SIMPLE GUIDE TO CHPQA UNCERTAINTY

Abstract
This is a simple guide to CHPQA uncertainty covering the definition of uncertainty and how it is determined, the CHPQA 'best practice' uncertainties, and how to deal with excess uncertainty.

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1. Introduction

The 'Simple Guide To' series is designed to assist Responsible Persons (RPs) in understanding various aspects of the CHPQA process. The content here is a simplified and condensed form of that found in the detailed Guidance Notes 13, 17-19 and 23 which are outlined below and can be accessed online with the following hyperlinks. References are made to these and other guidance notes in the form "**GNXX.X**" which refer to paragraphs within the detailed guidance notes. In any cases of doubt, please refer to the detailed guidance notes as they are comprehensive and shall always take precedence.

Detailed Guidance Notes:

GN13 – CHP Scheme Monitoring Information

GN17 – Uncertainty in Metered Inputs and Outputs

GN18 – Uncertainty in Calculated Energy Inputs and Outputs

GN19 – Adjustment of Energy Inputs and Outputs for Excessive Uncertainty

GN23 – Correction of Bias in Inputs and Outputs Information

CHPQA Guidance Notes:

https://www.gov.uk/guidance/chpqa-guidance-notes

Any CHP monitoring system is subject to levels of uncertainty in its measured values. The measured values are reported to CHPQA to determine a CHP Scheme's performance. Since the benefits available to a CHP Scheme are dependent on its performance, accurate determination of any performance values is essential in ensuring that the correct fiscal benefits are received.

Consequently, CHPQA has procedures in place to keep uncertainty of monitored values within accepted ranges, or if such ranges are exceeded, there is a system to correct a CHP's performance appropriately. It is therefore in the RP's interest to minimise the uncertainty of their monitoring system to ensure that the maximum fiscal benefits are received.

2. What is uncertainty?

Any measurement is subject to imperfections, uncertainty is a quantitative indication of the quality of a measured value. Uncertainty is expressed as a range ±n% of the measured output. For example, a value that can be determined with an uncertainty of ±2% has a high probability (usually greater than 95%) that it lies within the range 98% to 102% of the true value.

Example

The manufacturer of a flow meter states that the uncertainty of its device is ±2% of reading (% RD)*. The flow meter records a water flowrate of 10l/s through a pipe. The real flowrate through the pipe is therefore likely (with greater than 95% probability) to lie within the range of 9.8l/s and 10.2l/s.

**Note that this uncertainty is stated a percentage of reading. See Section 2.1 for an explanation of uncertainty as percentage of reading vs full-scale.*

Applied to CHPQA, uncertainty is an essential indicator of the quality of the monitoring of the performance (energy inputs and outputs) of a CHP Scheme. Since the financial benefits available to a CHP Scheme are dependent on its performance, accurate monitoring of a Scheme is essential in ensuring that the correct fiscal benefits are received.

CHPQA therefore has procedures in place to encourage that the uncertainties in monitored performance values lie within an acceptable **best practice** range. Where a monitored value has an uncertainty greater than that of the accepted best practice, this monitored value is deemed to have **excess uncertainty**. A CHP Scheme's performance is corrected when a monitored performance value has excess uncertainty. **Uncertainty Adjustment Factors** are derived from excess uncertainty and act to reduce the power efficiency, heat efficiency and consequently, the Quality Index (QI)[*] value of a Scheme.

[*] *The Quality Index (QI) is the scoring system developed for CHPQA that provides a means of assessing the quality of CHP Schemes.*

2.1. Uncertainty as percentage of reading vs full-scale

Uncertainty is either quoted as a percentage of reading (% RD) or as a percentage of full-scale (% FS). The example above stated an uncertainty based on percentage of reading. If the monitoring device had an uncertainty specified at full-scale, then it would have a fixed error no matter where the measured value is within the measured limits of the device.

Example

A flow meter calibrated for a flow of 10/ls has an uncertainty of ±2% full-scale (% FS). At a full-scale reading of 10l/s, the true value is likely to lie within 9.8l/s and 10.2l/s (±0.2l/s).

However, as the flow moves away from full-scale, the uncertainty remains as ±2% FS (±0.2l/s). So, at a flow of 5l/s, the error of ±0.2l/s becomes a larger percentage of the flowrate ±4%.

2.2. What is Bias?

Bias is not the same as uncertainty, it is a systematic error in a measurement or calculated value that arises from a recognised over, or understatement in a quantity that influences the measurement. Bias can arise from incorrect calibrations or wrong assumptions. If such a systematic effect is significant in size, (relative to the required accuracy of the measurement), a correction (or correction factor) should be applied to compensate for the resulting error. See **GN23** for detailed guidance on evaluation and correction of bias.

3. How should uncertainty be determined, reported and maintained?

3.1. Determining uncertainty

Uncertainties of metered values, where possible, should be obtained from the meter manufacturer's specifications or accepted standards. It is recognised that uncertainties may not always be available and so a methodology of calculating uncertainty has been detailed in both **GN17** and **GN18**. Calculation of the uncertainty must take into account all components of the measurement (e.g. the sensor(s) or measuring element(s), transducer, transmitter, and integrator, recorder or computations). Note that additional uncertainties are applied to account for excessive time elapsed since calibration as set out in **GN17**. In addition, all metered or derived energy inputs and outputs must be checked to detect bias (errors) in the recorded values. All calculations of uncertainty and checks for bias must be fully documented.

3.2. Reporting uncertainty to CHPQA

It is necessary to detail the uncertainty of monitoring devices when submitting a F2 form. All uncertainties are to be expressed as percentage to two decimal places e.g. 3.05%. The uncertainties of a monitoring arrangement will also be requested when submitting an F3 form (for new or upgraded schemes). It is appreciated that the components of a monitoring arrangement may not yet of been specified when completing an F3 form. In such instances, please provide an indicative uncertainty, so that CHPQA are aware if the uncertainty is likely to fall within best practice or not. An example of a completed monitoring arrangement section of an F2 form is shown below:

Q5 : Scheme Details (Monitoring Arrangements)

See: GN13 , 14, 15, 16, 17, 18, 20 & 22

- Use this table to list all existing and proposed metering stations (including. the meters by which you are billed) for your Scheme inputs and outputs. See GN12.7 to GN12.13
- Identify each meter by tag number using the notation in the Guidance Notes. (Each meter should be identified on your Scheme line and energy flow diagrams). See GN12.3
- Provide details of all export metering (heat and electricity). See GN15.10 to GN15.14 & GN16.5 & GN16.7
- Attach details of any indirect methods used to derive unmetered inputs or outputs (include below the monitoring upon which these rely). See GN20 to GN22
- Identify the meter uncertainty % (= 100 - accuracy of reading %), attach supporting calculations. See GN17 & GN18

Tag prefix	Tag no.	User tag	Year installed		Metered service	Outputs		Uncertainty	
M	1	M1(FcQ)	2018		Fuel	80-1600	m3/hr	% 1.55	delete
Model type	Example Gas Turbine Meter		MPR meter	Yes	MPR no.	9339232669	Serial no.	1509112935	
M	2	M2(EQ)	2018		Electricity	N/A	MWh	% 1.55	delete
Model type	Example Power Meter - Class 2		MPR meter	No	MPR no.	N/A	Serial no.	6243972	
M	3	M3(HQ)	2018		Heat	0.6-30000	m3/hr	% 1.05	delete
Model type	Example Heat Meter		MPR meter	No	MPR no.	N/A	Serial no.	5351234	

3.3. Calibration of meters

To ensure that monitoring system uncertainties are maintained within the meter's specification, a calibration schedule should be developed for your monitoring system. Guidance on the frequency and method of calibrating the primary metering element(s) and secondary components such as transmitters and computations is provided in **GN13**. Failure to meet these requirements will incur the imposition of excess uncertainties as set out in **GN17**. An exemption option is available for minor streams as set out in **GN13**. Minor streams are defined as energy inputs or outputs that cumulatively constitute no more than 5% of the annual total energy input, power output or heat output of the Scheme. Evidence of the integrity of monitoring arrangements, valid calibration records and calibration schedules will be inspected as part of a CHPQA Scheme Audit.

4. CHPQA 'best practice' uncertainties

To be deemed best practice, the maximum uncertainties (including, where applicable any additional uncertainties associated with time elapsed since calibration or variations in fluid properties) associated with the measurement of energy flows of different types are as follows:

4.1. Energy input best practice uncertainties

Best practice uncertainties for energy inputs, as listed in GN13.11.

Energy Input	**Best Practice Uncertainty**
Metered Fuels	±2.00% of reading
Metered Hot Water (or other circulating fluid)	±4.50% of reading with concessions for Schemes with TPC* <2MWe (see GN16.15)
Metered Steam	±2.00% of full-scale, ±3.00% of reading
Indirectly determined energy input	±2.00% of value, except for heat outputs from Schemes with TPC <2MWe where ±5.0% of value applies.

* The Total Power Capacity (TPC) is the registered maximum power generation capacity of the CHP Scheme (in MWe), at International Standard Atmospheric conditions.

4.2. Power output best practice uncertainties

Best practice uncertainties for energy inputs, as listed in GN15-1.

Power Output				
Rated Capacity	**Watt-Hour Meter Standard and Accuracy Class**	**Current Transformer Accuracy Class** (Note 1)	**Voltage Transformer Accuracy Class** (Note 2)	**Best Practice Uncertainty** (Note 3)
> 100 MVA	BS EN 62053 (2003) - Class 0.2S	0.2S	0.2	±0.50%
< 100 MVA	BS EN 62053 (2003) - Class 0.5S	0.2S	0.5	±1.00%
< 10 MVA	BS EN 62053 (2003) - Class 1	0.5	1	±1.50%
≤ 1 MW	BS EN 62053 (2003) - Class 2	0.5	1	±2.50%
Indirectly determined mechanical power				±2.00%

Notes:
(1) CTs to IEC 60044-1 (2002)
(2) VTs to IEC 61869-3 (2011) and 61869-5 (additional requirement)
(3) It should be noted that the actual uncertainty is influenced by power factor and metered load (percent of rated measuring current). The nominal values tabulated shall be used to assess the excess uncertainty of metering systems (meters, current and voltage transformers) that do not meet the applicable standard for their rated capacity.

4.3. Heat output best practice uncertainties

Best practice uncertainties for heat outputs, as listed in GN13.11.

Heat Output	**Best Practice Uncertainty**
Metered Hot Water (or other circulating liquid)	±4.50% of reading with concessions for Schemes with TPC <2MWe (see GN16.15)
Metered Steam	±2.00% of full-scale, ±3.00% of reading
Indirectly determined heat output	±2.00% of value, except for heat outputs from Schemes with TPC <2MWe where ±5.0% of value applies.

5. What happens if uncertainty exceeds the 'best practice'?

If the uncertainty of a metered or calculated input/output exceeds that of the best practice uncertainties, that input/output is considered to have excess uncertainty. Excess uncertainty is simply defined as the additional difference between the actual uncertainty and the best practice uncertainty:

If $\mathbf{U_o} > \mathbf{UBP}$, then $\mathbf{UX} = \mathbf{U_o} - \mathbf{UBP}$

If $\mathbf{U_o} \leq \mathbf{UBP}$, then $\mathbf{UX} = \mathbf{0.00}$

Where $\mathbf{U_o}$ = Uncertainty of value, **UBP** = Best practice uncertainty and **UX** = Excess uncertainty.

5.1. Uncertainty Adjustment Factors

If it is found that an energy input or output has an excess uncertainty, it will be necessary to calculate the Uncertainty Adjustment Factor for that corresponding energy input or output. The Uncertainty Adjustment Factor will act to reduce the power and heat efficiencies (η_{power} and η_{heat}) of the Scheme, consequently reducing its QI value. There are three Uncertainty Adjustment Factors which are to be provided by the RP in Form F4:

- F_{OI} – Energy Inputs
- F_{OP} – Power Outputs
- F_{OH} – Heat Outputs

If there is no excess uncertainty in the monitoring of the Scheme, the adjustment factors will be equal to 1.0000 (note that adjustment factors are to be expressed to 4 decimal places). Excess uncertainty in the inputs will increase the F_{OI} to be greater than 1.0000 and excess uncertainty in the outputs will reduce the F_{OP} or F_{OH} to be less than 1.0000. In such cases, the adjustment factors will reduce the power and heat efficiencies using the below equations:

$$\eta_{power} = \frac{CHP_{TPO} \times F_{OP}}{CHP_{TFI} \times F_{OI}}$$

$$\eta_{heat} = \frac{CHP_{QHO} \times F_{OH}}{CHP_{TFI} \times F_{OI}}$$

What happens if uncertainty exceeds the ‘best practice’?

The procedure for calculating the Uncertainty Adjustment Factors has been outlined in **GN19.10-19.21** with accompanying worksheets and examples **GN19-1**, **19-2** and **19-3**. The RP should complete and submit the worksheets to CHPQA wherever an adjustment factor has been calculated.

An example of a completed Uncertainty Adjustment Factors section of an F4 form is shown below:

Q6 : CHP Scheme Efficiency

See GN24.2.

UNCERTAINTY ADJUSTMENT FACTORS

Please enter the uncertainty adjustment factors derived in accordance with GN19.

Fuel Uncertainty Adjustment Factor FOI:	1.0921
Power Uncertainty Adjustment Factor FOP:	1
Heat Uncertainty Adjustment Factor FOH:	0.9012

Power Efficiency = 100 x (CHP_{TPO} x F_{OP}) / (CHP_{TFI} x F_{OI})

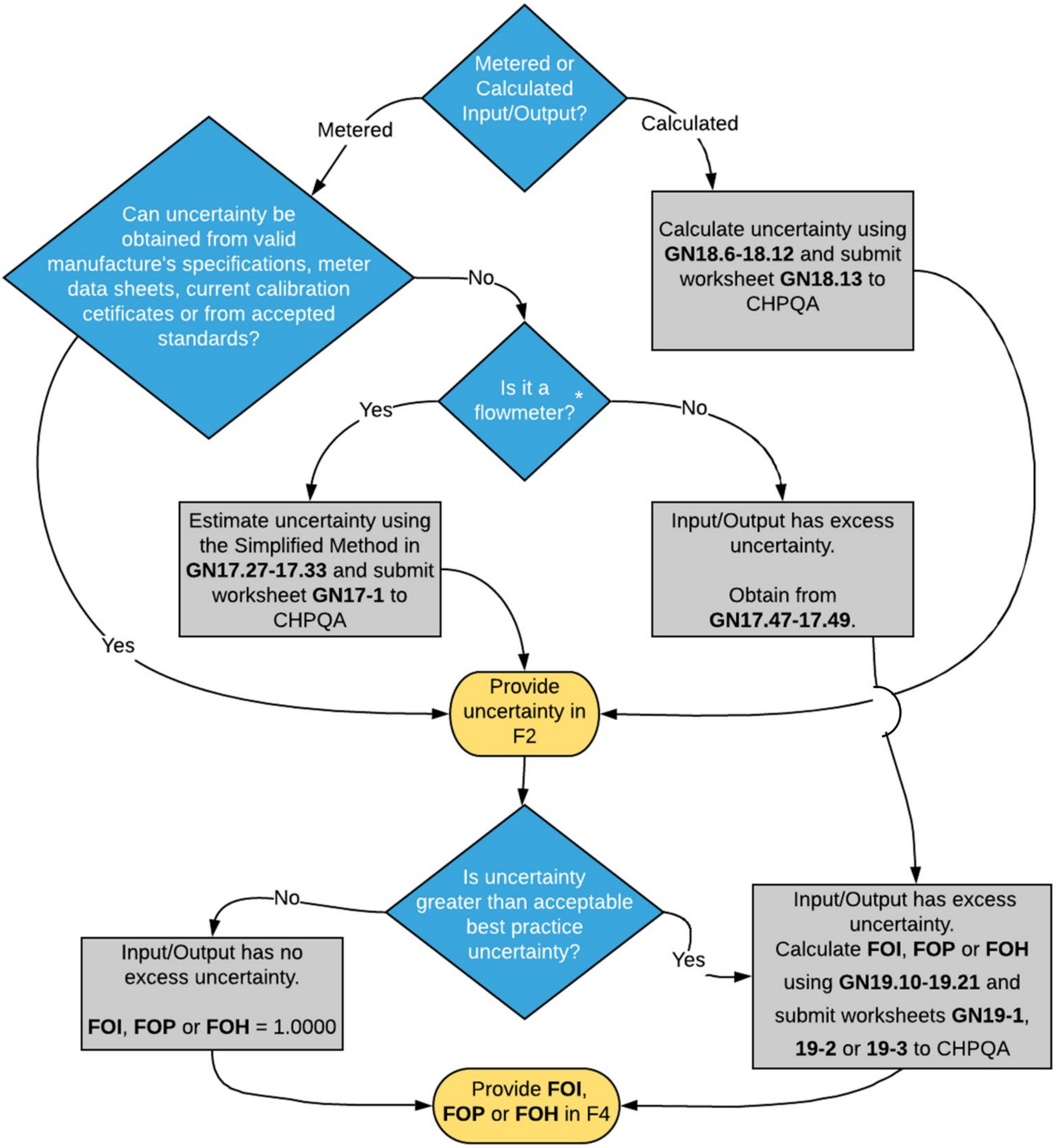
η POWER = 100 x (18285 x 1) / (104055 x 1.0921) = 16.09 %

Heat Efficiency = 100 x (CHP_{QHO} x F_{OH}) / (CHP_{TFI} x F_{OI})

η HEAT = 100 x (61258 x 0.9012) / (104055 x 1.0921) = 48.58 %

6. Uncertainty determination flowchart

The flowchart below describes the route an RP would take in determining the overall uncertainty and Uncertainty Adjustment Factor of an energy input/output.



**CHPQA have developed a methodology to estimate the uncertainty of flow meters, should the uncertainty not be readily available from documentation. Unfortunately, there is no estimation method for other types of meters, therefore, an automatic excess uncertainty is applied.*

7. Further information

7.1. Further guidance

See the accompanying series of ‘Simple Guide to’ guides and the detailed guidance notes here: https://www.gov.uk/guidance/chpqa-guidance-notes

7.2. Contact Us

In the first instance, all queries on CHPQA should be directed to the CHPQA helpline, or emailed to the Administration team using the details below:

CHPQA Helpline:

- Tel: 01235 753004
- E-mail: chpqainfo@chpqa.com
- Website: https://www.gov.uk/combined-heat-power-quality-assurance-programme