Jemena Gas Networks (NSW) Ltd

2020-25 Access Arrangement Proposal

Attachment 6.8

Independent review of JGN's UAG

Howard Wright Gas Measurement Pty Ltd

ACN 138 405 820 ATF Wright Discretionary Trust ABN 90 878 090 374
PO Box 147 Glen Iris, Vic. 3146
Tel: 0419 318 775

Report No: HWGM 17-19-003

Title: **Jemena Gas Networks – Review of JGN UAG**

Issue: Final

Author: Dr Howard Wright

Date: 17 June 2019

Client: Jemena Gas Networks (NSW) Ltd

Client Contacts: Fred Khalil
Ana Dijanosic

Released to Client:

17 June 2019

Date

Contents

Document History

Version	Date	Comment
Final	17/06/2019	Final - Public

1. Disclaimer

This report has been prepared specifically for Jemena Gas Networks (NSW) Ltd for the purpose of providing a review of the un-accounted for gas in their NSW gas distribution networks.

This report is based upon information supplied by Jemena Gas Networks (NSW) Ltd and from published information, reports and standards. This information has been used in good faith but Howard Wright Gas Measurement Pty Ltd makes no warranty as to the accuracy or completeness of that material.

Although certain recommendations have been made as part of this review Jemena Gas Networks (NSW) Ltd should carry out their own assessment of the appropriateness, practicality and cost/benefit of such recommendations.

2. Executive Summary

The results of a requested review of the calculation methodology, management and magnitude of Jemena Gas Networks (JGN) unaccounted for gas (UAG) are summarized below;

1. The JGN methodology and approach to calculating and reporting UAG is appropriate and in keeping with good industry practice.
2. The current 2017 to 2018 JGN UAG is comparable to other distribution networks.
3. The JGN processes for managing the various factors that may influence UAG are appropriate and in keeping with good industry practice.
4. It is recommended that an audit of data collection, data processing and energy calculation processes be conducted to ensure that documented procedures are actually being followed and that no data is being missed (or double counted).

3. Terms and Abbreviations

In this report the following terms have the indicated description.

Term	Description
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
Base conditions	For natural gas: 15°C and 101.325 kPa absolute
Basic meter	A meter that only records total accumulated volume
CTM	Custody Transfer Meter ï A meter which measures the gas passing between a transmission pipeline and a gas distribution network.

DR	Daily residuals ï Notional total daily basic meter flows calculated from CTM flows minus daily interval meter flows but also includes daily UAG /losses.
EDD	Effective Degree Day ï The effective degree day is a composite measure of weather coldness incorporating the effect of temperature, wind, sunshine and day of the year.
ENA	Energy Networks Australia
F_{pv}	Supercompressibility Factor = $(Z_{base}/Z_{meter})^{1/2}$
ESC	Essential Services Commission (Victoria)
GC	Gas Chromatograph ï Instrument for determining the composition of gas.
HV	Heating Value ï the energy released in the combustion of a cubic metre of gas.
Interval meter	A meter that records volume passed for specific intervals e.g. hourly, usually incorporating volume correction.
JGN	Jemena Gas Networks (NSW) Ltd
Linepack	The quantity of gas contained within a pipeline.
NX-19	PAR Research Project NX-19 ñExtension of Range of Supercompressibility Tablesò, American Gas association Pipeline Research Committee, Dec 1962.
SAP	Systems Applications and Products ï An enterprise Resource Planning system produced by SAG AG (Germany)
Standard conditions	As defined in AS 4564 ñSpecification for general purpose natural gasò- a temperature of 15ºC and an absolute pressure of 101.325 kPa
SUG	System Use Gas ï gas used within the pipeline system e.g. water bath heaters.
TJ	Tera Joules
UAG	Un-Accounted for Gas ï The difference between the gas measured into a pipeline system and the gas measured out of the same system with appropriate allowance made for any change in quantity of gas within the system.
WBH	Water Bath Heater ï Used to heat pipeline gas before pressure reduction

Z	Gas Compressibility - a measure of the non-ideal behavior of a gas (a function of gas composition, pressure and temperature).
Z_{base}	Gas Compressibility at base conditions (15°C and 101.325 kPa absolute)
Z_{meter}	Gas Compressibility at the temperature and pressure of the gas flowing through the meter.

Table 1 Terms and abbreviations

4. JGN Review of UAG

Jemena Gas Networks (NSW) Ltd (JGN) has requested an independent review of:

1. The methodology used to calculate un-accounted for gas (UAG) to determine whether it is reasonable, and in line with good industry practice
2. An opinion on the (distribution system) efficiency (i.e. relative value) of JGNĜs reported UAG since 2015-16, with reference to other gas distribution network operators.
3. An opinion on the suitability of JGNĜs processes for managing UAG.

This review does not extend to an audit of the data flow through data collection, storage and calculation processes.

This review does not extend to meter calibration procedures or practices.

The review does not include an in-depth analysis of UAG data.

5. JGN Networks

The gas distribution networks operated by Jemena Gas Networks (NSW) Ltd (JGN) are shown in Figure 1.

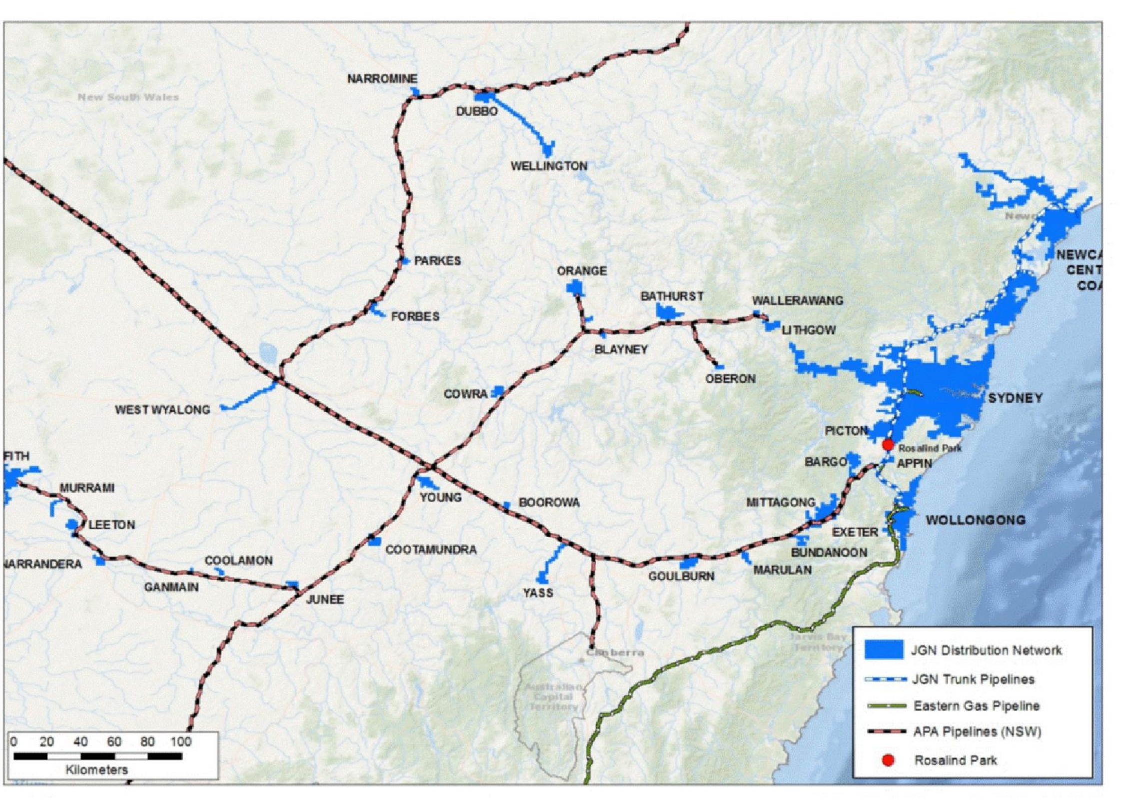

Figure 1JGN Gas Distribution Networks[1]

The JGN UAG is reported for the whole aggregated network but is also calculated by JGN for each isolated (regional) network on a monthly basis.

6. Documentation Reviewed

Main documents supplied for review:

- ñDesign Basis ï Unaccounted for GasòMeasurement ï Jemena, 31 March 2016.
- Procedure ñUnaccounted for Gas (UAG)ò, DOC-STP-OSAP2-1926 (JEM PMM PR 2924 SAP) Rev 1.0 4/12/2015.
- ñBilling factors for gas v2.docò A document outlining the formulae for correcting gas volumes from basic meters.
- Procedure ñGas Consumption Reconciliation to Support UAG Calculationò 28/06/2017.
- Procedure ñDemand BillingòDOC-BTP-OSAP2-1926 (JEM PMM PR 2866 SAP) 28/03/2016.
- ENA Report ñNatural Gas Distribution Benchmarking Report 2017-18 ï Jemena (NSW).
- PowerPoint presentation ñUAG Jemena changes 28032019.pptxò
- AEMO ñRetail Market Procedures (NSW and ACT)ò Version 20.0 12 Dec 2018

[1] From Chapter 2 Jemena Gas Networks (NSW) Ltd 2015-20 Access Arrangement Information

- 20190402 Unaudited Data for UAG Review.xlsx (Regulatory reporting statement ï Historical information)
- JGN February 2019 Imbalance Report.docx

Also reviewed were supporting documentation, emails, screen-shots, and telephone responses to specific queries.

7. JGN Methodology for Calculating UAG

The various inputs to the UAG determination are considered in the following sub-sections.

7.1. JGN UAG Equation

Un-Accounted for Gas (UAG) is the difference between the gas measured into a pipeline system and the gas measured out of the same system with appropriate allowance made for any change in quantity of gas within the system.

The basic equation for UAG for a distribution network is thus:

UAG Equals: Gas received into distribution network

Minus: Gas delivered by distribution network (which usually includes system use gas)

Minus: Change in quantity of gas within the distribution network

For the JGN gas distribution system the equation in the various items of documentation reviewed is expressed (in JGN terms)[2] as:

UAG = I/P ï IM_B ï BM_B ï WBH - CLP

Where:

UAG	=	Monthly quantity of accounted for gas (in TJ)
I/P	=	Monthly quantity of gas injected into the networks from CTMs (Daily) in TJ
IM_B	=	Monthly quantity of gas from Interval meters (Daily data) in TJ
BM_B	=	Monthly quantity of gas from Basic meters (Billing period data, profiled across the billing period into daily quantities, using the daily residuals (DR)) in TJ
WBH	=	Monthly quantity of gas used by water bath heaters (Monthly data) in TJ (and any other system use gas)
CLP	=	Change in linepack from start of month to end of month in TJ (This would normally also include gas required to fill new pipelines)

The following points were noted:

[2] ñDesign Basis ï Unaccounted for Gasò Measurement ï Jemena 31 March 2016.

- This form of UAG equation is not unusual in the gas industry in Australia. It fully expresses the intent of the UAG calculation. It is optional whether items such as WBH usage is listed as a separate item or is included as part of metered ˜gas deliveriesò.
- The profiling applied using daily residuals to basic meters is reasonable for applying readings taken at three monthly intervals (at different times of the month for different basic meters) to monthly UAG intervals.
    - It should be noted that an unfortunate feature of this profiling is that an unmetered loss from the pipeline system will be ˜hiddenò as the loss will be compensated for by the allocation of a greater proportion of the basic meter consumption to that month. From an annual UAG reporting accuracy perspective this profiling feature usually has minimal impact. The major impact arises in the investigation of UAG anomalies, where profiling based on EDD may provide better correlations with UAG influences.

The current profiling methodology does not have a significant impact on reported UAG as the only impact will be any marked seasonal difference between the starts and ends of adjoining UAG reporting years. Any effect at the end of one year will be compensated for in the next year.

7.2. Basic Meter Volume Correction

The formulae[3] and assumptions used for correcting the basic volume meter reading were checked for correctness.

Pressure

The pressure correction to standard conditions (101.325 kPa) is based on meter regulator settings plus an average barometric pressure, corrected for altitude, based on the zone where the meter is installed.

The sea level pressure is set at 101.6 kPa absolute which corresponds to long term average sea level atmospheric pressure at Sydney[4].

[3] ˜Billing factors for gas v2.docò A document outlining the formulae for correcting gas volumes from basic meters supplied by JGN

[4] Barometric pressure sourced from: https://www.worldweatheronline.com/sydney-weather-averages/new-south-wales/au.aspx

Meteorological Area	Temperature Zone	Barometric Pressure Zone	Elevation Range (m)	Barometric Pressure (kPa)
MCSL	Coastal	SL	0 ï 99	101.6
MC20	Coastal	200	100 ï 299	99.3
MM20	Mid Inland	200	100 ï 299	99.3
MM40	Mid Inland	400	300 ï 499	97.0
MF60	Far Inland	600	500 ï 699	94.7
MF80	Far Inland	800	700 ï 899	92.4
MF10	Far Inland	1000	900 ï 1099	90.1

Table 2 Atmospheric pressures used for basic meter volume correction

Independent re-calculation of altitude correction indicates minor rounding errors of no material consequence (less than 0.1% error)

Temperature

The temperature correction to standard conditions (15ºC) is based on historical monthly average 9:00am ambient temperatures based on the temperature zone where the meter is installed.

The temperatures currently used are shown in Table 3

The use of the 9:00am average temperatures is seen as prudent as it represents periods of gas consumption during the cooler parts of the day.

The actual metering temperature will depend on ground temperature and gas flow rate. The use of a 9:00am ambient temperature is regarded as quite reasonable as the metal casing of gas meters would provide good heat exchange with the surrounding air. However it should be noted that the ambient air temperature is typically measured more than 1.2 meters above ground level.

The temperature applied in the volume correction is based on a weighted average of the temperatures of the months that a meter reading refers to. In the absence of knowledge of when the gas was actually consumed during the reading period a weighted average temperature is reasonable.

Month	Far Inland	Mid Inland	Coastal
January	19.1	23.4	22.0
February	18.3	22.4	21.5
March	16.5	20.5	20.7
April	12.1	16.4	17.3
May	7.8	11.3	13.6
June	4.8	7.6	10.5
July	3.7	6.5	9.1
August	5.7	8.5	11.2
September	9.3	12.2	14.7
October	13.2	17.2	18.4
November	15.6	20.0	18.9
December	18.2	22.5	21.1

Table 3 Monthly average atmospheric temperatures used for basic meter volume correction as a function of temperature zone.

Gas Compressibility

The gas compressibility corrections are based on gas compressibility calculated using NX-19[5] .

For metering pressures between 0 and 80 kPag, the compressibility volume correction Z_{base}/Z_{meter} where Z_{base} and Z_{meter} are the gas compressibilities at base and metering conditions respectively, is set to 1.000. This is a reasonable approximation as the maximum error (at 80kPa) would be less than 0.17%.

For metering pressures from 80 to 120 kPag, the compressibility volume correction Z_{base}/Z_{meter} is calculated by the following equation.

$$Z_{base}/Z_{meter} = 1.0028 - 0.001 * (T_{meter}/35)$$

Where: T_{meter} is the weighted average metering (i.e. 9:00 ambient) temperature in ºC

Independent calculations[6] show that this approximation is reasonable and leads to errors no greater than 0.05% over the indicated pressure range and from 0 to 30 ºC.

For metering pressures above 120kPag the compressibility correction is manually calculated.

It should be noted that the "supercompressibility factor" defined in JGN documents[7] (Z_{base}/Z_{meter}) is different from the "supercompressibility factor" $F_{pv} = (Z_{base}/Z_{meter})^{½}$ as defined in NX-19 although one can be calculated from the other.

[5] PAR Research Project NX-19 "Extension of Range of Supercompressibility Tables", American Gas Association Pipeline Research Committee, Dec 1962.

[6] These calculations were carried out using NX-19 formulae with gas composition data the same as used for interval meter flow correctors. (Specific gravity = 0.5938, N_2 = 1.0040% and CO_2 = 1.5560%)

AEMO ñRetail Market Procedures (NSW and ACT)ò implies the application of the NX-19 F_{pv} for correcting volume whereas the JGN defined (Z_{base}/Z_{meter}) should actually be used.

The JGN calculations for volume correction including gas compressibility are reasonable and appropriate.

7.3. Interval Meter Volume Correction

Interval meter volume correction is carried out in flow correctors at each meter location using continually measured metering pressure and temperature and continuously calculated compressibility correction.

The pressure transducers installed measure the absolute pressure so there is no need to apply average barometric pressure or altitude correction. This is most appropriate and avoids possible errors in performing corrections and assumed barometric pressure.

The gas composition data currently used by the flow correctors is:

Specific gravity = 0.5938
N_2 = 1.0040%
CO_2 = 1.5560%

These values have not been updated recently and should be reviewed, but even significant compositional changes are not expected to change the calculated compressibility by significant amounts. Any compressibility calculation errors are expected to be less than 0.1%.

7.4. Bulk Hot Water Metering

The gas usage of bulk gas-fired hot water heaters at multi-residence units is apportioned by the use of hot-water meters supplying each unit.

The methodology of apportioning hot water meter readings to bulk gas meter readings used by JGN[8] is straight-forward and appropriate.

7.5. Estimated Reads

It is not always possible to read every meter and so a portion of meter readings are based on estimates. Such estimates are based on past consumption data. When subsequent real readings are obtained any over or under estimation will be effectively balanced out.

Figure 2 shows the percentage of basic meter readings which had to be estimated since April 2016. There has been a reassuring steady reduction in estimated readings since that time.

[7] Appendix A of ñBilling factors for gas v2.docò A document outlining the formulae for correcting gas volumes from basic meters supplied by JGN
[8] Appendix D of ñBilling factors for gas v2.docò A document outlining the formulae for correcting gas volumes from basic meters supplied by JGN

The current rate of estimated basic meter reads would have minimal impact on rolling 12 month UAG.

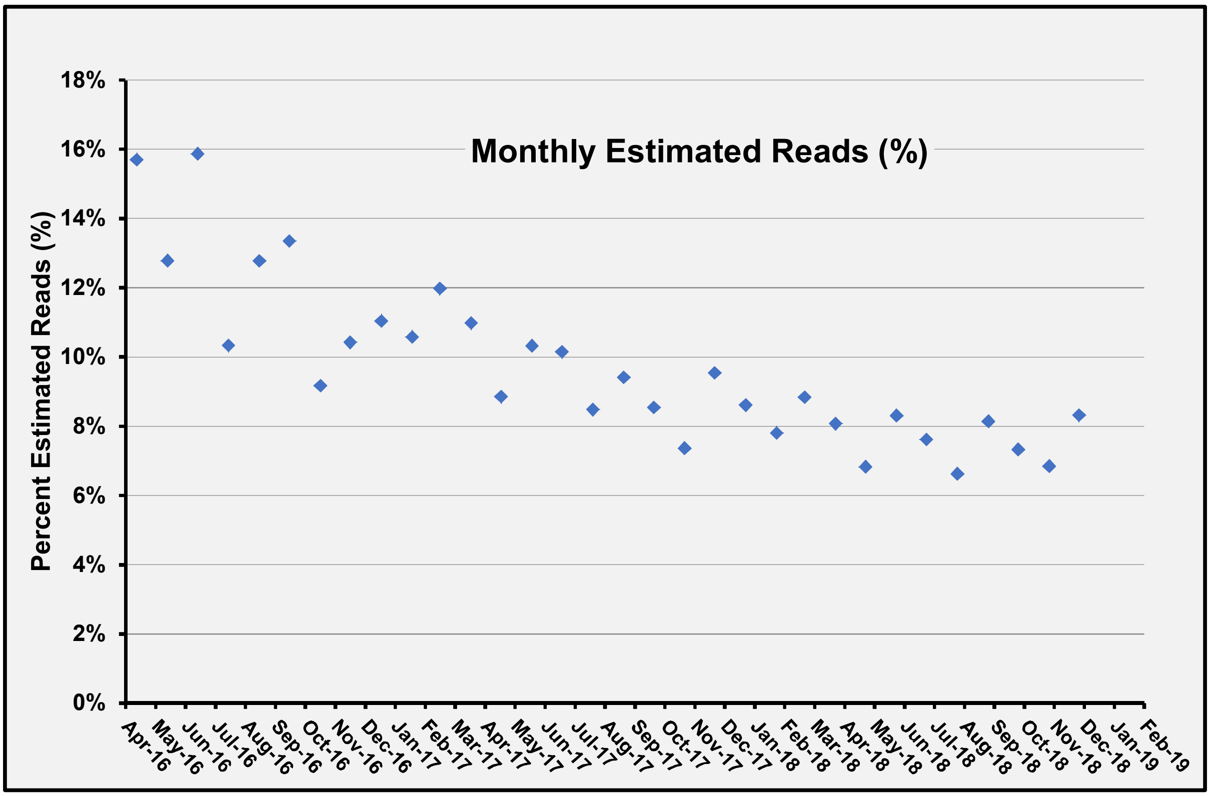

Figure 2 Percentage of Basic Meter reads which are estimated

There was no correlation found between monthly estimated basic meter reads and monthly UAG.

7.6. Heating Value Allocation

The conversion of corrected volumes to energy is based on multiplying the corrected gas volumes by the heating value of the gas that was measured. The gas heating value is measured by gas chromatographs (GCs) at distribution receipt points and the appropriate flow-weighted value is based on the heating value zone where the meter is installed.

This approach is a common methodology and is reasonable and appropriate.

Using a flow-weighted average will minimize the likelihood of any systemic effect on total UAG.

7.7. Linepack Calculation

The linepack calculation was not reviewed. The impact on rolling annual UAG for a distribution network would be negligible. The monthly linepack corrections are very small compared to the UAG and should ňaverage outò over the year with very little net change over the year.

7.8. Custody Transfer – Input metering

Custody transfer metering is usually of very high quality but any errors or biases can contribute to distribution network UAG. An error in a CTM will change both transmission and distribution UAG, one will go up and the other will go down depending on the nature of the error.

To a large extent, apart from witnessing calibrations and maintenance activities, it is difficult for JGN to have much control over any custody transfer metering that they do not control.

The average uncertainty of receipt meter energy determination is expected to be around ±1.25%[9]. This value is consistent with the typical uncertainties associated with custody transfer energy metering the actual uncertainty of individual meters will vary from meter to meter.

8. Magnitude of JGN UAG

The magnitude of the actual measured JGN UAG is of interest as it can have significant financial impacts.

8.1. Changes to JGN UAG

Following some anomalous UAG results, investigations by JGN discovered that there had been double counting of some gas consumption after Jul 2015. The descriptions of the issues given in a JGN PowerPoint presentation ñUAG Jemena changes 28032019.pptxò are quoted below.

- ***Hot water meters****. JGN, identified the current process for calculating the gas consumption for hot water meters was overstated due to the double counting of the gas volume being measured by the, approximately 1000, master gas meters that had been installed since SAP go-live in May 2016 and the inferred volume of gas measured by the individual hot water meters servicing the actual apartments;*
- ***Demand customers.*** *JGN, identified the current process for calculating the gas consumption contribution for some demand customers was overstated. The issue relates to a <u>limited</u> number of demand customer sites where daily consumption is not available. When interval data becomes available, the change of meter type (basic to interval meter) causes double counting of the volumes used in the calculation of UAG.*
- *This had a net effect of increasing the 12 monthly-rolling UAG to a level approximately 1% higher than currently reported for JGN….*

[9] This was based on a detailed analysis carried out by VENCorp on delivery meters on the Victorian Declared Transmission System but is typical of custody transfer meters in other systems. The JGN receipt meters are expected to have a similar average uncertainty.

The effect of these errors is shown in Figure 3[10], where recalculation of past UAG results indicates a significant increase in recorded UAG.

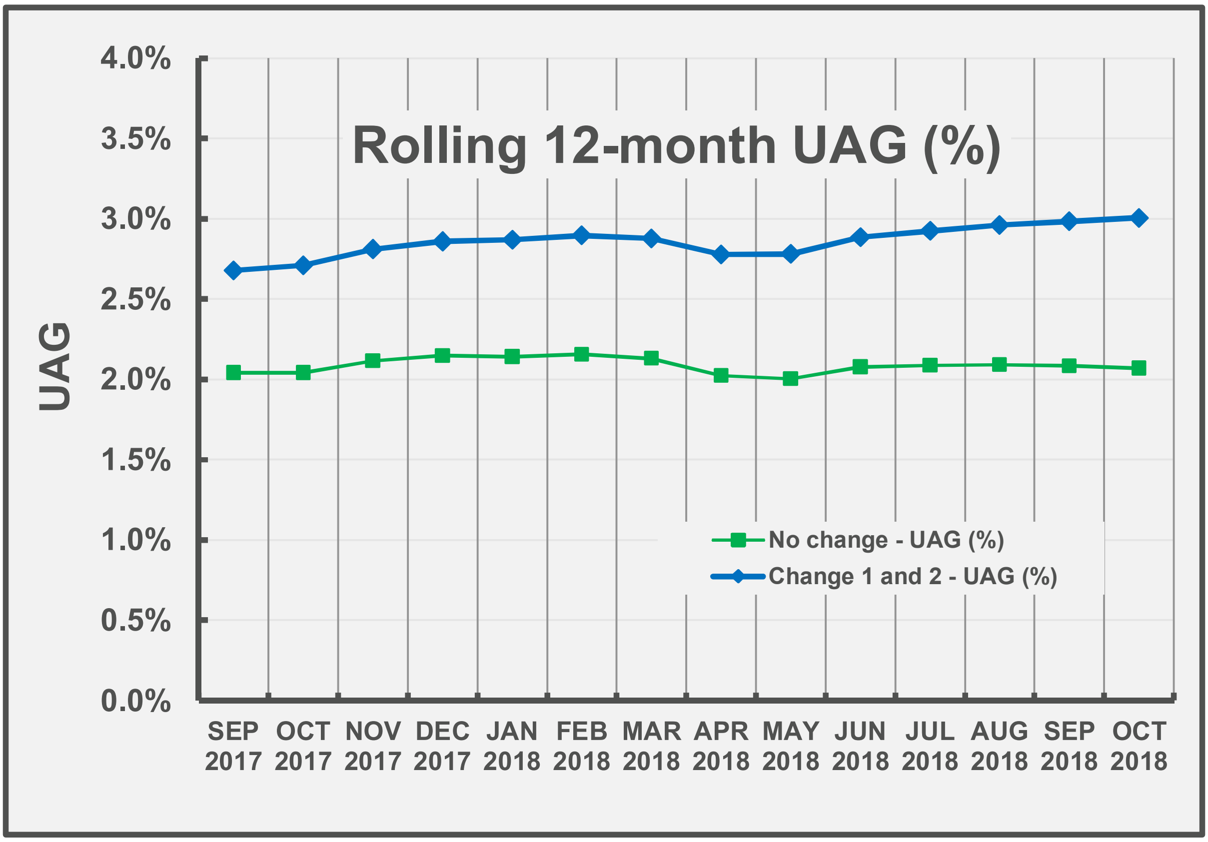

Figure 3 Effect of identified errors on past calculations of UAG

8.2. JGN UAG Data

The major inputs into the JGN UAG calculation are shown in Figure 4. For clarity the minor components of water bath heater consumption and linepack change are not shown as they are only minor contributors to the over-all UAG.

The UAG figures shown in Figure 4 relate to the recalculated values after correction for the two errors described in section 8.1. The UAG axis is on the right hand side of the graph.

From Figure 4 it can be seen that the interval meter consumption remained relatively constant over most of the period whilst receipt (input) flows, basic meter consumption and UAG follow a seasonal cycle. This is normal as much large industrial consumption is not weather dependent.

[10] Based on graph in presentation ñUAG Jemena changes 28032019.pptxò (Supplied by JGN for the purposes of this report)

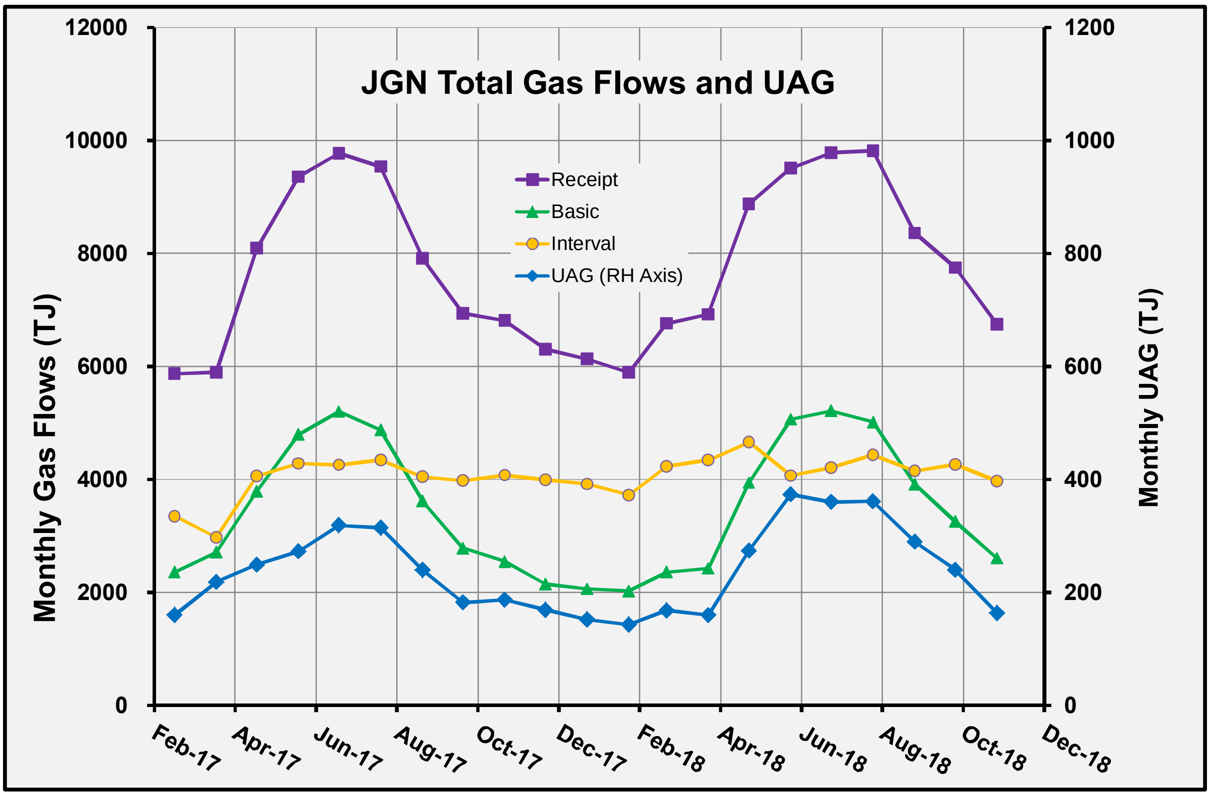

Figure 4 Major inputs to UAG calculation and monthly calculated UAG (WBH/SUG and CPL omitted for clarity)[11]

From Figure 4 it can be seen that the UAG is relatively low and constant over the summer months. The higher peaks of UAG correspond to flow-related influences that increase UAG above the underlying pipeline leakage/losses and low-flow measurement uncertainty level.

Thus a proportion of UAG is flow measurement related and not simple pipeline leakage.

The flow- related influences could include things such as:

- Metering errors and biases (receipt and delivery)
- Pressure measurement errors and biases
- Temperature measurement errors and biases
- Heating value application errors and biases
- Data collection errors and missing data
- Calculation errors
- Theft

The cyclic nature of the monthly UAG may lend itself to further investigation into the underlying causes but this is beyond the scope of the current review.

[11] Based on data from Excel workbook ñJGN Network Imbalance analysis 04 March 2019 (Feb to Feb 19).xlsmò(Supplied by JGN for the purposes of this report)

8.3. Benchmarking Distribution Network UAG

Comparison of JGN UAG with other networks is of interest in providing a measure of what is ñnormalò and what may be realistically achievable.

The UAG comparison with other networks is complicated because gas distribution networks vary considerably in terms of their geographical layout, materials of construction, age of infrastructure, operating pressures, types, sizes and configuration of both receipt and delivery meters, metering and volume correction practices, heating value allocation, etc.

Figure 5 shows the reported actual UAG for a range of Australian gas networks.

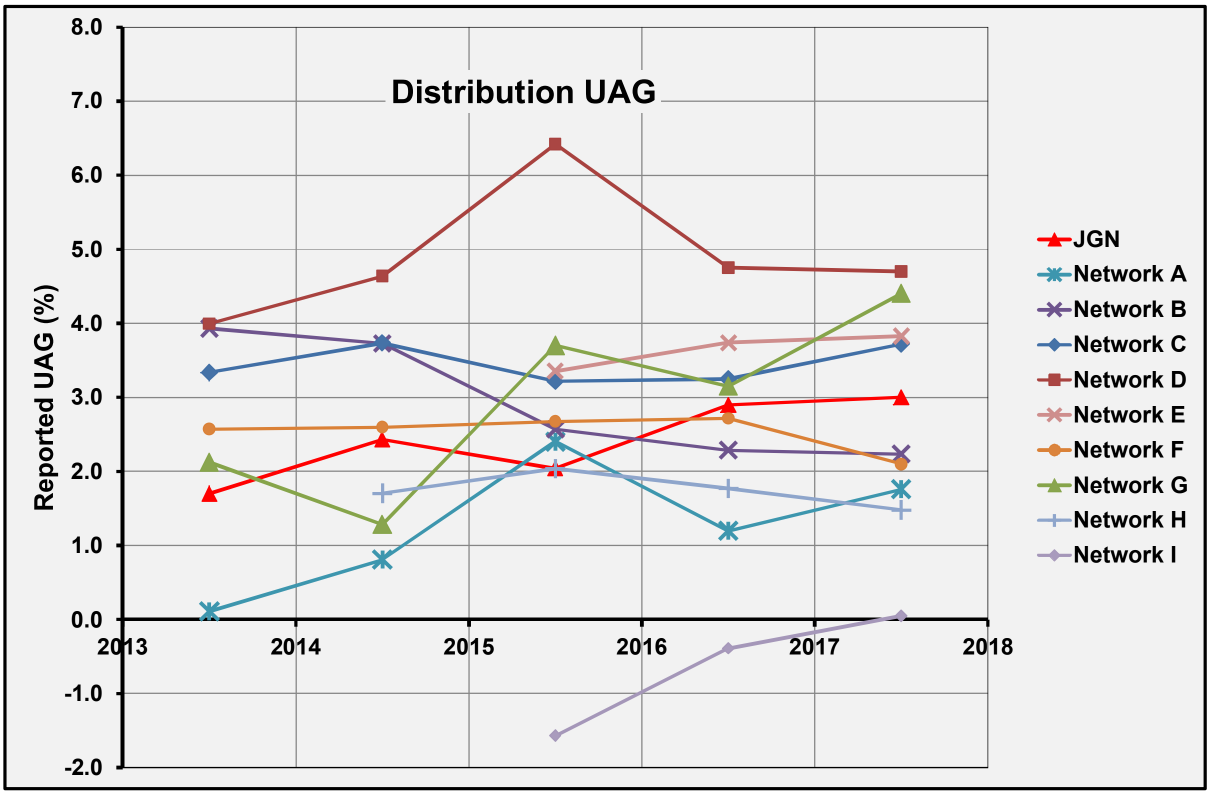

Figure 5 Distribution UAG for a range of Australian Gas Networks[12].

It can be seen in Figure 5 that UAG varies considerably between different networks and also over time for individual networks.

Some points to note:

JGN
The JGN 2016/17 and 2017/18 data points have been corrected for the errors described in section 8.1.

Networks A, D and G
These networks show significant year-to-year variation in UAG potentially indicating changing leakage rates which can sometimes result from changing

[12] Graph based on data from Energy Networks Australia analysis (2019)

soil conditions. However, this variation may also be due to un-detected measurement errors or biases in either receipt or delivery meters.

Network I
The negative values of UAG are an indication of the effect of measurement uncertainty on the determination of UAG. A true negative UAG would require the creation of gas within the pipeline network. The measured actual UAG can be negative due to the measurement uncertainties of the various measurements that make up the UAG. However, it is also possible that there may be underlying errors (yet to be found) in the UAG determination.

8.4. JGN UAG Comparison with Other Networks

Direct comparisons between distribution networks are problematic as no two of the networks shown in Figure 5 would be expected to have the same mix of network size, pipeline materials, age, consumer load, distribution pressures, meter populations, etc.

The current JGN percent UAG can be seen to be within the spread of ñormalò (1.5% to 4%) distribution network UAG (Ignoring outliers such as Networks A, D and I). This comparison is based on total gas throughput but gas leakage is expected to be correlated to the size of the network[13] and so it is instructive to also consider the actual UAG per kilometer of distribution main.

Figure 6 shows the actual UAG per kilometer of distribution main for a range of Australian gas distribution networks plotted in order of UAG magnitude.

[13] A network spread over a larger area might be expected to have greater numbers of leaks even though the throughput may be the same.

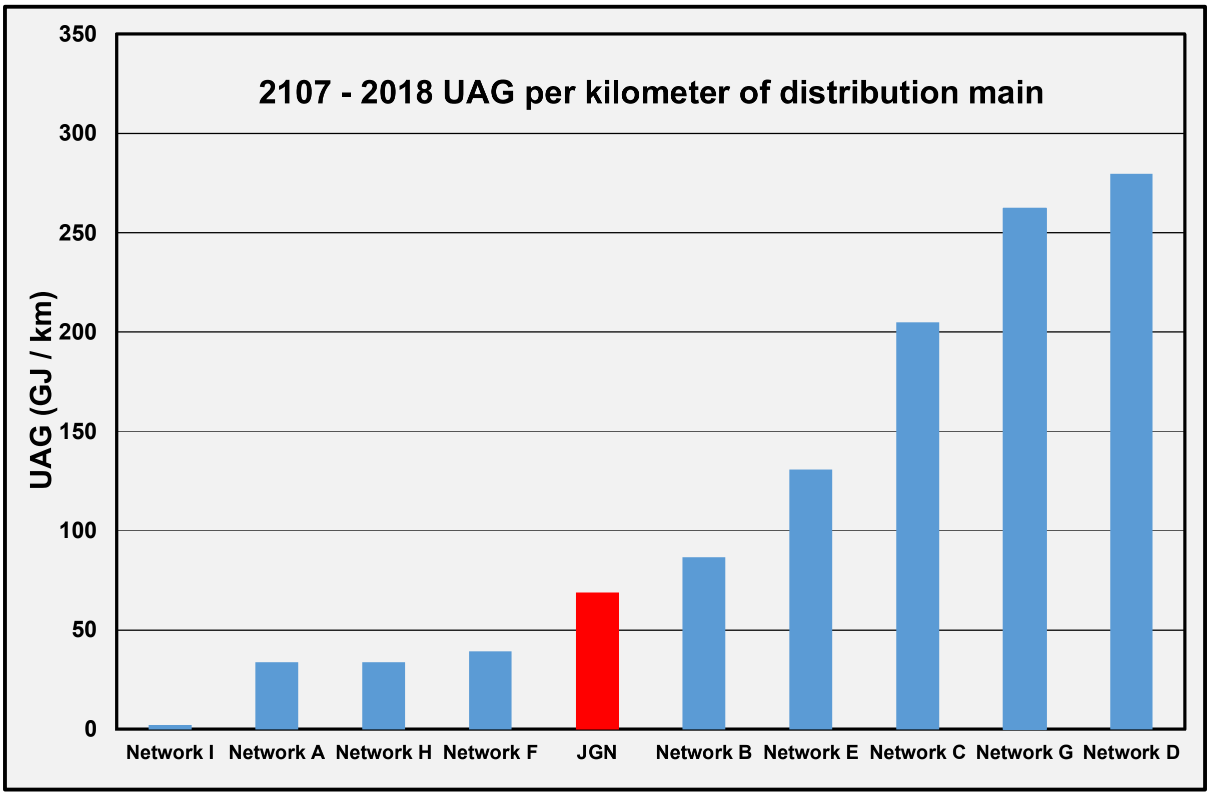

Figure 6 UAG per Kilometer of Distribution Main for a Range of Distribution Networks[14]

From Figure 6 it can be seen that JGN UAG is at the lower end of the reported UAG values when compared on a UAG per kilometer of main basis.

9. Uncertainty of UAG Values

UAG is made up of a combination of the summation of random biases within the measurement uncertainties of the various inputs into the calculation as well as actual gas losses from the network.

It is important to estimate the uncertainty of the gas measurement components of the UAG calculation. This assists in providing an estimate of how much of the UAG is definitely due to gas losses and how much may possibly be attributed to measurement errors.

Table 4 shows the major contributors to UAG measurement uncertainty. The uncertainty contribution from changes in linepack over 12 months is considered negligible and has been omitted. The uncertainty of water bath heater usage is included in the delivery meter uncertainty as it is a metered delivery. The delivery meter energy is a flow-weighted combination of the basic and interval meter uncertainties as calculated in Appendix A.

[14] Graph based on data from Energy Networks Australia analysis (2019)

Contribution	Bias (%)	Uncertainty (%)	Comment
Receipt meter energy	0	±1.25	As described in section 7.8
Delivery meter energy	-0.5	±1.62	As described in Appendix A
Net UAG calculated Uncertainty	**0.5**	**±2.05**	Added by quadrature[15] =ã($1.25^2 + 1.62^2$)

Table 4 Uncertainty of UAG measurement

The net uncertainty of UAG determination of 2.05% (or more correctly 205 percent basis points as UAG is usually expressed as a percentage). I.e. the UAG determination is expected to be within the uncertainty band +0.5±2.05%.as shown in Figure 7

That is, any fraction of UAG above 2.55% (i.e. 0.5%+2.05%) is almost certainly due to gas losses or un-metered flows as it is above the calculated UAG measurement uncertainty.

As shown in Figure 7 UAG up to 2.55% might conceivably be due solely to measurement uncertainties. But note that at 2.55% UAG there is only a 2.5%[16] probability that it is solely due to measurement uncertainties i.e. conceivable but unlikely.

The actual reported UAG is around 3.0% indicating that (as expected) there is almost certainly a component (at least 0.45%) due to actual leakage/theft/un-metered offtake/ operational use gas.

The seasonal change in monthly actual (TJ) UAG indicates that a portion of UAG is most probably due to flow uncertainty related issues and not simple pipeline leakage.

Although losses include theft, the actual determination of the theft component of UAG is almost impossible without hard evidence. The difference between domestic versus industrial theft would most likely be significant.

Operational usage gas (gas lost through construction and maintenance) can be estimated (albeit poorly) and could be included in deliveries, so to some extent it could potentially be accounted for. In this analysis it is included in gas losses.

[15] Adding by quadrature (the square root of the sum of the squares) accounts for the probability that it is unlikely that different uncertainty values will all be at their extreme limits at the same time.

[16] All uncertainties in this report are based on 95% uncertainty which means a probability that 2.5% could be above the range and 2.5% could be below the range.

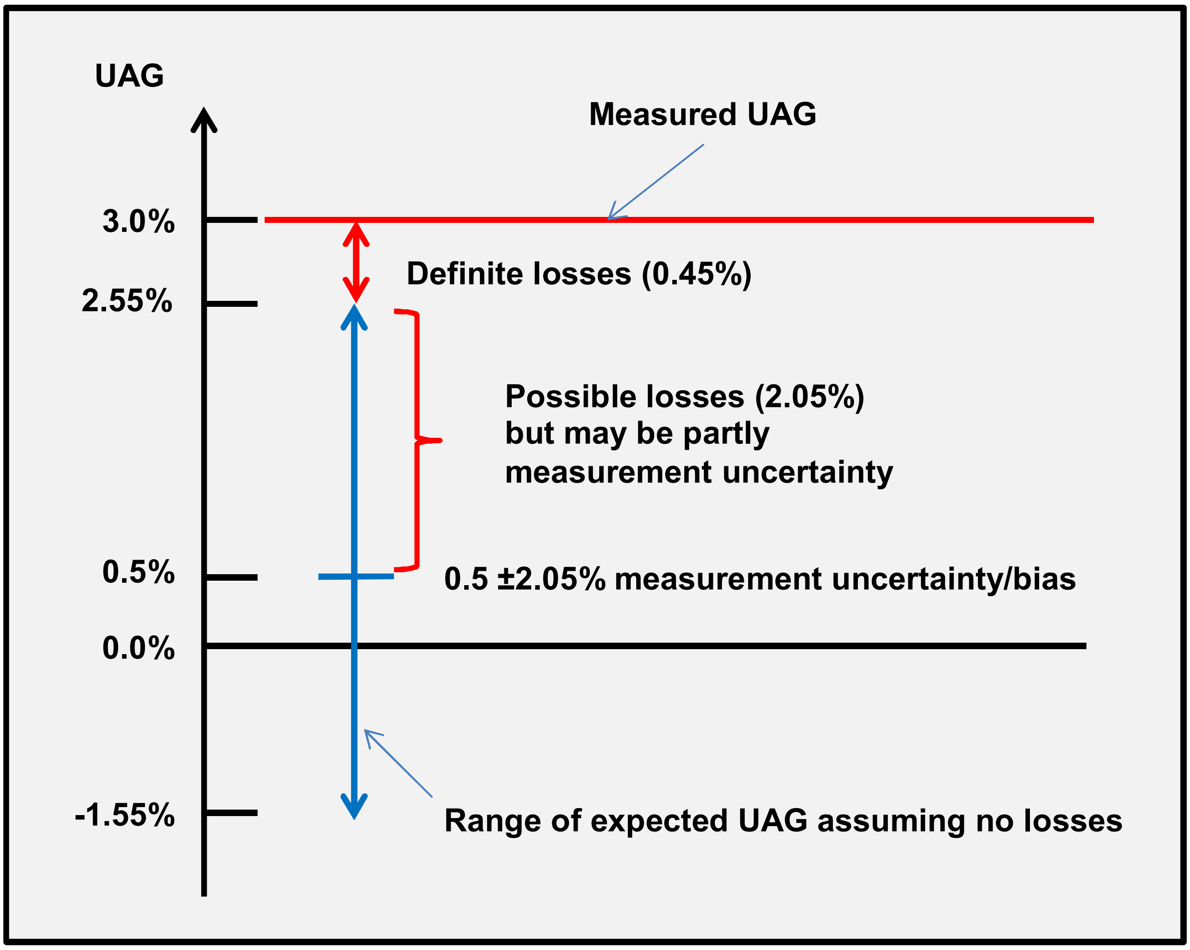

Figure 7 Diagram of UAG measurement uncertainty, bias and measured UAG showing overlap of UAG uncertainty and possible losses.

10. Management of UAG by JGN

Unaccounted for gas (UAG) can have significant impact on a distribution network business.

The various things which influence UAG need to be monitored and controlled.

Management of these influence factors include minimisation of uncertainties in metered quantities and control of actual loses from the distribution system.

JGN controls the uncertainties of metered quantities by:

- Applying volume correction to basic meters that include correction for delivery pressure, ambient temperature, average barometric pressure and altitude
- The pressure and temperature transducers at interval meters are calibration tested on a routine cycle. Absolute pressure transducers are used at interval meters to avoid errors in volume pressure correction.
- All metered quantities are validated and substituted if necessary.
- Basic meter performance is monitored by way of sample testing and removal of families of meter that fail acceptance criteria.

- Estimated reads follow standard estimation practices[17]
- Metering assets are controlled to ensure all are accounted for
- Applying heating values to meters based on flow-weighted average of measured receipt inputs

JGN controls actual losses from the distribution system by:

- Replacing or repairing leaking mains and services
- Monitor third party damage[18]
- Carrying out leakage surveys
- Participating in the "Dial Before You Dig" service and media campaigns.
- Responding to public notifications of detected gas[18].

JGN actively monitors UAG:

- UAG is measured and reported on a monthly basis[19]
- Basic meter reads are profiled to monthly UAG to improve accuracy of monthly UAG[20]
- Anomalies are analysed[19]
- Errors in UAG determination are rectified (e.g. double counting issues described in section 8.1)

11. Recommendations

Although the current UAG is comparable to the UAG of other Australian gas distribution networks it is recommended that:

1. An audit be conducted of the data flow through the data collection, data processing and calculation processes to ensure that (a) the data is being processed correctly and (b) that do data sources are missed (or double counted).
2. The gas consumption at bulk hot water units apportioned by hot water meters be entered into the UAG calculations based on the readings from the bulk gas meter (not from the summation of the apportioned gas calculated from the hot water meters). The data used for UAG calculation should be based as much as is possible on the physical gas passing into and out of the pipeline system Similarly, actual gas flows should be used rather than any "deemed" or "contractually agreed" flows.

12. Conclusions

1. The JGN methodology and approach to calculating and reporting UAG is appropriate. The volume and energy corrections to delivery meters are all appropriate and no specific errors were identified.

[17] AEMO "Retail Market Procedures (NSW and ACT)" Version 20.0 12 Dec 2018
[18] 20190402 Unaudited Data for UAG Review.xlsx (Regulatory reporting statement – Historical information)
[19] JGN Network Imbalance analysis 04 March 2019 (Feb to Feb 19).xlsm
[20] Jemena Procedure "Unaccounted for Gas" DOC-BTP-OSAP2-1926 (JEM PMM PR 2924 SAP)

2. The current JGN UAG is comparable to other distribution networks on an energy throughput basis but is relatively low on a GJ per kilometre of distribution main basis.
3. The low actual (TJ) UAG during the summer months indicates that there may be a near-constant contribution to UAG of gas leakage but that there may also be a flow-related component of gas losses during the winter months, which would include any offtake not recorded in the system (including theft) and as well as any gross (unknown) meter errors or flow/seasonal-dependent uncertainty biases. The measured UAG includes both leakage/loss and flow related contributions.
4. JGN processes for managing the influence factors for UAG are appropriate and in keeping with good industry practice and JGN's processes for monitoring UAG are also appropriate.

---ooo---

H.Wright
Report HWGM 17-19-003 JGN UAG Final.docx

APPENDIX A Calculation of delivery meter uncertainty

A1 Basic meter bias and uncertainty

The average uncertainty of a widely diverse population of diaphragm meters is going to be somewhat subjective but it is expected that new meters will be within ±1% as per purchase specifications and that a proportion of older meters may have drifted towards the +2%/-3% regulatory limits.

JGN meter life extension testing ensures that if too many meters within a population of meters drift outside the regulatory limits then that population of meters is removed from service. Thus it is expected that the majority of meters will still be within the regulatory specification but the average metering error may have drifted towards the regulatory limit.

Although some diaphragm meters may drift fast the majority tend to drift slow (under measure) as bearings wear and will also tend to under-measure at very low flows.

A possible under-measurement bias of 0.5% is estimated with an uncertainty of ±0.5%. That is, the total measured volume is estimated to be under-measured by 0.5% but could be in the range of zero to 1.0%.

The temperature, pressure and gas compressibility corrections applied by JGN to ñfixed factorò meters are relatively sophisticated and are not expected to result in a known bias one way or the other.

The actual gas temperature may not equal the average monthly 9am ambient temperature. A possible ±3ºC temperature correction error corresponds to a ±1% volume error (3 in 288.15 Kelvin i.e. 273.15K + 15 ºC).

The actual barometric pressure and the metering pressure may not be the values assumed for the fixed factors discussed in section 7.2. A possible ±1 kPa pressure correction error corresponds to a ±1% volume error (1kPa in ~101.325 kPa absolute) at low supply pressures. The pressure ñstepsò between JGN barometric pressure zones are larger than 1 kPa and daily ambient pressure can also change by this amount.

The gas compressibility correction errors are likely to be less than ±0.1% as described in section 7.2.

The heating value measurement and allocation uncertainty (on a monthly average basis) is expected to be better than ±0.5% in energy terms. There will be random measurement and allocation errors but there should not be a known bias.

Table 5 shows a summary of the above factors contributing to the uncertainty of basic meter measurement.

Contribution	Bias (%)	Uncertainty (%)	Comment
Basic meter volume		±1.0	As purchased
Meter age/degradation	-0.5	±0.5	Mix of new and old meters
Temperature correction		±1.0	±3ºC at near ambient temperature
Pressure correction		±1.0	±1 kPa at near atmospheric pressure
Compressibility correction		±0.1	Section 7.2
Heating value allocation		±0.5	
Basic meter energy uncertainty/bias	**-0.5**	**±1.87**	

Table 5 Basic meter uncertainty contributors

Thus using the above metering and correction uncertainties, the average basic meter energy uncertainty is expected to be ã$(1.0\%^2 + 0.5\%^2 + 1.0\%^2 + 1.0\%^2 + 0.1\%^2 + 0.5\%^2)$ = ±1.87% i.e. 95% of energy values are expected to be within the band[21] -- 0.5±1.87%.

A2 Interval meter bias and uncertainty

The average uncertainty of a widely diverse population of different types and capacity interval meters is also going to be somewhat subjective but, as before, it is expected that new meters will be within ±1% as per purchase specifications and that a proportion of older meters may have drifted towards the regulatory limits.

Turbine meters tend to under-measure as bearings age and friction increases and also when measuring very low flows. Large diaphragm meters also have a tendency to under-measure as bearings wear.

A possible under-measurement bias of 0.5% is estimated with an uncertainty of ±0.5%. That is, the total measured volume is estimated to be under-measured by 0.5% but could be in the range of zero to 1.0%.

The total temperature, pressure and compressibility corrections for interval meters are expected to be better than the ñfixed factorsò used for basic meters. The application of temperature measurement probes and absolute pressure transducers removes a large part of the uncertainties relevant to basic meters. Possible uncertainties are estimated as ±1.5ºC for temperature uncertainty, ±0.5% for absolute pressure uncertainty and ±0.1% for gas compressibility correction uncertainty

[21] More significant figures have been retained than are probably justified to make the derivations of the figures more transparent.

The heating value measurement and allocation uncertainty (on a monthly average basis) is expected to be better than ±0.5% in energy terms. There will be random measurement and allocation errors but there should not be a known bias.

Table 6 shows a summary of the factors contributing to the uncertainty of basic meter measurement.

Contribution	Bias (%)	Uncertainty (%)	Comment
Interval meter volume		±1.0	As purchased
Meter age/degradation	-0.5	±0.5	Mix of new and old meters
Temperature correction		±0.5	±3ºC at near ambient temperature
Pressure correction		±0.5	±1 kPa at near atmospheric pressure
Compressibility correction		±0.1	Section 7.3
Heating value allocation		±0.5	
Interval meter energy uncertainty/bias	**-0.5**	**±1.42**	

Table 6 Interval meter uncertainty contributors

A3 Combined basic and interval meter bias and uncertainty

The uncertainty (and bias) of delivery energy is the flow-weighted contributions of the basic meter and the interval meter uncertainties (and bias). Approximate annual gas flows for 2018[22] were 40,000TJ for basic meters and 50,000TJ for interval meters.

Thus the total uncertainty of delivery gas energy is expected to be (1.87% x 40,000 + 1.42% x 50,000)/90,000 = ±1.62%. However this uncertainty is applied to an estimated bias (under estimate) of 0.5%.

---ooo---

[22] Rounded volumes from ñJGN Network Imbalance analysis 04 March 2019 (Feb to Feb 19).xlsmò spreadsheet.

Dr Howard Wright

Howard Wright Gas Measurement Pty Ltd
0419 318 775
ASCHWrightm@bigpond.com
www.hwrightgasmeasurement.com.au

Dr Wright is an expert in gas measurement and gas properties and has extensive knowledge of the Australian gas industry spanning over forty years.

Since 2009 he has operated a successful consulting business providing expert advice, conducting training, carrying out data analyses and investigations, reviewing processes and procedures and carrying out technical audits.

The areas covered by this work include; gas properties and behavior, fuel gas quality and odorisation, hydrogen/natural gas mixtures, fuel gas quality standards and measurement systems, custody transfer measurement systems, gas meter calibration systems, energy calculation of fuel gases, measurement uncertainty and un-accounted for gas.

From 1998 to 2009 Dr Wright was the measurement specialist for the Victorian Energy Networks Corporation (VENCorp) (a predecessor of AEMO). At VENCorp he was responsible for the measurement of the quantities and qualities of gas entering and leaving the Victorian gas market transmission system and responsible for the correct allocation of gas heating value to custody transfer meters and the heating values and pressure factors used for consumer billing in Victoria.

At VENCorp he was also responsible for analysing transmission un-accounted for gas and identified a number of significant un-metered and incorrectly metered flows.

At VENCorp he also carried out the definitive work on the impacts of off-specification gas on pipeline systems and end users and he was part of Standards Australia committee AG 010 "Natural Gas Quality Specifications".

From 1995 to 1998 he was a specialist manager/consultant with Gas Technology Services. In this role he provided expert information and advice to the gas (energy) industry in the measurement of gas and energy flows, measurement accuracy, flow standards and data analysis.

At Gas Technology Services he was also responsible for the operational management and professional and technical leadership of a group of scientists, engineers and technical staff in the areas of chemical and environmental analysis, gas flow measurement, gas quality, physical and gas grid materials research, development, testing and evaluation, (18-27 staff).

Brief periods were also spent as Manager- Gas Appliance Test and Development and Manager- Gas Technology Services.

From 1974 to 1995 in his early career in various scientific and managerial roles with the Victorian Gas & Fuel Corporation Dr Wright was a pioneering researcher in gas flow calibration standards. He worked extensively on the development of innovative calibration and transfer standards for gas meters and also developed natural gas and air calibration primary standards and was both NATA and Verifying Authority signatory for these facilities.

The above work resulted in a number of industry awards and two provisional patents.

During his long career he has published and given presentations on calibration standards and systems, quality management, gas quality standards and monitoring, energy billing calculation and un-accounted for gas. His most recent publication was ñTargeting the Causes of High Un-accounted for Gasò, 2016 APGA Annual Convention and Exhibition, Perth, October 2016.

He has a BSC (Hons) in Physics (Monash), PhD in Materials Engineering (Monash) and a Post Grad Diploma in Management (Deakin), and is;
Individual Member, Australian Pipeline and Gas Association,
Fellow, Institute for Instrumentation, Control and Automation,
Member, Metrology Society of Australasia,
Member, Australian Institute of Physics and
Member, Australian Institute of Energy.

---ooo---

14 June 2019.