Proposed approach to estimating UIG from volume conversion assuming a fixed temperature

Tony Perchard, November 2019

1 BACKGROUND

UIG is calculated as an energy value. However, the gas consumed at supply points is measured as a volume and then converted to energy. For some larger sites, volume conversion devices are fitted to the meter which record the actual conditions (pressure, temperature and sometimes composition) of the gas. This allows an accurate conversion of the measured volume to energy under standard conditions. Overall, based on data provided by the CDSP, approximately 18% of total throughput energy is recorded by meters with a volume conversion device[1]. For the remaining meters, a number of assumptions are used in order to perform the volume to energy conversion. These assumptions lead to UIG.

The AUGE has previously assessed this issue and findings were reported in the 'Final Allocation of Unidentified Gas Statement for 2019/20'[1]. The previous analysis showed that the effect of temperature is significant and will vary based on geographical location and by time of year. At that time, the AUGE's opinion was there was too much uncertainty in the available gas temperature data to justify a change from the current assumption of an average gas temperature of 12.2C.

Based on additional data which is now available, the AUGE is reviewing the impact of temperature on UIG. The new information may allow the estimation of the UIG resulting from using a fixed temperature of 12.2C and a corresponding update to the methodology for calculating UIG factors.

This document is an update to industry parties on progress of the temperature analysis to allow for an initial review and feedback prior to publication of the proposed AUGS. It provides a summary of the data sources used, the results of some initial analysis and the current proposed approach.

2 DATA SOURCES

The following sections provide an overview of the data on which the AUGE is basing its analysis.

2.1 Domestic Meter Temperature Study (DMTS)

The Domestic Meter Temperature Study (DMTS) was carried out by BG Technology (formerly the research division of BG plc, rebranded to Advantica, subsequently acquired by National Grid and then sold to Germanischer Lloyd and merged with DNV to become DNV GL) and was designed to estimate the temperature of the gas that a domestic meter experiences during typical operation. The study was to support Transco in calculating LDZ level shrinkage factors. The DMTS was a multi-year project with an initial report in June 1999[2] and then a final report in August 2000[3]. Unfortunately, the AUGE is not able to locate the raw data collected. We are therefore reliant upon the information contained within the reports.

In total, 5,900 electronic gas meters with internal temperature sensors were fitted in homes as randomly as possible between LDZs and meter locations. The meters provided corrected and uncorrected reads which were used to calculate the Flow Weighted Average Temperature (FWAT) of the gas over the interval of the reads. For each installation a pro forma survey form was completed giving information on the location of the meter and other details such as the type/size of the property and the gas appliances installed.

Meters were installed across the country from late 1997 to mid-1998. The meters were then read in April 1999. On average, these meter reads covered a period of 15 months. The intention was to read the meters again in April 2000, but delays resulted in most meters being read in May 2000 such that the period covered was ~13 months. There are therefore 3 sets of temperature data which could be used

- The 1999 Data – valid reads taken in 1999 providing a FWAT over the first year only (15 months on average). There were a total of 3,998 valid reads across all meter locations (1,249 internal meters, 2,420 external meters and 329 meters in unheated locations)
- The 2000 Data – valid reads taken in 2000 providing a FWAT over the whole 2 year period (28 months on average). This data is referred to in the DMTS as the "2000 Data after Survey Form Analysis". There were a total of 3,900 valid reads (1,425 for internal meters and 2,475 for external meters)
- The 1999-2000 Common Set – valid reads taken in 1999 and 2000 providing a FWAT over the second year only (13 months on average). There were a total of 3,083 valid reads (1,022 for internal meters and 2,061 for external meters)

During the first year of the study, analysis was broken down by 3 meter locations, namely internal, external and internal unheated (meters in unheated spaces such as a garage). The analysis in the final report[3] was based only on an internal/external meter location split (the previous unheated category being included in internal meters). The report does not explicitly state why this change was made but does make reference to the uncertainty in the meter location between internal and internal unheated categories. This may be one reason for removing the internal unheated category. The internal unheated category is also more sparsely populated, having only 329 meters with valid reads (8% of the 3,998 total).

As part of the DMTS, an analysis of meter temperature sensor accuracy was carried out. As a result, temperature corrections were applied differently during the final analysis. The AUGE therefore believes that although the results reported in the initial report[2] are useful, the results from the final analysis[3] should be used in preference. One potential use for the initial analysis results[2] is to understand the temperatures in meters located in unheated spaces.

A number of consistency checks carried out during the final analysis highlighted some discrepancies for meters which had been read in both 1999 and 2000 leading to additional meters being removed as invalid. The AUGE therefore believes that the most reliable dataset is the "1999-2000 Common Set". Unfortunately, this dataset has the smallest sample sizes.

Initially it was hoped that the DMTS would allow the estimation of gas temperature for each meter location (internal or external) by LDZ to an accuracy of +/-0.5C with 95% confidence. This was achieved in the case of external meters but not for internal meters in all LDZs (only achieved in 2 LDZs). This is in part because the internal temperatures are more variable, but also because only a small sample of internal meters was available in some LDZs. The DMTS notes the greater difficulty of access for internal meters.

2.2 I&C Temperature Study (ICTS)

In order to estimate the LDZ shrinkage resulting from the assumption of a fixed temperature value for volume conversion, Transco procured a study from XKO and Advantica Ltd (BG Technology, the research division of BG plc was rebranded to Advantica, subsequently acquired by National Grid and then sold to

Germanischer Lloyd and merged with DNV to become DNV GL). This work involved taking data from approximately 7,500 daily read metering sites that use volume conversion devices over a four year period (gas years 1996 to 1999). Using the converted and unconverted meter reads, it was possible to calculate the flow weighted gas temperatures. The AUGE is not able to locate the raw data from the original study, but summary results are provided in "The derivation of LDZ gas temperatures for the period 1996-2000"[4].

The Flow Weighted Average Temperature (FWAT) calculated from all meters was "un-flow weighted" using the appropriate consumption data. This Unweighted Average Temperature (UAT) was then "flow-weighted" using the appropriate consumption data for domestic properties (presumably 01B) to obtain an estimate of domestic temperatures which was compared with the earlier DMTS work. The ICTS provides FWAT data based on the following groups

- DM
- Large I&C
- Small I&C
- Domestic (derived from I&C data)

At the time of this study, the CDSP believes there were ~2,000 DM sites. The data for the I&C groups (small + large) is therefore based on a sample size of ~5,500 meters. The CDSP believes that these will be NDM sample sites.

Unfortunately, this study provides no information on meter location. The resulting temperatures therefore represent the sample split of meter locations and may not be representative of the overall population split of meter locations.

2.3 Other Data Sources

The following sections give a brief overview of other sources of data being considered by the AUGE.

2.3.1 Air Temperature

The CDSP have provided the AUGE with historic actual hourly air temperature by weather station for the period 1996-2000 to align with the DMTS and ICTS work. This is based on the weather stations in use at that time. The AUGE may use this data to

- assess the relationship between gas temperature in the meter and LDZ temperature
- allow the correction of the DMTS temperatures to annual FWATs (requires consumption data also)
- allow the measured gas temperatures in the meter for a specific historic year to be converted to Seasonal Normal (SN) conditions

2.3.2 Historic Consumption

The available information on gas temperature in the meter spans the period 1996-2000 (gas years). This data is flow weighted based on the consumption at the time. If consumption patterns have changed it may be necessary to adjust the temperatures to account for this.

In the case of the DMTS, temperatures were measured over a period of more than a year. The FWAT will not therefore represent a true annual FWAT. Using historic consumption together with historic temperatures an assessment can be made regarding the need for a correction.

The AUGE is in discussions with the CDSP to determine the best source of data for this.

2.3.3 Ground Temperature

Soil temperature data are collected and archived by the UK Met Office at several hundred weather stations and are made available for academic purposes via the British Atmospheric Data Centre (http://badc.nerc.ac.uk/home). The data are recorded at 09:00 each day at depths of 5, 10, 20, 30, 50 and 100 cm.

Ground temperatures are highly correlated with air temperatures and relationships exist which can calculate one from the other given depth and assumptions about local soil composition. Ground temperatures are generally lagged compared to air temperatures and the values are damped giving a lower range.

The British Geological Society (BGS) have analysed soil temperatures from 106 Met Office weather stations, located across the UK[5]. Mean annual temperatures at 1m depth, reduced to sea level, were found to range from 12.7 °C in southern England to 8.8 °C in northern Scotland, with corresponding seasonal ranges in temperature of 10.3 °C and 7.9 °C respectively.

BGS also reported[5] an average Urban Heat Island (UHI) effect at 1 m depth of 0.55°C at localities adjacent to urban green spaces. They go on to suggest that the UHI effect will be greater in densely developed city and town centres.

A key conclusion of the BGS analysis is that on average (across 12 UK locations), mean annual soil temperatures at 1m depth are 0.9 °C higher than mean annual air temperatures.

The CDSP have confirmed that they do not currently have ground temperature data. The AUGE would therefore need to purchase ground temperatures if required. At this stage, the AUGE sees no benefit in obtaining ground temperatures given we already have gas temperatures measured at the meter.

2.3.4 Internal Temperatures

It has been reported that the gas temperature within internally located meters is significantly affected by the temperature in the immediate vicinity of the meter. In fact, a study by KIWA noted that "It follows that the temperature of the gas in the gas meter is almost exclusively determined by the temperature in the room where the meter is installed"[8]. It is therefore important to gain an understanding of the likely temperatures to be experienced by internally located gas meters.

The AUGE has identified two reports relating to internal domestic temperatures[6][7]. To date, no equivalent information for I&C sites has been identified.

The AUGE issued an industry data request regarding internal temperature data in the hope that data collected from building energy management systems may be available. This request can be found on the JoT website (http://www.gasgovernance.co.uk/augenex/2021).

From the reports on internal domestic temperatures, the key findings are

- Variability between homes was large (see Figure below) from Energy & Buildings report[6] which shows temperatures from a sample of 248 homes.
- There has been little or no increase in living room temperatures during winter and spring over the last 40 years[7].

- There has been an increase in average bedroom temperatures during winter and spring over the last 40 years, probably due to growth in central heating ownership, together with reductions in whole-house heat loss[7].

As internal meters are likely to be located in rooms other than the main living room, they may be subject to the increase in temperature as a result of the growth in central heating and reduction in overall heat loss.

G.M. Huebner et al. / Energy and Buildings 66 (2013) 688–696

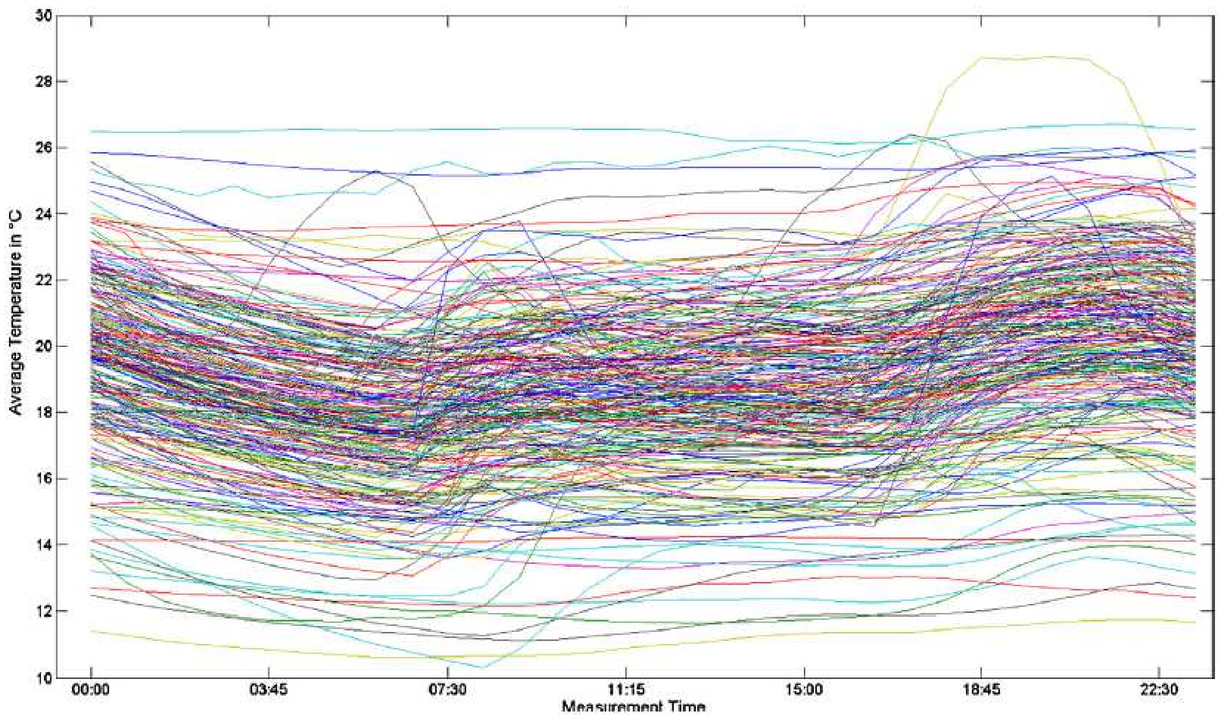


Fig. 2. The individual lines correspond to average weekday winter temperature data for the $N = 248$ individual homes.

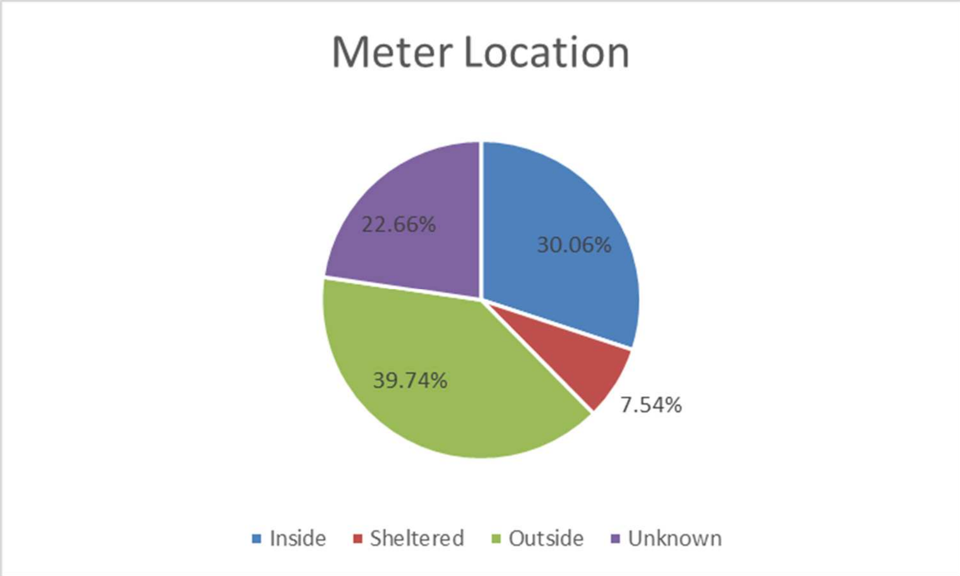
2.3.5 Meter Location

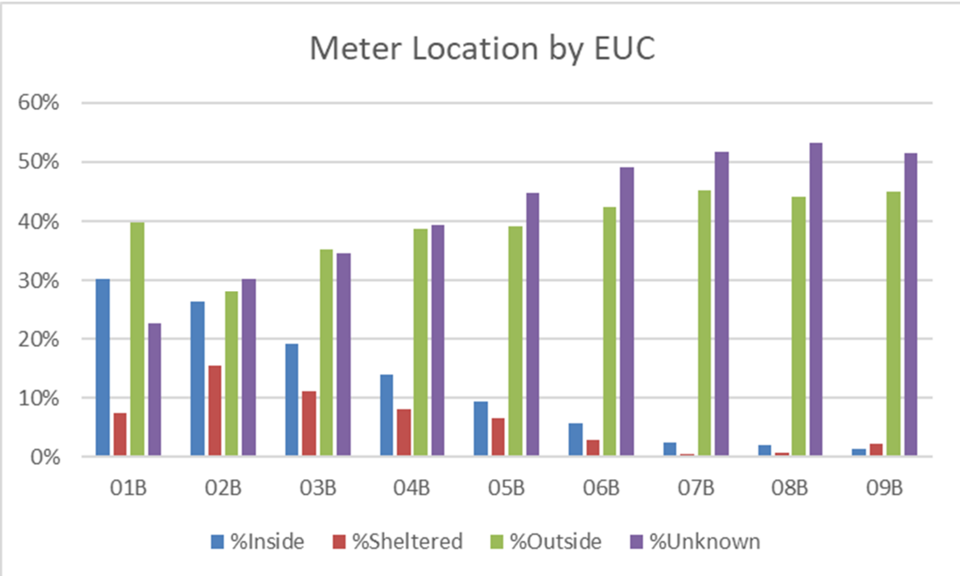
Meter location information has been provided by the CDSP. Location data is available for ~77% of all meters. The following charts show the split of meter locations in total and broken down by EUC respectively.

Given that ~23% of meters are in an unknown location, the AUGE proposes assuming the same split for the unknown meters as for the known population unless evidence is found suggesting the unknown meters are split differently for some reason.

There is also the possibility that meter locations vary by property type e.g. more internal meters in flats. This would mean that the internal/external split from a consumption viewpoint would be different than the split based on meter numbers. No information is currently available on this.

The AUGE would like to see a push from the industry to improve the recording of meter location information.



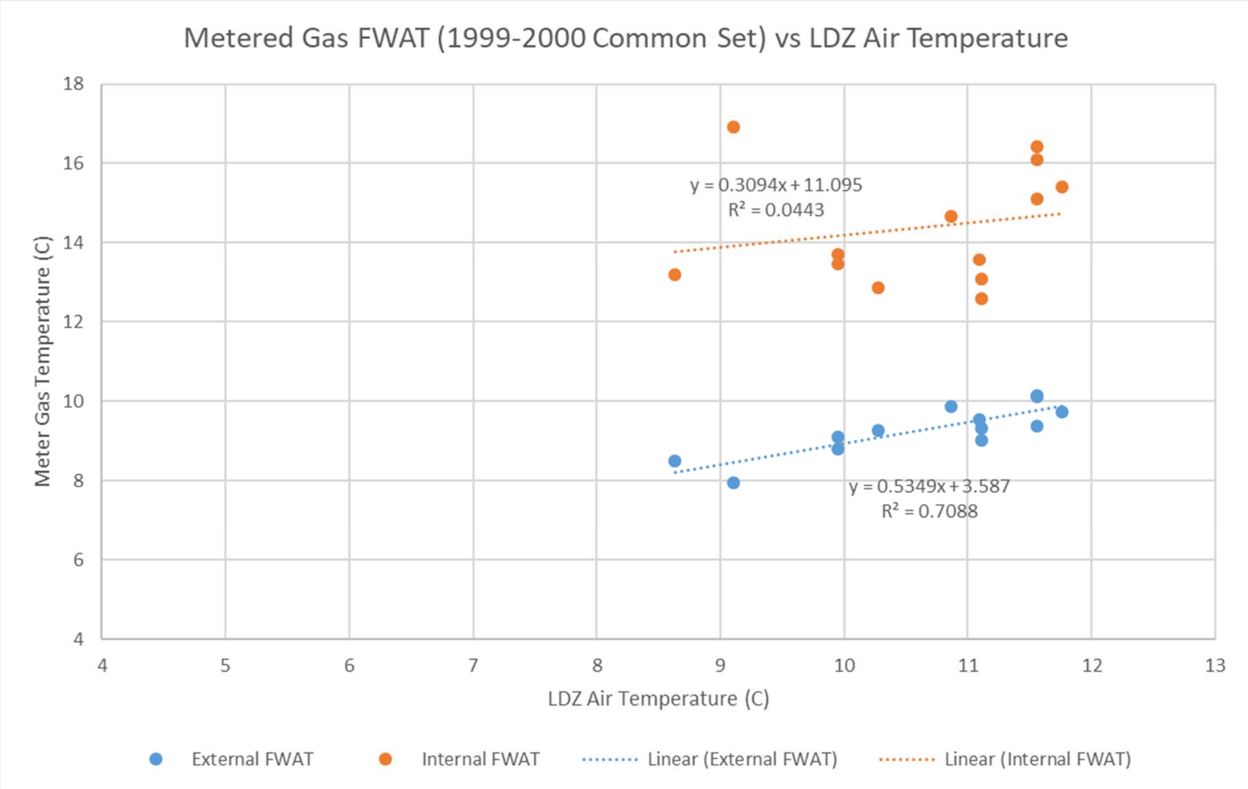


3 INITIAL ANALYSIS

Some initial analysis was carried out around the two main meter temperature datasets

- The DMTS 1999-2000 Common data
- The ICTS

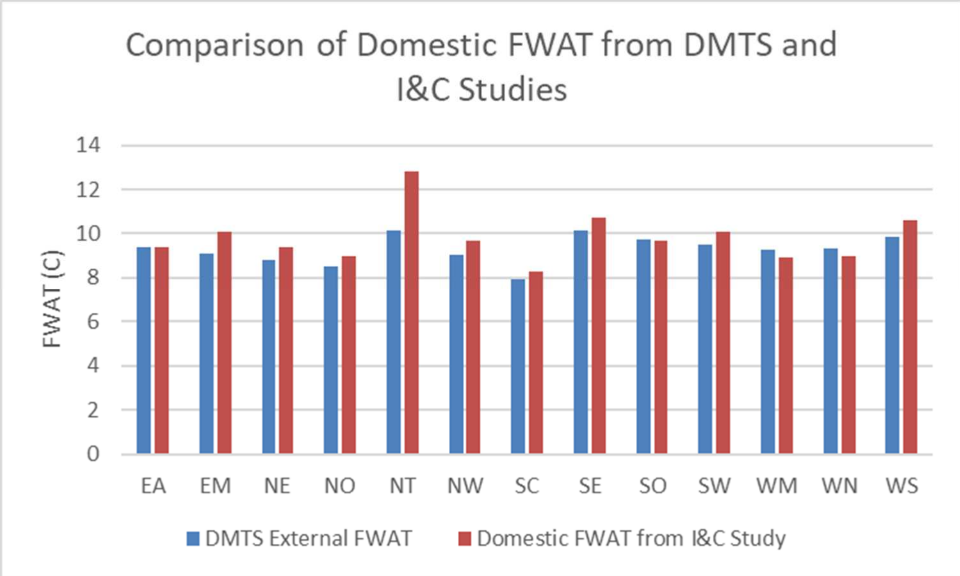
Hourly LDZ air temperatures were sourced via the CDSP for the period 1996-2000. This data was based on the weather stations used at the time and the relevant mapping to LDZs. From this data, average daily temperatures for each LDZ were calculated (simple averages, not flow weighted averages). These air temperatures were then compared to the DMTS temperatures for internal and external meters over the same time period (1 April 1999 – 30 April 2000). The results are shown below with each data point representing an LDZ.



Note the high level of correlation between the gas temperatures in external meters compared to LDZ air temperature shown in blue (r^2=0.7088). However, the gas temperature for internally located meters shows a very poor correlation with LDZ air temperature as shown in orange (r^2=0.0443). This is consistent with the conclusions of other studies[8] which found that the gas temperature of internally located domestic meters is primarily driven by the temperature in the vicinity of the meter. It is noted that the internal temperature appears anomalously high for 1 LDZ, but there is no reason to suspect that this is a data error. Excluding this data point improves the correlation for internal temperatures but it still only increases to r^2= 0.357.

Based on data from the initial DMTS report[2], gas temperature in meters located in unheated spaces was on average 2.6C warmer than gas temperature in external meters. However, this is based on a sample of just 329 meters in unheated spaces.

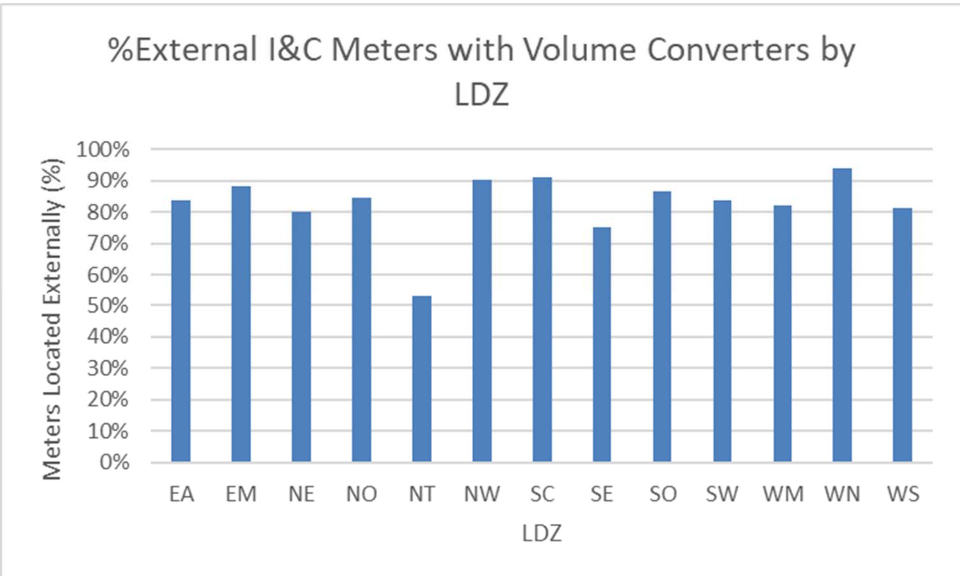
The ICTS derived an estimated domestic temperature based on the I&C temperatures in order to compare and sense check the results against the DMTS. The ICTS noted that the derived domestic temperatures are generally very close to the external meter temperatures from the DMTS. This is expected as a high proportion of the meters in the ICTS work are external (higher proportion of external meters in higher EUCs), especially when expressed in terms of consumption split. A comparison of the ICTS derived domestic temperatures and the DMTS external meter temperatures is shown below.



The average difference is -0.54C (DMTS temperatures are on average colder). This may be due to the following

- Different temperatures between the time periods used in the 2 studies
- The ICTS contains some internally located meters
- Random variations due to sampling

NT is a significant anomaly and is probably the result of a significant number of internally located I&C meters in this LDZ used in the I&C temperature study work. This theory is supported by looking at the locations of I&C Meters with volume converters currently shown below. NT clearly has a much lower proportion of external meters (in EUC02B and above with volume converters) than other LDZs. Excluding NT, the average temperature difference reduces to -0.36C.



This level of consistency between the 2 studies suggests that gas temperatures in external meters are relatively insensitive to the size of the meter (flow rate) and that it may be possible to use a single relationship between air/ground temperature and gas temperature for all EUCs.

Further work will look at the LDZ air temperature differences between the time periods used in the DMTS and ICTS as well as comparing these temperatures to Seasonal Normal.

4 PROPOSED APPROACH

The proposed approach consists of the following steps

1. For each EUC, estimate a Flow Weighted Average Seasonal Normal Gas Temperature (FWASNGT). This step is described in more detail in the following sections and will take into account meter locations as described.
2. For each EUC and Product Class (PC) combination (note that temperature varies by EUC only, not PC) calculate the Potential UIG based on the total AQ and the difference between the estimated FWASNGT and 12.2C.
3. For each EUC and PC estimate the Actual UIG by multiplying the Potential UIG by the proportion of AQ from meters without volume conversion devices.

Note that these calculations will all be by LDZ and will therefore allow for temperature and consumption variations between regions. The results will then be summed to get the National level UIG from temperature. This value will then be treated as a directly calculated component of UIG and added to other directly calculated sources. Note that if the temperature related UIG is positive, the Balancing Factor (BF) will reduce and vice versa.

The following sections detail the proposed approach for estimating the FWASNGT for each EUC. The level of data available means that FWASNGT is estimated for groups of EUC bands rather than by individual EUCs.

4.1 Domestic (01B)

It is proposed that temperatures from the DMTS are used for EUC group 01B. It was stated above that the AUGE currently believes the most appropriate dataset is the 1999-2000 Common Set. However, the AUGE plans to review this, comparing the 2000 Data (covering 28 months) and the 1999-2000 Common Set (covering 13 months). The decision will be based on the following considerations

- Sample size and therefore confidence in temperature estimate
- Error in estimate as a result of measuring FWAT over a period not an exact multiple of whole years
- Assessment of actual weather (air temperatures) over the measurement periods compared to Seasonal Normal (SN) conditions.

The AUGE will assess whether corrections are required to account for the following

- Adjust FWATs to a true 12 month average using 01B consumption profiles (the DMTS reported[2] that the difference in FWAT between 12 month and 15 month periods “would be no greater than 0.3C and usually considerably less.”)

- Adjust FWATs to current consumption profiles i.e. to account for any differences between 01B consumption in 1999/2000 compared to now
- Adjust 1999/2000 FWATs to current SN conditions
- Merge some LDZs where sample populations are low
- Use a single internal temperature across all LDZs

Having made any corrections deemed necessary, the Flow Weighted Average Seasonal Normal Gas Temperature (FWASNGT) will be calculated for each LDZ using the current split of 01B meters between internal (including unheated internal) and external located meters using a simple weighted average.

4.2 Small I&C (02B-03B)

There are two potential sources of temperature data for the small I&C meters.

Firstly, the DMTS data could be used as described for domestic meters above. The big assumption here is that internal I&C meters measure gas at similar temperatures to internal domestic meters.

The other potential source of data is the ICTS. The assumption in using this dataset is that the internal/external split of I&C meters is the same as the internal/external split of meters in the I&C study. The study makes no mention of meter location.

The fact that the observed temperatures for small I&C meters are very close to the external domestic temperatures suggests that most of the meters sampled are externally located. The exception to this is NT LDZ where the small I&C temperatures are significantly warmer than the external domestic meters. This is likely due to a significant number of small I&C sites with internally located meters in the sample for this LDZ (NT is known to have a larger proportion of internally located meters in EUCs 02-05).

The small I&C temperatures are also lower than the large I&C temperatures which is counter-intuitive given that there are more internally located meters in the small I&C sector. We therefore believe that internal meters are under-represented in the small I&C sample.

For these reasons, we propose using the domestic internal and external meter temperatures for EUC02B & 03B as well as 01B. This assumes that internally located meters in the small I&C sector are experiencing similar temperatures to internally located domestic meters. We consider this to be a reasonable assumption rather than using the ICTS temperatures which appear to be biased towards externally located meters.

The calculation of FWASNGT for small I&C sites will therefore be similar to the domestic calculation but will use EUC specific meter location and allocation data.

4.3 Large I&C (04-08)

It is proposed that Large I&C temperatures from the ICTS are used for EUC groups 04 to 08. The AUGE will assess whether corrections are required to account for the following

- Adjust FWATs to current consumption profiles i.e. to account for any differences between Large I&C consumption in gas years 1996-1999 compared to now
- Adjust FWATs from 1996-1999 to current SN conditions
- Merge some LDZs where sample populations are low

Having made any corrections deemed necessary, the Flow Weighted Average Seasonal Normal Gas Temperature (FWASNGT) will be calculated for each LDZ but will take no account of the split of meters between internal and external locations. It is assumed that the sample of meters used in the ICTS was representative of the true meter locations.

4.4 Daily Metered (09B and PC1)

It is unlikely that this group of meters will contribute to UIG as all meters would be expected to have volume conversion devices. However, for completeness the AUGE will calculate a DM FWASNGT in the same way as for Large I&C sites above except the DM temperatures from the ICTS will be used.

5 ASSUMPTIONS

The proposed approach relies on a number of assumptions as follows

- Meter locations held by the CDSP are accurate.
- Unknown meter locations have the same distribution (internal/external split) as known meter locations.
- Internally located meters for smaller I&C sites have similar gas temperatures to internally located domestic meters.

6 REFERENCES

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