20230306_AR21_Extract_Pop_Prop.xlsx
- New Connections since 2008.xlsx

2. Demand model updates

Rebasing the demand model to 2021-22 required a full review of all model components to update year profiles, redirect relevant formulas and, where appropriate, insert updated data. Table 2-1 summarises changes made to each worksheet in the Excel model, while the following subsection identifies further items of note. A copy of the revised Excel model (v4.19) is provided alongside this technical note.

Table 2-1 - Summary of updates to demand forecast model

Worksheet	Description of sheet	Summary of changes
Front Sheet	List of worksheets in the model	• Model version updated to 4.19
Abbreviations	Abbreviations	N/A
Scenario selection & outputs	Water Resources Management Plan (WRMP) tables for baseline and final planning demand forecasts under various planning scenarios. Ability for the user to specify different aspects of the forecasts which plot in a series of micro-component graphs in rows 12 to 53.	• Update WRMP Row ref's to align with latest WRMP table formats. Just relevant rows included and not full WRMP tables • Updated 36BL (Total Resource Zone Properties (incl voids)) to include 34.7BL • Copied in final plans option data for 12.2FP, 13.1FP, 14.1FP and 15.1FP to feed into final plan table outputs
WRSE output calcs		N/A
WRSE outputs	Template for WRSE demand data	• Update references to link with updated WRMP table inputs in Scenario selection & outputs sheet
POPROC split	Re-bases the population and property forecasts to SES Water reported households.	• Total measured/unmeasured property and population figures automatically updated through links to POPROC inputs sheet. • Total new connections updated (C11) using 'New connections since 2008.xlsx' with data added to reflect addition of 2 years to base year • Updated linked cells from the Annual reported figures table (B17:H22) to show profile from 2016/17 up to 2021/22. • Updated Base year to 2021/22 in forecast and Outputs tables (Rows 27:70). • Updated linked formulas in the 'Method and calculations' section to point to new Base year • Update check formula in C49 to allow for up to 0.01% tolerance in totals
POPROC inputs	Population and property data from Annual Returns and the WRMP	• Updated the Pre- and Post-MLE totals in cells D14:E15 from '20230215_MLE_AR22Extract.xlsx'.

Worksheet	Description of sheet	Summary of changes
		• Updated property and population totals in D20:D23 from '20230215_Population_Properties_AR22Extract.xlsx'. • Extended Annual Return Water Balance components to include 2021-21 and 2021-22 (Note: value for 2020-21 interpolated from adjacent years). • Updated Meter Optant and change of occupancy property values from dWRMP22 Tables (34.2FP, 34.3FP and 34.4FP) • 2020-21 measured and unmeasured properties figures taken from '20230306_AR21_Extract_Pop_Prop.xlsx' • Updated Edge Analytics population and property forecasts in rows 76:94 from 'WRSE VICUS Forecasts – February 2023.xlsx'
Non HH forecast	Non household central, lower and upper forecasts. Supplied from Artesia.	N/A
AMP7 targets and PC Tracker		N/A
Average Yr calcs	Normal Year Annual Average (NYAA) and Dry Year Annual average (DYAA) Distribution Input (DI) data (copied and pasted as values) for central growth forecast, with probability of occurrence percentages for dry years vs normal years. This data is used to generate overall average Distribution Input.	N/A
Charts tables	Data inputs to 'Scenario selection & outputs' worksheet micro-component graphs in row 12 to 53	• Updated all year columns headings to reflect new base year. • Update index formulas to include all years up to 2100 for charts on 'Scenario selection & outputs' worksheet. • Updated baseline BL demand checks (rows 459:464) to work with updated WRMP tables
Graph data	Worksheet collating the data inputs for graphs in the 'Charts tables' worksheet. Climate change factor input required. Currently includes the annual average and critical period climate change factors.	• Updated climate change uplift factors to reflect correction previously applied accounting for 2012-2040 profile of 0.88 and 2.4 climate change factors. • Updated annual headings to reflect 2021/22 base year.
Summary graphs	Various graphs summarising the trends in the subcomponents of the demand forecast such as	N/A

Worksheet	Description of sheet	Summary of changes
	the split of households (existing measured, unmeasured, optants, change of occupier and new properties).	
PCC variation	Calculates Dry Year (DY), market trend and sustainable trend measured household /unmeasured household PCC for each year of the planning period. Calculations based on PCC variation for each scenario which is a user input.	• Updated year column heading to reflect new base year. • Market trend and sustainable trend figures shifted to reflect new base year but not updated.
POPROC	Summarises the population and property forecasts calculated in the 'POPROC split' worksheet. Occupancy rates are calculated as Population divided by Properties.	• Updated year column heading to reflect new base year.
Scenarios	Metering scenarios to determine the forecasts for optants and selective metering. Data linked from the 'POPROC split' worksheet. User input required to define scenarios.	• Formulas in 'New connections' (row 7) updated to reflect new base year.
Base year	Collates base year per property consumption data from POPROC inputs worksheet and base year occupancy data from POPROC tab. Also collates final year occupancy data from POPROC worksheet. Percentage change in occupancy rate from base year to final year calculated. Contains NYAA and DYAA calculations. Contains critical period peak week calculations.	• Updated base year references to reflect updated base year and linked cells. • NYAA/DYAA adjustment factors not updated.
OVFs	Artesia micro-component OVF (ownership, volume and frequency) model intercept and slope. User can input 'Change of Occupier metering reduction' assumption.	• Updated headings to reflect base year and linked data.

Worksheet	Description of sheet	Summary of changes
umHH PHC mHH PHC Existing PHC New prop PHC Optant PHC COO PHC	Normal Year micro-component forecast for specified group (per household consumption). Calculations use linked data from 'POPROC'.	• Updated year column headings to reflect base year (includes shifting micro-component change factor forecasts but not updating). • Updated water efficiency savings to achieve PCC targets from 3.5% for external, 0% for shower and 1.5% for tap to 10.5% for external, 3.5% for shower and 6.5% for taps.
mHH total umHH total Existing total New prop total Optant total COO total	Micro-component forecast for specified group (total household consumption). Calculated from linked data in other worksheets.	• Updated year column headings to reflect base year.
umHH PCC mHH PCC Existing PCC New prop PCC Optant PCC	Micro-component forecast for specified group (per capita consumption). Calculated from linked data in other worksheets.	• Updated year column headings to reflect base year

2.1. Items of note

As noted earlier a number of items of note have been identified as not being updated in this instance that SES Water may want to review.

Metering Scenarios

The metering scenarios in the 'Scenarios' worksheet have not been updated. These were previously entered by SES Water and may need review to confirm they are still correct. The current scenarios include:

- Baseline 1 current model
- Baseline 2 – continue AMP5 percentage of unmeasured
- Scenario 3 – 80% metering by 2025
- Scenario 4 – 85% metering by 2025

Water efficiency savings

As noted in Table 2-1 against the PHC worksheets, the water efficiency saving assumptions have been significantly increased so that the overall PCC estimate for 2024-25 continues to hit PCC target. The PCC targets are outlined on the AMP7 targets and PC Tracker sheet to be 138 l/h/d equating to approximately 148.5 l/h/d DYAA. It is noted that given the increase required to continue to meet these targets SES may want to review these changes.

Hidden and transient population estimates

Hidden and transient population estimates are currently provided separately to the main population and property forecasts as static figures across the time horizon in the 'POPROC inputs' worksheet. These figures came from ‘2020 Population Estimates - Edge Analytics.xlsx’ but have not been updated in the current round of work.

Non HH forecast

The non-household forecast is a static element within the model and has not been updated as part of this work.

Input data rows in ‘Scenario selection and outputs’ sheet

There are a number of rows from the WRMP tables in this worksheet that are input cells and not linked to other elements of the model. These data points have all been check against SES Water’s latest published WRMP tables however may need additional validation.

PHC Occupancy figure

The PHC worksheets for umHH, existing, new prop, optant and COO contain a PHC Occ figure based

$$(FY(NY) - OVF(PHC))/29$$

This formula is consistent with the original spreadsheet model. However, we are not clear on the reasoning behind this specific calculation and have highlighted for further investigation in case an update may be needed.

Covid-19 adjustment

With the demand forecast rebased to 2021-22 it is also necessary to update the approach to forecasting impacts associated with Covid-19. The previous base year was considered to pre-date the impacts of Covid-19 on demand and a percentage adjustment on household and non-household demand was therefore made and profiled within the WRSE headroom template. By rebasing to 2021-22, after the emergence of Covid-19, the baseline demand data incorporates its impacts such as those of more homeworking. This therefore necessitates that the previously applied Covid-19 headroom adjustment be removed so that Covid-19 impacts are not double counted. To align with the approach of other WRSE water companies, the Covid-19 of component of headroom has been removed completely rather than reprofiled to zero impact in 2040 as it was, or some other future date, on the assumption that the altered behaviours we now see that affect demand will endure.

To achieve this Atkins has updated the ‘Covid impact calculation’ worksheet within: WRMP19 headroom analysis for WRSE data request_Apr20221_V4 MS 2023.xlsx. This was done using outputs from the SES Water MC HHCF Model v4.19.xls (from the worksheet titled ‘WRSE outputs’) to update the following rows:

- Measured Non Household - Consumption (Ml/d)
- Unmeasured Non Household - Consumption (Ml/d)
- Measured Household - Consumption (Ml/d)
- Unmeasured Household - Consumption (Ml/d)

No other data within the headroom analysis spreadsheet have been updated.

Appendix D.

D.1. Non-household demand forecasts 2020 to 2100

artesia

Water Resources South East – SES Water

Non-household demand forecasts 2020 to 2100

Company report - Final

Project reference: 2467

Report number: AR1393

2020-12-14

Report title:	Non-household demand forecasts 2020 to 2100
Project reference:	2467
Report number	AR1393
Date:	2020-12-14
Client:	Water Resources South East – SES Water
Client lead:	Alison Murphy (SES Water)
	Faisal Butt (Southern Water)
Collaborators:	Affinity Water, Portsmouth Water, SES Water, South East Water, Southern Water, Thames Water
Project manager:	Rob Lawson
Technical lead	Sarah Rogerson
Contributors:	Dene Marshallsay, Francesca Cecinati, Daniele Di Fiore, Aidan Gibbons, Robert Mayger, Jamie Urwin Bruce Horton (Environmental Policy Consulting)

Version	Author(s)	Reviewed by:	Description	Date
1	Dene Marshallsay, Sarah Rogerson, Francesca Cecinati	Rob Lawson	Draft	22/10/2020
2	Dene Marshallsay	Kayleigh Powell	Final draft	27/11/2020
3	Dene Marshallsay, Francesca Cecinati	Kayleigh Powell, Sarah Rogerson	Final	11/12/2020

Any enquiries relating to this report should be referred to the authors at the following address:

Artesia Consulting Ltd, Unit 2 Badminton Court, Yate, Station Road, Bristol, BS37 5HZ.

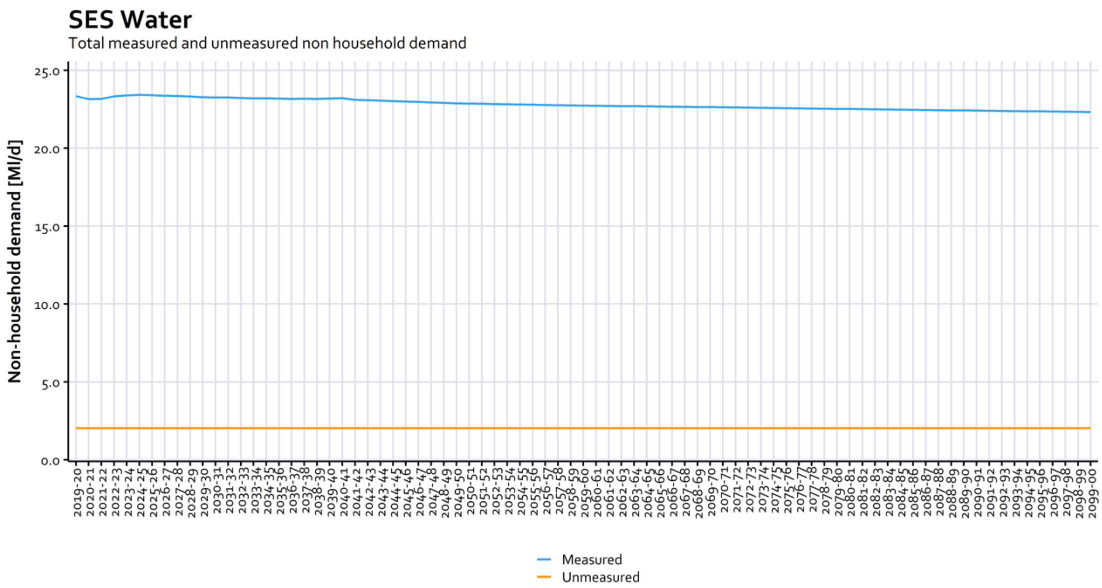
Telephone: + 44 (0) 1454 320091 Website: www.artesia-consulting.co.uk

Executive summary

Water companies in England and Wales are required to develop a Water Resource Management Plan (WRMP) under the Water Industry Act 1991 where they set out their plans to ensure that they will have sufficient resources to meet demand under different climate conditions over a minimum of 25 years. Forecasting future demand for water is a key part of the process and consumption by the non-household sector is a major component of demand. This report describes the initial development of the demand forecasts for non-households in the Water Resources South East (WRSE) region.

We have produced a set of non-household demand forecasts for all 37 water resource zones in the WRSE region from 2019-2020 out to 2099-2100. These are presented for metered and unmetered properties at company level, water resource zone level and dis-aggregated by industrial sector. The approach used follows existing industry best practice, taking into account the recommendations from a review of non-household demand forecasting methods carried out by WRSE in early 2020. Robust multiple linear models have been produced for 4 cohorts of industrial sectors for each company in WRSE, using explanatory factors that include population, gross value-added metrics, employment rates, population density and other factors. This report provides an overview of the WRSE results and detailed results for SES Water.

The overall conclusion is that non-household demand in the SES Water region at the start of the planning period (2025), is predicted to be 25 Ml/d within an overall range of 17 to 30 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL. By the end of the planning period the non-household demand is predicted to be 24 Ml/d (a decrease of 1 Ml/d) within a range of 16 Ml/d to 38 Ml/d.



We have also made a prediction of the amount of non-public water supply (non-PWS) demand in the Portsmouth Water region and how this might change over the planning period. For Portsmouth Water, the current estimate of non-PWS non-household demand of 3.67 Ml/d in 2019-20 is predicted to increase to 5.0 Ml/d by 2050.

The first year of the forecast (2020) has seen an unprecedented change in non-household demand due to the policies introduced to combat the COVID-19 pandemic. This creates added uncertainty going forward as we still do not fully understand what the enduring impacts will be from changes in working practices, such as increased working from home. The sector also faces a number of future unknowns in demand from non-households, such as population change, Brexit, climate change and how water efficiency will be delivered in the non-household sector. Since the last set of non-household forecasts were completed for WRMP19, the non-household retail sector has undergone a transformation with the introduction of retail competition. We have observed a change in data quality and consistency since the change in 2017, which has complicated the modelling and has increased the uncertainty around the demand forecasts. Therefore, we have included all these factors in the scenario and uncertainty modelling.

We have presented the forecasts from a base year of 2019-20. The intermediate years 2020-21 through to 2024-25 are presented for information prior to the start of the planning period in 2025-26. These intermediate years are potentially volatile with a number of unknowns around the impact of the COVID-19 pandemic and the impact from Brexit on non-household consumption. Therefore, we recommend that the baseline and scenario forecasts are updated prior to the submission of the final water resource management plans.

During the course of the work, we have identified a number of improvements that could be implemented for future forecasts. These are included in the recommendations section of the report and cover: improving data quality, investigating different industrial sectors, looking at modelling WRZ groups by the way they behave as opposed to by company, and producing forecasts more frequently to reduce the step change transitions between forecasts every 5 years.

Glossary

Term	Description
A classification of residential neighbourhoods (ACORN)	This is a socio-demographic classification of neighbourhoods published by CACI Ltd. The system is based on the assumption that people who live in similar neighbourhoods are likely to have similar behavioural and consumption habits.
Abstraction	The removal of water from any source, either permanently or temporarily.
Active leakage control (ALC)	Management policies and processes used to locate and repair unreported leaks from the water company supply system and customer supply pipes.
Annual average demand	The total demand in a year, normally measured as the amount of treated water entering the distribution system at the point of production, divided by the number of days in the year.
Annual return	An annual report made to Ofwat by water companies to advise on progress within that Asset Management Period.
Asset management period (AMP)	Five-year period for which water companies are funded by Ofwat according to their Business Plans.
Base year	The first year of the planning period/horizon, forming the basis for the water demand and supply forecasting of subsequent years.
Baseline forecast	A demand forecast of customer consumption without any further water company intervention during the planning period. A baseline customer demand forecast should take account of: customer demand without any further water efficiency or metering intervention, forecast population growth, change in household size, changes in property numbers and the impact of climate change on customers' behaviour. Leakage in the baseline forecast should remain static from the start of the plan to the end of the planning period.
Business plan	Business Plans are produced by the water companies for Ofwat and set out the investment programme for the water industry. These plans are drawn up through consultation with the Environment Agency and other bodies to cover a five-year period. Ofwat accept the Business Plan following detailed scrutiny and review.
Capital expenditure (Capex)	Spending on capital equipment. This includes spending on machinery, equipment and buildings. Capital expenditure is also termed investment.
Central market operating system (CMOS)	This is the computer system that manages all the electronic transactions involved in switching customers and provides usage and settlement data which is used in the billing process.
Consumption monitor	A sample of properties whose consumption is monitored in order to provide information on the consumption and behaviour of households served by the company.

Demand management	The implementation of policies or measures which serve to control or influence the consumption or waste of water (this definition can be applied at any point along the chain of supply).
Department for Environment, Food and Rural Affairs (Defra)	UK Government department with responsibility for water resources in England.
Deployable output (DO)	A measure of the available water resource during a drought year for a given level of service.
Distribution input (DI)	The amount of water entering the distribution system at the point of production.
Dry year annual average (DYAA)	The dry year annual average represents a period of low rainfall and unrestricted demand and is used as the basis of a water company's WRMP.
Dry year critical period (DYCP)	The generic term for the planning scenario which drives investment, i.e. at what point during the dry year (1 in 10 years severity of conditions) is the water supply most at risk of failing to meet planned levels of service.
Environment Agency	UK government agency whose principal aim is to protect and enhance the environment in England and Wales.
Final planning demand forecast	A demand forecast which reflects a company's preferred policy for managing demand and resources through the planning period, after taking account of all options through full economic analysis.
Mega litres per day (Ml/d)	One mega litre = one million litres (1,000 cubic metres) per day.
Meter optants	Properties in which a meter is voluntarily installed at the request of its occupants.
Micro-component analysis (MCA)	Detailed analysis of individual components of a customer's water use.
Non-households (NHH)	Properties receiving potable supplies that are not occupied as domestic premises, for example, factories, offices and commercial premises.
Normal year annual average (NYAA)	The total demand in a year with normal or average weather patterns, divided by the number of days in the year.
Operating expenditure (Opex)	Operating expenditure comprises day-to-day (planned and unplanned) routine expenses, which have no effect on the decline in service potential.
Optant metering	Customer led metering programme.
Peak demand	The highest demand that occurs, measured, either hourly, daily, weekly, monthly or yearly over a specified period of observation.
Per capita consumption (PCC)	The average annual consumption expressed in litres per person per day. Per capita consumption in an area is defined as the sum of measured household consumption and unmeasured household consumption divided by the total household population.
Per household consumption (PHC)	The average annual consumption expressed in litres per household per day. Per household consumption in an area is defined as the sum of measured household consumption and

	unmeasured household consumption divided by the total number of households.
Planning period	An agreed look ahead period for which the WRMP is prepared.
Social tariff	Tariff where the customer charge takes into account factors such as household size, medical needs, income levels or if certain state benefits are claimed.
Statement of response	A document that is produced at the end of the public consultation period for the draft WRMP. The document outlines the comments received from customers and the changes that will be made to the draft WRMP as a result of these comments.
Supply pipe losses	The sum of underground supply pipe losses and above ground supply pipe losses.
Target headroom	Headroom is a margin of safety which serves as a buffer between supply and demand. Target headroom is the threshold of minimum acceptable headroom which would trigger the need for water management options to either increase water available for use or decrease demand.
Underground supply pipe losses	Losses between the point of delivery and the point of consumption.
Void property	A property connected to the distribution network but not charged because it has no occupants.
Water available for use (WAFU)	Deployable output – less any sustainability reductions – plus any bulk supply imports – less any bulk supply exports – less any reductions made for outage allowance.
Water resource zone (WRZ)	The largest possible zone in which all resources including external transfers can be shared, and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.
Water resources management plan (WRMP)	A water company's plan for supplying water to meet demand over a 25-year period.
Water resource planning guidelines (WRPG)	Guidance produced by the Environment Agency for developing water resource plans.

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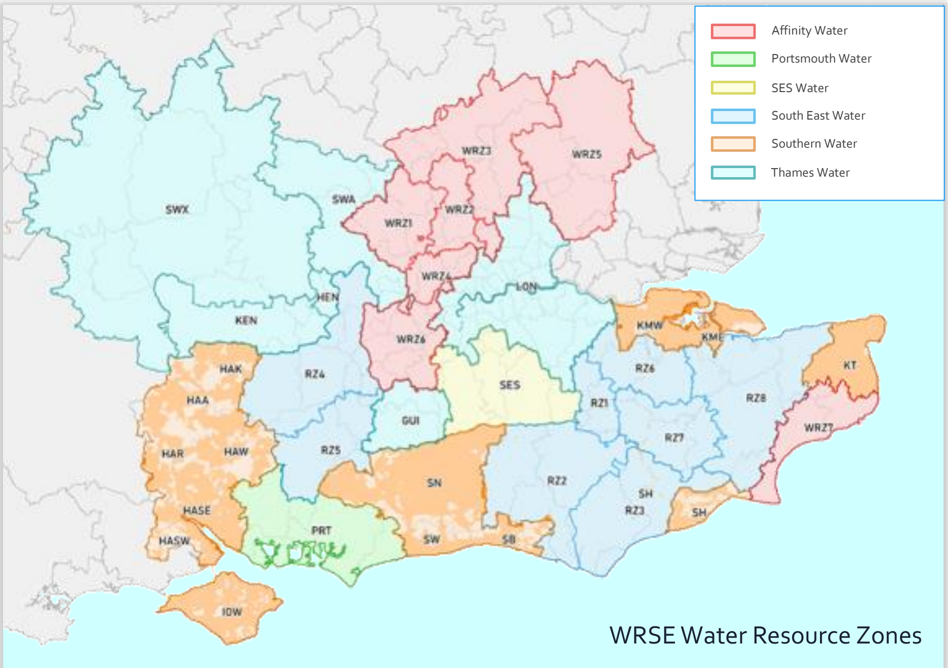
1 Introduction

1.1 Background

Water companies in England and Wales are required to develop a Water Resource Management Plan (WRMP) under the Water Industry Act 1991 where they set out their plans to ensure that they will have sufficient resources to meet demand under different climate conditions over a minimum of 25 years. The plans are updated every 5 years. Forecasting future demand for water is a key part of the process and consumption by the non-household sector is a major component of demand. Robust assessment of future demand is a pre-requisite for developing credible and resilient plans. This report describes the initial development of the demand forecasts for non-households in the Water Resources South East (WRSE) region (Figure 1).

Figure 1 WRSE region showing the 37 water resource zones



WRSE is one of the five regional groups looking to provide strategic oversight and co-ordination of water resources within the context of the new National Water Resources Framework[1]. The aim of the regional groups is to build resilience to drought and other pressures in a cost-effective way, taking account of regional and inter-regional solutions.

WRSE will be producing a sustainable regional resilience plan later in 2020. This plan will inform the Water Resource Management Plans of each member water company within the WRSE alliance. It will set out the schemes, investments and other actions which companies and other stakeholders will need to take to deliver our shared objective. It will also link with

[1] Meeting our future water needs: a national framework for water resources. Environment Agency. 2020.

the other regional plans across England to form the national picture for water resources management.

1.2 Regulatory requirements

The Environment Agency sets out its expectations and guidance for non-household demand forecasts in the Water Resource Management Plan (WRMP24) Guidelines (WRPG, currently draft)[2]. Water companies are required to forecast the demand for water being used by non-household premises (such as businesses and industrial processes) and for the population living in communal establishments (for instance hospitals, prisons and educational establishments).

Since the last non-household demand forecasts were developed, the non-household market has been opened for competition. The definition of non-households should be in line with Ofwat's guidance on whether non-household customers in England and Wales are eligible to switch their retailer[3] [4]. For WRMP24, water companies are also expected to work with non-household customers to improve water efficiency where you believe there are savings to be made.

The broad needs of the regulators are:

- A plan that contains an estimated demand forecast for non-households.
- To work with retailers and through regional groups (where applicable) to share information, data and expertise to ensure the forecasts and solutions are robust.
- A description of how figures and assumptions in the forecast have been derived.
- The plan makes use of the Market Operator Services Ltd (MOSL) system that stores retail company data as needed.
- The plan describes the makeup of non-household demand in different sectors either by using the service and non-service split (identifying the main sectors), or by using Standard Industrial Classification (SIC) categories published by the Office for National Statistics.
- We explain the existing water efficiency initiatives planned by both the wholesaler and retailer. The baseline forecast should reflect non-household demand without any further intervention.
- The final plan should include any forecast savings from water efficiency programmes.
- Consideration of non-household water efficiency as an option to manage the supply-demand balance.
- To consider any uncertainty associated with reducing demand and show how you will monitor the water efficiency programme and how the plan can be adapted if required
- That the plan considers the potential demand for other sources such as: agriculture and those on private water supply in a significant drought.

1.3 Best practice for developing non-household demand forecasts

There are a series of best practice documents in addition to the regulatory requirements, and an overview of these is presented in Figure 2.

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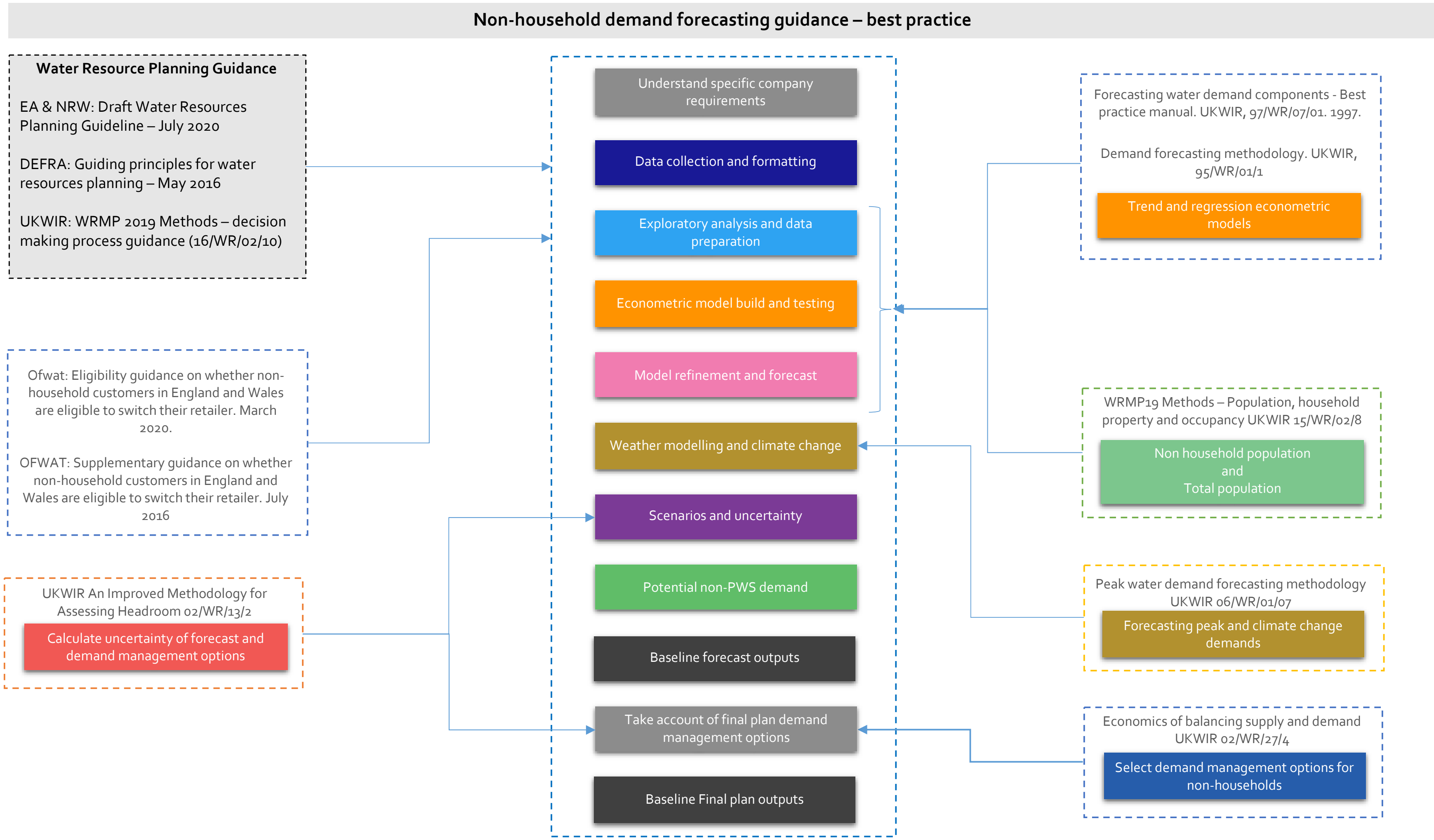
[2] Water Resource Planning Guideline, draft for consultation July 2020. Environment Agency.
[3] https://www.ofwat.gov.uk/wp-content/uploads/2016/07/Eligibility-Guidance.pdf
[4] https://www.ofwat.gov.uk/wp-content/uploads/2016/03/pap_gud201607suppretaileligibility.pdf

Figure 2 Non-household demand forecasting best practice overview



1.4 WRSE requirements for the non-household demand forecast

1.4.1 Review of methods used in previous forecasts

Prior to updating the non-household demand forecasts, WRSE commissioned a study[5] to review the current methods used by water companies for non-household demand forecasts and compare them to the water resources planning guidance.

This study developed a number of conclusions and recommendations. The key ones in relation to the non-household forecasts for regional and WRMP24 planning are:

- The use of data derived from Central Market Operating System (CMOS); information from the previous billing systems is increasingly outdated and by 2024 the last year of non-MOSL consumption data will be 8 years old.
- Accounting for the potential impacts of water efficiency improvements due to the retail market, beyond long term trends are already present within the model.
- Any influences of the Covid-19 pandemic on long-term trends in non-household consumption should be included in the forecasts.
- All WRMP stakeholders need to recognise that the quality of CMOS data is an issue for non-household demand forecasting.
- There is a general risk associated with models developed from poor quality data producing inaccurate or misleading outputs. This is exacerbated when there are changes in data quality over time as the models may reflect changes in data quality, rather than trends in the underlying data.
- The following set of industry groupings would form a reasonable stratification that balances data limitations with separating out those industries likely to have different underlying drivers for non-household consumption:
    - Agriculture (and other weather dependent industries)
    - Non-service industries (excluding Agriculture)
    - Service industries – population driven
    - Service industries – economy driven
    - Unclassified
- An alternative stratification could be used if this is shown to provide a better model.
- Due to COVID-19 and an unusually hot spring/summer, it is clear that reporting year 2020-21 will be unusual in terms of both the macro-economic climate and non-household consumption. The important aspects to consider for non-household demand forecasting to support WRMPs and regional planning are any long-term impacts of the current recession and the growth trajectory thereafter.
- Climate change scenarios need to be included for Agriculture and any other industries where weather is shown to be a significant explanatory factor for consumption, to identify their impact on consumption.
- The national framework report also considers a low demand scenario with a 4% reduction in non-household consumption by 2050 compared to the base case. In the absence of further evidence, this would represent a reasonable assumption for a water efficiency scenario driven by Government policy to reduce water demand.

[5] https://www.wrse.org.uk/media/h1nhiuyg/wrse_file_1345_wrse-non-household-demand-forecast-methodology.pdf

- WRSE member companies should in general adopt a standard set of scenarios and assumptions regarding economic growth, except where there are specific issues to a particular area of supply that need to be accounted for.
- WRSE member companies should use the information within the UK Climate Projections (UKCP18) datasets to develop scenarios of climate change for incorporation where weather is shown to be a significant influence on consumption.
- WRSE member companies should identify whether there are any major customers that should be treated separately because they have a significant impact on the supply-demand balance for a Water Resource Zone (WRZ). It may be appropriate to model scenarios related to these customers if they are likely to impact on the preferred option selection.

1.4.2 WRSE specific requirements

Following the recommendations from the review of current non-household demand forecasts (section 1.4.1), WRSE developed a specification for the initial non-household demand forecast. The scope of this work was to develop a non-household demand forecasting model and produce a non-household demand forecast for the period 2025-2100 that is fully compliant with the WRPG. The key tasks carried out against this requirement are described below.

Segmentation of customers and base year demand

The WRPG requires segmentation of non-household customers into appropriate industrial sectors and forecasting demand separately for each sector, taking account of the factors that affect demand in the sector. The review commissioned by WRSE (see section 1.4.1) has recommended the following five segments for this purpose.

- Agriculture and other weather dependent sectors
- Non-service industries (excluding agriculture and other weather dependent sectors)
- Service industries – population driven
- Service industries – economy driven
- Unclassified.

The source data for this work comes from the Central Market Operating System (CMOS) operated by Market Operator Services Ltd (MOSL) for the period 2017 to 2020. MOSL has regulated the non-household sector since the separation of household and non-household water retail services on 1 April 2017. Additional data from the pre-MOSL period has also been used to develop longer term trends in historic non-household consumption data.

Standard Industrial Classification (SIC) codes are a convenient way of the sub-dividing customers into sectors, especially when the nature of the business cannot be directly inferred from the business name. However, the SIC code data within CMOS dataset is neither complete nor entirely accurate. Several companies have datasets which use AddressBase Classifications for industry sectors, and these have been used to augment or cross check the SIC classifications.

In the process of segmenting the non-household consumption into the industrial sectors described above, we have attempted to keep the number of customers in the 'unclassified' segment as low as possible, ideally not exceeding 20% in any WRZ. In some instances, this has not been possible due to the nature of the data provided and we have described these cases in the following sections.

Non-household demand in certain WRZs may primarily be driven by a single customer. Examples include airports, universities and large manufacturing units. We have attempted to identify these and exclude them from the modelling. This is not always possible due to water companies' different policies on data protection, and also where consumption data is provided already aggregated into sectors. In these cases, we have developed alternative means for excluding large customers, and these are described in subsequent sections.

The base year for this initial forecast is 2019-20 and all companies have calculated non-household demand in each WRZ for annual regulatory reporting. Once segmentation of the customers and modelling was completed, we rebased the base-year consumption to the annual reported volume for 2019-20.

Identify explanatory factors for each customer segment

We have identified the key factors that influence demand in the sector and derived historic and predicted values for these factors from:

- Oxford Economics (region specific gross value added and employment)
- Edge Analytics (Population predictions)
- Water companies (historic population data and property data).
- Office of National Statistics (Population density).

Assess the impact of climate change

We have assessed the impact of climate change on the demand by various sectors and developed scenarios that include climate change impacts on demand.

Assess the impact of water efficiency

A key objective behind creation of a separate retail market for non-household customers was to promote water efficiency. There is limited evidence to suggest water efficiency in the non-household sector has improved beyond historical trends since market separation (see section 1.4.1). We have therefore included the recommended 4% reduction in demand by 2050 (in line with the National Framework[6]), and also included a range of other glidepaths in alternative scenarios.

Assess demand by other sectors

Going forward, water companies are expected to take account of demand by sectors that do not currently take water from public water supplies (PWS) but may be required to do so in case of severe droughts and/or climate change. Wood plc have recently completed a study[7] on behalf of the Environment Agency that has looked at demand by other sectors.

[6] www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources
[7] Understanding future water demand outside of the water industry, Defra, 28/02/2020

There are however gaps in the Wood report and we have carried out additional analysis to supplement the report with additional information and provided estimates of demand by other sectors at the WRZ level.

Develop a demand forecasting model

We have then developed a demand forecasting model that brings together outputs from the tasks above and allows demand for each sector to be forecast over the planning period. The model:

- Has been developed at the company and WRZ level and aggregated regional level for each sector.
- Includes multiple scenarios that have been generated to take account of uncertainties in various assessments.
- Has been developed to be fully transparent and able to withstand scrutiny at a public inquiry.
- The outputs have been incorporated into a commonly used tool that allows companies to select the various outputs and scenarios at different levels. We are in discussion with WRSE about how best to make the model available in an open way to the WRSE group.

Recommend improvements

As we have gone through the tasks above and analysed the data, we have identified a number of areas where the modelling, forecasting and outputs can be improved going forward. These are explained and in the recommendations section.

2 Methodology

This section provides additional details on the methodology we implemented to meet the requirements detailed in section 1.4.2.

2.1 Data collection and formatting

A consistent data requirement specification was provided to each of the companies is WRSE.

Ref	General data requirements	Data type
1	Data transfer preferences (e.g. email, SharePoint, DropBox, etc.)	Information
2	Key data contact	Information
3	Forecast granularity	Information
4	Number of areas	Number
5	Base year	Year
6	Population (total) forecasts by WRZ (from Base Year)	Population
7	Non-HH property forecasts by WRZ (from Base year) - Split measured and unmeasured	Property
8	Historic annual return: non-HH property numbers split by measured and unmeasured by WRZ	Property
9	Historic annual return: total population numbers by WRZ	Population
10	Pre 2017 annual non-HH consumption data (per property or per segment or industry code)	Consumption
11	2017 to 2020 annual non-HH consumption data (per property or per segment or industry code)	Consumption
12	Data to link non-HH consumption to industry code (SIC, ABP or Land Registry)	Data link
13	Data to link non-HH consumption to WRZ	Data link
14	Weather data for each WRZ: Monthly (or finer) mean temperature and mean rainfall	Weather
15	GVA and employment data by WRZ and industry segment (historic and forecast)	Economic Activity
16	Historic annual return consumption data up to and including base year	Consumption
17	Base year consumption data for each property linked to WRZ and Segment (may be included in Ref. 11)	Consumption
18	Climate change scenario predictions for temperature and rainfall	Climate
19	Scenario trend data	Trend
20	Non-PWS demand predictions	non-PWS
21	WRMP19 non-household consumption forecast outputs	Information

Each of the water companies provided data against these requirements. This data was assessed and formatted consistently for each company and water resource zone. Some companies had missing data, or different levels of granularity/length of time series. These differences were captured and discussed with relevant persons from the water companies. Additional data was collected where possible if gaps were identified. In some cases, full data was not available, and in these cases amendments to the process were agreed.

2.2 Exploratory analysis and data preparation

The outputs from the exploratory analysis and data preparation, were a set of consistent data frames. These consisted of:

- Segmented consumption
- Explanatory variables
- Annual return data

2.2.1 Consumption data

Data granularity

Consumption data was provided by companies at either individual property level or aggregated to industry classification (normally SIC[8] or AddressBase[9]). Table 1 shows the breakdown of how the data was provided by company.

Table 1 Consumption data granularity

Company	Consumption data granularity
Affinity Water	Property level
Portsmouth Water	Aggregated to SIC level
SES Water	Property level
South East Water	Property level
Southern Water	Property level
Thames Water	Property level

Voids and large users

If consumption data was provided at property level, and if we received data on which properties were void, we could exclude void data from the modelling stage. Having consumption data at property level also allows us to also identify and exclude large users, which may have a significant impact on consumption at WRZ level. Some companies provided us with data on specific large users. We were able to use this to determine a consumption threshold value above which we could classify users as a large user. We determined that this threshold should be set at 2%, i.e. if a single user consumes greater than

[8] https://www.gov.uk/government/publications/standard-industrial-classification-of-economic- activities-sic
[9] https://www.ordnancesurvey.co.uk/business-government/products/addressbase-premium

2% of the WRZ non-household consumption then we would flag this property as a large user. Table 2 highlights which companies could have voids and large users excluded.

Table 2 Inclusion of voids and large users

Company	Voids		Large users	
	Include	Exclude	Include	Exclude
Affinity Water		x		x
Portsmouth Water	x		x	
SES Water	x		x	
South East Water		x		x
Southern Water	x			x
Thames Water	x			x

Data checks

Data quality checks were performed, looking at the following:

- Proportion of properties that were unclassified or unmatched to a SIC group, split by year.
- Percentage of reported (annual return) volume that is contained within either the classified or unclassified consumption data.

2.2.2 Population data

Population forecast data and annual return by year and WRZ are imported and combined to create a joint population dataset. Populations for overlapping years (2019-20) for both historical and forecast data are compared to check data accuracy.

For the baseline population we use Housing Plan - P.

2.2.3 Industry sector mapping

SIC groups or AddressBase classifications are mapped to industry grouping using various mapping files, we developed mapping files for SIC_1980, SIC_1992, SIC_2003, SIC_2007 and

AddressBase. These were then used to group the properties' consumption into the industrial sectors shown in Table 3.

Table 3 Industry groupings

Industry grouping	SIC_2007 sections	Reference
Agriculture (and other weather dependent industries)	A	1
Non-service industries (excluding Agriculture)	B, C, D, E, F	2
Service industries – population driven	O, P, Q, R, S, T	3
Service industries – economy driven	G, H, I, J, K, L, M, N	4
Unclassified		5

Table 4 shows the proportion of properties and the proportion of consumption for each company that falls into each of the industry groupings identified in Table 3.

Table 4 Proportion of properties and consumption in each industry group by company (2019-20)

Company	Industry grouping	Proportion of properties in group	Proportion of consumption in group
Affinity Water	Agriculture	1%	1%
	Non-service	4%	4%
	Service – population	10%	17%
	Service – economy	46%	28%
	Unclassified	39%	50%
Portsmouth Water	Agriculture	NA	12%
	Non-service	NA	22%
	Service – population	NA	27%
	Service – economy	NA	37%
	Unclassified	NA	2%
SES Water	Agriculture	2%	2%
	Non-service	14%	14%
	Service – population	26%	26%

	Service - economy	55%	55%
	Unclassified	3%	3%
South East Water	Agriculture	13%	13%
	Non-service	15%	15%
	Service – population	65%	66%
	Service – economy	N/A	N/A
	Unclassified	8%	6%
Southern Water	Agriculture	3%	3%
	Non-service	9%	10%
	Service – population	34%	35%
	Service – economy	45%	39%
	Unclassified	9%	13%
Thames Water	Agriculture	2%	3%
	Non-service	5%	7%
	Service – population	18%	27%
	Service – economy	29%	31%
	Unclassified	46%	34%

2.2.4 *Weather data*

Compiled weather data is loaded with average daily rainfall and average maximum temperature by year.

2.2.5 *Econometric data*

Econometric data was provided by Oxford Economics (OE). This data is formatted into employment and gross value added (GVA) by SIC group and region. All WRSE companies currently use the "South East" region, with the only exception being Thames Water where the London WRZ uses the "London" OE region. Historic data was provided from 1991, and forecast data was provided to 2040.

2.2.6 *Data collation*

A maximal theoretical dataset was created by creating all combinations of year (from OE, weather, consumption, and population datasets), WRZ (weather, consumption, and population) and SIC/industry groups (consumption), with all variables joined to these where available.

This is then aggregated to industry grouping level, with group-specific numerical variables summed (consumption, employment, GVA) and other numerical variables re-joined at aggregated level (weather and population).

Both the SIC and industry grouping aggregation datasets are output for use in subsequent modules.

2.3 Model build, testing and refinement for baseline forecasts

2.3.1 Non-household forecast modelling

The non-household forecast modelling is carried out in line with best practice[10] and takes into account the findings of the WRSE review of non-household demand forecasts (section 1.4.1).

Choosing the right modelling process is a complex task that needs to take into consideration statistical model performances, but also many other variables that require the modeller's expert judgement (availability of variables, reliability of data, overfitting problems, and more). Therefore, the modelling process is based on offering all the statistical tools to the modeller, who then takes a decision based on all considered aspects.

The non-household (NHH) forecast modelling process is divided in the following steps:

1. Build the MLR model based on past aggregated consumption data, considering Oxford Economic variables and potentially other factors.

2. Calibrate the model for the base year, in this case 2019-20, first by industry sector using the property consumption data, then by WRZ using the Annual Return (AR) consumption.

3. Apply the MLR model and the calibration to future explanatory variables to estimate future NHH consumption.

The MLR modelling is done at company level, but considering industry groups independently. Calibration is instead performed at WRZ level.

At each stage adjustments and improvements can be made specifically for each company, depending on the specifics of the data. Therefore, in Appendix A there is a complete modelling report for SES Water which identifies all the specific modelling details.

2.3.2 MLR modelling

Multi linear regression (MLR) modelling aims at finding a linear relationship between the observed consumption and explanatory variables. At first, all available explanatory variables are considered. Subsequently, the model is refined choosing only the significant variables. The choice is based on:

- model performances excluding the variables one by one
- interaction between variables

[10] Forecasting water demand components - Best practice manual. UKWIR, 97/WR/07/01. 1997.

- logical inclusions/exclusions based on the relationship between the expected effect of each variable on consumption, and the estimated coefficients
- exclusion of outliers
- other modellers' considerations.

SES Water specific results for each MLR model for each industry sector are included in Appendix A and include the following:

- model term
- estimate
- standard error
- p value.

2.3.3 Calibration

The MLR model is based on MOSL data in the base year, which may not represent the total annual reported NHH Measured consumption. For this reason, the results of the model need to be calibrated against the Annual Report data for the base year, in this case 2019-20. This also helps account for differences between WRZ, not accounted for building the model at company level.

To ensure the proportion between different sectors is maintained, the calibration has been further refined:

- First, modelled consumption is calibrated against property consumption for each industry group and WRZ, deriving an additive factor,

- Then the total measured consumption is calibrated against AR data at WRZ, deriving a multiplicative factor.

Appendix A includes the calibration factors for SES Water and each WRZ for each industry sector.

2.3.4 Baseline forecasts

Final NHH baseline forecasts are obtained separately for the measured and the unmeasured component.

For the measured component, NHH is forecast with the following steps:

- apply the MLR model separately for each industry group and WRZ,

- apply the two-step calibration,

- forecasts are then extended from 2040-41 to 2099-00 using a combination of the trend along with modelling using the population, depending on the presence of population in the baseline model, as follows:

    – where population is not present in the baseline model, then the forecast is kept constant after 2040-41

- where population is used, either alone or in combination with other variables in the baseline model, then a new simpler linear model is used to find a relationship between the consumption forecasted between 2025-26 and 2040-41 and the population forecast for the same years. The linear model is then used to forecast consumption between 2040-41 and 2099-00.

- minimum consumption is set to 10% of the observed years' average, with exclusion of 2020-21 that is allowed to go to zero considering the COVID crisis.

A simpler approach is followed for unmeasured non-household demand, as this is a minor component of the total non-household consumption. Unmeasured forecasts are obtained extending the base year unmeasured consumption as reported in the AR up to 2040. Then the extension from 2040-41 to 2099-00 is achieved using the same total company trend used for all other components.

The forecast outputs are presented and discussed in Appendix A, and a summary of the WRSE high level company outputs are presented in section 3.1.

2.4 Scenarios and uncertainty

2.4.1 Introduction

The concepts of uncertainty and scenarios are often used interchangeably and partially overlap in terms of meaning. Both represent unknowns that may affect water consumption forecasts. For the purpose of the WRMP24 non-household demand forecasts we need to separate the concepts through definitions:

- **Uncertainty** refers primarily to the variability we have in forecasts due to data uncertainty and unexplainable variability uncertainty. Uncertainty is non-zero even in the present figures and grows with time in a gradual way, due to uncertainty propagation. Uncertainty can be described by probability distributions and derived statistics, like mean, standard deviation, or quantiles.
- **Scenarios** refer to the variability in future projections due to foreseeable (at least in terms of happening) events. Scenarios' variability is only applicable to future figures, not to the present, and can grow or decrease in time according to the specific events we are considering. Scenarios are usually represented by a discrete number of alternative forecasts.

As the WRMP24 non-household (NHH) forecasts are derived through a complex process, the sources of uncertainty can be many and very little is known about the quantification of uncertainty. Similarly, the number of factors that can affect NHH water consumption can be large and unexpected events and technologies may alter the way we will consume water; therefore, it is very difficult to consider all plausible scenarios.

In this work, we introduce some approximations to overcome the unknown quantification and the technical limitations involved in modelling both the uncertainty and the scenarios. We first proceed in delineating a large number of foreseeable scenarios, from which we derive plausible central, lower and upper thresholds. Then we proceed in applying uncertainty estimations for quantifiable factors on the three selected thresholds.

Details on the scenarios' definition and the uncertainty quantification are reported in following sections.

2.4.2 Modelling scenarios

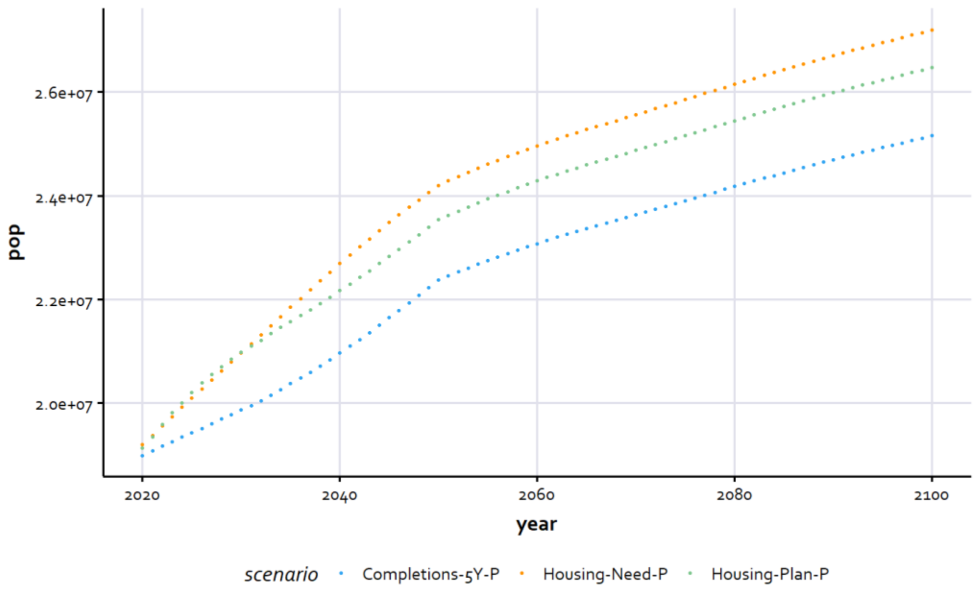
The scenarios represented in the WRMP24 NHH forecasts are chosen based on scenarios that are likely to happen in the short and long term and considering how these may quantitatively affect the NHH water consumption forecasts. We consider six factors, each represented by an upper, central and lower scenario. All combinations are tested, resulting in 3^6 scenarios, i.e. 729 individual scenarios.

Population scenarios

Population scenarios are chosen from the 72 Edge Analytic population forecasts. The scenario used for the baseline, Housing-Plan-P, is already on the upper range of Edge Analytic population scenarios. To maintain it the central scenario, to keep a balanced forecast, and to keep the risk-adverse approach, three scenarios on the upper spectrum are selected and these are shown in Figure 3:

- Population upper scenario: Housing-Need-P
- Population central scenario: Housing-Plan-P
- Population lower scenario: Completion-5Y-P

Figure 3 Three population scenarios are chosen from the 72 Edge Analytic scenarios



Brexit

At the moment of writing this report, the United Kingdom has left the European Union and is in the transition period for which the majority of EU regulations are maintained, while the government negotiates an exit deal. The outcome of such negotiations is expected to impact the economy and the immigration scenarios for both the short and the long term. However, the short-term forecasts consider both Brexit and Covid-19 impacts on the economy, and these two factors are difficult to separate. So, we decided to apply only the long-term impacts for the Brexit scenarios, as the short-term effects are already represented in the three COVID-19 scenarios.

NHH water consumption is modelled considering GVA, employment and population among other factors, and these factors are the ones impacted by Brexit.

The impact on population is estimated from Lomax, 2019[11], considering the percentage variation between the three reported Brexit scenarios: EU-membership, soft Brexit and hard Brexit. Considering our baseline as the middle scenario, we can consider a change in population of +2.6% by 2040 under the upper Brexit scenario, and a decrease of -2.6% under the lower Brexit scenario.

For employment estimates, we considered the HM Government report *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives*[12], which states that "unemployment would reach 7% to 8% in 2020, compared with a projected rate of 5% if the UK remained in the EU". Assuming our estimates correspond to the central, we can consider a variability around 3%, so +/- 1.5% for the upper and lower scenarios. Not having further temporal information, we keep this steady in time.

In terms of GVA (proportional to GDP if fixed taxation is assumed), the report proposes wider ranges, going between 1.2% and 2.8%, considering the uncertainty. For consistency we consider 1.5% like for the employment estimates. The summary of Brexit impacts is presented in Table 5.

Table 5 Brexit scenarios and their impact

	Population	GVA	Employment
Upper Brexit scenario	+2.6% by 2040	+1.5% fixed	+1.5% fixed
Central Brexit Scenario	baseline	baseline	baseline
Lower Brexit Scenario	-2.6% by 2040	-1.5% fixed	-1.5% fixed

COVID-19

COVID-19 has had a strong negative impact on the economy and on NHH water consumption, due to lockdown measurements and economic recession, as well as due to remote-working measurements. At the time of writing this report, a vaccine is estimated to be available in 2021, and the impact of the pandemic is expected to gradually reduce after. The impact of COVID-19 is modelled in three different ways:

[11] Lomax, N., Wohland, P., Rees, P. & Norman, P. The impacts of international migration on the UK's ethnic populations. J. Ethn. Migr. Stud. 46, 177–199 (2019).

[12] HM Government. *HM Treasury analysis: the long-term economic impact of EU membership and the alternatives*, 2016, Cm 9250, Web ISBN 9781474130905

1. GVA and Employment are modified on the short term, according to the expected impact on the economy.
2. Water consumption is reduced across all sectors.
3. Water consumption is shifted between sectors.

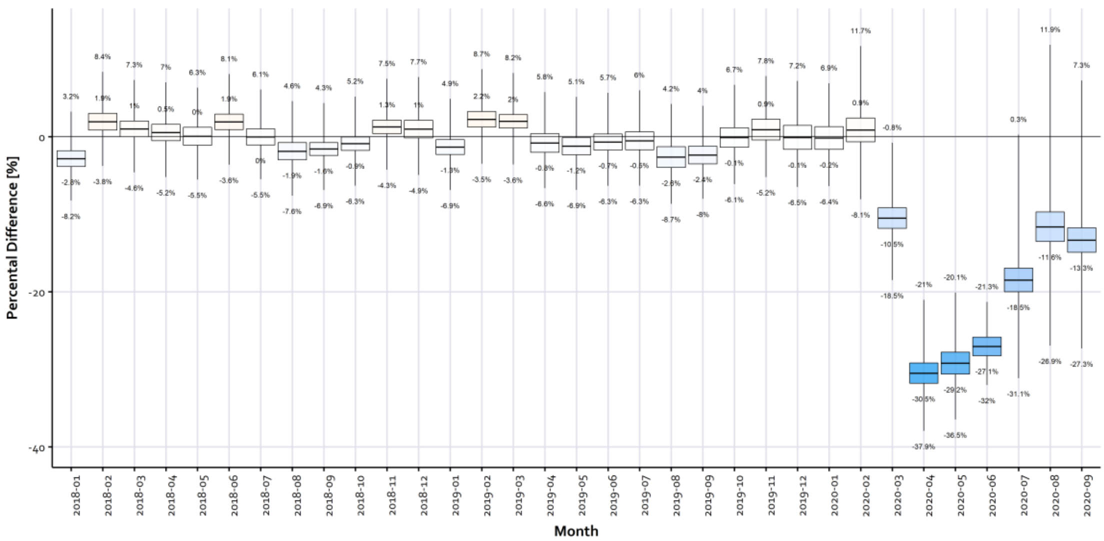
COVID-19 impact on GVA and Employment

The impact of COVID-19 on GVA and Employment is estimated from the *Forecasts for the UK economy 2020* by the HM Treasury[13]. The report compares independent forecasts. The baseline was estimated using the Oxford Economic (OE) forecasts for GVA and Employment. From the report the upper and the lower thresholds are estimated for GVA (derived from GDP, Table M1 of the report, with the assumption of proportionality) and for employment (derived from unemployment forecasts, table M5 of the report), using the upper and the lower independent estimate. For GVA, OE is a central forecast, therefore is used as the central scenario, while for employment OE is already the upper forecast, so it is used as the upper scenario. The result is a set of percentage changes to apply to the baseline for years 2019-2024. These estimates also include the short-term impact of Brexit.

NHH water consumption reduction due to COVID-19

Beyond the effects on the economy, COVID-19 has an effect on water consumed by businesses and non-household properties due to different operations and remote working. Artesia has conducted an independent study on the impact of COVID-19 on the NHH sector. Figure 4 shows the reduction in water consumption during summer 2020, compared to the previous year, considering weather, holidays, and other influencing factors.

Figure 4 Reduction in NHH water consumption during summer 2020 months compared to previous months.



The three scenarios are considered as follows:

- Upper COVID-19 scenario: no variation on the baseline.

[13] HM Treasury, Forecasts for the UK economy: a comparison of independent forecasts, 2020, No. 397, ISBN 978-1-913635-61-9

- Central COVID-19 scenario: -12% in 2020-21 and -6% in 2021-22, then baseline.
- Lower COVID-19 scenario: -20% in 2020-21 and -10% in 2021-22, then -3% on the baseline (long terms effects due to permanent home-working adjustments and business closing).

Shift between sectors due to COVID-19

The COVID-19 impact on water consumption is due to its impact on the economy and the change of operations due to a mass remote-working approach. However, both these factors, quantified above as a total effect, affect differently the different economic sectors. Therefore, a final step of the modelling is to shift water consumption across sectors.

To do so, we use data from the ONS Business Impact of COVID-19 Survey (BICS) from September 2020[14] (assumed to be the best representation to date to the post-lockdown COVID-19 scenario). The dataset reports both the changes in turnover and the percentage of workers working remotely, by sector. Combining the two factors we could derive that under the September 2020 conditions, NHH water consumption is likely to have shifted:

- Agriculture +0.4%
- Non-service +9.1%
- Service-economy -4.1%
- Service-population -5.8%
- Unclassified +0.4%

The shift is only considered in the lower COVID-19 scenario, where long term impact of remote-working is considered. Note that the figures above only report a shift (they sum up to zero) because the reductions per sectors are accounted at the previous step.

Summary of COVID-19 scenarios

Table 6 lists the summary of the COVID-19 scenarios and their impact.

Table 6 COVID-19 scenarios and their impact

	GVA	Employment	Consumption reduction	Sector shift
Upper COVID-19 scenario	Upper independent forecast	OE forecast	baseline	baseline
Central COVID-19 Scenario	OE forecast	Central independent forecast	-12% in 2020-21 -6% in 2021-22 then baseline	baseline
Lower COVID-19 Scenario	Lower independent forecast	Lower independent forecast	-20% in 2020-21 -10% in 2021-22	Agric: +0.4% Non-serv: +9.1%

[14] ONS, BICS Wave 14 edition of this dataset 7 September to 20 September 2020.

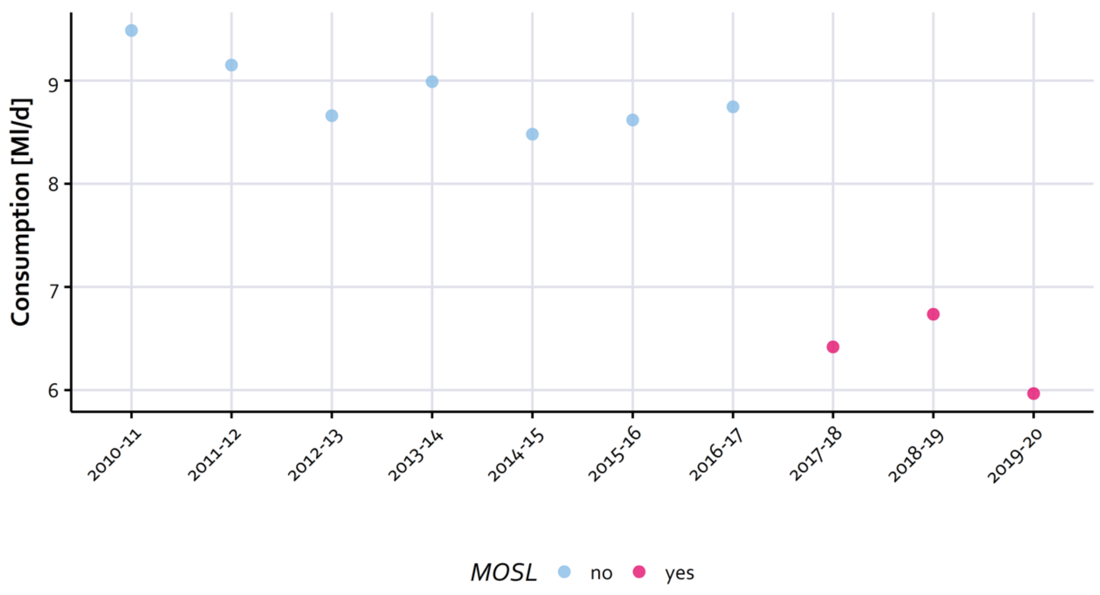
			then -3%	Serv-eco: -4.1% Serv-pop: -5.8% Unclass: +0.4%

MOSL

The liberalisation of the water market for the commercial sector has had an impact on the water consumption reporting, operated by MOSL, the market operator for the water retail market in England. During this time, MOSL has failed to deliver some of its targets for improving data quality (notably in the "Long term unread meter category" and the "level of properties flagged as vacant" areas)[15]. The MOSL annual market performance report identifies that 1 in 6 premises is now flagged as vacant, and meters unread for more than a year have increased from 7% at 2017 to 15% at March 2019, with one-third of these not being read since market opening.

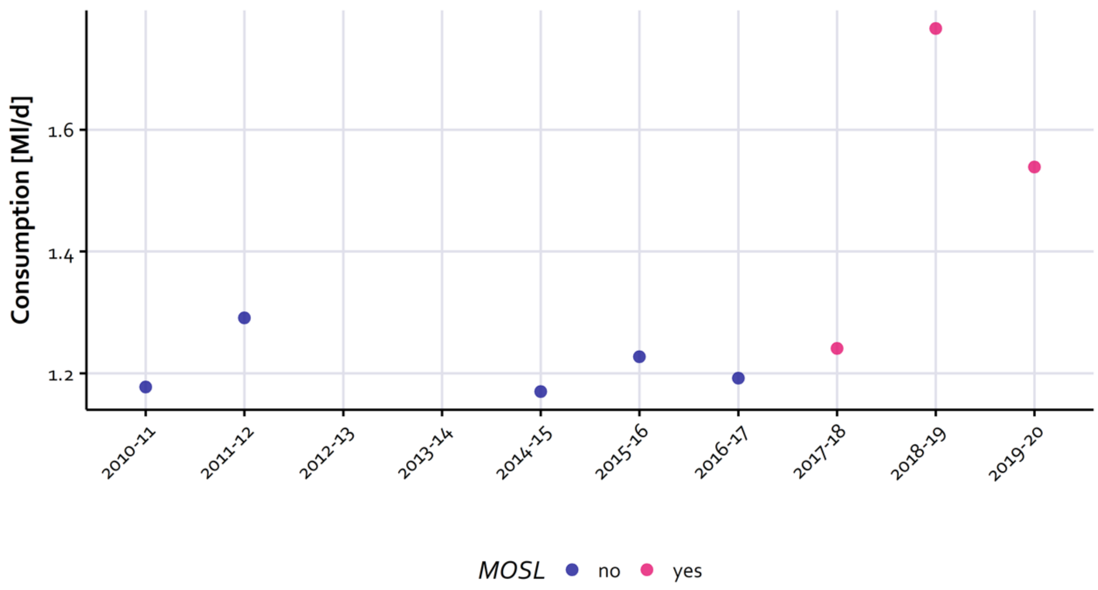
The effects are observable as the difference between the reporting before 2017 and after 2017. Step changes can be seen in the property level data that is used for the modelling, and if these step changes are not taken into consideration, they will impact the robustness of the models. Examples of this can be seen in Figure 5 and Figure 6. To account for this in the modelling a flag is used, which is set to zero before 2017 and set to 1 after.

Figure 5 Example (SEW-Maidstone) step change in property level consumption data post 2016



[15] Annual Market Performance Report 2019/20. MOSL.

Figure 6 Example (SWS-Hampshire Andover) step change in property level consumption data post 2016



However, there are commitments from MOSL to improve in this area and signs in 2019 that progress is being made. We are unsure how these improvements will impact reporting in the future, depending on how the water retail market evolves. Therefore, the following three scenarios are considered, quantifying the impact that the shift to MOSL reporting has had on each water resource zone and industry group separately:

- Upper MOSL scenario: the MOSL effect doubles in 2030, then remains at that level (data quality deteriorates).
- Central MOSL scenario: the MOSL effect remains constant in the future (data quality remains the same).
- Lower MOSL scenario: the MOSL effect gradually declines to zero in 2030 and remains at that level (data quality improves to pre-2017 levels).

Climate change

Modelling residuals

To consider weather effects on water consumption, a residual model is used, i.e. the difference between the actual consumption and the one that the MLR model estimates (residuals) are further modelled as a function of weather variables like temperature and rainfall.

Building the residual models for each WRZ independently is correct theoretically, but due to the low number of points in time it can result in unstable models. Therefore, we changed the approach to consider all residuals from all WRZs and all companies in one model. To make the residuals comparable, we standardised them, dividing them by the consumption itself:

$$residuals = \frac{(consumption - prediction)}{consumption}$$

Using this method, the resulting model predicts standardised residuals in the future as a function of weather variables (*average rainfall* and *average maximum temperature*). The residuals can then be adapted to each WRZ by multiplying them by the mean consumption of past years.

Modelling historic weather trends

The first step in the analysis is to establish the change in weather patterns that are occurring due to climate change. The weather variables under examination are *average maximum temperature* and *average rainfall*. Figure 7 and Figure 8 show that the trends of these variables over the years can be well represented with linear regressive models.

Figure 7: A plot showing the trend of peak daily temparatures since 1959.

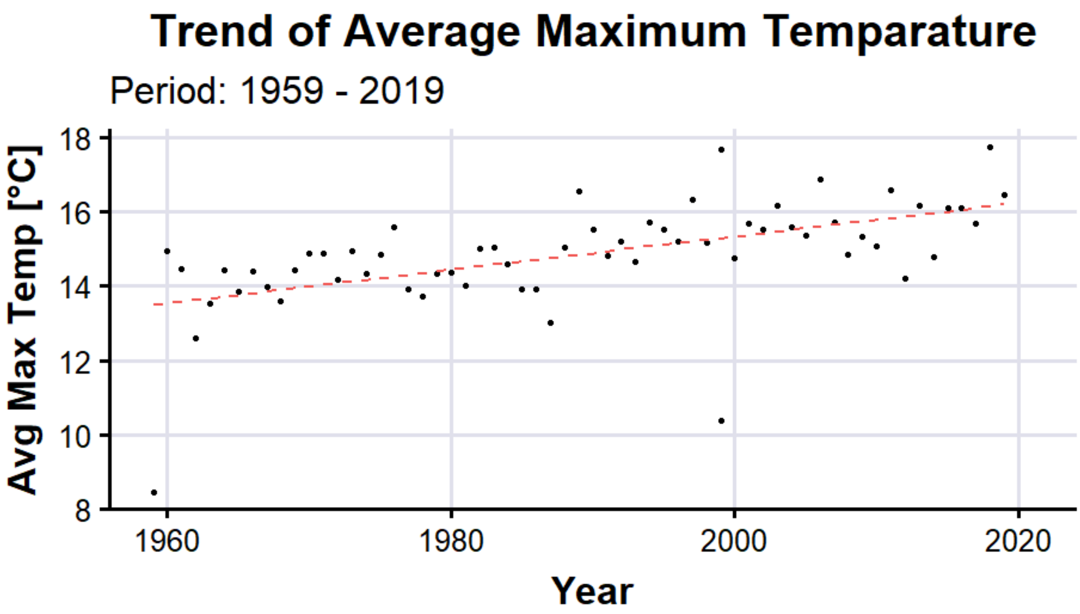
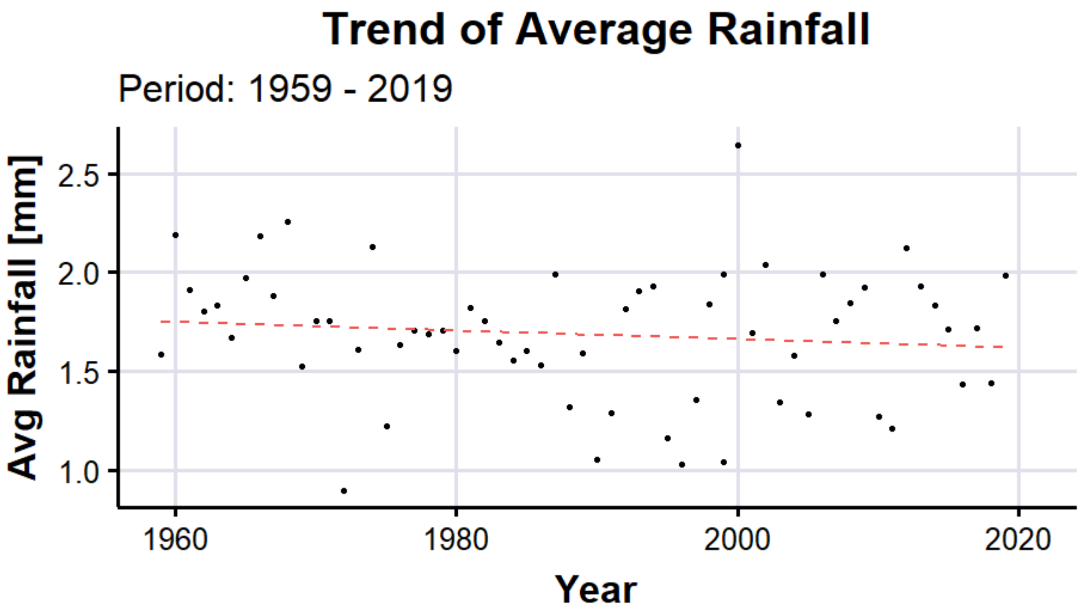


Figure 8: A plot showing the trend of average daily rainfall over since 1959.



Forecasting Weather and Climate Change Residuals

The weather models developed in Figure 7 and Figure 8 are used to forecast *average maximum temperature* and *average rainfall* through the forecast period.

We used additive climate change models in conjunction with the weather forecasts. These models provide 12 scenarios of potential temperature and rainfall patterns.

The forecasts of the weather variables are each summed with the 12 relevant climate change scenarios to produce 12 forecasts for *average maximum temperature* and *average rainfall*. The 12 scenarios for each are then fed into the residual model to obtain residual forecasts.

However, all 12 scenarios are not required for this analysis, only a *low*, *central*, and *high* scenario. To extract three scenarios from the 12, the 10th, 50th, and 90th quantile of the scenarios are taken for each financial year.

The climate change scenarios only go up to the year 2080, whereas we need forecasts up to the year 2100. The forecasts must therefore be extended to meet client needs. To perform this extension, a linear regressive model is fitted to each of the *low*, *central*, and *high* scenarios and used to predict the final 20 years to the desired end year, 2100.

Water efficiency

The evolution of technology and regulations is expected to contribute reducing NHH water consumption, by improving water efficiency.

The three water efficiency scenarios below were selected in consultation with the WRSE steering group:

- Upper water efficiency scenario: water consumption is reduced by 2% by 2050-51.
- Central water efficiency scenario: water consumption is reduced by 7.5% by 2050-51.
- Lower water efficiency scenario: water consumption is reduced by 16% by 2050-51.

2.4.3 Combining scenarios

All the scenarios described above result in a total of 729 scenarios for each Company/WRZ. This is a large number to report, so they are summarised as a central, upper, and lower thresholds. The thresholds have been derived as:

- Upper threshold: 90th percentile of all the scenarios each year.
- Central threshold: 50th percentile of all the scenarios each year.
- Lower threshold: 10th percentile of all the scenarios each year.

An example of 81 of the 729 scenarios is shown in Figure 9. A derivation of the Upper, Central and Lower thresholds from all 729 scenarios is illustrated in Figure 10 for Affinity Water as an example.

Figure 9 Example of 81 of the 729 scenarios for Affinity Water

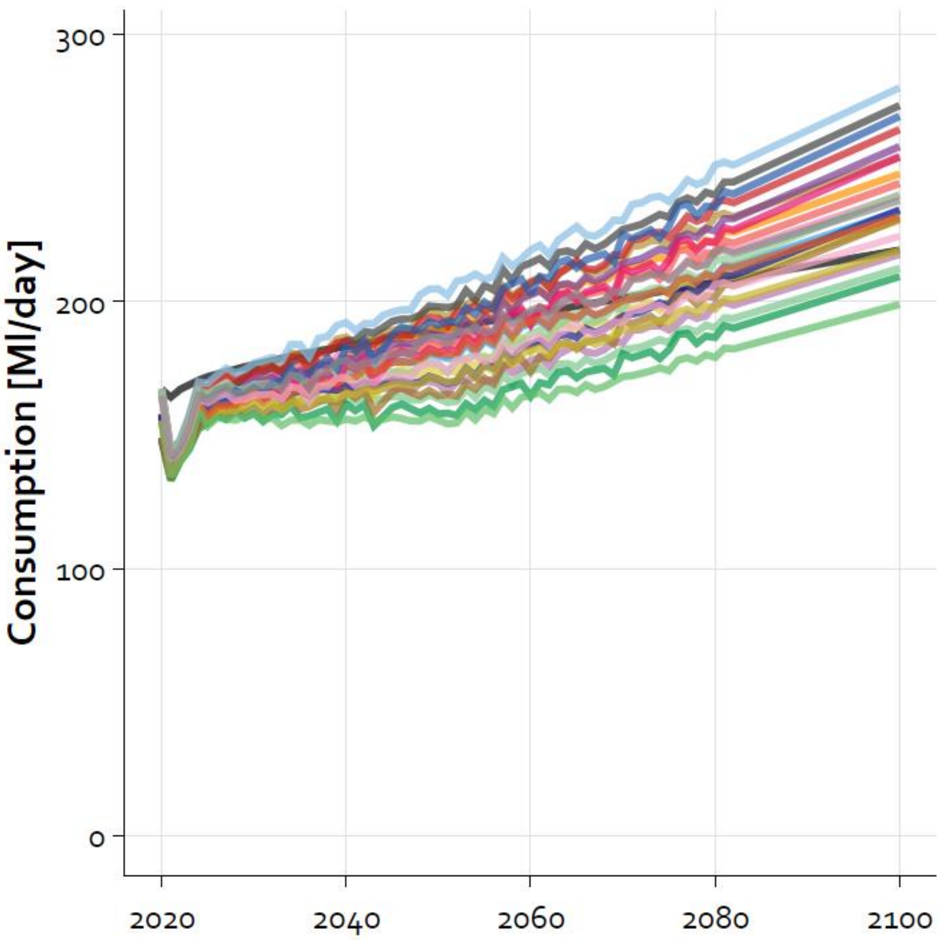
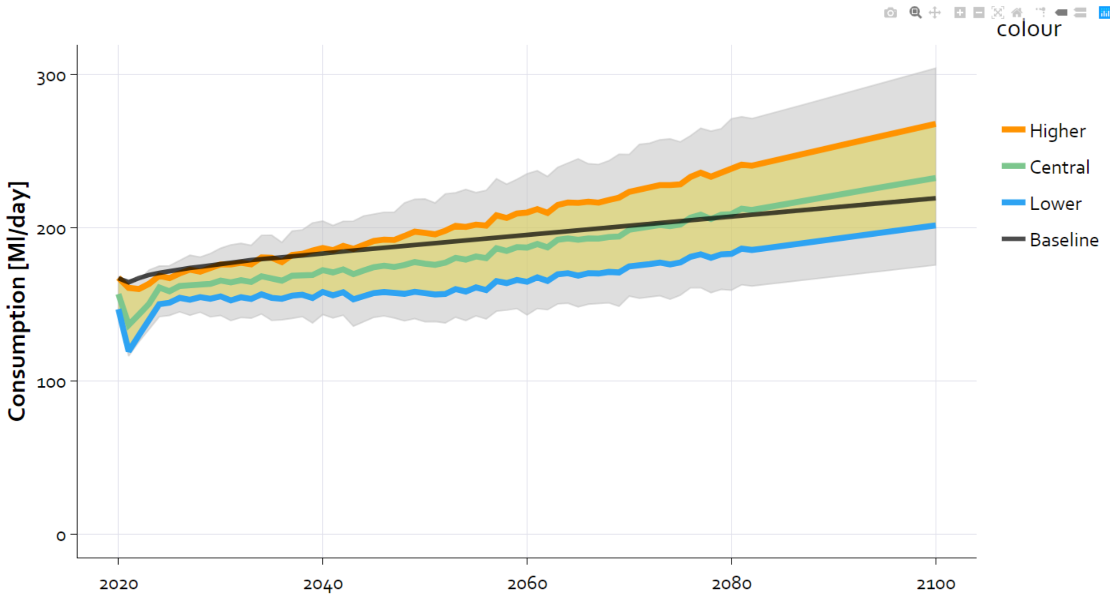


Figure 10 Example derivation of the Upper, Central, and Lower thresholds from the total scenario variability for Affinity Water



2.4.4 *Modelling uncertainty*

Every single element of the complex WRMP24 NHH forecasts is affected by a certain degree of uncertainty, but the quantification is difficult. Therefore, we decided to focus on the elements the have the biggest impact on the forecasts:

- the explanatory variables used in the model
- the model
- climate change.

The quantification of uncertainty for each component is described in the following sections.

Explanatory variable uncertainty

Each explanatory variable is affected by a different degree of uncertainty. It is not easy to separate the uncertainties and to evaluate the effects of each on the resulting water consumption. However, thanks to the linear nature of the model, if we consider the explanatory variables to have the same uncertainty, e.g. ±10%, we can derive that the same uncertainty will affect water consumption. The following explanatory variables are considered for uncertainty:

- GVA
- Employment
- Population

Other minor explanatory variables are expected to have a lower uncertainty and to affect the water consumption estimations to a smaller degree.

Observing the population scenarios from Edge Analytics, we can observe that their uncertainty is very small in the present and grows steadily in the future, reaching a value of ±6% to ±12% depending on what scenarios we consider.

In terms of GVA and employment we can observe in the *Forecasts for the UK economy 2020* by the HM Treasury, the larger uncertainty is actually in the short term and varies between ±30% to ±50% for GVA to ±1.5% to ±3% for Employment.

Considering the uncertainties estimated above, the general uncertainty for the explanatory variables is estimated as:

- ±8% of the water consumption in 2019-20.
- Growing to ±12% of the water consumption in 2025-26.
- Growing to ±18% of the water consumption in 2099-00.

Model uncertainty

Model uncertainty is estimated separately for the considered industry groups and companies, as different models are used. A model's R^2 value represents the variability in the data that the model is able to explain. We estimate the model uncertainty as $1 - R^2$, i.e. the variability in the data that the model is not able to explain. This is a simplification, as effects such as overfitting can increase the R^2 value beyond what the real capabilities of the model are, but overall it is a good proxy for the model uncertainty.

Climate change uncertainty

Climate change uncertainty has been estimated from the UKCP18 Climate Change Over Land infographic[16], that estimates the following:

- Rainfall is expected to show a variability up to ±25-30% in summer and ±12-19% in winter by 2060-79. It can be approximated as a ±20% on a yearly basis by 2060-79.
- Temperature is expected to show a total variability between 2.5-3.5 °C in winter and 3.3-4.7 °C in the summer, so about 4 °C on a yearly basis by 2060-79. Assuming an average yearly temperature around 15°C, that is about 15°C±2°C, i.e. ±13%. by 2060-79.

Combining the two estimates, we can consider a climate variability of about 16% by 2070, so we assume 18% by 2099.

2.4.5 Application of uncertainty

Once the uncertainty of the single components is defined, as stated in the previous sections, they are then combined in a quadratic way:

$$u = \sqrt{u_{EV}^2 + u_{model}^2 + u_{climate}^2}$$

[16] Met Office, 2018, UKCP18 Science Overview Report – November 2018 (Updated March 2019) – Infographic Headline Findings

The resulting uncertainty, estimated for each Company, WRZ, industry group and year, is applied on the three derived scenario thresholds.

2.5 Potential non-PWS demand

2.5.1 *Data*

For the calculation and forecast of non-PWS demand we used the output created for the Wood plc study for Defra and the Environment Agency, specifically the spreadsheet:

- Existing and new authorisations in SouthEast.xlsx

From this spreadsheet we mainly used data from the following TABS:

- **Existing_Abstractions_All** which contains combined surface water abstractions (SWABS) and groundwater abstractions (GWABS) point-purpose licence (extracted from WRGIS database February 2019) including multiple GWABS entries where impacts are apportioned to multiple surface water bodies.
- **New authorisations data** which contains any new abstraction licences since February 2019.

2.5.2 *Analysis*

Existing abstractions

Firstly, we removed all the public water supply abstractions by filtering them out using the "PWS" flag in the "secondary code" column. We then need to segment the non-PWS observations into industrial sectors. This was done using the codes shown in Table 7.

The data is then checked for duplicates and any duplicates removed.

Table 7 Sector segmentation – exisitng abstractions

Ref	Sector	How to reference
E1	Spray irrigation	Use the following Tertiary codes: 380 390 400 410 420
E2	Paper and pulp	Use secondary code: PAP
E3	Chemicals	Use secondary code: CHE
E4	Food and Drink	Use secondary code: FAD
E5	Power	Use primary code: P

E6	Agriculture (non-spray irrigation)	All remaining agriculture after E1 is removed.
E7	Navigation	Use secondary code: NAV
E8	Minerals and extraction	Use secondary codes: EXT and MIN
E9	Other	Anything that is left

The abstractions are then grouped by industry code and WRZ. We then for each WRZ, sum the following:

- Recent actual point purpose annual quantity in m3/year, consumptive quantities only (RAPTPANQM3).
- Consumptive only - Best Estimate Growth Factor Applied to RAPTPANQM3
- Consumptive only - 75th Percentile Growth Factor Applied to RAPTPANQM3.

The derivation of the "Best estimate growth" and the "75th percentile growth" factors are described in the Wood plc report[7].

Annual predicted non-PWS needs projecting from 2025 to 2100. For 2025 to 2050 use a linear interpolation between baseline and growth to 2050. For 2051 to 2100 we keep the non-PWS flat for this first iteration (alternative scenarios for post 2050 growth could be applied later).

New authorisations

The new authorisations sheet does not include WRZ information. So, for the purpose of this analysis, the field "NA_Catchment" was matched to water company through visual inspection. This results in sometimes allocating more than one water company to a catchment. In these cases, the volumes were split equally across the companies. This could be improved in the future.

The data is then checked for duplicates and any duplicates removed. We then need to select which industry sectors should be included, along with the best estimate growth factors. These are shown in Table 8.

Table 8 Sector segmentation – new authorisations

Ref	Sector	How to reference	Best estimate growth
N1	Horticultural watering	abpAbsPurposeDesc	2.01
N2	Make up or top up water	abpAbsPurposeDesc	1.00
N3	Spray irrigation -direct	abpAbsPurposeDesc	1.44
N4	Spray irrigation – storage	abpAbsPurposeDesc	1.44
N5	Trickle irrigation – direct	abpAbsPurposeDesc	1.44

N6	Trickle irrigation - storage	abpAbsPurposeDesc	1.44

For new abstractions we only have the licenced volume, and therefore will assume that is an approximation to actual consumptive volume. The industry groups we have selected are the ones likely to have consumptive demand. After grouping by industry code, we then sum the following:

- Abstraction quantity per year ('apnAbsQtyYear').
- Compute the best estimate of growth to 2050 using the growth rate in Table 8.

The derivation of the "Best estimate growth" is based on similar sectors in the Wood plc report.

Annual predicted non-PWS needs projecting from 2025 to 2100. For 2025 to 2050 use a linear interpolation between baseline and growth to 2050. For 2051 to 2100 we keep the non-PWS flat for this first iteration (alternative scenarios for post 2050 growth could be applied later).

3 Results

3.1 Baseline forecast for non-household public water supply demand

Baseline forecast outputs are provided in the following attached file "01_Artesia-WRSE_NonHousehold-Demand-Forecasts_Phase1-final-results_20201008.xlsx". This file includes the following breakdown of baseline non-household consumption forecasts from 2019-2020 through to 2099-2100:

- 01: Forecasts of measured non household demand for each industry sector in each water resource zone.
- 02: Forecasts of unmeasured non household demand for each WRZ (currently flat forecasts).
- 03: Aggregates of measured non household demand forecasts for each WRZ.
- 04: WRZ total forecasts (measured plus unmeasured).
- 05: Company total forecasts (measured plus unmeasured).
- 06: WRSE region total forecasts (measured plus unmeasured).

It is important to consider the baseline forecasts in the context of the uncertainty in the data and modelling, as well as future uncertainties (described in section 2.4). Therefore, we have produced scenarios for non-household demand forecast outputs are provided in the following attached files for the central, lower and upper scenarios:

- "01_Artesia-WRSE_NonHousehold-Demand-Forecasts_central_Scenario_preliminary_result_20201016.xlsx".
- "01_Artesia-WRSE_NonHousehold-Demand-Forecasts_lower_Scenario_preliminary_result_20201016.xlsx"
- "01_Artesia-WRSE_NonHousehold-Demand-Forecasts_upper_Scenario_preliminary_result_20201016.xlsx"

These files includes the following breakdown of scenario non-household demand forecasts from 2019-2020 through to 2099-2100:

- 1_PWS_WRZ_ measured_scenario
- 2_PWS_WRZ_unmeasured_scenario
- 3_PWS_WRZ_total _scenario
- 4_PWS_Company_ measured_scenario
- 5_PWS_Company_ unmeasured_scenario
- 6_PWS_Company_ total _scenario
- 7_PWS_Region_ measured_scenario
- 8_PWS_Region_ unmeasured_scenario
- 9_PWS_Region_ total _scenario

WRSE level graphs of non-household baseline demand and scenarios are presented in Figure 11, Figure 12 and Figure 13. Company graphs for non-household demand scenarios are then shown in Figure 14 through to Figure 31.

3.1.1 WRSE regional results

At start of the planning period (2025), the WRSE region total non-household demand is predicted to be 921 Ml/d within an overall range of 594 to 1121 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 1032 Ml/d (an increase of 111 Ml/d) within a range of 630 Ml/d to 1637 Ml/d.

Figure 11 WRSE region measured and unmeasured non-houshold demand forecasts

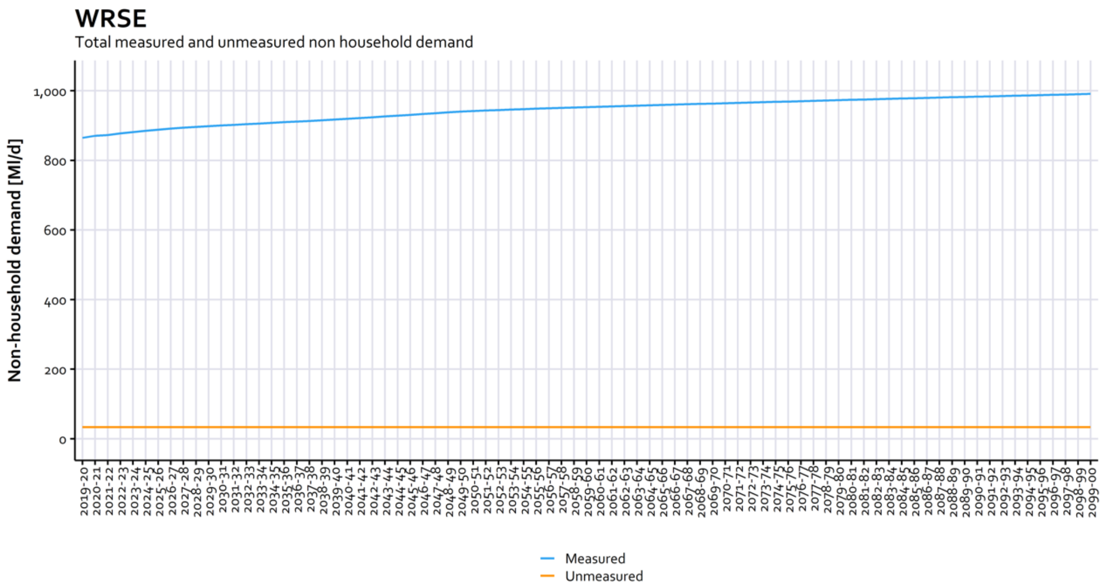


Figure 12 WRSE region non-houshold consumption central, lower and upper scenarios

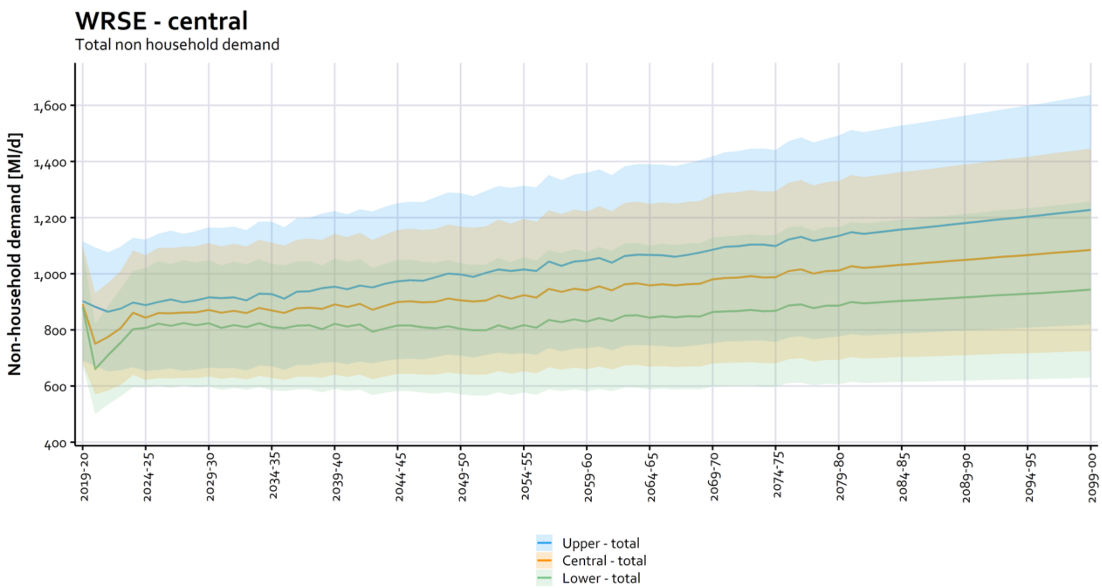
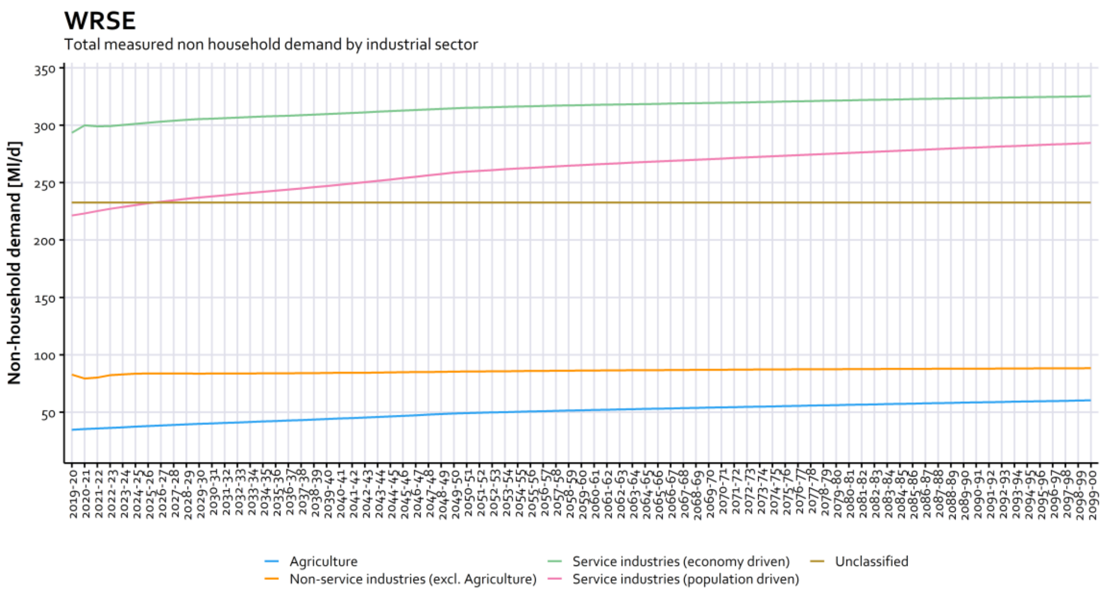


Figure 13 shows how the non-household demand is broken down into the standard industry sectors. There is limited growth in the 'non-service industries' i.e. manufacturing etc. Most of the growth is in the service sectors, which are driven by population and economy.

Approximately one quarter of the non-household demand in the WRSE region falls into the 'unclassified' category. These are properties that could not be allocated into an industry sector because either the property has no industry code assigned to it or the industry code is incorrectly recorded and cannot be matched to a sector. We did attempt to model this unclassified sector, but because of the inconsistency in the data it was not possible to derive meaningful relationships or models, therefore we held the forecast for the unclassified sector flat across the planning period.

Figure 13 WRSE region non-houshold demand forecasts by industry sector



3.1.2 Affinity Water results

The results for Affinity Water are shown in Figure 14 to Figure 16. At start of the planning period (2025), the Affinity region total non-household demand is predicted to be 174 Ml/d within an overall range of 87 to 242 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 208 Ml/d (an increase of 34 Ml/d) within a range of 100 Ml/d to 371 Ml/d.

Figure 14 Affinity Water measured and unmeasured non-housheold consumption

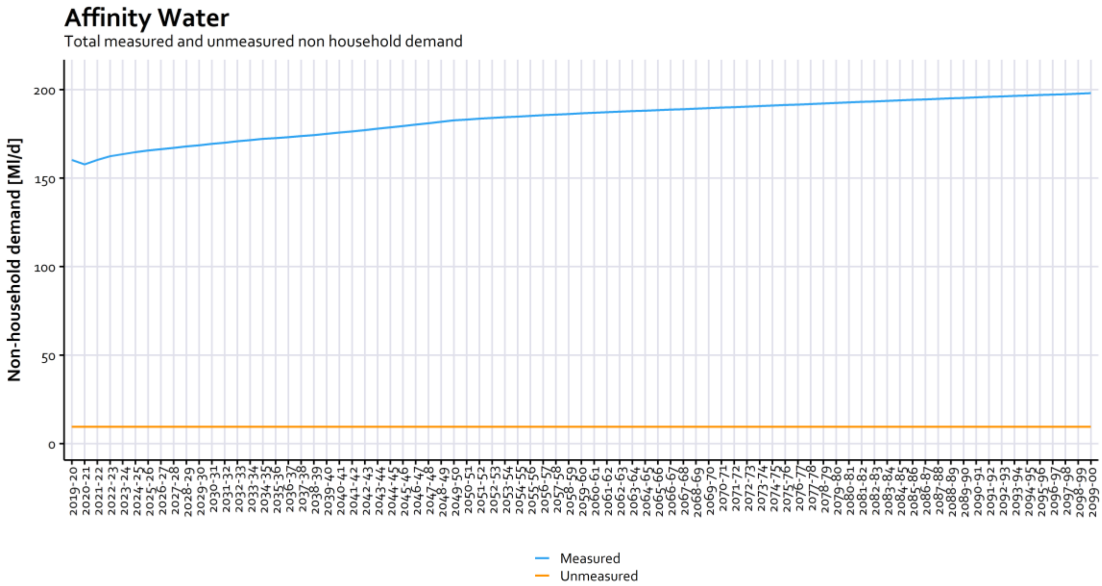
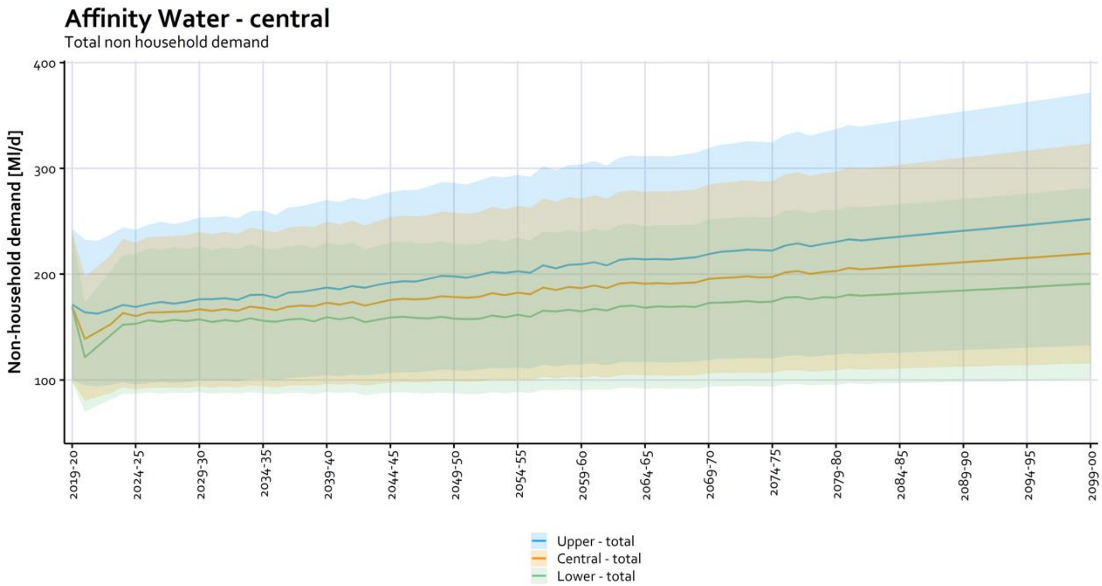
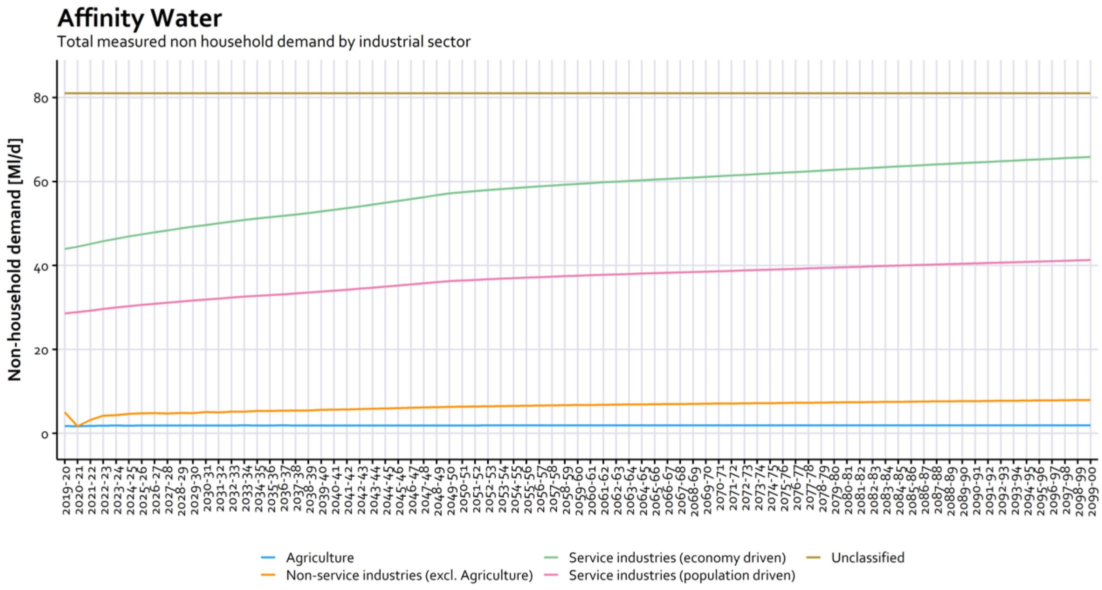


Figure 15 Affinity Water region non-houshold consumption central, lower and upper scenarios



Most of the growth in the Affinity region comes from the service sectors, with the non-service sector and agriculture remaining approximately flat across the planning period. Approximately one third of the demand in the Affinity region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 16 Affinity Water non-housheold consumption by industry sector



3.1.3 Portsmouth Water results

The results for Portsmouth Water are shown in Figure 17 to Figure 19. At start of the planning period (2025), the Portsmouth region total non-household demand is predicted to be 35 Ml/d within an overall range of 23 to 41 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 40 Ml/d (an increase of 5 Ml/d) within a range of 20 Ml/d to 69 Ml/d.

Figure 17 Portsmouth Water measured and unmeasured non-housheold consumption

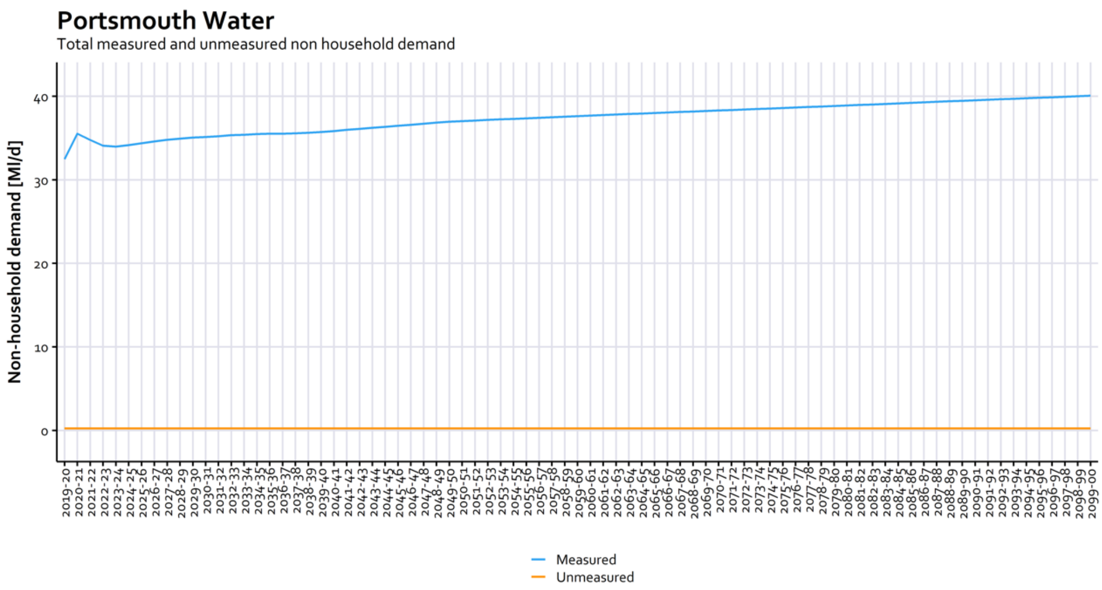
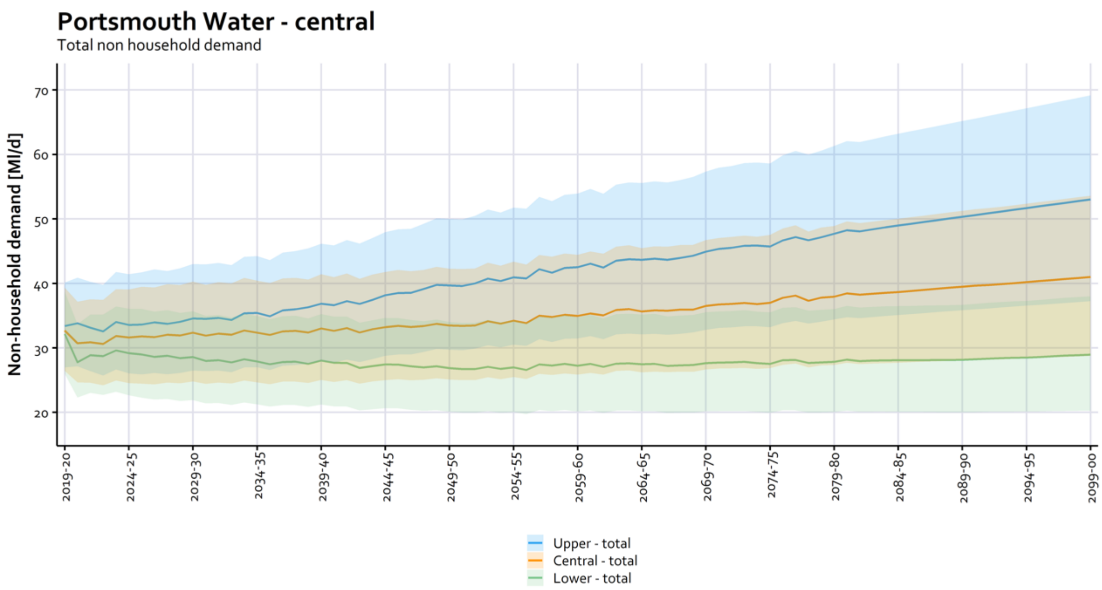
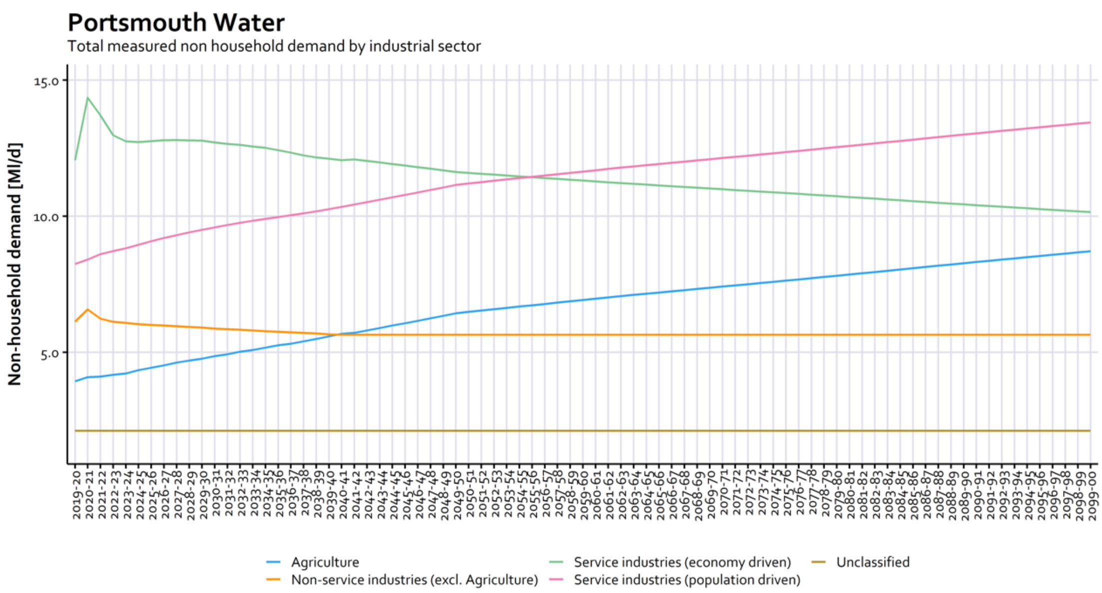


Figure 18 Portsmouth Water region non-houshold consumption central, lower and upper scenarios



Most of the growth in the Portsmouth region comes from the service-population driven and agriculture sectors, with the service-economy and non-service sector reducing across the planning period. Less than 1% of the demand in the Portsmouth region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 19 Portsmouth Water non-housheold consumption by industry sector



3.1.4 SES Water results

The results for SES Water are shown in Figure 20 to Figure 22. At start of the planning period (2025), the SES region total non-household demand is predicted to be 25 Ml/d within an overall range of 17 to 30 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 24 Ml/d (a decrease of 1 Ml/d) within a range of 16 Ml/d to 38 Ml/d.

Figure 20 SES Water measured and unmeasured non-housheold consumption

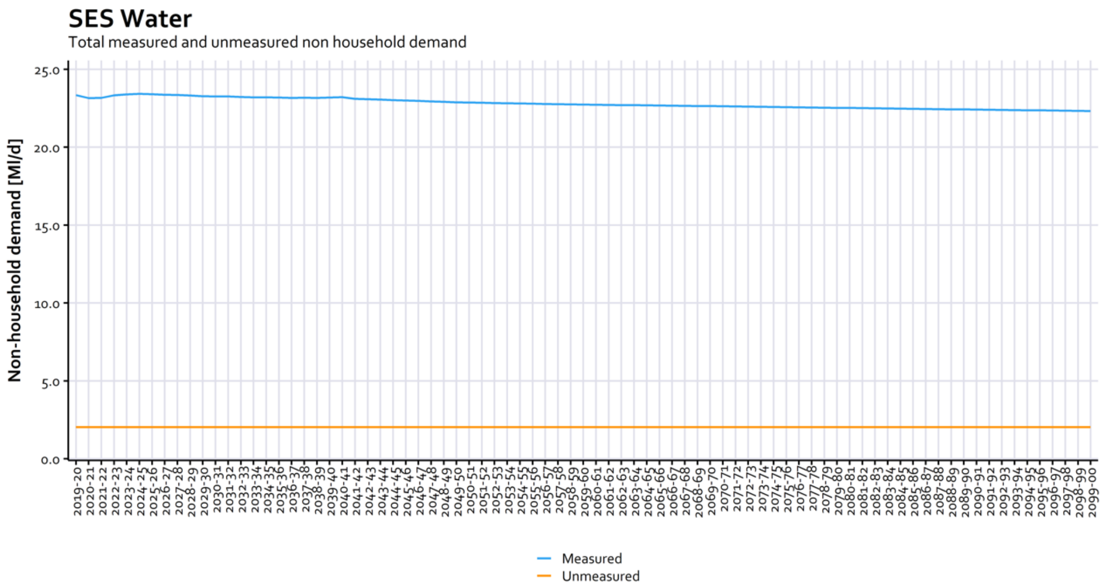
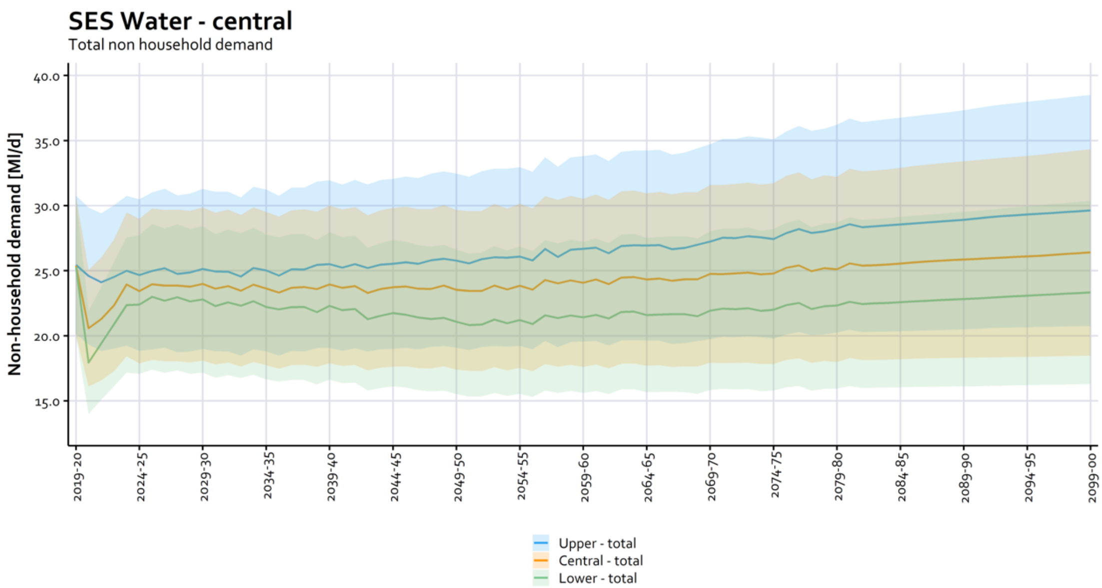
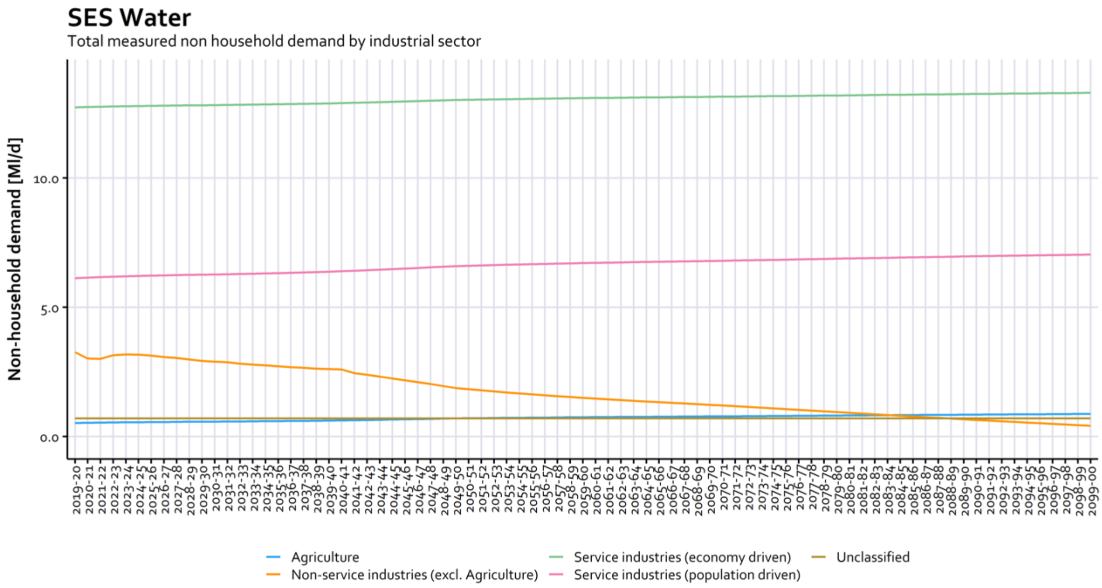


Figure 21 SES Water region non-houshold consumption central, lower and upper scenarios



There is slight growth in the SES region from the service sectors, with the non-service sector reducing across the planning period. About 3% of the demand in the SES region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 22 SES Water non-housheold consumption by industry sector



3.1.5 South East Water results

The results for South East Water are shown in Figure 23 to Figure 25. At start of the planning period (2025), the South East Water total non-household demand is predicted to be 98 Ml/d within an overall range of 63 to 120 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 113 Ml/d (an increase of 15 Ml/d) within a range of 72 Ml/d to 180 Ml/d.

Figure 23 South East Water measured and unmeasured non-housheold consumption

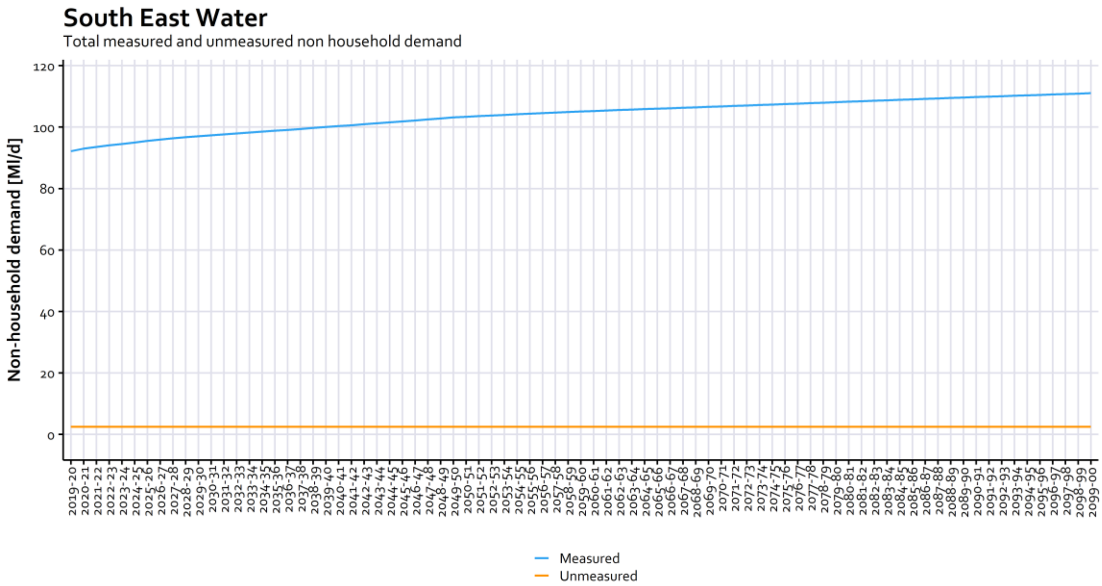
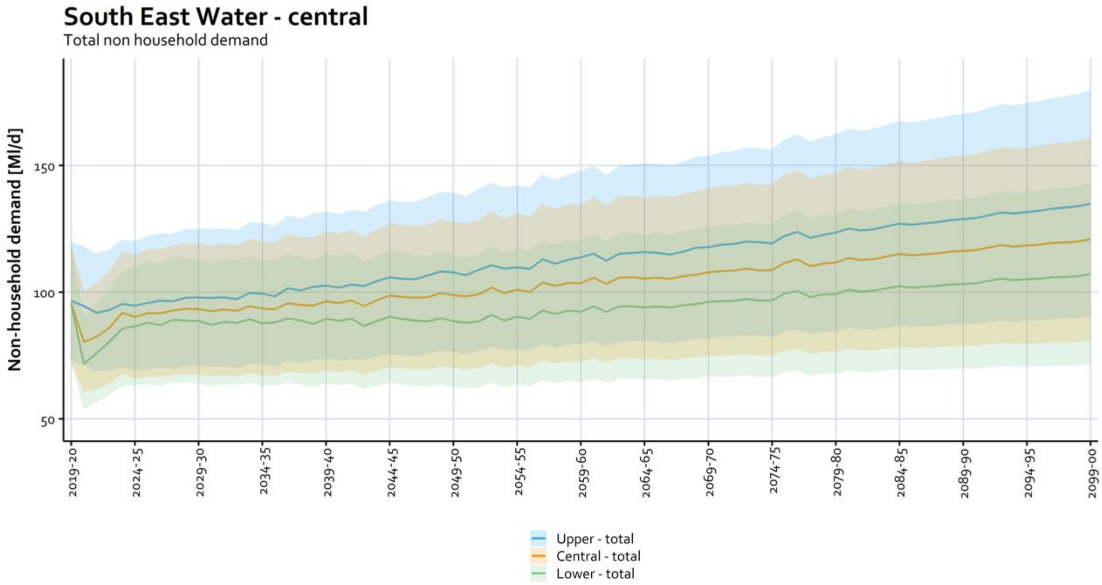
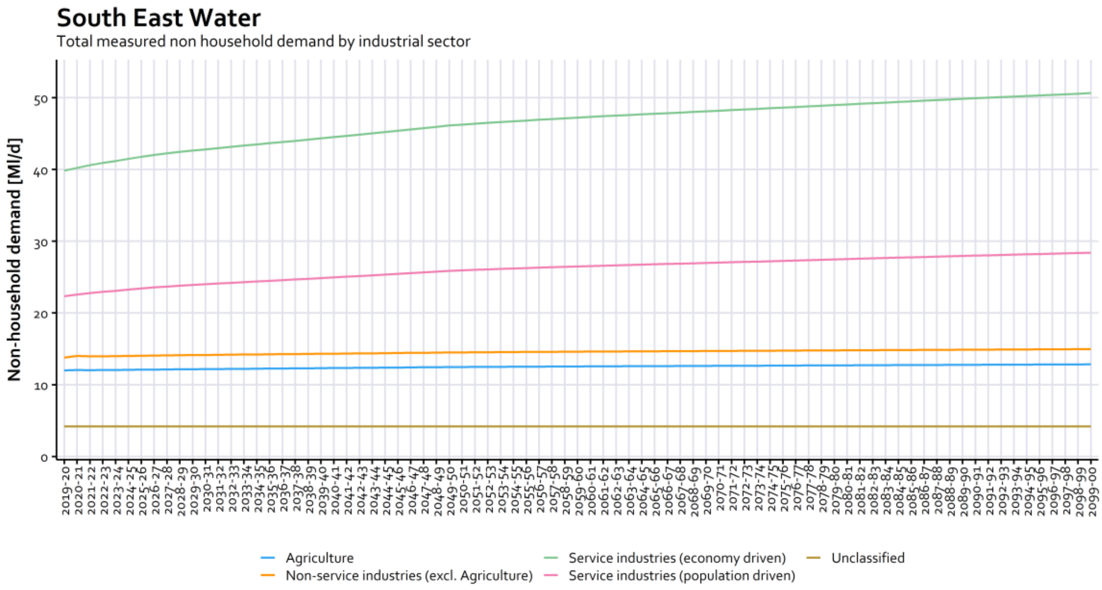


Figure 24 South East Water region non-houshold consumption central, lower and upper scenarios



There is growth in the South East region from the service sectors, with the non-service sector and agriculture sectors remaining flat across the planning period. About 4% of the demand in the South East Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 25 South East Water non-housheold consumption by industry sector



3.1.6 Southern Water results

The results for Southern Water are shown in Figure 26 to. Figure 28. At start of the planning period (2025), the Southern Water region total non-household demand is predicted to be 115 Ml/d within an overall range of 71 to 142 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 122 Ml/d (an increase of 7 Ml/d) within a range of 107 Ml/d to 207 Ml/d.

Figure 26 Southern Water measured and unmeasured non-housheold consumption

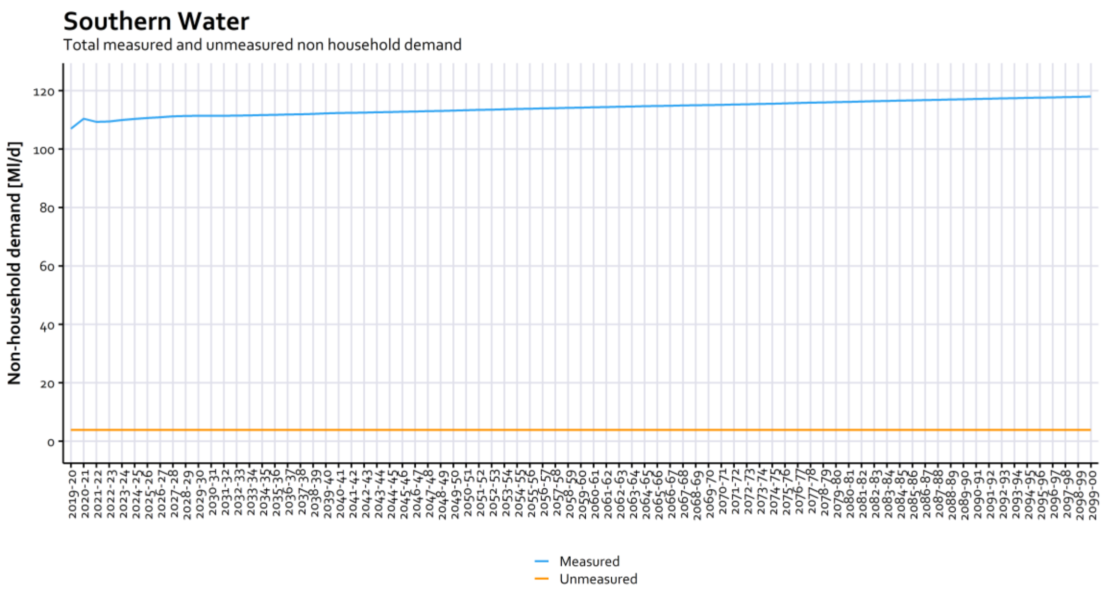
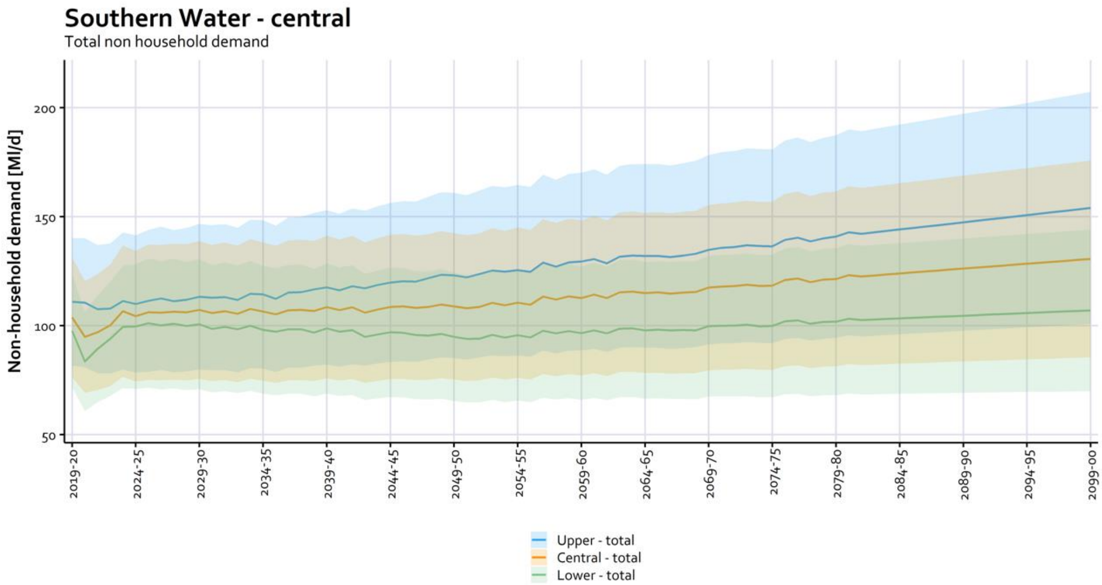
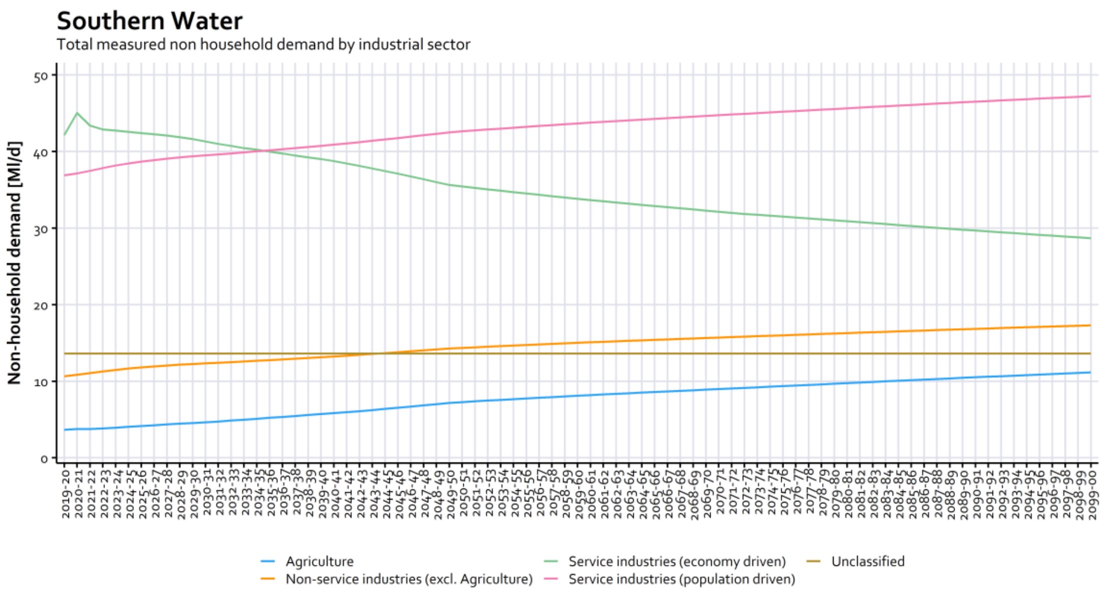


Figure 27 Southern Water region non-houshold consumption central, lower and upper scenarios



There is growth in the Southern Water region from the population service, non-service and agriculture sectors, with economy service sector reducing across the planning period. About 12% of the demand in the Southern Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period.

Figure 28 Southern Water non-housheold consumption by industry sector



3.1.7 Thames Water results

The results for Thames Water are shown in Figure 29 to Figure 31. At start of the planning period (2025), the Thames Water region total non-household demand is predicted to be 471 Ml/d within an overall range of 334 to 546 Ml/d. Much of the early uncertainty is due to the impact of COVID-19 and uncertainty over the quality of non-household consumption data from MOSL.

By the end of the planning period the non-household demand is predicted to be 516 Ml/d (an increase of 45 Ml/d) within a range of 351 Ml/d to 771 Ml/d.

Figure 29 Thames Water measured and unmeasured non-housheold consumption

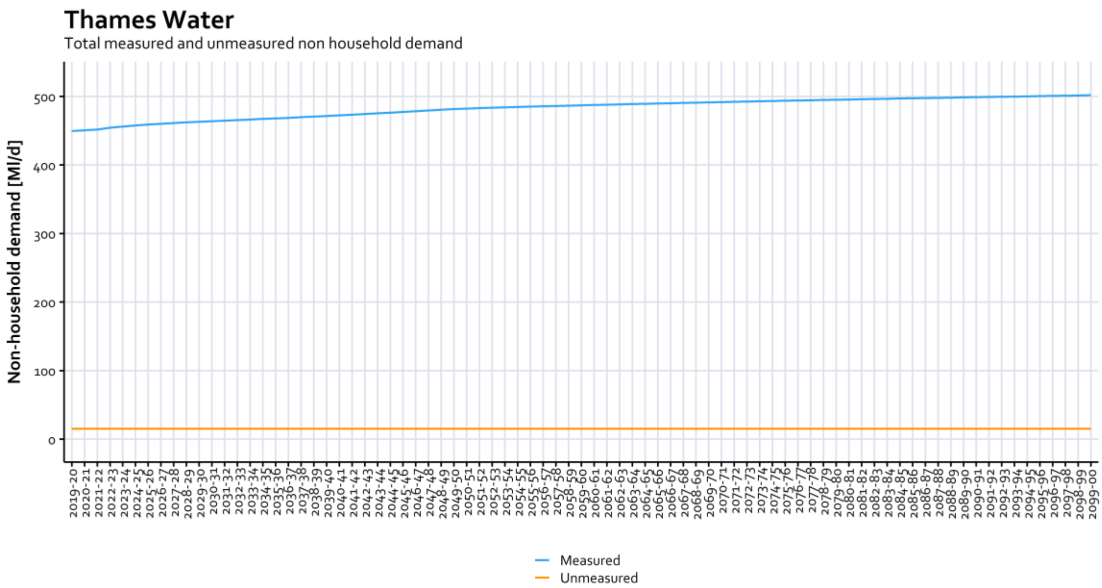
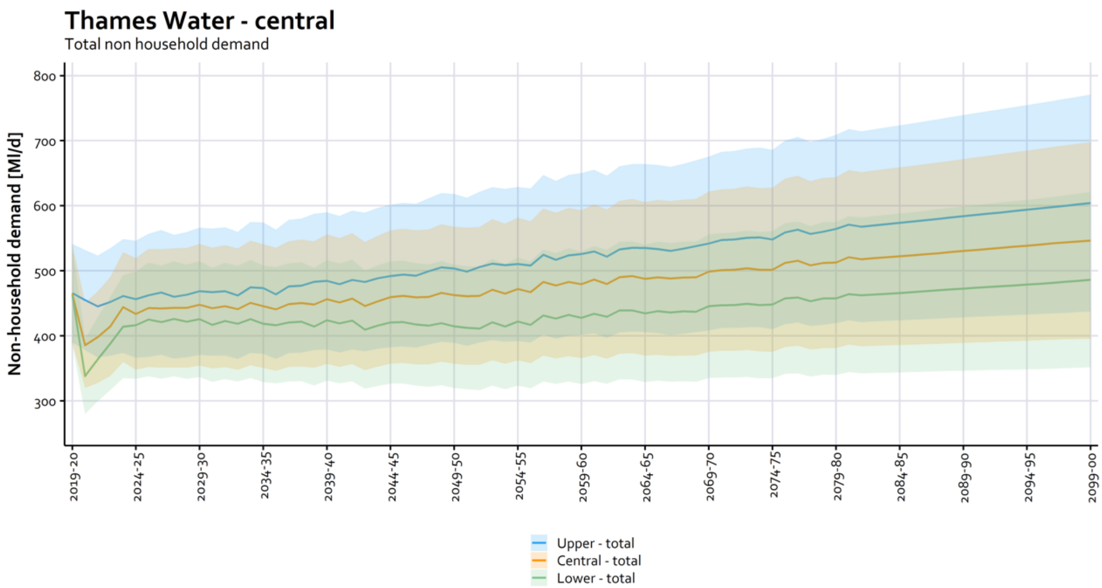


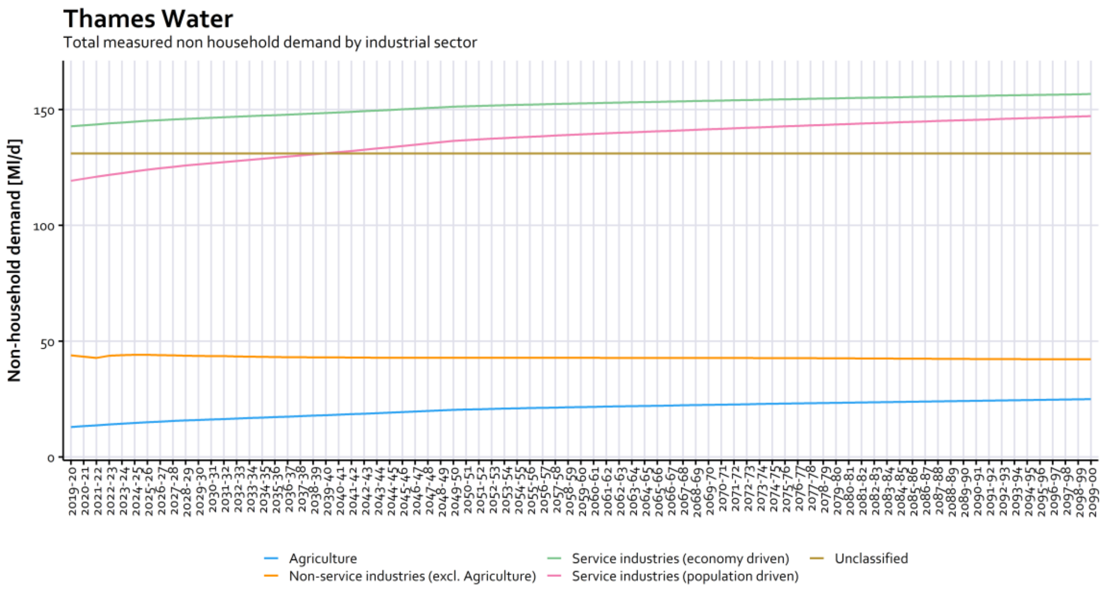
Figure 30 Thames Water region non-houshold consumption central, lower and upper scenarios



There is growth in the Thames Water region from the service sectors, with a small increase in agriculture, the non-service sector remains flat across the planning period.

About 27% of the demand in the Thames Water region falls into the unclassified group, and as explained in section 3.1.1, this is held flat across the planning period. These are properties that could not be allocated into an industry sector because either the property has no industry code assigned to it or the industry code is incorrectly recorded and cannot be matched to a sector. We did attempt to model this unclassified sector, but because of the inconsistency in the data it was not possible to derive meaningful relationships or models, therefore we held the forecast for the unclassified sector flat across the planning period.

Figure 31 Thames Water non-housheold consumption by industry sector



3.2 Potential non-public water supply demand

Projections for non-PWS non-household demand are provided in the following file "01_Artesia-WRSE_NonHousehold-Demand-Forecasts_non-PWS_Phase1-final-results_20201008.xlsx".

These files includes the following breakdown of scenario non-household demand forecasts from 2019-2020 through to 2099-2100:

- 1 Existing abstraction, Best estimate, Recent actual consumptive volume with growth to 2050, By WRZ and sector
- 2 Existing abstraction, 75th percentile, Recent actual consumptive volume with growth to 2050, By WRZ and sector
- 3 New licence, New licenced volume with growth to 2050, By WRZ and sector
- 4 Existing abstraction, Best estimate, Recent actual consumptive volume with growth to 2050, Summed to WRZ
- 5 Existing abstraction 75th percentile Recent actual consumptive volume with growth to 2050 Summed to WRZ
- 6 New licence, New licenced volume with growth to 2050, Summed to WRZ

- 7 Total non_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At WRZ
- 8 Total non_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At WRZ
- 9 Total non_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At company
- 10 Total non_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At company
- 11 Total non_PWS, Best estimate, Recent actual consumptive volume plus new abstractions with growth to 2050, At region
- 12 Total non_PWS, 75th percentile, Recent actual consumptive volume plus new abstractions with growth to 2050, At region

The base year abstraction by sector is shown in Figure 32, with the best estimate of growth to 2050 shown in Figure 33. The estimated new abstractions by sector are shown for the base year in Figure 34, with the projected growth to 2050 shown in Figure 35.

These have been aggregated to regional level in Figure 36. The figures are then segregated to water company level and are shown in Figure 37, split out by water company with the best estimate, 75th percentile estimate and new abstractions for the base year (2019-20) and for 2049-50.

Figure 32 Base year exisitng abstractions by sector for the WRSE region

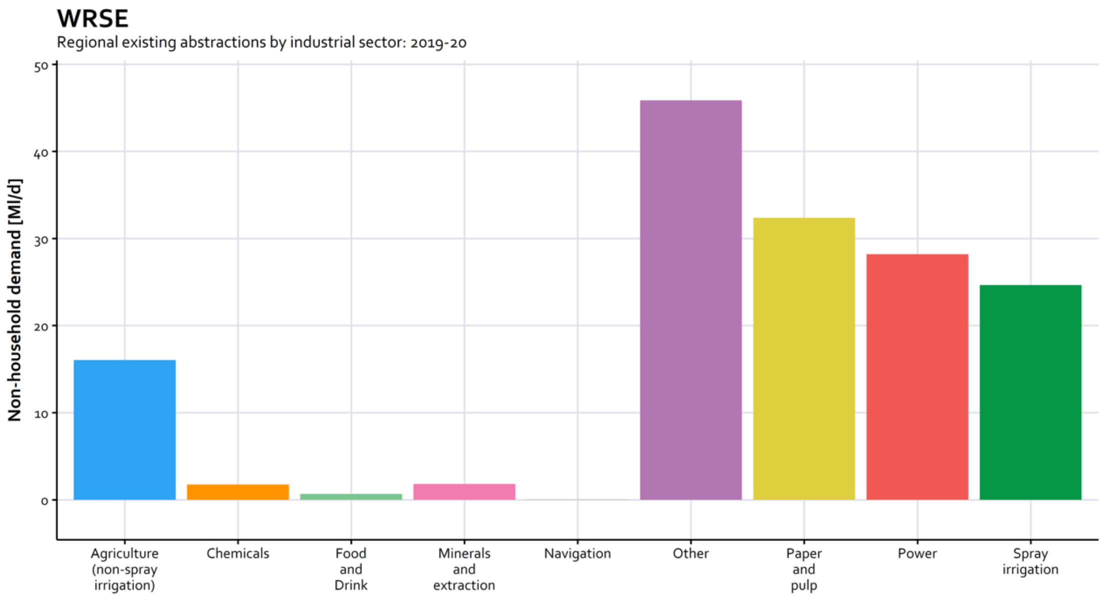


Figure 33 Best estimate of exisitng abstractions growth to 2050 by sector for WRSE region

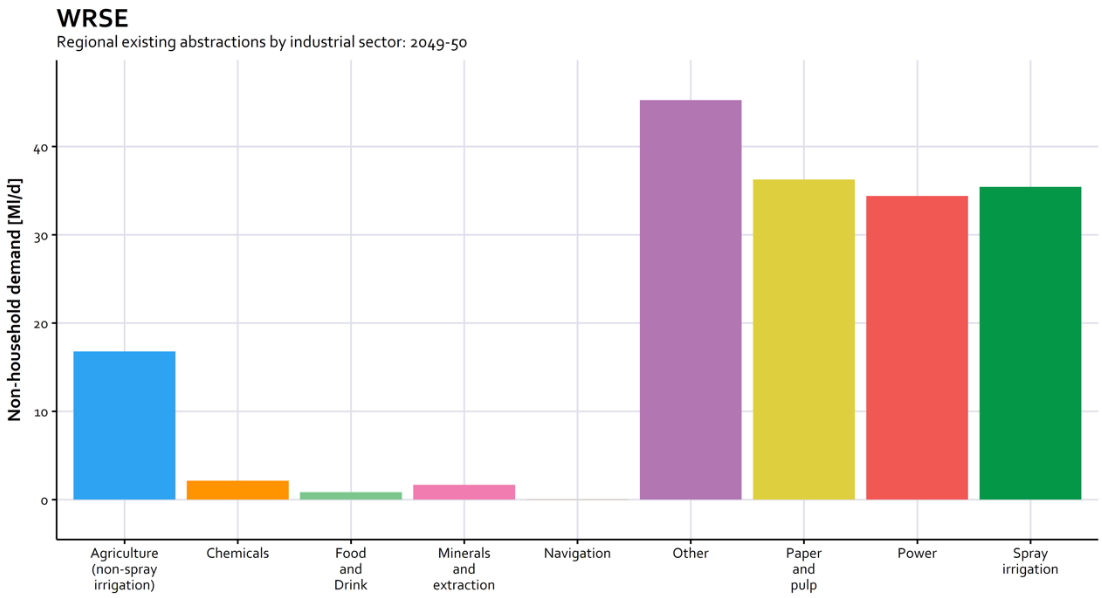


Figure 34 Base year new abstractions by sector for WRSE region

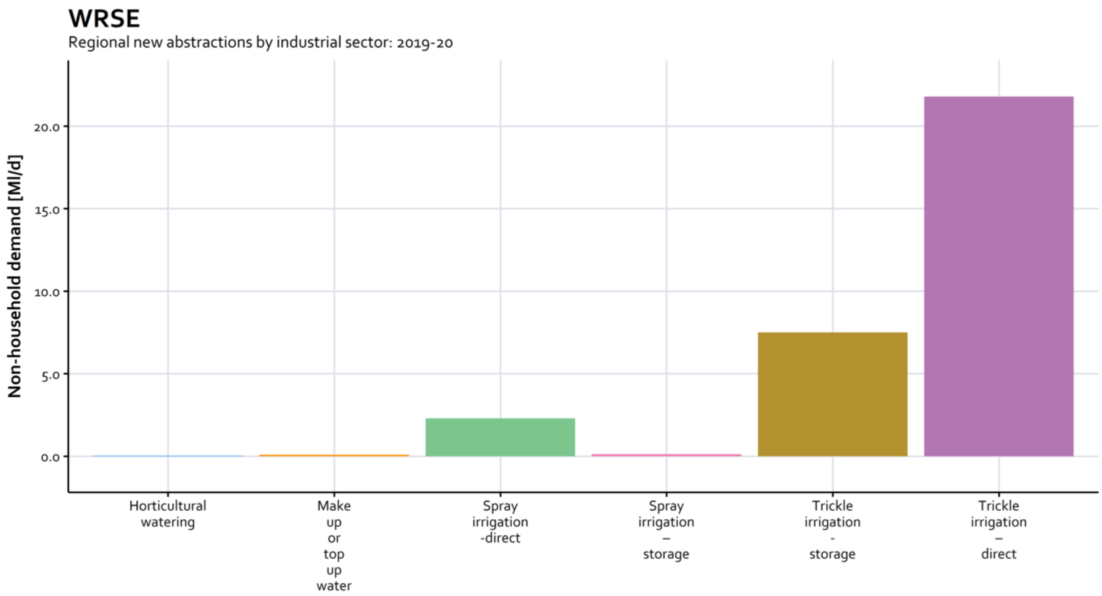


Figure 35 Best estimate of new abstractions growth to 2050 by sector for WRSE region

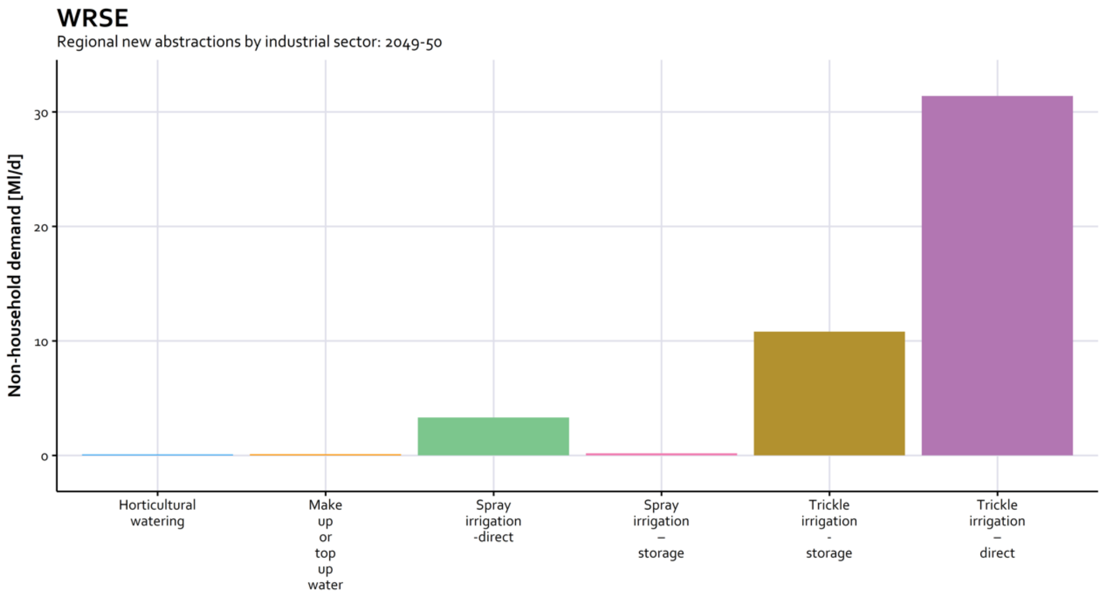


Figure 36 Non PWS in base year and 2050 at WRSE region split out by best and 75th percentile estimate and new abstractions

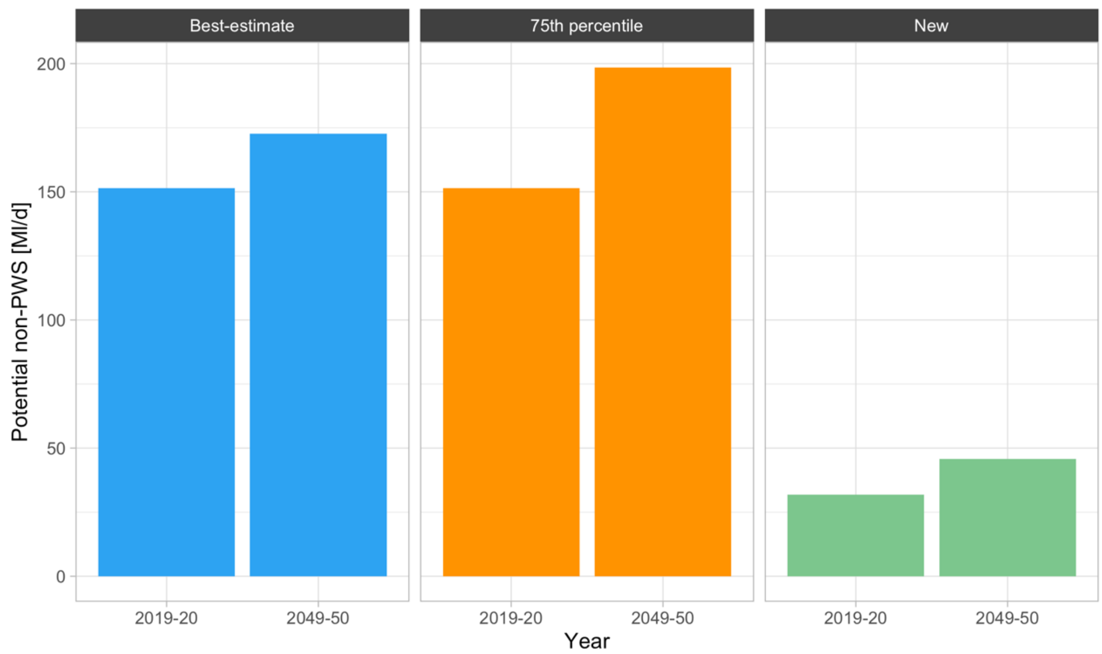
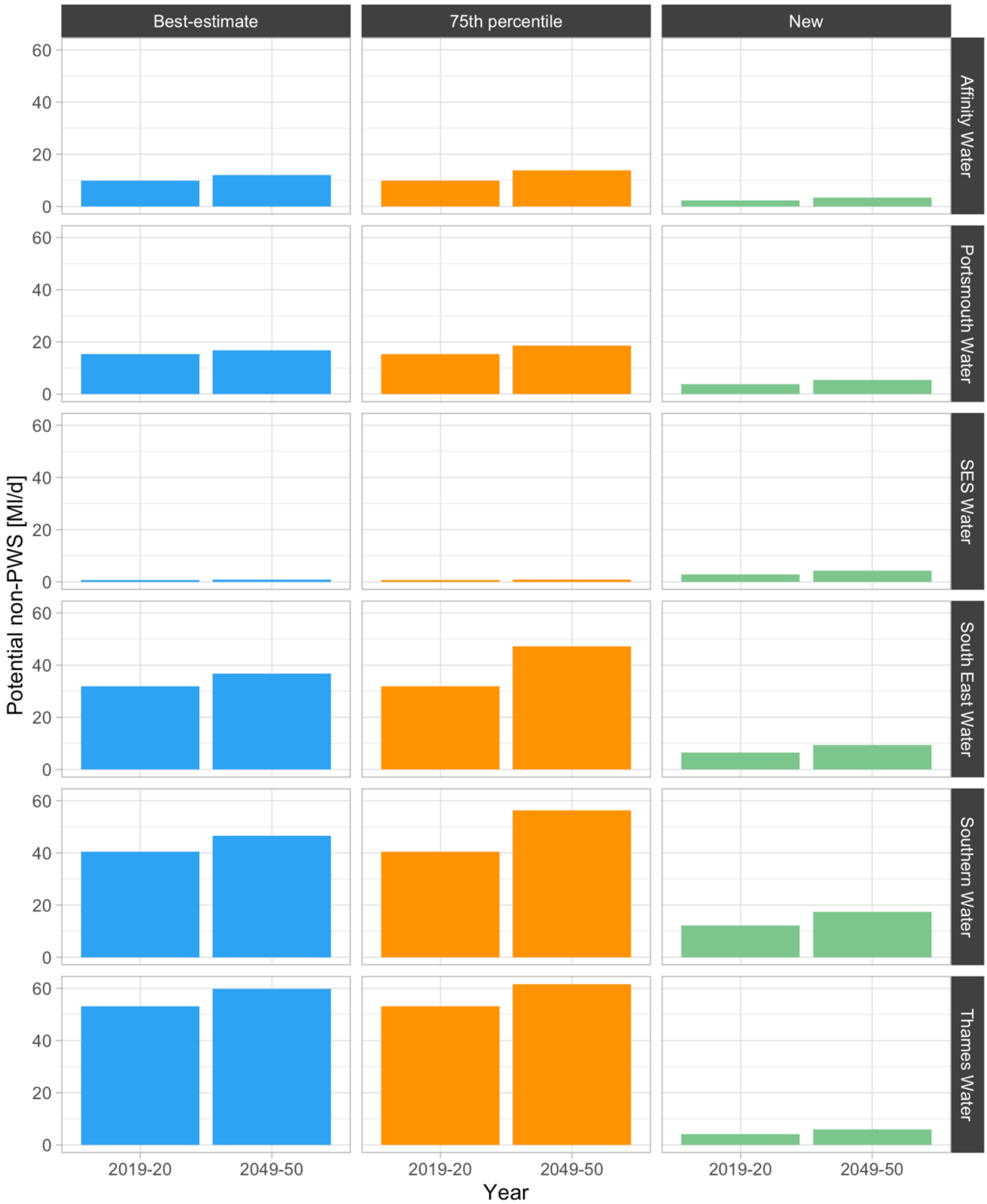


Figure 37 Non PWS in base year and 2050 by company split out by best and 75th percentile estimate and new abstractions



4 Discussion of findings

This section discusses the overall results and findings that are consistent across WRSE, any company specific findings are discussed in Appendix A. The discussion is broken down into the following sections:

- The modelling approach used for this study.
- Uncertainty in the predictions.
- Data issues.
- Potential alternative industry segments.
- Weather impacts.
- Other potential improvements.

4.1 Modelling approach

As explained in sections 1.4.1 and 1.4.2, this project followed well prescribed approach, based on an initial review of best practice and previous WRMP company models carried out by WRSE. This has ensured that a consistent approach has been applied to modelling non-household consumption across all 37 WRZs in the WRSE region. As part of this approach, the industry sector grouping, along with expected drivers for each group, were prescribed in Table 3 of the WRSE review[5] described in section 1.4.1. The groups and drivers are set out in Table 9. This grouping seems sensible based on the review of previous non-household models, and therefore was used for this study.

Table 9 Industry sector groupings and drivers from the initial WRSE review

Sector_Name	Sector _Description
Agriculture	Agriculture clearly has a stronger relationship to weather than other sectors, and therefore if it is significant it warrants separate treatment, particularly in the context of climate change scenarios. There may be other weather-dependent industries that behave similarly.
Non-service industries (excl. Agriculture)	These are again more likely to show trends related to the economy, but are likely to contain different trends in patterns of water use and efficiency.
Service industries (economy driven)	Other areas of the service sector, such as retail and entertainment, are more likely to show trends related to the size of the economy or employment.
Service industries (population driven)	Certain areas of the service sector, such as education and health, are more likely to be driven by population size rather than measures of economic output, and therefore it is worth including these as a separate grouping.

Unclassified	Some non-households may not readily be assigned to any of the other categories. It is also unlikely to be able to assign industry sectors to every property, and a significant volume of consumption will not be assigned to one of the previous sectors. Care needs to be taken that strong trends in this sector are not simply reflecting changes in data quality over time.

In the process of developing the non-household consumption models we started with the different drivers for each sector group. However, some models were weak, and therefore we allowed the data for each sector's model to guide us in the selection of the explanatory variables, i.e. all explanatory variables were applied to each sector model and the models refined through a process of variable reduction until the strongest models remained. The resulting significant variables for each company model across WRSE are shown in Table 10.

Table 10 Significant explanatory variables in each sector model

Company	Sector model	Population	GVA	Employment	MOSL flag	Other
Affinity	Agriculture	X	X	X	X	
	Non-service	X	X	X	X	
	Service-economy	X			X	
	Service-population	X			X	
Portsmouth	Agriculture	X	X	X	X	
	Non-service		X		X	
	Service-economy	X	X	X	X	X
	Service-population	X		X	X	X
SES Water	Agriculture	X				X
	Non-service	X		X		X
	Service-economy	X				X
	Service-population	X				X
South East	Agriculture	X	X		X	X
	Non-service	X	X		X	X

Company	Sector model	Population	GVA	Employment	MOSL flag	Other
	Service-economy	X			X	
	Service-population	X			X	
Southern	Agriculture	X		X	X	X
	Non-service	X			X	X
	Service-economy	X	X		X	
	Service-population	X		X	X	X
Thames	Agriculture	X			X	X
	Non-service	X		X		X
	Service-economy	X			X	X
	Service-population	X			X	X

What we see is quite a mix of explanatory factors, with population having a strong influence in nearly all models. Economy (GVA) is a factor in some of the non-service and service-economy models. Employment is a factor in some of the models across all four sector groupings. The MOSL flag (discussed in sections 2.4.2 and 4.3.1) is significant in nearly all models. Some models contain an additional factor which would typically be added following an analysis of residuals were relationships in the residuals are observed, for example population density. Note, that for the unclassified sector there was too much variation in the data to establish any robust models, therefore these were held flat across the planning period.

Overall, the picture is a lot more varied than the anticipated factors from the initial review (Table 9). For some of the segments the resulting models using the explanatory factors described above were very weak, so we expanded the modelling to allow all the explanatory factors to be used for each segment to develop stronger models. Where some of the models remained weak, we looked for other explanatory factors such as population density. We also did some additional exploratory work on why the segments as defined, didn't always result in strong models. This identified that within some of the segments we were seeing different SIC divisions showing a positive relationship with the explanatory variables whilst others showed a negative relationship which were cancelling each other out.

There are some opportunities to improve the industry groupings and explore some initial analysis on this in section 4.4 below.

However, all the models developed and used in this report are robust, but some will have wider uncertainty bands. In addition, the consistency of the approach across the WRZs within

WRSE brings additional benefits in comparing the results between zones and applying them in a consistent way to the planning solution.

4.2 Uncertainty in predictions

We have estimated unknowns that may affect water consumption forecasts through applying uncertainties and scenarios around the baseline forecasts. We have estimated uncertainties due to the data uncertainty and unexplained variability, and applied these across the forecasts such that they grow in a gradual way over time. For unknowns in future projections we have used scenarios to estimate the future variability. We created scenarios that include future variations in population, Brexit impacts, COVID-19 impacts, MOSL data quality, climate change and water efficiency. These are all explained in section 2.4.

The result is some significant uncertainty around the future projections of non-household consumption. For example, at WRSE level, the results show an uncertainty (including the scenarios) in the starting point of the forecast of approximately +22% and -35%, with these increasing to approximately +58% and -39% by 2100.

The forecasts start from a base year of 2019-20 and some of the early uncertainty will be due to Covid-19 impacts. Within the baseline models Covid-19 causes a decline in the GVA forecast from Oxford Economics in 2020/21, then a return to normal, however we have shown in section 2.4.2 that the effect on Covid-19 on demand is likely to be larger than this and so a larger adjustment for Covid-19 is made in the scenario forecasts.

The scenarios are produced independently to the baseline forecast. The baseline just takes into account the future trend in the explanatory factors. The scenarios allow us to that include future variations in population, Brexit impacts, COVID-19 impacts, MOSL data quality, climate change and water efficiency (these are all explained in detail in section 2.4).

The central scenario is not intended to be the same as the baseline, but should be similar, generally the baseline is slightly below central, and above the lower scenario. The baseline forecast is the outcome of the timeseries linear modelling as described in best practice and section 2, it is a prediction based just on the relationship between economic variables and the historic consumption. The central, and the upper and lower scenarios have additional data and assumptions behind them. Central is the 50th percentile of all of the 729 different combinations of assumptions around Covid-19, Brexit, water efficiency, climate change, population change and impact of MOSL data. The upper scenario is the 90th percentile and the lower is the 10th percentile. Uncertainties have been provided around each of the scenarios which have been based on modelling and data errors that are propagated through the forecasts and scenarios.

Therefore, companies may consider selecting a forecast which differs slightly from the baseline, but within the scenario ranges, depending on their own local knowledge and approach to risk.

4.3 Data issues

As anticipated in the review stage (section 1.4.1) we found a range of data issues whilst carrying out the work. These are discussed below.

4.3.1 MOSL data

The quality of the MOSL data had a direct impact on the quality of the forecasts. We found some significant step changes in consumption in the years since 2017, in the aggregate consumption data and in annual reported data. Most of these step changes are downward, although for some WRZs they are in the other direction.

Figure 38 to Figure 40 show examples of big swings in reported non-household consumption following 2016 for 3 WRZs from 3 different companies. In all cases the step changes in a single year are greater than observed in the historic company reported data. MOSL reported data is in pink. In the first example the change is about 28% in one year, in the second two the change is about 11%. As the forecasts are rebased to the annual reported consumption in the based year (2019-20), the accuracy of this data is important.

Figure 38 Example (Thames-SWOX) step change in reported non-household consumption post 2016

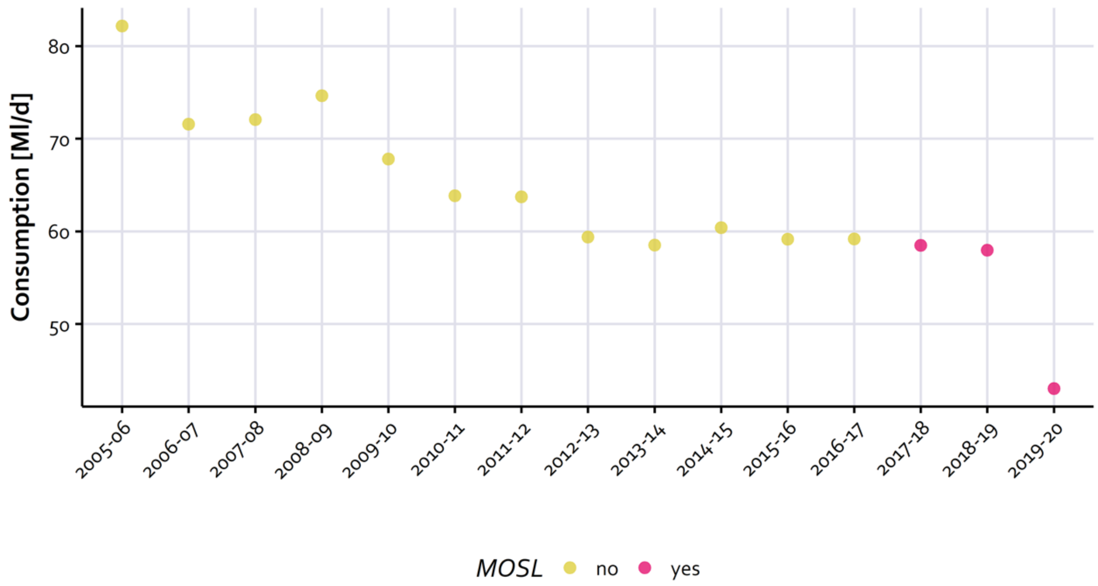


Figure 39 Example (SES Water) step change in reported non-household consumption post 2016

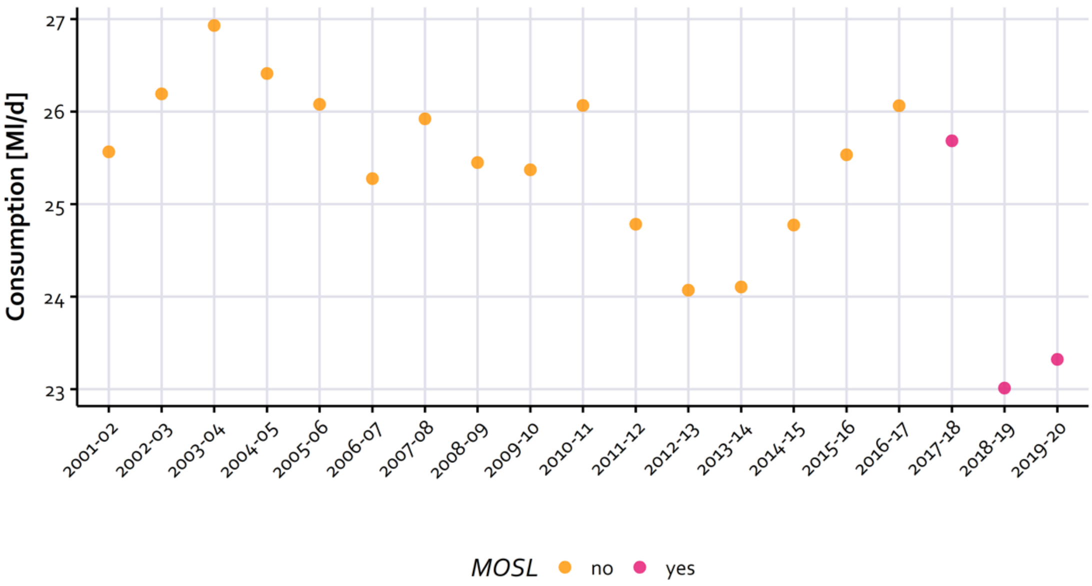
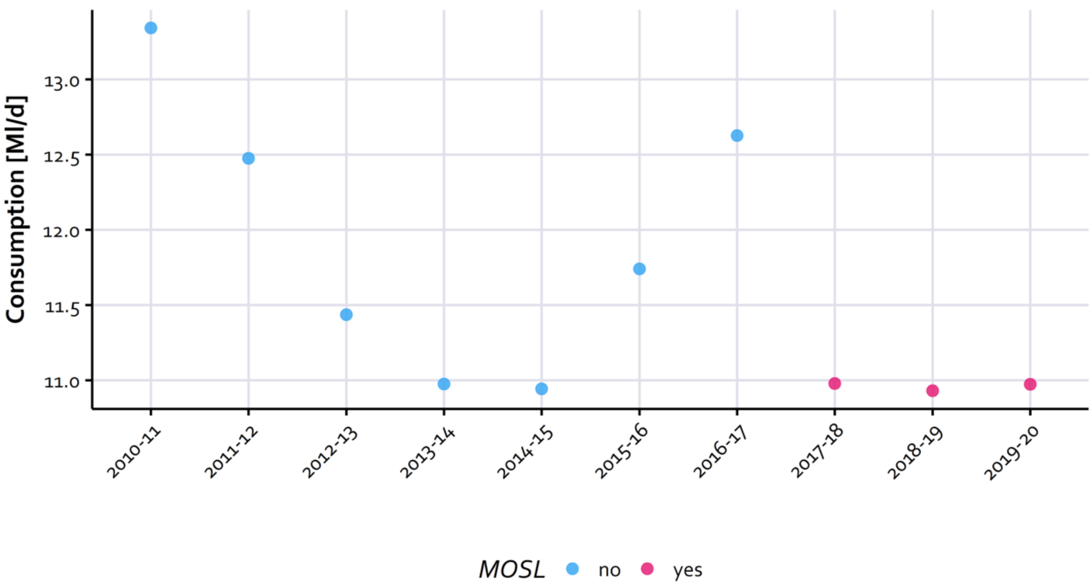


Figure 40 Example (SEW-Maidstone) step change in reported non-household consumption post 2016



We have dealt with the uncertainty about the data since 2017 in two ways. Firstly, we added a flag to the model to indicate the MOSL data, which allows the models to take into account any step changes resulting from the transition of retail separation.

Secondly, it would be useful to understand better whether the changes in the annual return aggregated property level data from MOSL are a long-term change or a short-term result of data issues during retail separation. MOSL's report for 2019-20 identifies that there are specific problems with long term un-read meters and high numbers of vacant properties (some with high consumption values)[15]. Therefore, we have included three future scenarios, one where the data improves, one where it deteriorates and one where it stays as it is currently.

For future forecasts, we need to consider further whether can we make better adjustments for the effects from retail separation, and consider if this is the new normal (e.g. due to the redefinition of NHHs to HHs) or is it due to erroneous data, that will eventually be resolved. It might be useful to flag to MOSL, Ofwat and the Environment Agency the significance of these data errors.

4.3.2 Matching pre and post MOSL data

Another factor that impacts the modelling in data post MOSL is the standard industry classification data. Data is often presented as a mix of SIC_1980, SIC_1992, SIC_2003 and SIC_2007 and often the SIC codes presented cannot be matched accurately to the correct SIC classification. Improvements in this area of data quality would help modelling.

Some companies have better matching of properties and industry classifications pre and post MOSL. This definitely helps build better models as there is a more consistent set of time series data for modelling.

4.3.3 Property level consumption data

Not all companies were able to provide property level consumption data (sometimes it was provided already aggregated to industry code level).

Having property level consumption data improves the identification of large users and voids, it improves consistency of data and allows for better quality checks on the data; all of which will improve the model results. It would be better to have a consistent smaller set of properties that are representative of an area, than try and reduce the overall size of the unclassified group.

For example, the Affinity Water data set had lower coverage than some, but the data was very consistent and tidy over time and provides a good coverage of industry types. This means that the variation that we observe is genuine and can be modelled better.

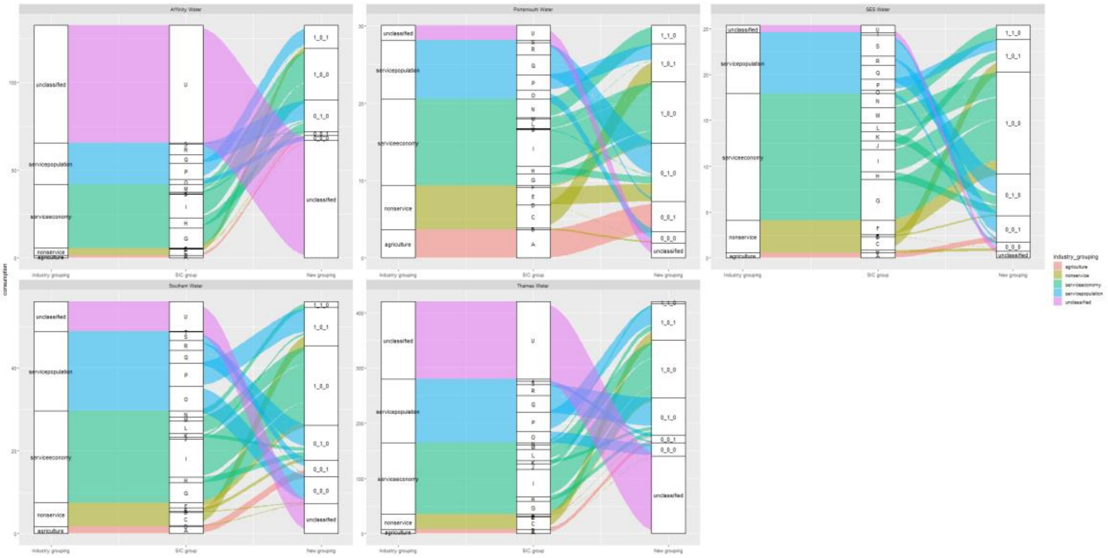
4.4 Industrial sector segments

Through analysing all the non-household data in the WRSE region we found that the industry grouping recommended in the earlier review (section 1.4.1), whilst logical, is probably too coarse and is masking some of the genuine relationships. This is based on what the data is telling us.

When we examined the 19 SIC divisions and how they mapped onto the 5 industry groupings we find that in some groupings there are competing trends, i.e. some are increasing and some decreasing. This is also true for some of the explanatory factor data (GVA and employment) which was also provided at the 19 SIC division level.

We did some analysis starting with the 19 SIC divisions and looked at grouping these together so that explanatory factors have coefficients that are in the intended direction and are significant in the modelling. Preliminary results of this are shown in Figure 41.

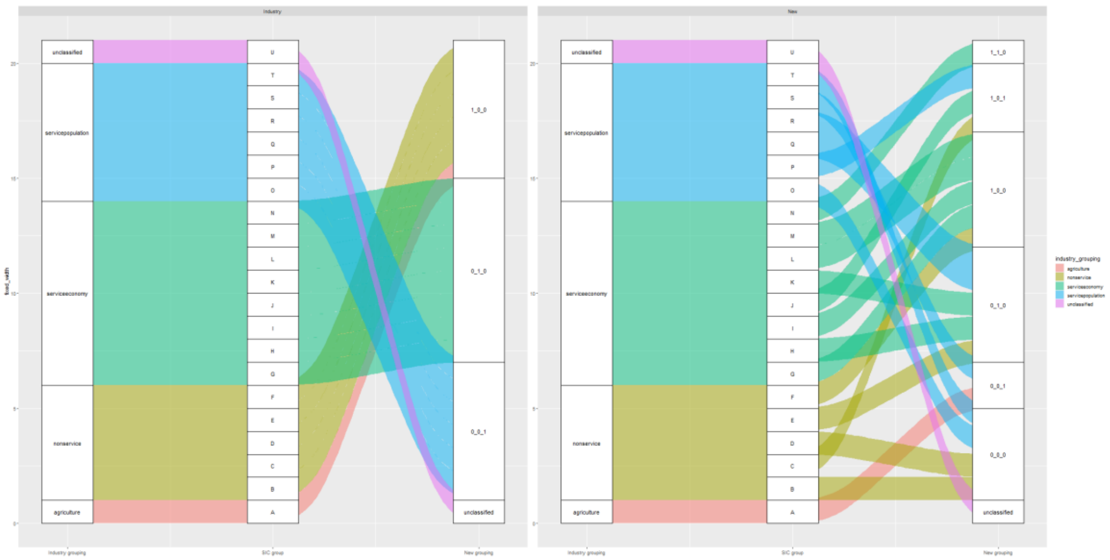
Figure 41 Exploring alternative industry groupings for each company



In Figure 41 we show the impact of grouping the SIC divisions so that the explanatory factor coefficients are in the correct direction and significant (new groupings on the right hand side of each figure), and then show this against the original industry grouping on the left side of the figure.

The groupings vary across the companies, but there is some consistency, and a version of this process for the whole region is shown in Figure 42, with the existing grouping on the left and the alternate grouping on the right.

Figure 42 Exploring alternative industry groupings for the region



This may be worth exploring further by taking the best and most consistent quality data from across the region to provide a single data set.

We also found that there were other significant explanatory factors, in addition to the econometric GVA and employment factors. We introduced a population density factor in the

Southern Water model (which had a positive impact), and it is likely that there are other factors that would improve models further.

4.5 Weather

The outputs from this modelling are raw un-normalised forecasts of non-household demand, calibrated to the reported values for AR 2019/20. This is in line with the scope of the project. The Water Resource Planning guidance does not specifically require companies to apply weather factors to non-household demand. The preliminary review of non-household forecasting carried out by WRSE states that "Companies should include weather variables for those industries and/or areas where this can be shown to be a significant factor in modelling non-household consumption".

Companies wishing to derive and apply NY (normal year) or DY (dry year) factors to the non-household demand forecasts derived in this project should consider the relative size of the weather driven non-household demand (i.e. from the agricultural sector) in their region and individual WRZs, compared to other non-household and total demand. They should also take into account the quality of the data for deriving these factors.

4.6 Other improvements

There is clearly an impact on the forecasts from the quality of the data. There should be further work to help water companies improve the quality the data they use for forecasts. It might be more cost effective to do this as a regional group, rather than individually.

The current best practice (developed in 1997) suggests the econometric approach and this has been applied quite consistently by individual companies over the past few WRMPs. However, looking at the data from the WRSE companies across the region shows that some of these relationships are quite weak and there might be alternative forecasting techniques that might be better given the quality constraints on some of the data. WRSE (or all the regions) should consider whether it is worth carrying out some wider industry research to evaluate alternate methods for modelling and forecasting.

Another option worth considering is a greater level of aggregation within the WRSE region. In this study we have modelled each company consistently, but independently. We have seen that there are limitations in the data, and it might be possible to look at all the WRZs across the region and group together WRZs based on how their non-household consumption behaves (as opposed to a company geographical boundary). This may allow more data to be pooled, and when combined with a more sophisticated approach to grouping industrial sectors (section 4.4), this may result in stronger models being developed.

5 Conclusions

We have produced a set of non-household demand forecasts for all 37 water resource zones in the WRSE region from 2019-2020 out to 2099-2100. These are presented for metered and unmetered properties at company level, water resource zone level and dis-aggregated by industrial sector.

The approach used follows existing industry best practice, taking into account the recommendations from a review of non-household demand forecasting methods carried out by WRSE in early 2020. Robust multiple linear models have been produced for 4 cohorts of industrial sectors for each company in WRSE, using explanatory factors that include population, gross value-added metrics, employment rates, population density and other factors.

Since the last set of non-household forecasts were completed for WRMP19, the non-household retail sector has undergone a transformation with the introduction of retail competition. A significant impact from this is that metered non-household consumption data is now the responsibility new retailers, managed by the new Market Operator Services Ltd (MOSL). We have observed a change in data quality and consistency since the change in 2017. This has complicated the modelling (which relies on a consistent set of time series data) and has increased the uncertainty around the demand forecasts. This has been taken into account in the models, uncertainty and scenario estimates.

The first year of the forecast (2020) has seen an unprecedented change in non-household demand due to the policies introduced to combat the COVID-19 pandemic. This increases uncertainty going forward as we still do not fully understand what the enduring impacts will be from changes in working practices, such as increased working from home. Therefore, we have included the COVID-19 impact in the scenarios and uncertainty estimates.

The sector also faces a number of future unknowns in demand from non-households, such as population change, Brexit, climate change and how water efficiency will be delivered in the non-household sector. Therefore, these have also been included in the scenario and uncertainty modelling.

The overall conclusion is that non-household demand in the WRSE region at the start of the planning period (2025), is predicted to be 921 Ml/d within an overall range of 594 to 1121 Ml/d. This is predicted to increase by the end of the planning period (2100) to 1032 Ml/d (an increase of 111 Ml/d) within a range of 630 Ml/d to 1637 Ml/d.

We have also made a prediction of the amount of non-public water supply (non-PWS) demand in the WRSE region and how this might change over the planning period. The non-PWS demand includes all existing abstractions used for non-household demand plus any new authorisations since February 2019. This is broken down by sector and water resource zone. Overall for the WRSE region, the current estimate of non-PWS non-household demand of 183 Ml/d in 2019-20 is predicted to increase to 218 Ml/d by 2050. Due to the uncertainty in the data we have held the forecast flat for the remainder of the planning period.

We have identified a number of improvements that could be implemented for future forecasts, and these are included in the recommendations.

6 Recommendations

Companies in WRSE should use the baseline and scenario forecasts presented in this report to select an initial WRMP baseline forecast for the metered and unmetered non-household demand forecast lines in the Environment Agency's water resource planning tables.

We have presented the forecasts from a base year of 2019-20. The intermediate years 2020-21 through to 2024-25 are presented for information prior to the start of the planning period in 2025-26. These intermediate years are potentially volatile with a number of unknowns around the impact of the COVID-19 pandemic and the impact from Brexit on non-household consumption. Therefore we recommend that the baseline and scenario forecasts are updated prior to the submission of the final water resource management plans.

For the first time we have presented an initial view of non-PWS forecasts. We suggest these should be used as an upper limit for the amount of non-PWS demand that could switch to PWS under drought conditions.

During the course of the work to develop the non-household demand forecasts we have identified a number of potential improvements to achieve more accurate forecasts. These are set out below.

WRSE should inform MOSL of the importance of getting consistent good quality data on non-household consumption for forecasts. MOSL's report for 2019-20 identifies that there are specific problems with long term un-read meters and high numbers of vacant properties. These have caused some volatility in the consumption data since the introduction of market reform, which have impact on the robustness of future forecasts.

The ability to allocate non-households to specific industry sectors through tools such as SIC or AddressBase Premium also aids the robustness of forecasts. Across the WRSE there is quite a bit of variability in the proportion of properties that need to be placed in the "unclassified" sector due to the quality, quantity or availability of non-household sector classifications. Companies in WRSE should investigate the most efficient way of improving this information for future forecasts. Note, it is important that there is good quality and consistency of data over time for a good coverage of industry types, which in turn means that the variation that we observe is genuine and can be modelled better.

WRSE should consider investigating different industrial sector groupings than those selected for use in this study. We have done some preliminary analysis that shows there are potentially better sector groupings that could improve the quality of the model outputs.

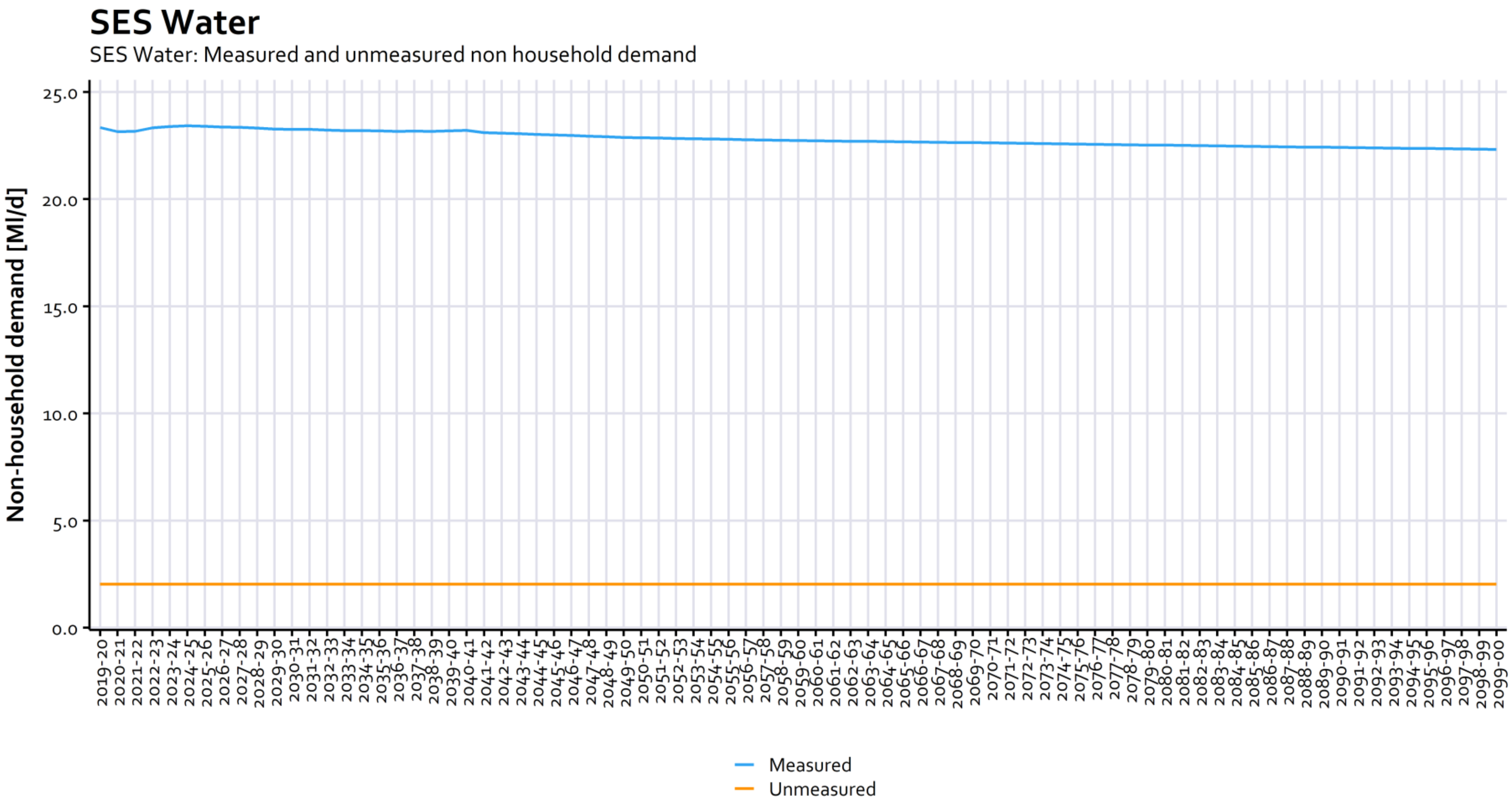
The consistency of approach and method across the WRZ's in WRSE is beneficial. As well as looking at improved sector groupings, we recommend investigating the grouping of WRZs based on how their non-household consumption behaves (as opposed to a company geographical boundary). This may help to overcome some of the data limitations.

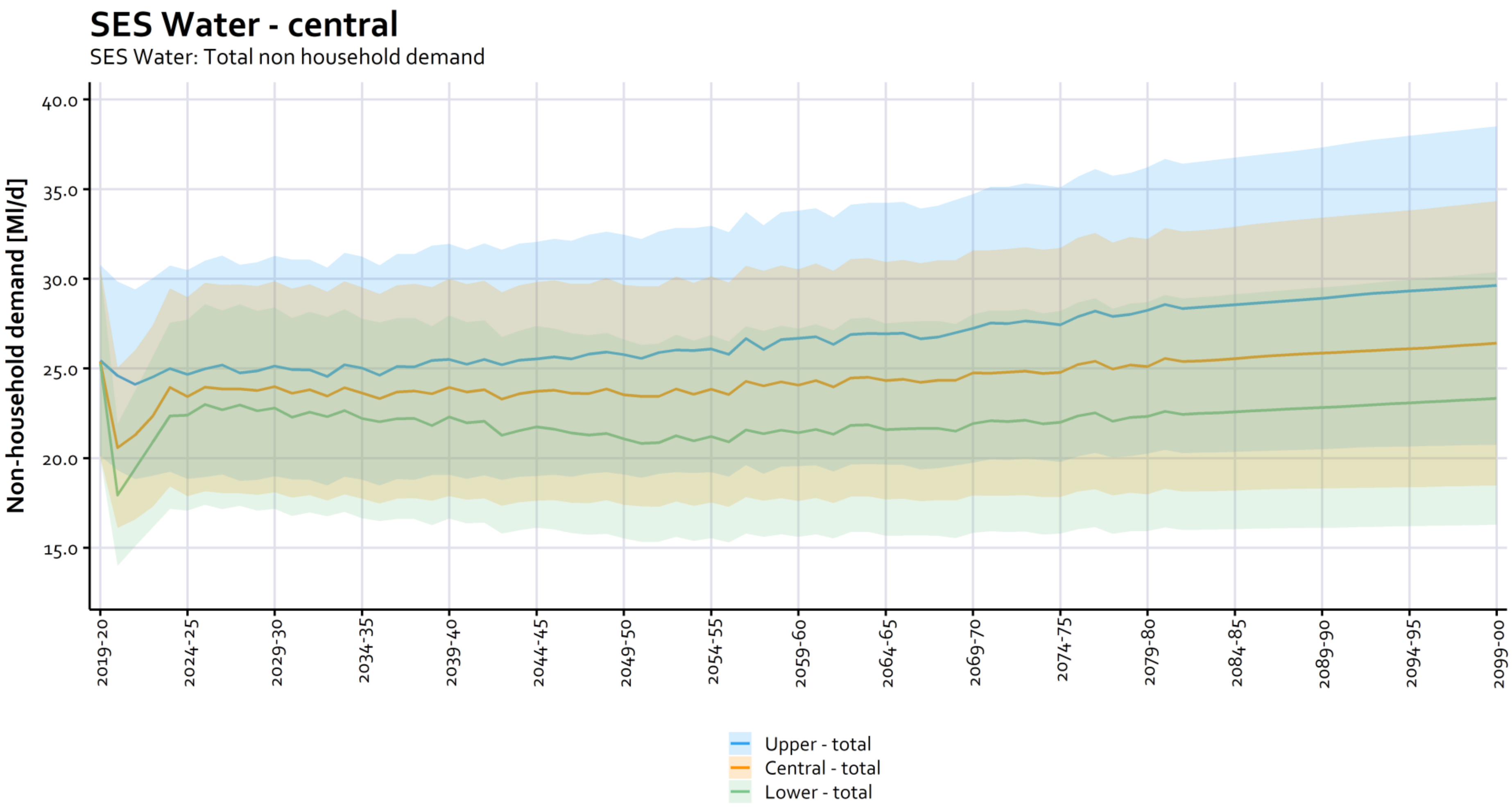
The forecast modelling in this study has been carried out using a functional programming approach that allows forecasts to be run and evaluated more efficiently. This approach allows forecasts to be produced more frequently, potentially sub-annually, as data is updated. A more continuous forecasting approach would remove the step-like transitions between AMP forecasts and could improve the robustness of the forecasts. The functional approach would also allow for different sectors grouping or WRZ grouping to be applied quickly and efficiently.

Appendix A: SES Water modelling results

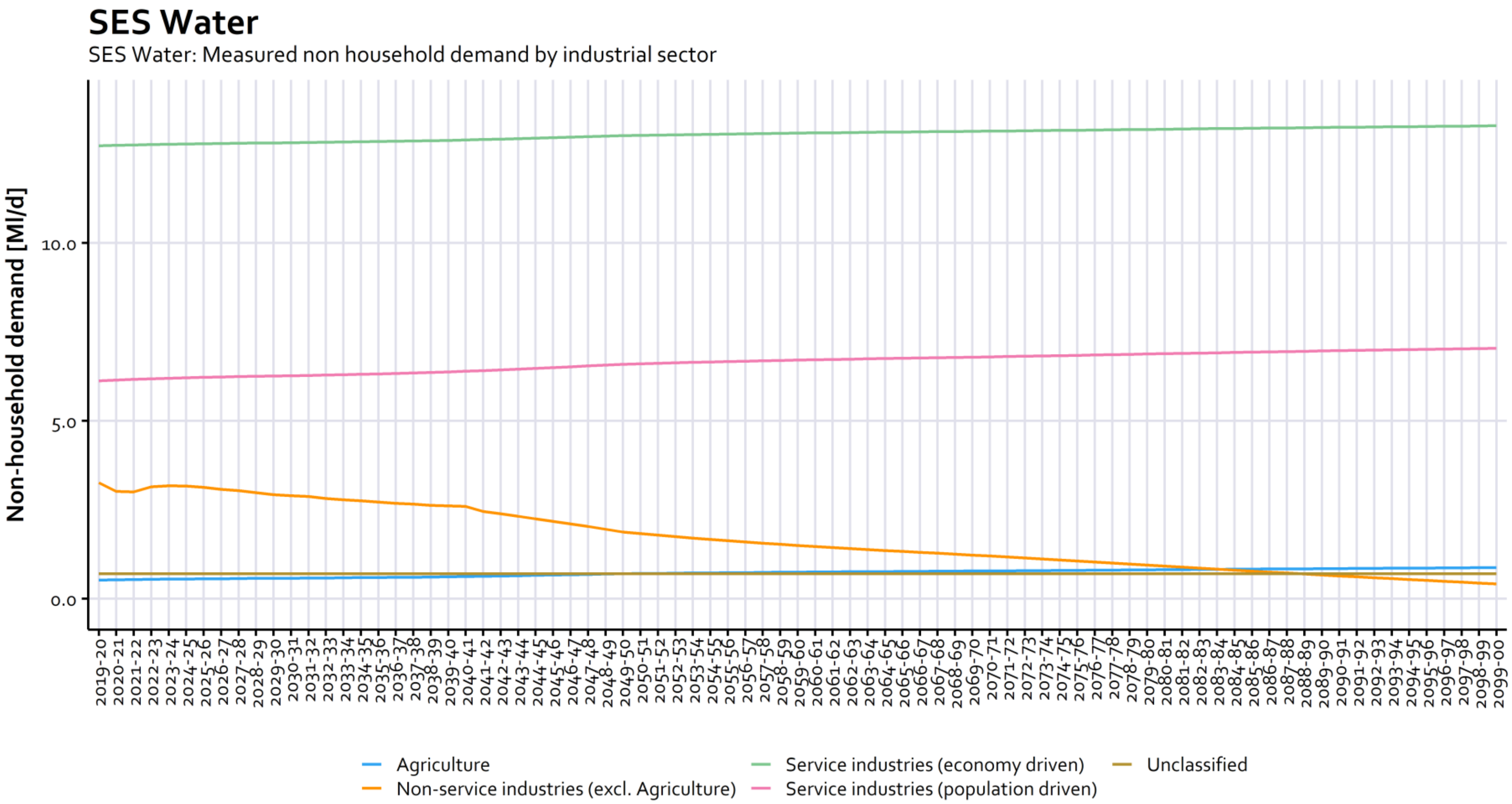
Note this appendix is presented in landscape format to improve the presentation of the graphs. Firstly we present the WRZ graphs for metered and unmetered NHH consumption, along with the scenario graphs. The we present the sector graphs for each WRZ. Then we present the MLR (multi linear regression model metrics for each section to identify the drivers for the forecast in each zone. Then we present the calibration factors for each WRZ and sector. A full set of graphs and tabulated sets of yearly forecasts for PWS and non-PWS demand are hosted on the WRSE SharePoint site.

Overview of WRZ results




SES Water - central
SES Water: Total non household demand
Non-household demand [Ml/d]
40.0
35.0
30.0
25.0
20.0
15.0
2019-20
2024-25
2029-30
2034-35
2039-40
2044-45
2049-50
2054-55
2059-60
2064-65
2069-70
2074-75
2079-80
2084-85
2089-90
2094-95
2099-00
Upper - total
Central - total
Lower - total

WRZ industry sector results



MLR modelling

Note:

- Years 2018-19 and 2019-20 in AR are significantly lower than previous years. This impacted the forecasts.
- The Unclassified sector has been forecasted as constant, keeping the base year value steady.
- There is slight growth in the SES region from the service sectors, with the non-service sector reducing across the planning period. About 3% of the demand in the SES region falls into the unclassified group

The result in the case of SES Water NHH consumption MLR model is reported in the following tables.

MLR model summary for the industry group "agriculture"

term	estimate	std.error	p.value
(Intercept)	-0.039	0.11	0.7199
population	0.0000017	0.00000018	0
london	-10.717	1.24	0

MLR model summary for the industry group "nonservice"

term	estimate	std.error	p.value
(Intercept)	-9.61	7.8	0.2221
employment	0.015	0.012	0.2107
population	0.0000047	0.0000011	0
london	-12.816	8.65	0.1429

MLR model summary for the industry group "serviceeconomy"

term	estimate	std.error	p.value
(Intercept)	2.24	0.82	0.0076
population	0.0000026	0.0000014	0.0621
london	78.902	9.49	0

MLR model summary for the industry group "servicepopulation"

term	estimate	std.error	p.value
(Intercept)	2.72	0.75	0.0005
population	0.0000043	0.0000013	0.0011
london	51.368	8.67	0

Calibration

The calibration factors for SES Water are reported below.

Calibration factors for the considered WRZs.

wrz	industry_grouping	factor1	factor2
Company	agriculture	-0.580	0.920
Company	nonservice	-1.062	0.920
Company	serviceeconomy	9.709	0.920
Company	servicepopulation	0.860	0.920
Company	unclassified	-5.648	0.920