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Guidance Document

MRR Guidance on Uncertainty Assessment – Example

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Status of this document:

This document is part of a series of documents provided by the Commission services for supporting the implementation of the "Monitoring and Reporting Regulation" (the "MRR" or "M&R Regulation") for the EU ETS (the European greenhouse gas Emission Trading System). A new version of the MRR has been developed for the use in the 4th phase of the EU ETS, i.e. Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 in its current version[1].

The guidance represents the views of the Commission services at the time of publication. It is not legally binding.

This document takes into account the discussions within meetings of the informal Technical Working Group on the MRVA (Monitoring, Reporting, Verification and Accreditation) under WG III of the Climate Change Committee (CCC), as well as written comments received from stakeholders and experts from Member States.

All guidance documents and templates can be downloaded from the Commission's website at the following address: **https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1** .

[1] Updated by Commission Implementing Regulation (EU) 2020/2085 of 14 December 2020 amending and correcting Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council; the consolidated MRR can be found here: **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R2066-20210101**.
Note: as some amendments to the MRR will start to apply on 1 January 2022 (see section 1.2 of GD 1 "What is new in the MRR"), they do not appear in the consolidated version in 2021. The complete amendment can be found under **https://eur-lex.europa.eu/eli/reg_impl/2020/2085/oj**

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November 2016	2nd draft for discussion	
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14 September 2021	Final updated version	

1 INTRODUCTION

This document supplements GD 4 “Guidance on Uncertainty Assessment” by presenting examples. For more details on uncertainty assessment in the context of the monitoring and reporting of GHG emissions in the EU ETS, please refer to that guidance document[2].

Note that operators should not be tempted to copy text from this document, but should always define their monitoring methodology in a very installation-specific way, choosing the most appropriate means of monitoring, with the lowest possible uncertainty and highest robustness against errors.

2 INSTALLATIONS WITH LOW EMISSIONS

This chapter presents an example uncertainty assessment of an “installation with low emissions” pursuant to Article 47 of the Monitoring and Reporting Regulation (hereinafter the “MRR”, see footnote **Error! Bookmark not defined.**).

2.1 Requirements

Article 47(3) of the MRR exempts installations with low emissions (i.e. with annual emissions < 25,000 t CO_2) from having to submit to the competent authority evidence for each source stream or emission source demonstrating compliance with the required uncertainty thresholds. However, this does not exempt them from determining whether they comply with the required tiers. Furthermore, Article 19(1) of the AVR requires verifiers to confirm the validity of the information used to calculate the uncertainty levels.

Pursuant to Article 60(1) all operators are required to “*ensure that all relevant measuring equipment is calibrated, adjusted and checked at regular intervals including prior to use, and checked against measurement standards traceable to international measurement standards, where available, in accordance with the requirements of this Regulation and proportionate to the risks identified.*” For this purpose Article 59(3) of the MRR requires the operator to establish and maintain written procedure(s) for quality assurance of the measurement equipment. Therefore, information about the performance of measurement instruments with respect to the accuracy and reliability of results obtained should be available at every installation. Note that for instruments under national legal metrological control the requirements of Article 60 are often met sufficiently without excessive effort (e.g. the check against traceable international standards is achieved by the official calibration).

In the following section an example for an uncertainty assessment commensurate for a “small installation” (i.e. an “installation with low emissions” pursuant to Article 47 of the MRR) is elaborated. The example installation is described in section 2.2. Section 2.3 contains the exemplar uncertainty assessment.

[2] https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/gd4_guidance_uncertainty_en.pdf

2.2 The example installation

The installation discussed in this chapter is producing bricks and pavers, and is emitting on average 15,000 t CO_2 per year. The following source streams need monitoring:

Fuel/Material	Category	Estimated emissions (t CO_2 / a)	Minimum monitoring requirements for activity data
Light fuel oil	Commercial standard fuel	6,500	Tier 1 (± 7.5%)
Clay	Ceramics: Method A	8,000	Tier 1 (± 7.5%)
Lignite	Other solid fuels (pore-forming agent)	498	De-minimis
Diesel	Other gaseous and liquid fuels (auxiliary power unit)	2	De-minimis

The methods described for monitoring in this example have been chosen due to their wide-spread use. However, they are examples only and should not be applied in practice without checking whether better methods (more reliable, more accurate etc.) are available.. Operators of an installation with low emissions must apply tiers higher than tier 1 if they can be achieved without additional effort[3]. It is in particular no additional effort to apply a tier higher than tier 1 if the measurement instrument already in use complies with a higher tier, i.e. a higher tier is actually applied.

Light fuel oil:

In the example this fuel is delivered by trucks and stored in tanks (storage capacity <5%). In the example there are clearly commercial transactions between independent parties. Therefore (as in most similar cases) the measurements used for the trading are subject to national legal metrological control (see Route CO-1 or CT-1 of Guidance Document 4 on Uncertainty). Therefore, **maximum permissible error in service** as allowed by the relevant national legislation can be used.

Background:

To show compliance the operator has to demonstrate evidence that the uncertainty threshold of the required tier is not exceeded, e.g. by requesting the trade partner to provide the official calibration certificate/protocol for the volume flow measurement instruments installed on the trucks. This evidence will allow verifiers to confirm the validity of data used to determine the tier which is actually met.

Please note that non-compliance here is very unlikely as it can be assumed that even the least stringent requirement set out in the relevant national legislation will ask for an uncertainty lower than 7.5%. Still, a document confirming that this instrument is subject to national legal metrological control is needed.

If the national legal metrological legislation also allows measurement instruments with a higher uncertainty for that purpose, further evidence would be needed. Such evidence may be documents clearly demonstrating which accuracy classes are allowed to be used, e.g. contractual arrangement with the supplier demonstrating that only measurement instruments with certain accuracy classes are to be used.

[3] Article 47(6): "*By way of derogation from Article 26(1) and 41(1), the operator of an installation with low emissions may apply as a minimum tier 1 for the purposes of determining activity data and calculation factors for all source streams and for determining emissions by measurement-based methodologies, unless higher accuracy is achievable without additional effort for the operator, without providing evidence that applying higher tiers is technically not feasible or would incur unreasonable costs.*"

Clay:

The clay in the example is gathered from the clay pit directly by the operator. Therefore, no commercial transaction takes place and hence any available measurement instrument used is not subject to national legal metrological control. Still, the operator transports the clay from the pit to the installation by trucks. There is a possibility for those trucks to be weighed on a weighing bridge owned by the operator.

The operator can simplify the uncertainty assessment here if the measurement instrument is used in an environment appropriate for its use specifications (→ see Steps 1 to 4, Route CO-2a/2b in Guidance Document 4 on Uncertainty).

Background:

For applying the proposed route CO-2a/2b, the operator has to demonstrate that:

1. *Operating conditions regarding relevant influencing parameters are available*
2. *Operating conditions regarding relevant influencing parameters are met*
3. *Performing of quality assured calibration procedures*
4. *Further quality assurance procedures for measuring activity data*

Please note that compliance with those four steps is also relevant for light fuel oil (see above). However, the obligations for compliance with national legal metrological control will assure that those four steps are met.

The application of these steps is demonstrated in the exemplar in section 2.3.

It is assumed that for this weighing bridge the manufacturer's specifications contain information about the appropriate operating conditions (requirement step 1 met).

For demonstrating that the requirements for step 2 are satisfied, the operator could prepare a simple checklist like the table displayed in section 2.3.

For demonstrating compliance with steps 3 and 4 to a verifier, the operator has to have in place an appropriate procedure for quality assurance of the measurement equipment and to ensure that all relevant measuring equipment is calibrated, adjusted and checked at regular intervals including prior to use, and checked against measurement standards traceable to international measurement standards (see above the requirements of Articles 58(3) and 59(1)). Please note that there is no exception for any installation to comply with the requirements in those Articles.[4]

Although the storage capacity in the example installation is above 5% of the annual used quantity of clay and, according to Article 47(5), the operator of an installation of low emission could still claim exemption from taking stock changes into account in the uncertainty assessment, this example assumes that the operator prefers to include them on grounds of best practice. The consumed quantity of clay is calculated as:

$$Q = P - E + (S_{begin} - S_{end})$$

Example 7 in section 8.3 of Guidance Document 4 shows how the uncertainty related to the stock changes can be calculated. The operator of the example installation uses this approach, as shown in section 2.3.

Note that Article 47(5)[5] *exempts installations with low emissions to include uncertainties related to stock data in an uncertainty assessment. However, stock data is included in the example to demonstrate how simple the calculation is and how marginal the impact of the associated uncertainty is on the overall uncertainty.*

For the determination of CO_2 emissions, activity data and all calculation factors must relate to the same state of the material stream, i.e. in particular to the same level of moisture in the case of clay. Therefore, the uncertainty associated with the determination of the moisture content has to be taken into account (see example 3 in section 8.2 of Guidance Document 4 for uncorrelated uncertainties of a product). The MRR refers to the "dry" clay in section 12 of Annex IV but the "moisture content" is not a calculation factor in the MRR. As a

[4] Note that complying with those steps is required regardless of the simplification routes being taken.

[5] Article 47(5): "*The operator of an installation with low emissions shall be exempt from the requirement of Article 28(2) to determine stock data at the beginning and the end of the reporting period, where the storage facilities are capable of containing at least 5 % of the annual consumption of fuel or material during the reporting period, in order to include related uncertainty in an uncertainty assessment.*"

consequence, it has to be taken into account for the determination of the uncertainty of the activity data (see calculation in section 2.3). For the determination of this moisture content as well as for the emission factor laboratory analyses are used, and consequently a sampling plan needs to be in place.

Lignite:

This pore-forming agent is a de-minimis source stream. Therefore, an estimation method may be applied for determining the annual emissions stemming from this source stream. Because this fuel/material is bought on the market by the operator of the installation, invoices may be used to determine the annual activity level. Because the example Member State has not published default values for lignite, which would allow the use of tier 2, emissions are obtained by multiplying the amount lignite used with the net calorific value and emission factor provided in Annex VI of the MRR (Tier 1).

Diesel:

Diesel is a de-minimis source stream as well. Precise measurement would be demanding (because Diesel is also used for mobile machinery such as truck loaders, fork lifts etc. and therefore, fuel invoices can't be used). For determining the diesel used in the auxiliary power unit an estimation method may be used. In the example a common formula is proposed:

$$Activity\ Data = AOH \times CAP \times (3600 / 10^9) \times (1 / NCV)$$

$$Annual\ emissions = AD \times NCV \times EF$$

AOH .... Annual operating hours

CAP .... Installed capacity of the auxiliary power unit (kW)

AD..... Activity data (t)

NCV .... Net calorific value (TJ/t, taken from e.g. Annex VI or National Inventory, if available)

EF ..... Emission factor (t CO_2/TJ, taken from e.g. Annex VI or National Inventory, if available)

2.3 Exemplar Uncertainty assessment

The following exemplar elaborates what the example installation's uncertainty assessment could look like.

Light fuel oil:

Tier applied for activity data: **Tier 2 (± 5.0%), based on invoices**

Evidence for complying with the tier requirements: *see attached the latest official calibration certificates for the rotor flow meters on the trucks from our three suppliers*

Clay:

Tier applied for activity data: **Tier 2 (± 5.0%)**, uncertainty achieved = 4.5% (see calculation below)

Evidence for complying with the requirements of the tier: Route CO-2a/2b is used.

"Step 1": *see manufacturer's specification ("MPES ± 4.0%") in the weighing bridge's operating manual; example: see sampling plan for determination of the moisture content of the (raw) clay;*

Error propagation taking into account stock changes:

- storage capacity: 7,000 t,
- (expanded) uncertainty related to stock estimation at end of year (conservative estimate): 10%;
- average annual amount of clay consumed: 125,000 t,
- max. permissible error in service laid down in manufacturer's specifications: 4%[6];
- uncertainty related to determine the moisture content: 2%

Calculation:

$$u_{wet} = \frac{\sqrt{2 \cdot (U_{stock})^2 + (U_{clay})^2}}{clay\ consumed\ \ annually} = \frac{\sqrt{2 \cdot (7{,}000 \cdot 10\%)^2 + (125{,}000 \cdot 4\%)^2}}{125{,}000} = 4.08\%$$

$$u_{dry} = \sqrt{u_{wet}^2 + u_{moisture}^2} = \sqrt{4.08\%^2 + 2\%^2} = 4.5\%$$

Evidence for complying with the requirements in "Step 2":

Checklist for relevant parameters of the weighing bridge:

Parameter listed in manufacturer's specifications	Value specified by manufacturer	Actual applied ranges/conditions	Compliant?
Temperature	-15 – 50 °C	-15 – 40 °C	Yes
Measurement range	2 - 50 tonnes	10 - 35 tonnes	Yes
Wind speed	< 20 m/s	< 15 m/s	Yes

[6] Note that in this case the manufacturer's specifications explicitly state that this error refers to "in service" condition taking into account influencing factors during use (aging, corrosion, drift, etc.), this value can be accepted as the MPES.

Calibration interval	Every two years	Every two years	Yes

Evidence for complying with the requirements in "Steps 3 and 4"[7]:

See attached the latest calibration certificates for the truck weighing bridge WB-XYZ123 and the quality management procedures in section 2.4.

Lignite:

Tier applied for activity data: **Tier 3 (± 2.5%), based on invoices**

Evidence[8]: *see attached the latest official calibration certificates requested from the trading partners delivering lignite*

Diesel:

Tier applied for activity data: **De-minimis**

Approach: Emissions are calculated based on the annual operating hours, the auxiliary power unit's installed rated thermal input and the inventory emission factor of Diesel. Conservative estimates of emissions are typically found to be in the range of 1 to 5 t CO_2 per year.

[7] Steps 3 and 4 require quality assurance (regular calibration) for the measurement equipment to be carried out. This needs to be covered by a written procedure in accordance with Article 59(3), point a). For further reading please consult section 3.1.1.4 of Guidance Document 4 on Uncertainty.

[8] Note: If those certificates are not available, activity data can still be determined using invoices. However, without demonstrating compliance with a tier, this would be a no-tier approach. It would be only applicable for de-minimis source streams.

2.4 Quality management for the example installation

The procedure required for quality assurance of measurement equipment could be defined as follows:

Example for a procedure (adapted version of procedure in GD1):

1. The installation is normally shut down between December and February. Measurement equipment (including that for EU-ETS) is usually calibrated during that phase.
2. Responsible person (deputy manager of O&M) maintains a calendar of appropriate calibration and maintenance intervals for all ETS instruments listed in table 7.b of the monitoring plan. Alert is set to 30 Nov of each year.
3. Responsible person (deputy manager of O&M) checks which QM activities are required according to the calendar within the next 4 weeks. As appropriate, he reserves resources required for this task in meetings with the plant manager.
4. Calibration and maintenance of ETS instruments is tracked and documented in file "Z:\ETS_MRV\QM\calibr_log.xls" electronically and hardcopy: Office HS3/27, shelf 3, Folder identified "QM 27-ETS -nnnn". (nnnn=year). Information documented contains: ID of instrument, date when instrument was installed, last calibration, meter reading after last calibration, laboratory hired for the last calibration, statement of the last calibrations, date until next calibration is due.
5. For all measurement instruments for which calibration in that particular year is due the responsible person follows the procedure:
    a. Responsible person (deputy manager of O&M) orders external experts (calibration institutes).
    b. Responsible person ensures that QM tasks are carried out on the agreed dates.
    c. Responsible person keeps records of the above QM activities.
    d. Responsible person reports back to plant manager on corrective action required. Corrective action is handled under procedure QM 28-ETS

<End of procedure>

The procedure itself, as elaborated above, is a document independent from the monitoring plan. However, a summary of the procedure has to be included in the monitoring plan in a standardised table (section K.22.b of the Commission's Monitoring Plan template). This could be as follows:

Item according to Article 12(2)	**Possible content (examples)**
Title of the procedure	QM for ETS instruments
Traceable and verifiable reference for identification of the procedure	QM 27-ETS
Post or department responsible for implementing the procedure and the post or department responsible for the management of the related data (if different)	Q&M office
Brief description of the procedure	• Responsible person maintains a calendar of appropriate calibration and maintenance intervals for all instruments listed in table 7.b of the monitoring plan • Responsible person checks which QM activities are required. As appropriate, he reserves resources required for this tasks in meetings with the plant manager. • Responsible person orders external experts (calibration institutes and/or service technicians of the manufacturer). • Responsible person ensures that QM tasks are carried out on the agreed dates. • Responsible person keeps records of the above QM activities. • Responsible person reports back to plant manager on corrective action required, if any. • Corrective action is handled under procedure QM 28-ETS, if relevant.
Location of relevant records and information	Hardcopy: Office HS3/27, shelf 3, Folder identified "QM 27-ETS - nnnn". (nnnn=year) Electronically: "Z:\ETS_MRV\QM\calibr_log.pst"
Name of the computerised system used, where applicable	MS Outlook calendar, also used for storing documents as attachments chronologically
List of EN standards or other standards applied, where relevant	In the instrument list (document ETS-Instr-A1.xls) the applicable standards are listed. This document is made available to the verifier upon request.

3 EMISSIONS FROM CATALYTIC CRACKING USING CEMS

3.1 Background information

Fluid catalytic cracking is used in refineries to convert high-boiling hydrocarbons into lower-molecular weight but higher value products. During this catalytic reaction part of the carbon-containing feedstock forms carbonaceous deposits on the catalyst that causes its inactivation. Therefore, the catalyst has to be regenerated by burning off the deposited carbon using air in a separated reactor, called the regenerator. The carbon in the flue gas formed from this regeneration is converted into CO_2 either already during the regeneration or during a subsequent post-combustion.

For the monitoring of emissions stemming from catalytic cracker regeneration section 2 of Annex IV states: "*[..] by way of derogation from Article 24 and 25, emissions from catalytic cracker regeneration, other catalyst regeneration and flexi-cokers shall be monitored using a mass balance, taking into account the state of the input air and the flue gas. All CO in the flue gas shall be accounted for as CO_2, applying the mass relation: t CO_2 = t CO * 1,571. The analysis of input air and flue gases and the choice of tiers shall be in accordance with the provisions of Articles 32 to 35. The specific calculation methodology shall be approved by the competent authority.*" This provision clarifies that the determination of emissions from catalytic cracker regeneration in general requires the use of appropriate analytical standards and accredited laboratories following the provisions in Articles 32 to 35.

One way to satisfy those criteria can be by application of continuous emissions monitoring systems (CEMS) following the rules set out in Articles 40 to 46 of the MRR. It has to be noted that the mass balance mentioned in Annex IV, section 2 is not a 'real' mass balance as defined in Article 25 but rather a flue gas volume balance according to Article 43(5)(a). According to Annex IV, section 2, the determination of the annual emissions from the regeneration of catalytic converters from cracking and reforming processes shall be monitored using a balance, taking into account the CO_2, CO, NO_x and SO_2 contents in the flue gas from the regeneration and in the amount of air supplied in accordance with Article 43(5)(a).

For CEMS, the annual emissions of the emitted GHG are calculated by the equation provided in Annex VIII, Section 3, equation 1 of the MRR):

$$Emissions_{annual}[t] = \sum_i GHG\ conc_{hour\ i}[g/Nm^3] \cdot flue\,gas\ flow_i\ [Nm^3/h] \cdot 10^{-6}[t/g]$$

where:

GHG $conc_{hour\ i}$ ..... concentrations of GHG in the flue gas flow measured during operation hour i

Flue gas $flow_i$ ..... flue gas flow determined for each hour i

For each hour i, therefore, the emissions from coke are determined as the product of the GHG $conc_{hour\ i}$ and the flue gas $flow_i$. As the same measurement equipment is usually used throughout the year for each hour i, the uncertainties associated with the emissions calculated for each hour should be treated as correlated (see section 8.2 of Guidance Document 4). Consequently, the uncertainty of the annual emissions is the same as for the emissions of each hour i.

In the subsequent processes, a complete conversion of CO to CO_2 is assumed:

$$E_{total,Coke} = GHG_{conc} \cdot V_{flue,dry}$$

$$GHG_{conc} = (a_{CO_2} + b_{CO}) \cdot \frac{44.01}{22.41 \cdot 1000}$$

$E_{total,coke}$ ..... overall CO_2 emissions from coke burned off in t CO_2

GHG_{conc}.....greenhouse gas (CO_2) concentration in the dry flue gas in g/Nm³

$V_{flue,dry}$.....calculated annual volume of the dry flue gas (see calculation below) in Nm³

aCO_2 .....measured carbon dioxide content in dry flue gas in % by volume

bCO .....measured carbon monoxide content in dry flue gas in % by volume

The volume flow rate of the flue gas to be used in the equation above is usually not measured[9], thus it must be calculated by a balance. In the regeneration, the coke-loaded catalyst is regenerated by an air supply and all combustible constituents are converted to CO_2, CO, H_2O, NO_x and SO_2. The calculation of the amount of dry flue gas from the amount of air supplied is done according to the following formula, assuming a constant inert gas content of 79.07% by volume:

$$V_{\text{flue, dry}} = \frac{79.07}{100 - a_{CO_2} - b_{CO} - c_{O_2} - d_{NO_x} - e_{SO_2}} \cdot V_{\text{air, dry}}$$

$V_{air,\ dry}$.....volume of dry air supplied in Nm³

aCO_2 .....measured carbon dioxide concentration in dry flue gas in % by volume

bCO .....measured carbon monoxide concentration in dry flue gas in % by volume

cO_2 .....measured oxygen concentration in dry flue gas in % by volume

dNO_x .....measured NO_x concentration in dry flue gas in % by volume

eSO_2 .....measured SO_2 concentration in dry flue gas in % by volume

A prerequisite for the balance shown is that coke contains hardly any nitrogen compounds or they are converted into NO_x (which is usually the case).

3.2 Determination of the uncertainty

For source streams the uncertainty thresholds set out in the MRR commonly refer to the determination of activity data. In contrast to that, the uncertainty threshold for emissions from cracking activities relate to the total annual emissions. Therefore, the uncertainty of $E_{total,coke}$ has to be assessed and compared against the thresholds of the required tier listed in table 1 of Annex II of the MRR.

As $E_{total,coke}$ depends on two input quantities, $V_{flue,dry}$ and the GHG_{conc}, the uncertainty associated with these two components has to be assessed:

$$V_{\text{flue, dry}} = \underbrace{\frac{79.07}{100 - a_{CO_2} - b_{CO} - c_{O_2} - d_{NO_x} - e_{SO_2}}}_{\text{B}} \cdot \underbrace{V_{\text{air, dry}}}_{\text{A}}$$

$$GHG_{conc} = (\underbrace{a_{CO_2} + b_{CO}}_{\text{C}}) \cdot \frac{44.01}{22.41 \cdot 1000}$$

Step 1: determination of the uncertainty of $V_{flue,dry}$

In order to determine the flow rate of the dry flue gas, $V_{flue,dry}$, The volume flow of dry air at standard conditions ($V_{air,\ dry}$) is needed as well as the composition of the components in the flue gas, namely the concentrations of CO_2, CO, O_2, NO_x and SO_2.

[9] However, if measured, Article 42(1) requires methods based on EN ISO 16911-2 (Stationary source emissions — Manual and automatic determination of velocity and volume flow rate in ducts)

Step 1.1: uncertainty item A ($V_{air, dry}$):

$V_{air, dry}$ is not measured directly. What is measured is the volume flow of the air supplied at operating conditions and at wet state. So in order to convert this parameter into the volumetric flow of dry air at standard conditions the measurements have to be corrected for temperature, pressure and water vapour content. Therefore, the uncertainty associated with the parameter $V_{air, dry}$ can be calculated as the product of uncorrelated input quantities from the measuring uncertainties of the air flow, the temperature, the pressure and the water vapour content using the following equation as independent uncertainties of a product (see example 3 in section 8.2.1 of Guidance Document 4):

$$u_{V_{air,dry}} = \sqrt{u^2_{V_{air,measured}} + u^2_T + u^2_p + u^2_w}$$

Each parameter would be determined using appropriate standards, respectively, which also cover the determination of associated uncertainties. Let's assume the relative uncertainty of each parameter is as follows:

Parameter	**Relative uncertainty u_i** (expanded at the 95% confidence level)
$V_{air, measured}$	± 2.0%
Temperature T	± 0.5%
Pressure p	± 0.5%
Water vapour content w	± 1.5%

Using these figures in the formula above leads to an uncertainty related to $V_{air, dry}$ of ±2.6%.

Step 1.2: uncertainty item B (component concentrations in the flue gas):

Out of the five parameters in the denominator of term B, CO_2 and CO usually show by far the highest concentrations. The concentration of NO_x and SO_2 are always very low compared to CO_2 and CO. Therefore, related uncertainties are negligible and can be omitted from the uncertainty assessment without any significant impact on the result. It has to be noted that O_2 can also be ignored if the measurement is performed *in front* of the CO post combustion unit. However, it cannot be ignored if the measurement is performed *after* the CO post combustion unit.

The concentration of CO_2 and CO is determined while emitted from the stack. The applicable standard for the continuous emissions monitoring system (CEMS)[10] is EN ISO 14181 which also covers the determination of the associated measurement uncertainty of the concentration.

Let's assume the resulting uncertainties of the CO_2 and CO concentrations obtained by CEMS are as follows:

Parameter (x_i, upper end of the measured range)	**Relative uncertainty u_i** (expanded at the 95% confidence level)	**Absolute[11] uncertainty Ui ($=x_i*u_i$)** (expanded at the 95% confidence level)
CO_2: $16\%_{vol}$	± 3.0%	± 0.48vol%
CO: $2\%_{vol}$	± 3.0%	± 0.06vol%

[10] For CEMS measurement of GHGs Guidance Document 7 provides further guidance on the application of EN ISO 14181 in the EU ETS.

[11] Note that despite figures given in percentages these are labelled as *absolute* uncertainties as they indicate percentage points related to the parameter concentration. For instance, using the figures in the table the concentration of CO_2 would be 16% ± 0.48%, i.e. between 15.52% and 16.48% at the 95% confidence level.

The uncertainty is determined using the following equation as independent uncertainties of a sum[12] (see example 2 in section 8.2.1 of Guidance Document 4):

$$u_{\mathrm{GHG}_{\mathrm{conc}}} = \frac{\sqrt{U_{CO_2}^2 + U_{CO}^2}}{100 - a_{CO_2} - b_{CO}} = \frac{\sqrt{0.48\%^2 + 0.06\%^2}}{82\%} = 0.6\%$$

Using these figures leads to an uncertainty related to the measurement of the concentrations of the flue gas components of ±0.6%.

Step 1.3: combined uncertainty of $V_{flue,dry}$:

The combined uncertainty of $V_{flue,dry}$ is 2.7% as determined by using again the formula for independent uncertainties of a product:

$$u_{V_{flue,dry}} = \sqrt{u_{V_{air,dry}}^2 + u_B^2} = \sqrt{2.6\%^2 + 0.6\%^2} = 2.7\%$$

Step 2: uncertainty item C (GHG_{conc}):

The combined uncertainty of GHG_{conc} can then be determined using the following formula for independent uncertainties of a sum (see example 2 in section 8.2.1 of Guidance Document 4):

$$u_{\mathrm{GHG}_{\mathrm{conc}}} = \frac{\sqrt{U_{CO_2}^2 + U_{CO}^2}}{a_{CO_2} + b_{CO}} = \frac{\sqrt{0.48\%^2 + 0.06\%^2}}{18\%} = 2.7\%$$

Using the figures from the table in step 1.2 leads to an uncertainty related to the GHG concentrations of ±2.7%.

Step 3: overall (combined) uncertainty of $E_{total,coke}$:

The uncertainty related to **$E_{total,coke}$** is calculated as independent uncertainty of a product as follows:

$$u_{E_{total,coke}} = \sqrt{u_{V_{flue,dry}}^2 + u_{GHGconc}^2} = \sqrt{2.7\%^2 + 2.7\%^2} = 3.8\%$$

The overall uncertainty of $E_{total,coke}$ is ±3.8%. Note that because expanded uncertainties were used in each step, this overall uncertainty also corresponds to the expanded uncertainty, i.e. the uncertainty at the 95% confidence level as required by the MRR. This value of 3.8% has to be compared against the tier thresholds in table 1 of Annex II of the MRR.

[12] Note that this formula is not fully correct here as parameters are in the denominator which leads to different results when calculating partial derivatives. However, the formula used is simpler but still provides very similar results. Furthermore, it is assumed that uncertainties associated with the concentrations of CO_2 and CO are uncorrelated. However, if e.g. the same equipment (analyser, sampling system, etc.) is used or measurements are performed simultaneously, these assumptions may not be valid and uncertainties would have to be treated as correlated, thus higher uncertainties.

4 FURTHER EXAMPLES

Further case studies can be found in:

- Annex III of the uncertainty training material held in 2016. This training material can be downloaded from DG CLIMA's website under the following link:
  https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/uncertainty_assessment_training_material_en.pdf
- Annex II of the uncertainty training material held in 2019. This training material can be downloaded from DG CLIMA's website under the following link:
  https://ec.europa.eu/clima/sites/default/files/ets/monitoring/docs/uncertainty_assessment_en.pdf
- There is furthermore a "tool for the assessment of uncertainties" available for operators, which can be downloaded from DG CLIMA's website:
  https://ec.europa.eu/clima/policies/ets/monitoring_en#tab-0-1