EUROPEAN COMMISSION
DIRECTORATE-GENERAL
CLIMATE ACTION
Directorate C - Climate strategy, governance, and emissions from non-trading sectors
CLIMA.C.2 - Governance & Effort Sharing

EU ETS Monitoring and Reporting –
Training on Uncertainty Assessment

M&R Training Event of 31st May 2016

This document comprises training material for competent authorities and verifiers for the checking of uncertainty assessments according to Commission Regulation (EU) No. 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas (GHG) emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (the **MRR**)[1].

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:181:0030:0104:EN:PDF

Table of content

1. LEGAL BACKGROUND

Article 12(1) MRR requires the operator to submit to the CA uncertainty assessments as supporting documents concerning approval of the monitoring plan (MP). CA interest extends to the following information:

- Evidence for compliance with the uncertainty thresholds for activity data
- Evidence for compliance with the uncertainty required for calculation factors, if applicable
- Evidence for compliance with the uncertainty requirements for measurement based methodologies, if applicable
- If a fall-back methodology is applied, an uncertainty assessment for the total emissions of the installation

Article 19(1) AVR requires the verifier to confirm the validity of the information used to calculate the uncertainty levels.

2. OBJECTIVE

The M&R training event of 31st May 2016 aimed at:

- providing technical support to the participants in performing their day-to-day tasks when assessing uncertainty involved in the approval of MPs;
- enhancing the efficiency and effectiveness of participants attending the training.

The training event was designed to provide representatives of EU ETS CAs with the opportunity to come together to exchange information with other experts on how they deal with uncertainty assessments. Furthermore, participants were enabled to discuss in an interactive way real-life cases of e.g. uncertainty assessments concerning weighbridges, or fuel oil delivered on trucks from many different suppliers, etc. The training was focused towards mainly new and medium-experienced staff members, but that did not preclude that also more advanced examples were used in the training.

Experience and feedback from discussions in the EU ETS MRVA Support Technical Working Group (TWG) and the EU ETS Compliance Forum M&R Task Force had shown that uncertainty assessment is an area where Member States (MS) and CAs would most welcome training. Information had shown shown major differences in how MS check uncertainty assessments. These differences between MS concern differences in experience, in background of staff members, in the resources of the CAs and in practices by which checks are carried out, e.g. level of detail, spot checks.

An additional objective for the training provided on 31st May 2016 was that it should allow for further cascade to other MS audiences based on the case studies and this document.

3. SET-UP OF THE TRAINING EVENT

The training was set up in the following two sessions:

- **A theoretical part** covering the principles of uncertainty assessment in EU ETS monitoring and reporting: This part included a short introduction and outline of uncertainty assessment in the EU ETS which followed the narrative of MRR Guidance Documents 4 and 4a. This was followed by a general outline on what national legal metrological control entails and to what extent it is harmonised across Europe.
- **A practical part** with MS representatives sharing their experiences in uncertainty assessments followed by discussion of case studies in six discussion groups: In this more practice-focused part, MS representatives gave first a brief overview of their common practices and experiences concerning the checking of operator uncertainty assessments. This was followed by group discussions based on real-life case studies submitted by MS. Group trainers were assigned to each discussion group to lead and steer discussions.

4. PROGRAMME OF THE TRAINING ON 31ST MAY 2016

Uncertainty Assessment in EU ETS • What is uncertainty and why is it needed? • Role of uncertainty in measurement in MRVA
Calibration and legal metrological control • National legal metrological control – what is it? How is it organised in the MS? • Calibration and (metrological) verification • Where to obtain evidence for uncertainty from? • State of play regarding harmonisation of calibration/verification across Member States • Implications of MID and NAWI Directive
How to demonstrate compliance • A “step-by-step guide” on how to demonstrate compliance • Measuring instruments under operator's or trading partner's control • Introduction to uncertainty propagation laws • Examples
Checking Compliance with the tier requirements: • Practical approach to checking operators' uncertainty assessments • Common difficulties and limitations • Required time effort and expertise (e.g. use of external consultants) • Best practice examples: What kind of checks are performed? • Best practice examples: What kind of evidence is requested from operators?
Group discussion on case studies • Discussions guided by volunteered trainers

5. CONCLUSIONS

During the training, the following issues have been identified as the main discussion points for further consideration:

- The importance of being clear whether an uncertainty provided relates to the standard or the expanded uncertainty;
- Difficulties with whether input quantities are to be treated as correlated or uncorrelated when calculating combined uncertainties;
- The relevance of the type of distribution of a given uncertainty, i.e. the consequences if the uncertainty is of a normal, rectangular, or other type of distribution.

In order to take follow-up actions, these findings will be considered for the forthcoming updates of the following documents:

- Guidance Document 4
  http://ec.europa.eu/clima/policies/ets/monitoring/docs/gd4_guidance_uncertainty_en.pdf
- Guidance Document 4a
  http://ec.europa.eu/clima/policies/ets/monitoring/docs/ex_4a_uncertainty_en.pdf
- FAQs regarding Monitoring and Reporting
  http://ec.europa.eu/clima/policies/ets/monitoring/docs/faq_mmr_en.pdf

Annex I: Main plenary presentations

Presentation:
Uncertainty Assessment in EU ETS

by Christian Heller

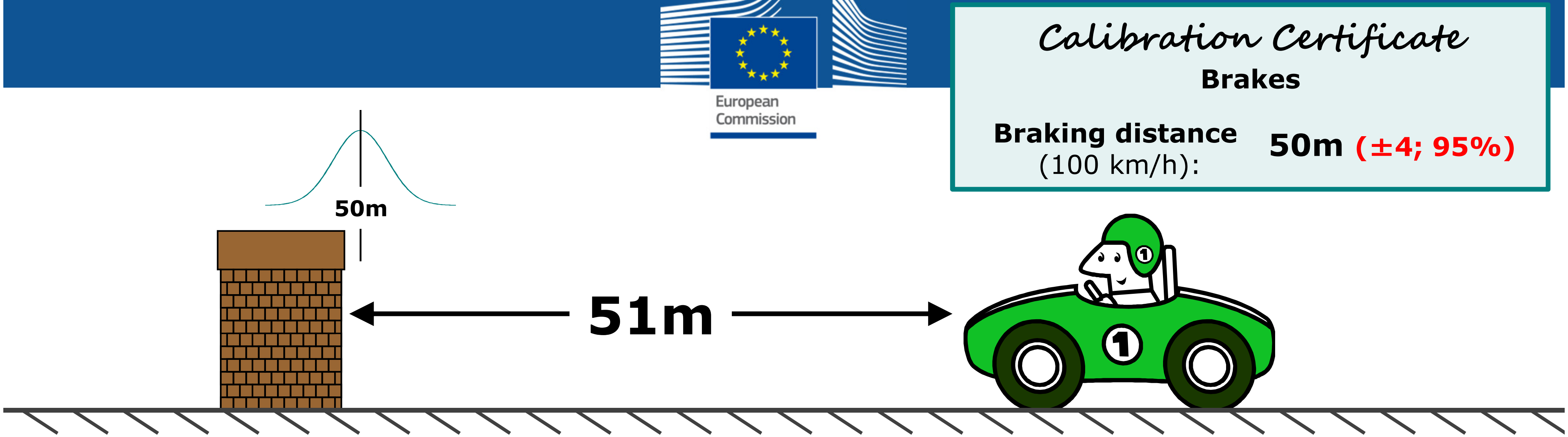
- What is uncertainty and why is it needed?
- Role of uncertainty in measurement in MRVA

Uncertainty assessment in the EU ETS

Christian HELLER

M&R Training Event on Uncertainty Assessment
Brussels, 31 May 2016

Climate Action



Why not exactly 50m?

- Car (wheels, brakes,..) tested for the certificate do not have exact same properties
- Temperature/material properties differences to testing conditions causes differences in:
  - Friction within the braking system
  - Rolling resistance between wheels and road
  - Air resistance (which also depends on density/viscosity of the air, wind speed)
- Speedometer display or its reading may not be correct
- Etc.

What is the best guess for your chances of stopping before hitting the wall?

≈69%

Uncertainty Assessment – Legal Requirements in MRVA

- **Article 12(1) MRR** requires the operator to submit to CA an uncertainty assessment as supporting document to the MP that should contain the following information:
    - Evidence for compliance with uncertainty thresholds for activity data
    - Evidence for compliance with uncertainty required for calculation factors, if applicable
    - Evidence for compliance with uncertainty requirements for measurement based methodologies, if applicable
    - If a fall-back methodology is applied, an uncertainty assessment for the total emissions

Uncertainty Assessment – Legal Requirements in MRVA

- **Article 19(1) AVR** requires the verifier to confirm the validity of the information used to calculate the uncertainty levels

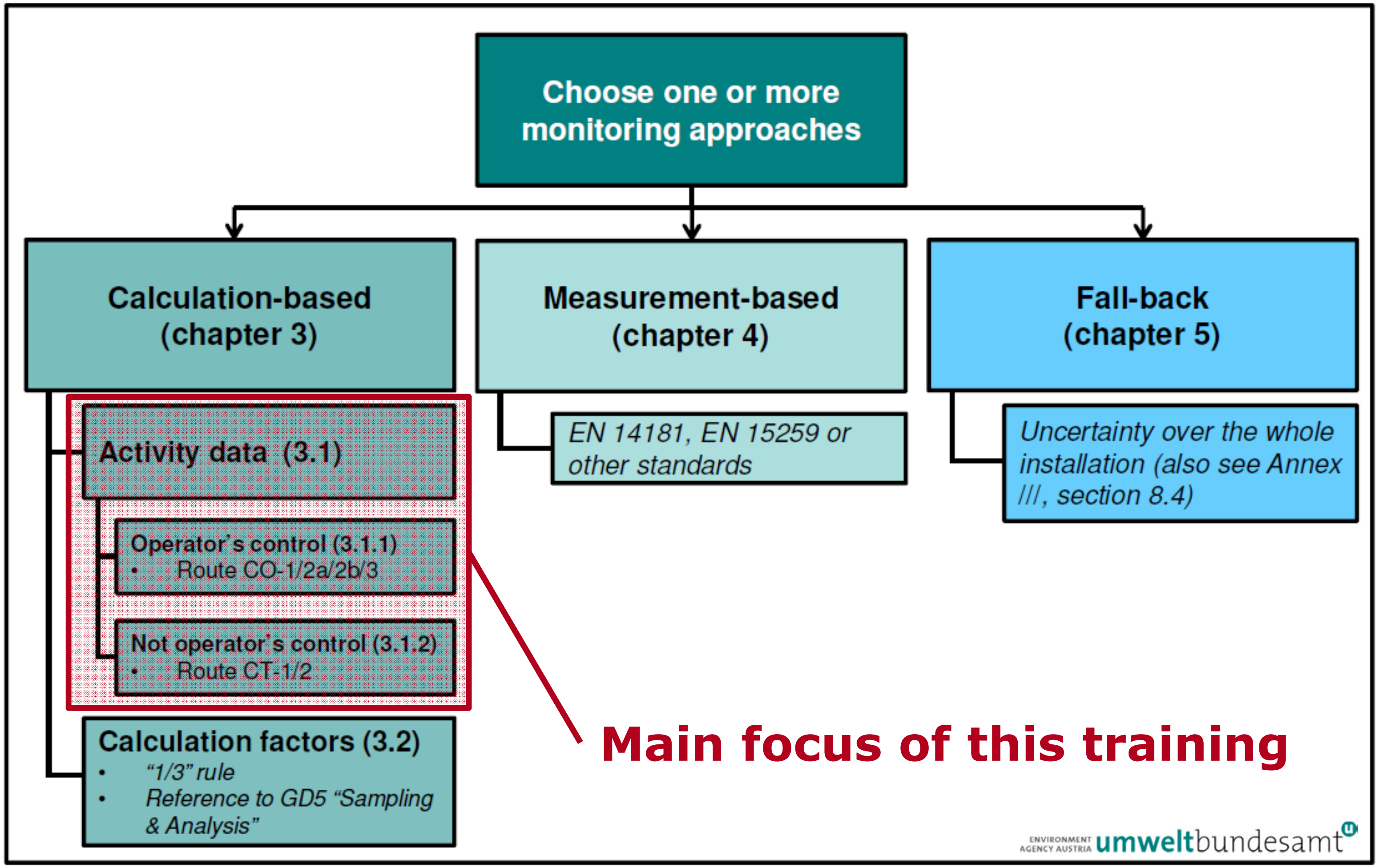
- **Article 47(4) MRR** exempts operators of installations with low emissions from submission of an uncertainty assessment to the competent authority.

  - Paragraph 5 also exempts those operators from including uncertainty of determining stock changes in their uncertainty assessment.

- **Article 22(b) MRR** requires operators to carry out an uncertainty asssessment annually, where fall-back approaches are applied

  - **Article 19(2) AVR** requires verifier to check details

Structure of Guidance Document 4

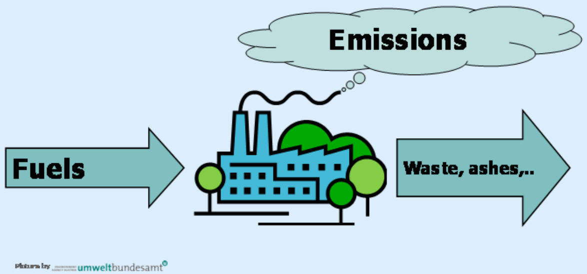


http://ec.europa.eu/clima/policies/ets/monitoring/docs/gd4_guidance_uncertainty_en.pdf

Calculation-based methodology
(Emissions from source streams)

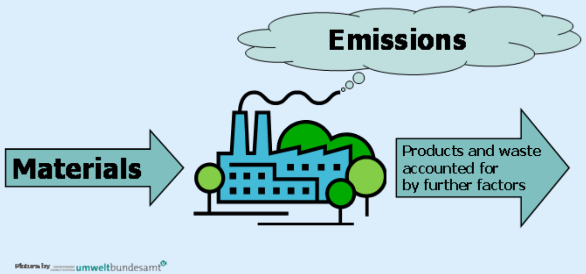
Combustion emissions

$$Em = \boxed{FQ} \cdot NCV \cdot EF \cdot OF$$



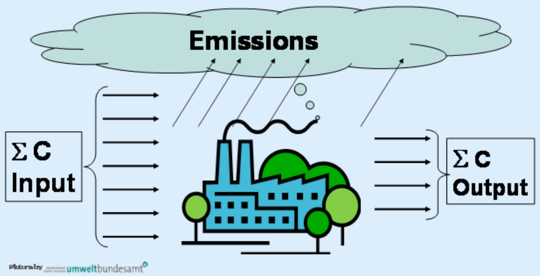
Process emissions

$$Em = \boxed{AD} \cdot EF \cdot CF$$



Mass balance emissions

$$Em = \sum_i \left(f \cdot \boxed{AD_i} \cdot CC_i \right)$$



Fuel and material quantities

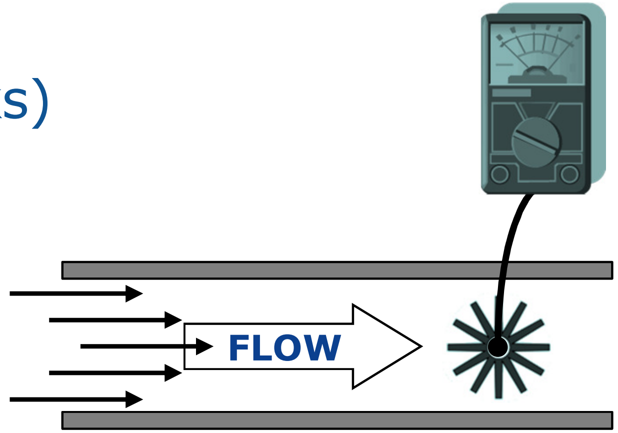
- *Article 27 of the MRR (No. 601/2012)*

- *There are two ways how the activity data (fuel/material quantity) can be determined:*
  - based on **continual metering** at process which causes emissions
  - based on **aggregation of metering of quantities** separately delivered (batch metering) taking into account relevant stock changes.

> ➢ *In both cases, the fuel or material quantity of source streams will be determined by **metering using measuring instruments** (MIs)*

Continual metering

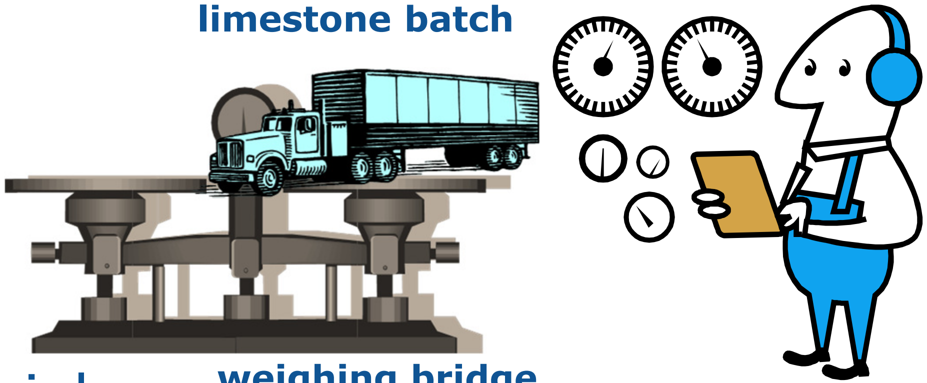
- *Fuel/material directly passing a MI*
- *Flow measurement metering of either:*
  - Gases (e.g. natural gas)
  - Liquids (e.g. fuel oil delivered on trucks)
  - Solids (e.g. (continuous) belt weigher)



- *Fuel/material consumed:*
  e.g. meter readings or invoices

Batch metering
(aggregation of metering of quantities)

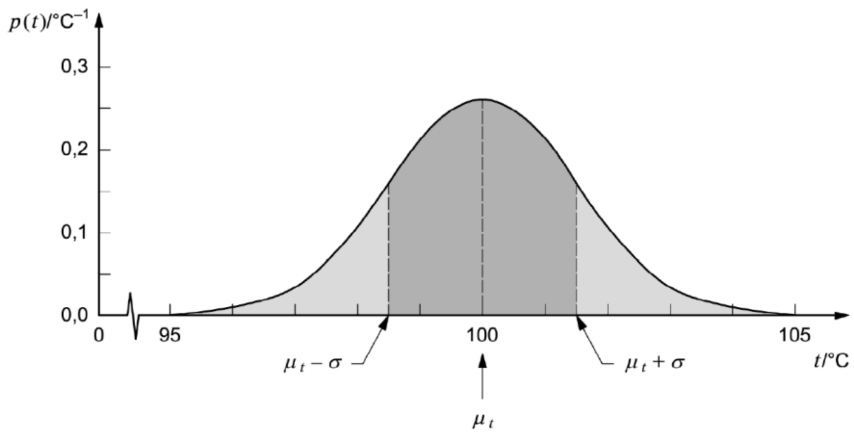
$$Q = P - E + (S_{begin} - S_{end})$$



- Q — Quantity of fuel/material
- P — Purchased quantity (e.g. invoices)
- E — Exported quantity (e.g. to non-ETS entity)
- S_{begin} — Stock of fuel/material at the beginning of the year
- S_{end} — Stock of fuel/material at the end

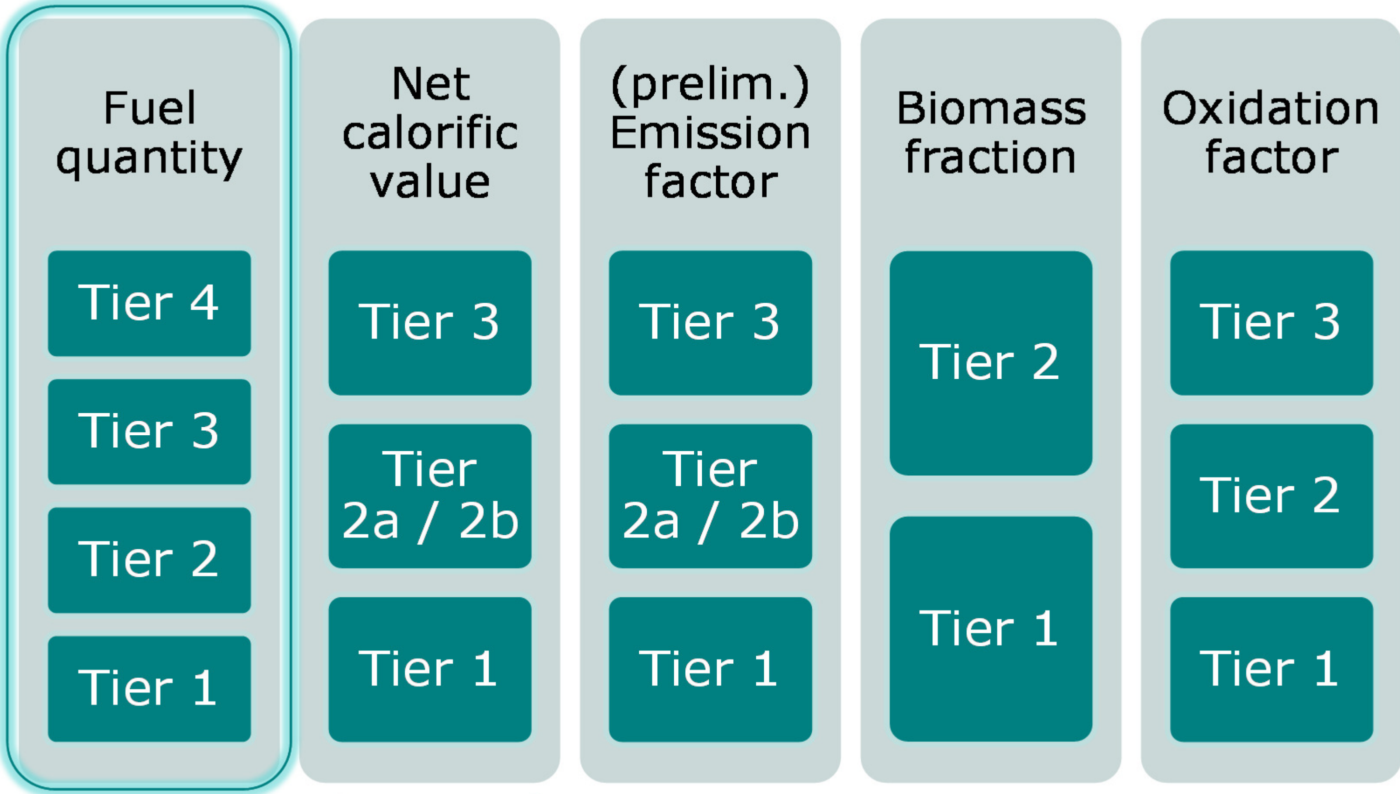
- ***Example:*** *limestone delivered on trucks, weighed on weighing bridges (invoices)*

Any questions so far?



Climate Action

The tier system (1)



Picture by ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

The tier system (2)

Tiers for activity data of e.g. solid fuels

Tier	Definition
1	Amount of fuel [t] or [Nm^3] over the reporting period is determined with a maximum uncertainty of less than **± 7.5 %**.
2	Amount of fuel [t] or [Nm^3] over the reporting period is determined with a maximum uncertainty of less than **± 5.0 %.**
3	Amount of fuel [t] or [Nm^3] over the reporting period is determined with a maximum uncertainty of less than **± 2.5 %.**
4	Amount of fuel [t] or [Nm^3] over the reporting period is determined with a maximum uncertainty of less than **± 1.5 %.**

- *Tiers for fuel/material quantity (activity data) relate to the **"permissible" uncertainty** of measurements*

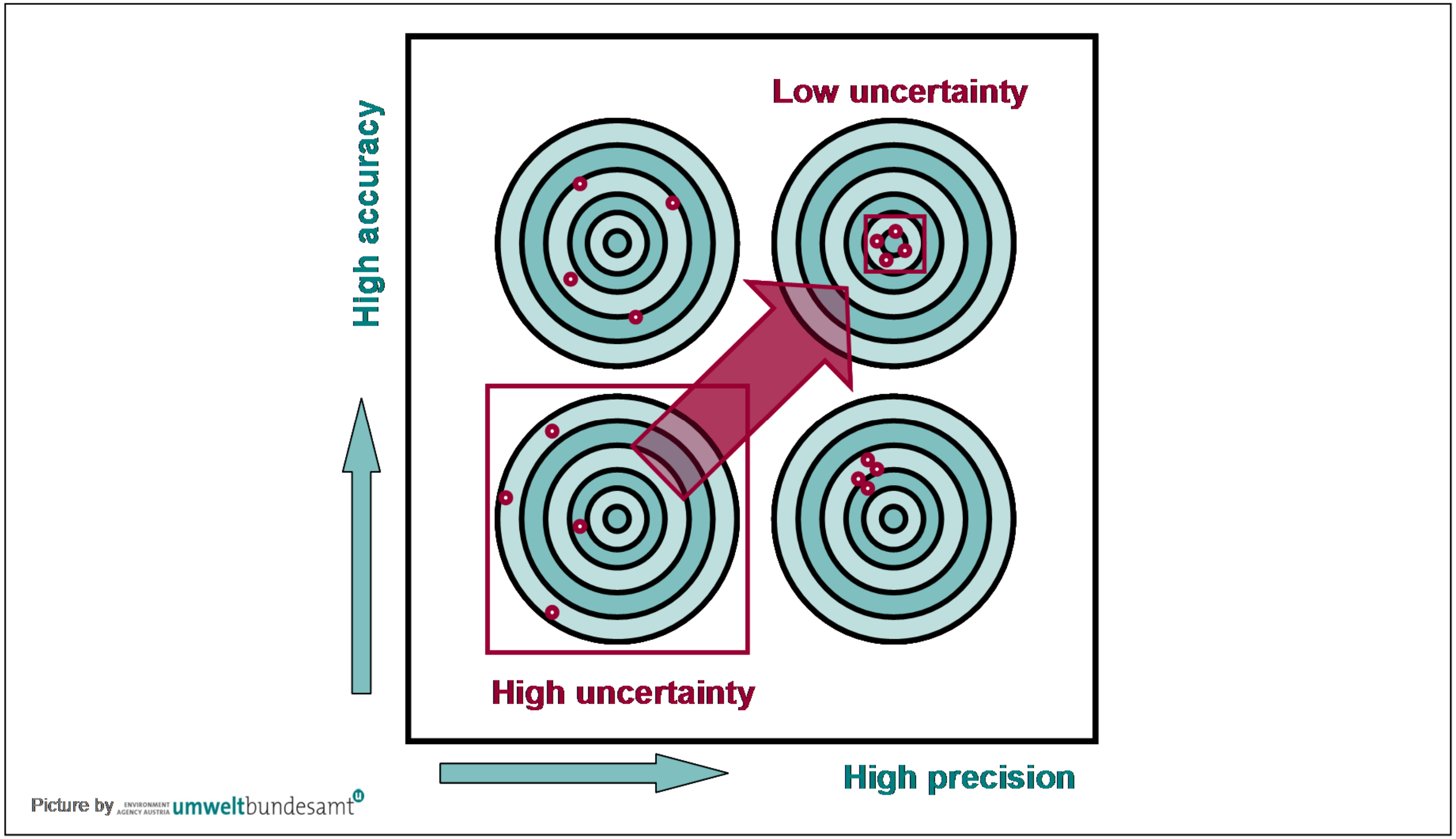
What are Accuracy, Precision, Uncertainty?

- ***Accuracy***: *This means closeness of agreement between a measured value and the true value of a quantity*
  → how close is the value to the "true" value
  → The "absolutely true" value is seldom ever known or even unknowable (exemption e.g. sum of angles in a triangle is 180°)

- ***Precision***: *This describes the closeness of results of measurements of the same measured quantity under the same conditions → repeatability*

- ***Uncertainty***: *This term characterizes the range within which the true value is expected to lie with a specified level of confidence. It is the overarching concept which combines precision and assumed accuracy.*

What is Uncertainty?



The "GUM"

JCGM 100:2008
GUM 1995 with minor corrections

Evaluation of measurement data — Guide to the expression of uncertainty in measurement

Évaluation des données de mesure — Guide pour l'expression de l'incertitude de mesure

First edition September 2008

Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG 1).

Document produit par le Groupe de travail 1 du Comité commun pour les guides en métrologie (JCGM/WG 1).

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Evaluation of measurement data — Guide to the expression of uncertainty in measurement (JCGM 100:2008)

Uncertainty – Definition in GUM

- *2.2.3: uncertainty (of measurement): parameter, associated with the result of a measurement, that **characterizes the dispersion of the values** that could reasonably be attributed to the measurand*

- 3.3.1: *The uncertainty of the result of a measurement reflects the **lack of exact knowledge of the value of the measurand** (see 2.2). The result of a measurement after correction for recognized systematic effects is still only an estimate of the value of the measurand because of the **uncertainty arising from random effects and from imperfect correction of the result for systematic effects**.*

- D.5.1: *Whereas the exact values of the contributions to the **error of a result of a measurement are unknown and unknowable**, the **uncertainties associated with the random and systematic effects that give rise to the error can be evaluated**. [..]*


I THOUGHT I WAS
INTERESTED IN UNCERTAINTY
BUT NOW I'M NOT SO SURE
TOSHIO

Sources of Uncertainty – GUM

3.3.2: In practice, there are many possible sources of uncertainty in a measurement, including:

- incomplete definition of the measurand;
- imperfect realization of the definition of the measurand;
- nonrepresentative sampling — the sample measured may not represent the defined measurand;
- inadequate knowledge of the effects of environmental conditions on the measurement or imperfect measurement of environmental conditions;
- personal bias in reading analogue instruments;
- finite instrument resolution or discrimination threshold;
- inexact values of measurement standards and reference materials;
- inexact values of constants and other parameters obtained from external sources and used in the data-reduction algorithm;
- approximations and assumptions incorporated in the measurement method and procedure;
- variations in repeated observations of the measurand under apparently identical conditions.

Uncertainty – Definition in MRR

- ***Article 3(6) MRR:***
  "'uncertainty' means a parameter, associated with the result of the determination of a quantity, that characterises the dispersion of the values that could reasonably be attributed to the particular quantity, including the effects of systematic as well as of random factors, expressed in per cent, and describes a confidence interval around the mean value comprising 95% of inferred values taking into account any asymmetry of the distribution of values."

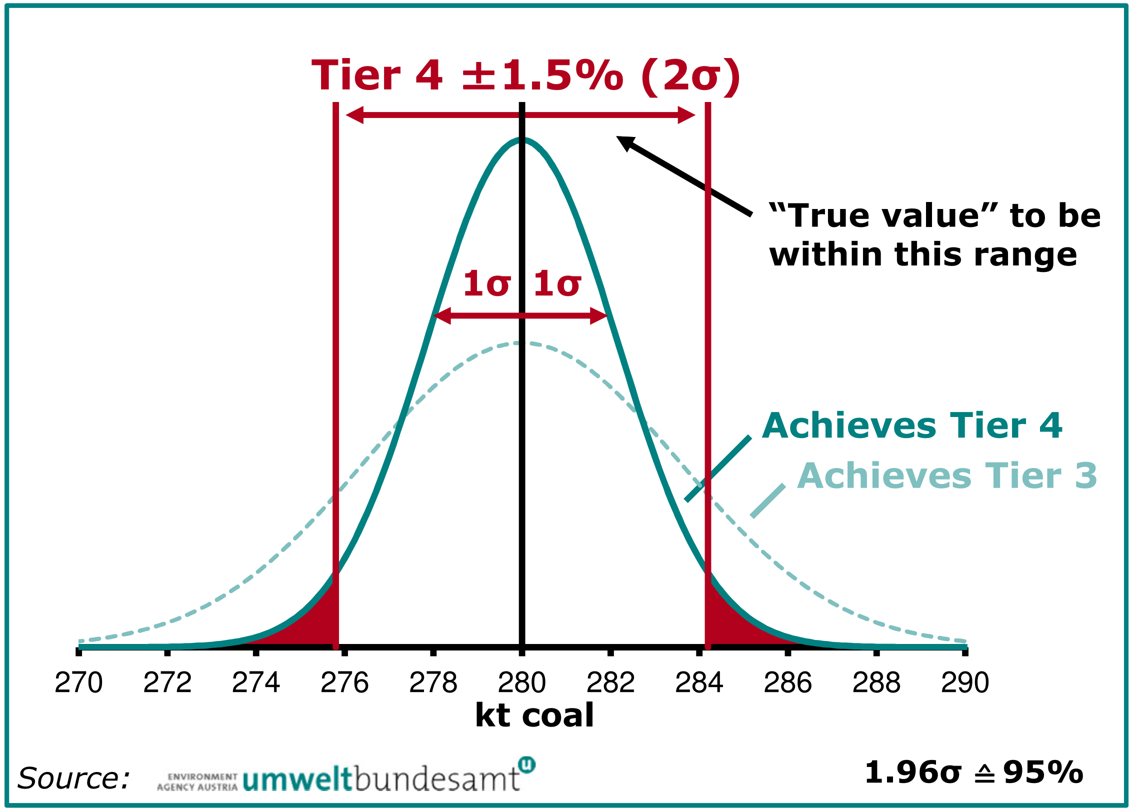
> ➢ *Uncertainty threshold of x% can be understood as the requirement that there is a* ***95% chance that the "true value" lies within x%*** *of the measured value*

Uncertainty – What it means

*Example: A category C installation consumes **280 kt coal***

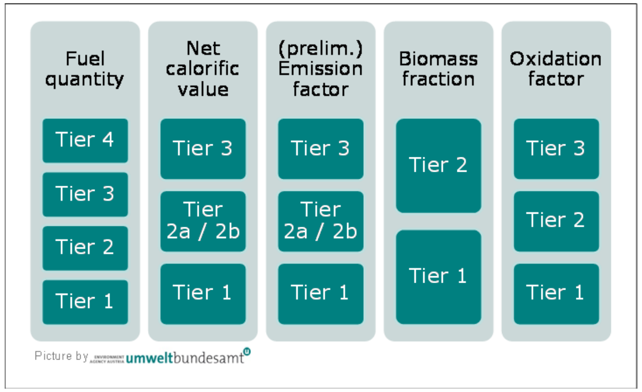
- ***Tier 4** is required for the determination of the fuel quantity **(Uncertainty: ±1.5%)***

> ➢ *This means that the measurement system needs to provide results that allow the "true value" to be within **280 ± 4.2 kt** (±1.5%) at the **95% (2σ) confidence level**.*



Uncertainty of emissions

- *What about other factors than AD?*
- *Uncertainty of emissions in general not assessed**
  - This is the way MRVA works
    → modular approach („building block system“) using tiers



- *Uncertainties of calculation factors (e.g. NCV, EF) dealt with by other approaches → default values, analysis,..*

**Exceptions: fall-back approaches (Art. 22 MRR) and continuous emissions monitoring systems (CEMS)*

European Commission

Where to obtain uncertainties from?

- *In princple, **uncertainty** has to be demonstrated using **appropriate standards** (e.g. GUM)*
- ***BUT, MRVA allows for simplifications**, where appropriate:*
  - Using **maximum permissible error in service**, e.g. as specified in relevant national legal metrological control (**NLMC**), where available
  - based on the **uncertainty from other sources (e.g. calibration)**, if the measuring instrument is used properly

Next steps

- *What is NLMC, what is regulated by it and to what extent is it harmonised across the EU?*
- *What is the maximum permissible error and where is it stated?*
- *What is calibration and what is (metrological) verification? When, how and by whom are they to be done?*
- *How is the relevant uncertainty obtained and where is it stated?*

> ***Answers are given in the next presentation***

Questions?

Where to find more information?

Regulation No. 601/2012 (MRR)
http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1462274244220&uri=CELEX:02012R0601-20140730

Guidance Documents on European Commission's website
http://ec.europa.eu/clima/policies/ets/monitoring/documentation_en.htm
in particular Guidance Documents 4 and 4a

Presentation:
Calibration and legal metrological control

by Jeroen Rommerts

- National legal metrological control – what is it? How is it organised in the MS?
- Calibration and (metrological) verification
- Where to obtain evidence for uncertainty from?
- State of play regarding harmonisation of calibration/verification across Member States
- Implications of MID and NAWI Directive

Legal metrology in Europe

legal – terms – MPE – uncertainty

Jeroen Rommerts
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078 633 23 55

TRUE VALUE

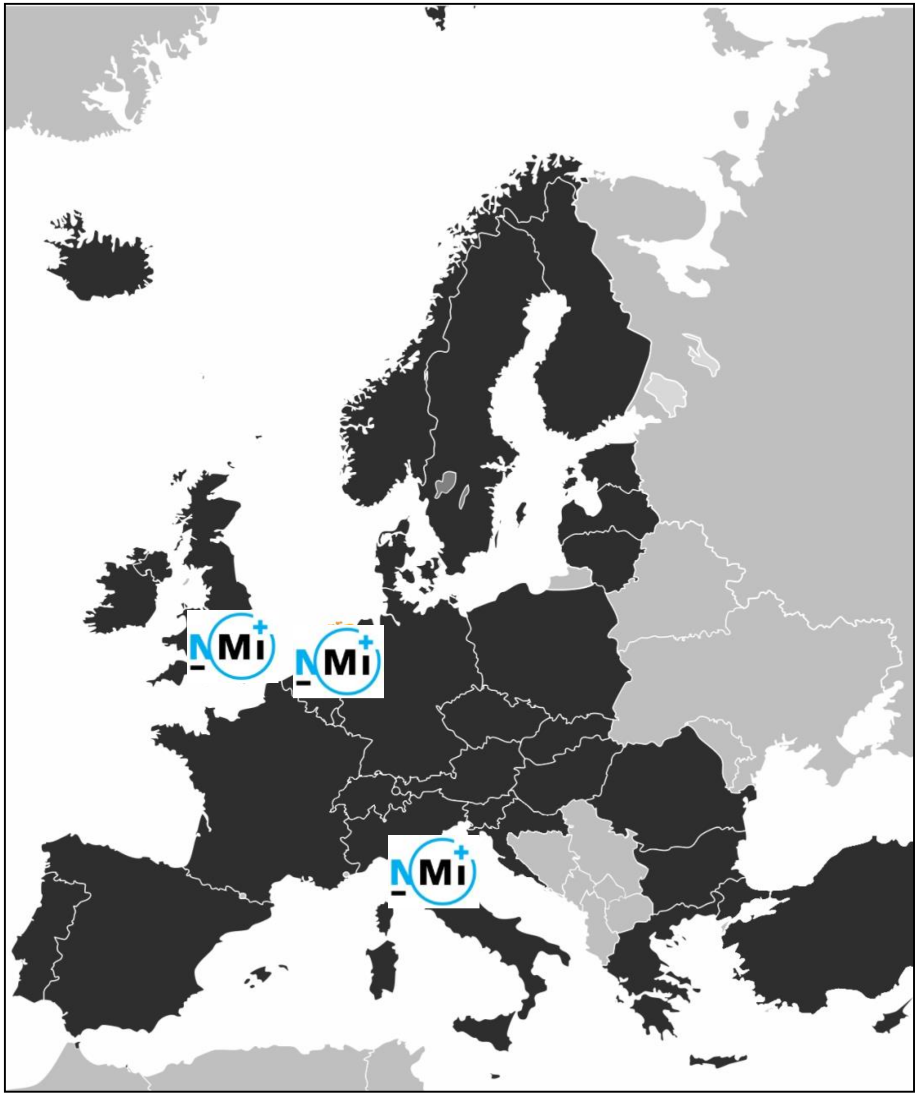
Plan

- intro
- what is Legal Metrology  

  instruments – applications – markings – tolerances
- terminology: what is what

  calibration – (legal) verification – adjustment
- where are ‘sources’ of uncertainty
- MID and NAWI-Directive
- questions

NMi



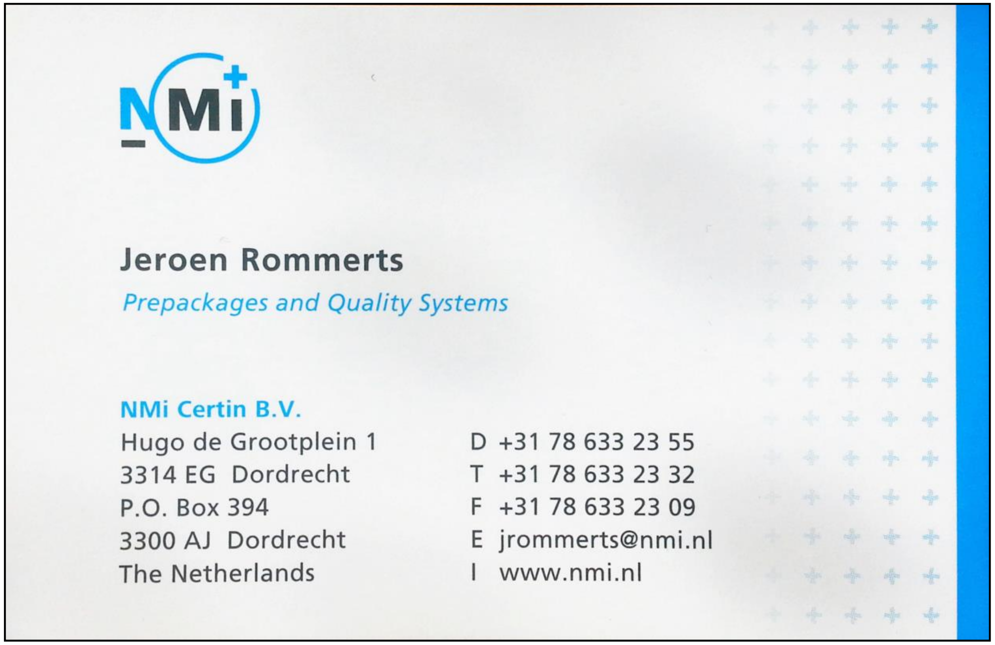
Notified Body (0122) for MID and NAWI Directive.

Accreditations:

- ISO/IEC 17021 system certification
- ISO/IEC 17020 product certification
- ISO/IEC 17025 measuring & calibration

Representing Netherlands in WELMEC, OIML, NEN

Jeroen Rommerts



- expert prepackaged products
- lead assessor in legal metrology
- product manager quality systems
- representating Netherlands in WELMEC and OIML

what is ‘legal metrology’

Legal metrology is the application of legal requirements to measurements and measuring instruments.

what is ‘legal metrology’
measuring instruments/systems




what is ‘legal metrology’
measuring instruments/systems

what is ‘legal metrology’
applications

- public interest
- public health
- safety and order
- protection of the environment
- protection of the consumer
- levying taxes and duties
- fair trading

where is ‘legal metrology’ regulated

	design of prototype	production of copies	use	maintenance and repair
liquid flow meters	MID	MID	national	national
gas meters flow computers	MID	MID	national	national
automatic weighing instruments	MID	MID	national	national
non-automatic weighing instruments	NAWI-directive	NAWI-directive	national	national
level meters + storage tanks	national	national	national	national

where is ‘legal metrology’ regulated

	design of prototype	production of copies	use	maintenance and repair
liquid flow meters	MID	MID	national	national
gas meters flow computers	MID	MID	national	national
automatic weighing instruments	MID	MID	national	national
non-automatic weighing instruments	NAWI-directive	NAWI-directive	national	national
level meters + storage tanks	national	national	national	national

verification marks

- Measuring Instruments Directive

CE **M 16** 0122

- notified body number (see NANDO)
- year of manufacture
- ‘M’ for ‘metrology

- NAWI-Directive

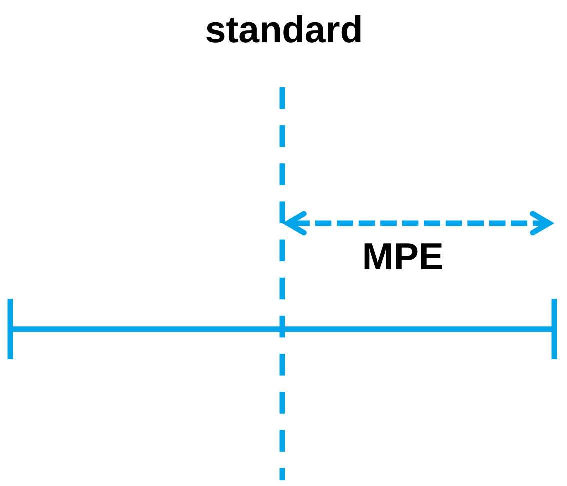
CE **M 16** 0122   M CE 15 0122

- national metrological markings

and more…

Maximum Permissible Error (MPE)

Extreme value of measurement error, with respect to a standard, permitted for a given measurement, measuring instrument, or measuring system.



Maximum Permissible Error

- MID 2014/32/EU
  - – gasmeters/flow computers: annex IV MI-002
  - – residential electricity meters: annex V MI-003
  - – residential heat meters: annex VI MI-003
  - – non-water liquid flow meters: annex VII MI-005
  - – automatic weighing: annex VIII MI-006

- NAWI Directive 2014/31/EU
  - – non-automatic weighing instruments: annex I

- national legislation

…

the data plate / sheet

What information must be on or acommpany the instrument

- product to be measured
- class
- MPE
- envoriment (temperature / pressure range)
- speed / flow rate range
- measured quantity range
- verification mark
- …

what is ‘Legal Metrology’

Legal metrology is the application of legal requirements to measurements and measuring instruments.

?

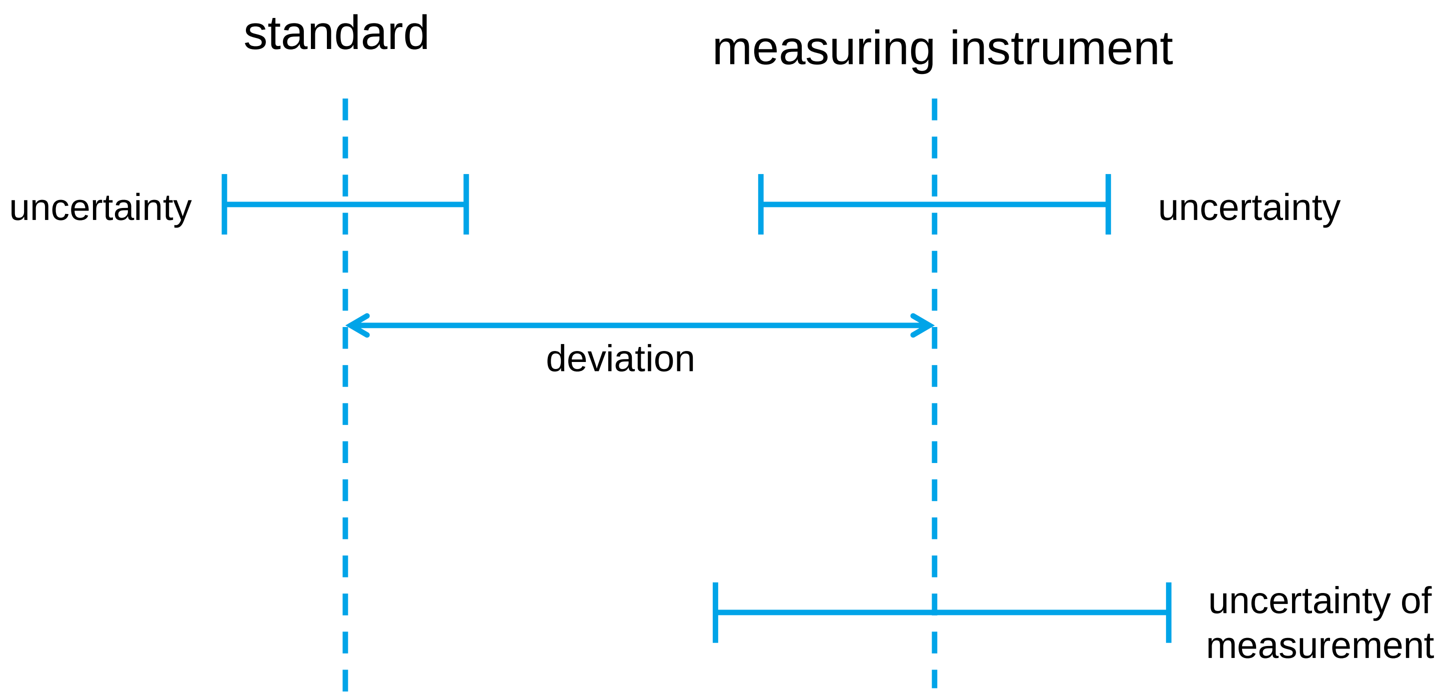
Legal metrology in Member States:
http://www.welmec.org/welmec/country-info/:

- Organisational Structure and Background
- Equipment Subject to National Controls
- National Type Approval and Initial Verification
- Inspection and Reverification
- Legal Metrology Practitioners and Scope
- Sanctions

terminology

- calibration: …
- verification: …
  - voluntary
  - legal: …
  - periodic re-verification: …
- inspection: …
- adjustment: …

terminology
calibration



responsible	result
user	certificate

terminology
calibration

Absolute uncertainty:

- 2,034 m ± 0,004 m
- (2,034 ± 0,004) m
- 2,034 m ± 4 mm

Relative uncertainty:

- 2,034 m ± 0,002
- 2,034 m ± 2 • 10-3
- 2,034 m ± 0,2 %
- (1 ± 0,002)2,034 m
- *l* = 2,034 m ± 0,002*l*

- result
- coverage factor & confidence level
- how uncertainity is estimated

VSL Dutch Metrology Institute

CERTIFICATE

Page 2 of 2

Results

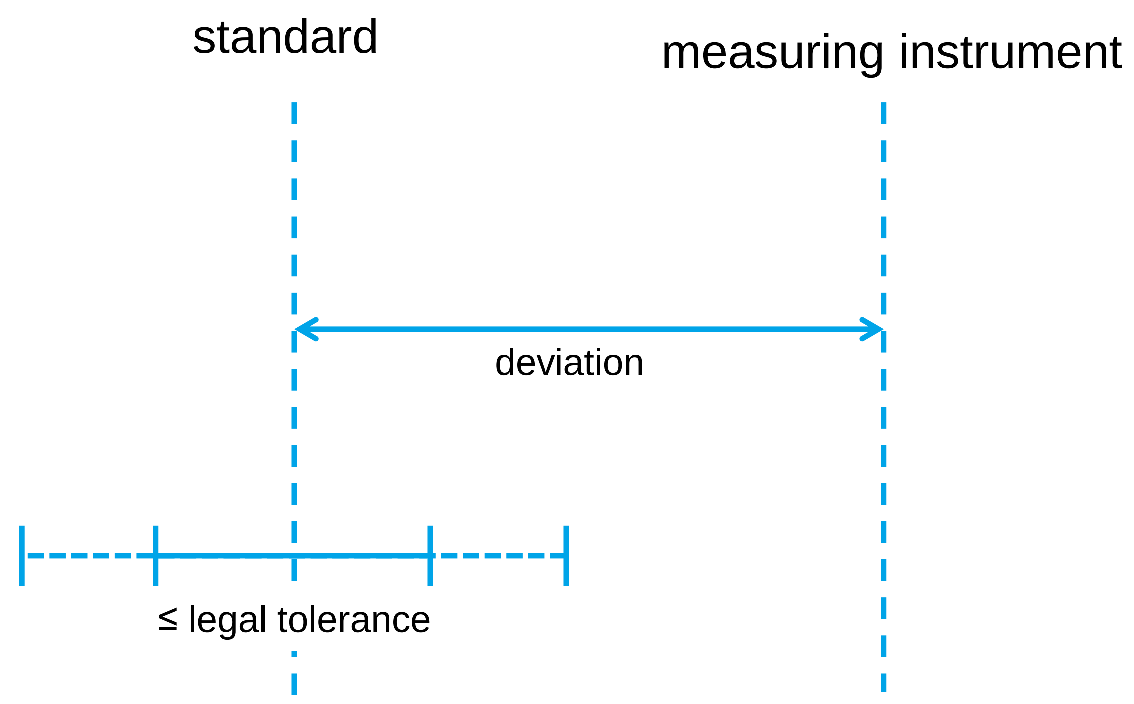
Remarks During calibration the following parameters has been used :

PIPE MATERIAL	Stainless Steel
PIPE OD	168.3 mm
PIPE WALL	3.4 mm
LINING	No
FLUID TYPE	Water
WATER TEMPERATURE	19.0 °C
REYNOLDS CORRECTION	Active
KINEMATIC VISCOSITY	1.001 E-6 m²/s
NUMBER OF TRAVERSES	2
TRANSDUCER SPACING	69 mm

Combination of absolute / relative uncertainity:

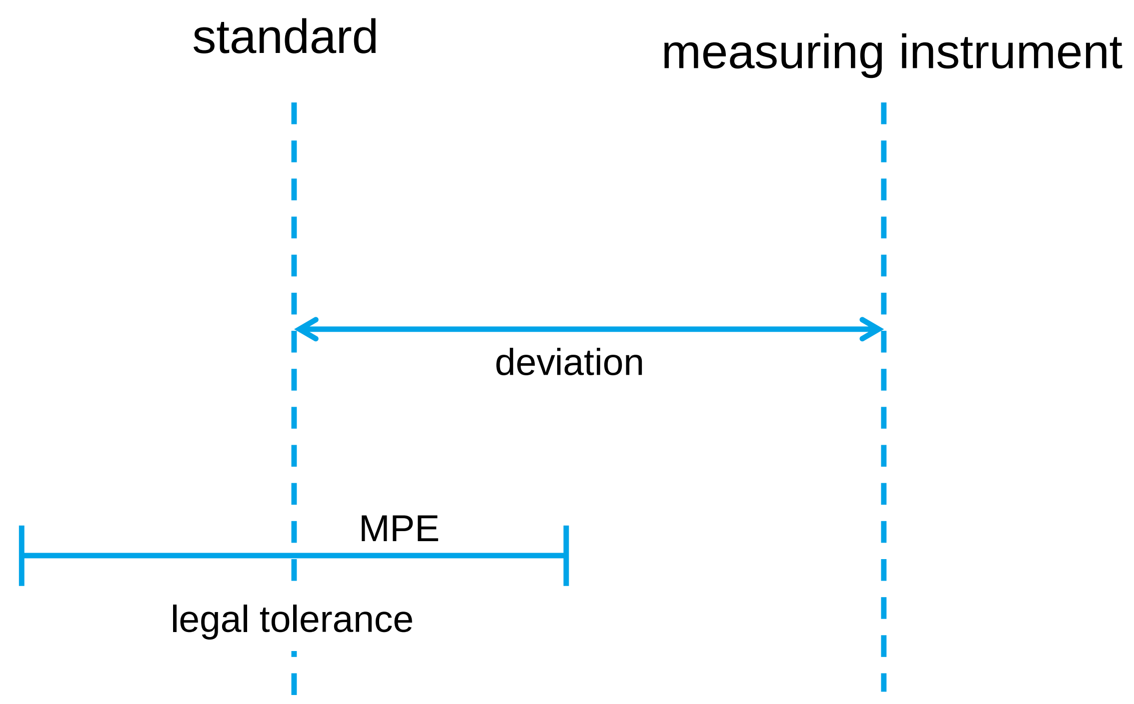
l = 2,034 ± (0,002 m + 0,002l)

terminology
(voluntary) validation



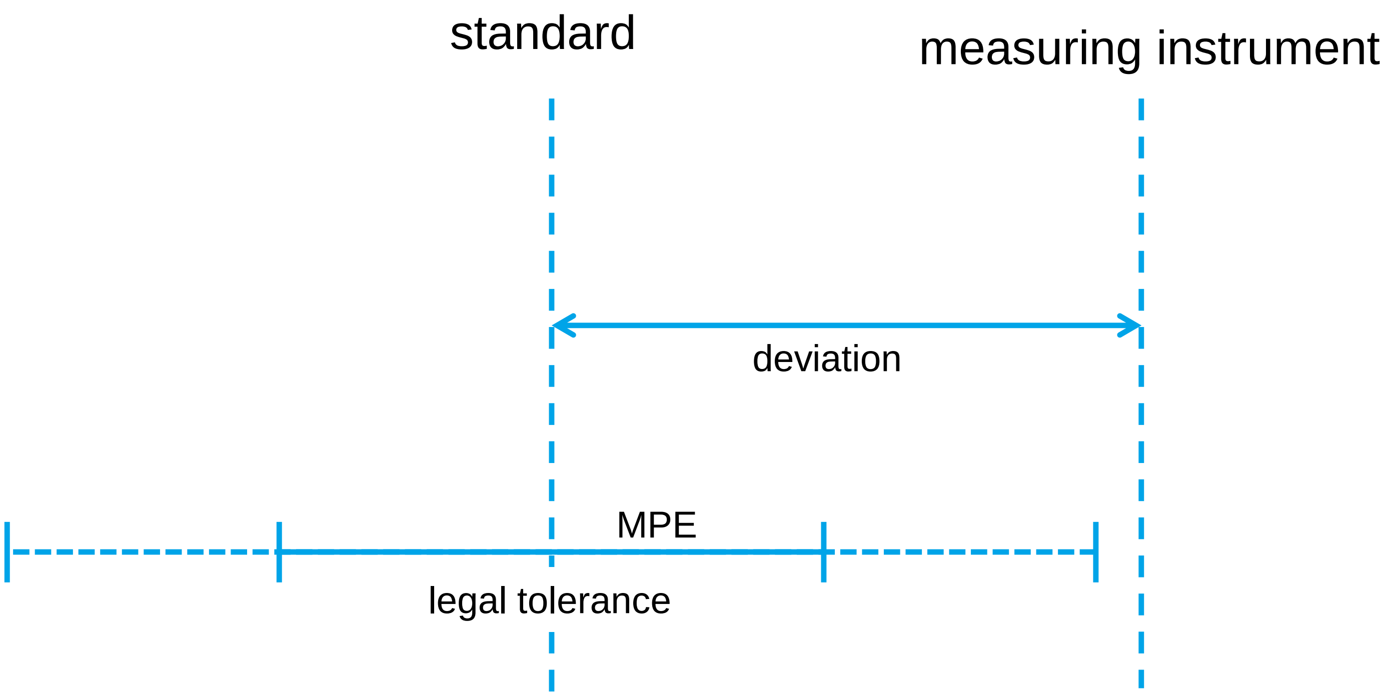
responsible	result
user	data sheet plate

terminology
legal verification and periodic re-verification



responsible	result
authorities	data sheet plate

terminology
inspection



responsible	result
authorities	data sheet plate

allowed errors in service

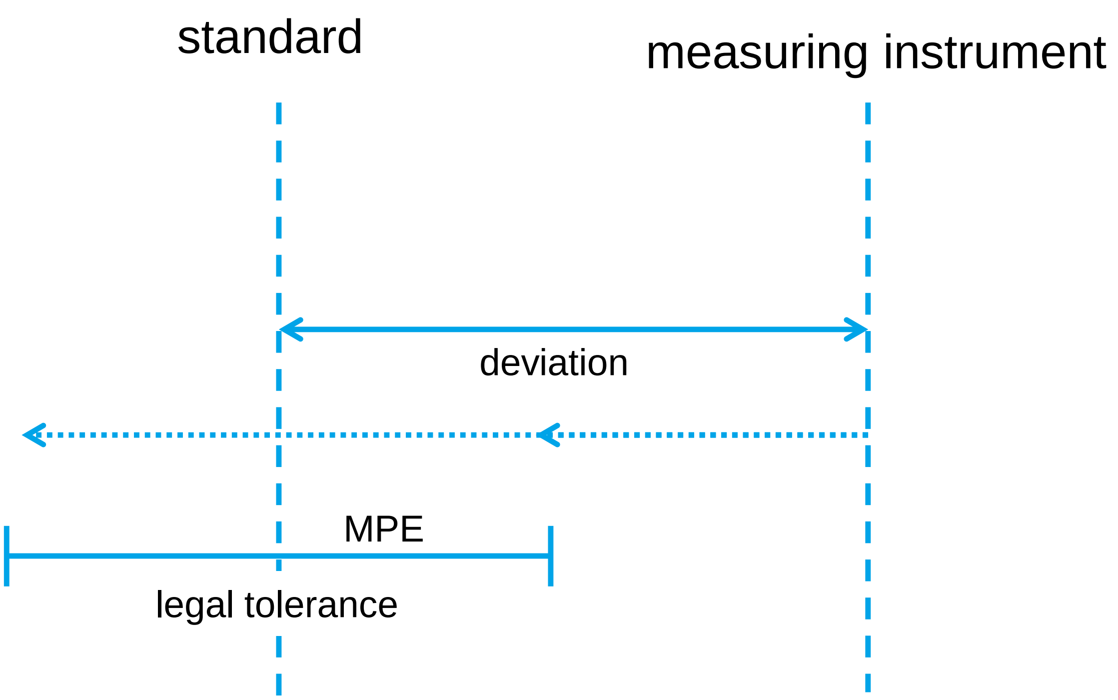
State	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Iceland	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Norway	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	Switzerland	Turkey	United Kingdom
MI-002: Gas Meters & Conversion Devises																																
Gas Meters:																																
residential, commerc. & light ind. use	+	+	=	=		=/+	+	+		+	+		=	+	=		=	=	=	=	+		+	=	+	+	+			+		=
Volume conversion devices:																																
residential use	+		=	=		=	+	=		+	+		=	+	=	=	=	=	=		+			=	+	+	+			+		
commercial & light industrial use	+		=	=		=	+	=		+	+		=	+	=	=	=	=	=		+			=	+	+	+			+		
MI-003: Active Electrical Energy Meters																																
residential	+	+	=	=		+	+	=			+		=	+	=		=	=	=		+	=	=	=	=	+	+	+		=		=
commerc. & light ind. use	+	+	=	=		+	+	=			+		=	+	=		=	=	=		+	+	=	=	=	+	+	+		=		=
MI-004: Heat Meters																																
residential use	+		=	=		=	+	=		+	+		=	+			+	=	=				=		=	+	+		+	+		
commercial & light industry use	+		=	=		=	+	=		+	+		=	+			+	=	=				=		=	+	+			+		
MI-005: Measuring Systems for Liquids other than Water																																
Fuel dispensers:																																
Liquids	+	=	=	=		=	+	=	=	=	=		=	+	+	=	=	=	=		=	=	=	=	=	+	=	=	=	+		+
Liquefied gases	=	=	=	=		=	+	=		=	=		=	+		=	=	=	=		=	=	=	=	=	+	=		=	+		
Systems on (un)loading ships:	+	=	=	=		=	+	=		=	=		=	+			=	=	=		=	=	=	=	=	+	=			+		
Systems on (un)loading rail:	+	=	=	=		=	+	=	=	=	=		=	+			=	=	=		=	=	=	=	=	+	=			+		
Systems on (un)loading road tankers:	+	=	=	=		=	+	=	=	=	=		=	+	=		=	=	=		=	=	=	=	=	+	=	=		+		=
Systems for refuelling aircraft:	+	=	=	=		=	+	=	=	=	=		=	+			=	=	=		=	=	=	=	=	+	=			+		
Systems for cryogenic liquids:	=	=	=	=		=	+			=	=		=	+			=	=	=		=	=	=			+	=			+		
Systems for liquids:	+	=	=	=		=	+	=	=	=	=		=	+		=	=	=	=		=	=	=	=	=	+	=			+		
Systems for liquefied gases:	=	=	=	=		=	+	=	=	=	=		=	+		=	=	=	=		=	=	=		=	+	=			+		
MI-006: Automatic Weighing Instruments																																
Automatic catchweighers:																																
Automatic checkweighers:	+	+	=	=		+	+	=	+	+	+		=	+	+		+	=	+	=	+	+	+	+	+	+	+		=	+		
Weight labellers:	+	+	=	=		+	+	=	+	+	+		=	+	+	=	+	=	+	=	+	+	+		+	+	+		=	+		+
Weight/price labellers:	+	+	=	=		+	+	=	+	+	+		=	+	+	=	+	=	+	=	+	+	+		+	+	+		=	+		+
Automatic gravim. filling instruments:	+	+	=	=		+	+	=	+	+	+		=	+	+	=	+	=	+	=	+	+	+	+	+	+	+		=	+		+
Discontinuous totalisers:	+	+	=	=		+	+	=	+	+	+		=	+	+	=	+	=	+	=	+	+	=		+	+	+		=	+		+
Continuous totalisers:	+	+	=	=		+	+	=	+	+	+		=	+	+	=	+	=	+	=	+	+	=	+	+	+	+		=	+		+
Rail-weighbridges:	+	+	=	=		+	+	=	+	+	+		=	+			+	=	+		+	+	=		+	+	+			+		+
NAWI Directive Non-Automatic Weighing Instruments															2 x MPE																	

equal MPE than MID: '=' larger MPE than MID: '+'

source: www.welmec.org

find MS contact details: http://www.welmec.org/welmec/country-info/

terminology
adjustment



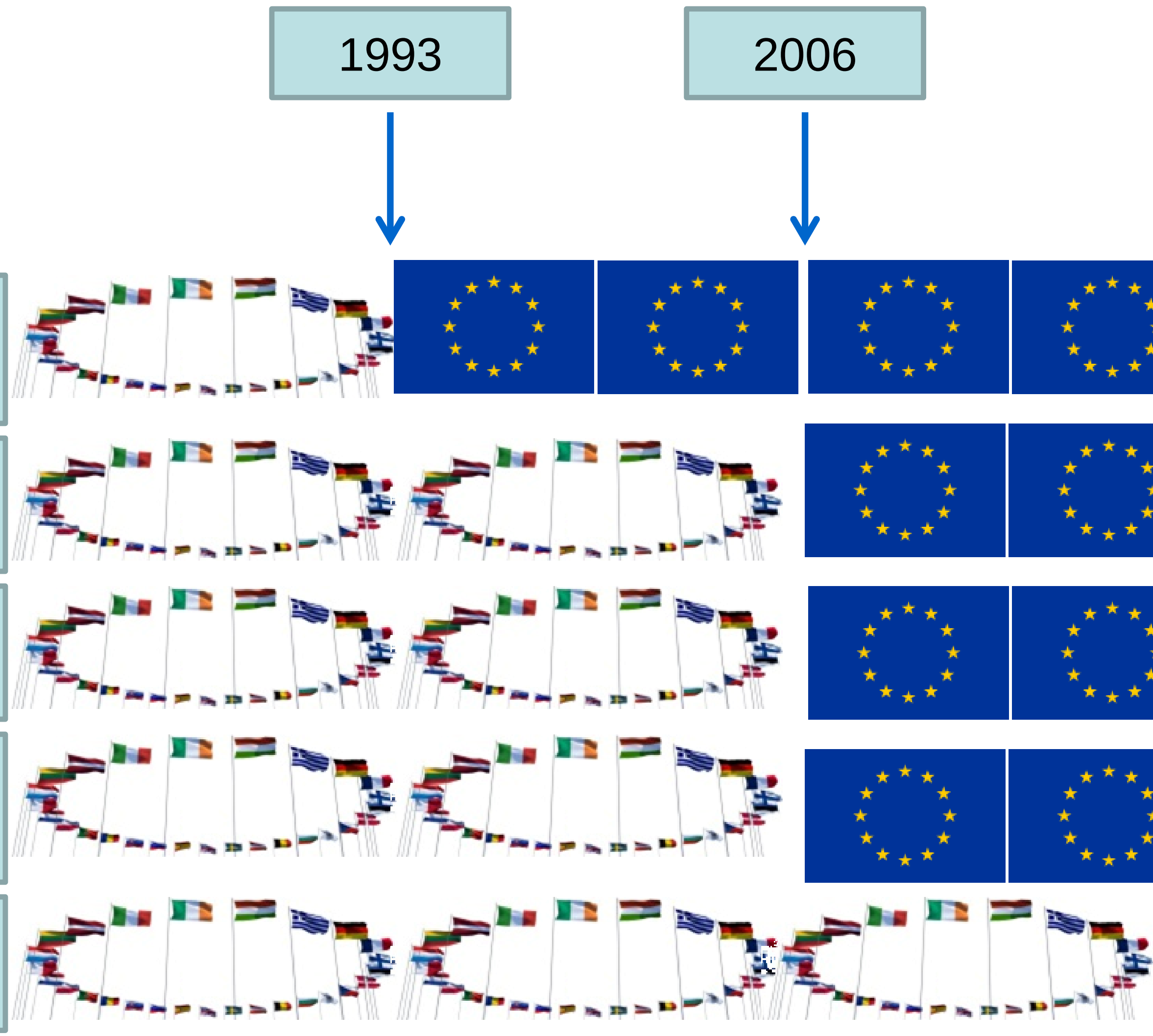
responsible	result
user / approved repair company	data sheet plate

terminology
summary

	what is it	result	responsible	uncertainty
calibration	establish deviation!	value ± uncertainty	user	certificate
verification	deviation within <u>a</u> tolerance?	yes / no marking / data plate	user	tolerance (often: MPE)
‘legal’ verification at ‘first use’	deviation within <u>MPE</u>	marking / data plate	manufacturer	MPE
‘legal’ periodical re-verification	deviation within <u>in-service</u> tolerance?	yes / no marking / data plate	user / authorities	‘in service’ tolerance
‘legal’ re-verification after repair	deviation within <u>MPE</u>	MPE	user / repair company	MPE
‘legal’ inspection	deviation within <u>in-service</u> tolerance?	yes / no marking / data plate	authorities	‘in service’ tolerance

legal metrology

- non-automatic weighing instruments
- liquid flow meters
- gas meters flow computers
- automatic weighing instruments
- level meters + storage tanks



MID & NAWI Directive: structure

MANUFACTURER | USER

design prototype → production copies → placing on market | use

module A

module B → module C, module D, module E, module F

Module D1, E1, F1

Module H1, H1

→ CE M 16 0122

M CE 15 0122

calibration

inspection

periodical verification

verification after repair

MID & NAWI Directive: scope

instrument	modules
watermeters	B+F, B+D, H1
gasmeters	B+F, B+D, H1
kWh meters	B+F, B+D, H1
heatmeters	B+F, B+D, H1
liquidmeters	B+F, B+D, H1, G
automatic weighing	B+F, B+D, H1, G (B+E, D1,F1)
taximeters	B+F, B+D, H1
material measures	A1, F1, D1, E1, B+E, B+D,H
dimensional	B+F, B+D, H1, G (F1, D1, E1, B+E ,H)
exhaust gas analysers	B+F, B+D, H1

non-automatic weighing	B+D, D1, B+F, F1, G

MID & NAWI Directive: scope

modules
what must a manufacturer do/have
(numbers refer to annexes of MID/NAWI Directive)

			self declaration	A + tests by Notified Body	A ex technical documentation	C + tests by by Notified Body	ISO 9001 ex design	D ex B	final product inspection	E ex B	unit test or sample (> 1 instrument)	F ex B	unit verification	full quality assurance	H + design examination
			A	**A2**	**C**	**C1**	**D**	**D1**	**E**	**E1**	**F**	**F1**	**G**	**H**	**H1**
measuring instruments (numbers refer to chapters iof MID)	MI001	water meters					B				B				
	MI002	gas meters + volume conversion devices					B				B				
	MI003	active electrical energy meters					B				B				
	MI004	heat meters					B				B				
	MI005	meters for non-water liquids					B				B				
	MI006	automatic weighing instruments													
		- mechanical					B		B		B				
		- electromechanical					B		B		B				
		- electronic or with software					B				B				
	MI007	taximeters					B				B				
	MI008	material measures													
		- length					B								
		- capacity serving measure					B		B						
	MI009	dimensional measuring instruments													
		- mechanical or electromechanical					B		B		B				
		- electronic or with software					B				B				
	MI010	exhaust gas analysers					B				B				
NAWI-directive		non-automatic weighing instruments (mechanical)					B				B				
		non-automatic weighing instruments (others)					B				B				

conclusion

- no general ‘structure’ in member states (see WELMEC.org)
- Measuring Instruments Directive and NAWI Directive: bringing on the market + putting into use

- measuring instruments ‘in use’, inspection periodic re-verification, verification after repair: <u>national</u> (contacts: see WELMEC.org)

- check data plate or data sheet for MPE → measurement uncertainty

questions

TRUE VALUE

- Testing
- Certification
- Calibration
- Training

Presentation:
How to demonstrate compliance

by Christian Heller

- A “step-by-step guide” on how to demonstrate compliance
- Measuring instruments under operator's or trading partner's control
- Introduction to uncertainty propagation laws
- Examples

How to demonstrate compliance

Christian HELLER

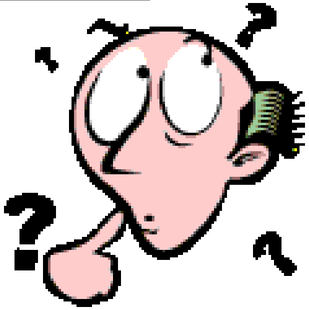
M&R Training Event on Uncertainty Assessment
Brussels, 31 May 2016

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\left[\frac{1}{2}\left(\frac{\partial^2 f}{\partial x_i \partial x_j}\right)^2 + \frac{\partial f}{\partial x_i}\frac{\partial^3 f}{\partial x_i \partial x_j^2}\right]u^2(x_i)u^2(x_j)$$

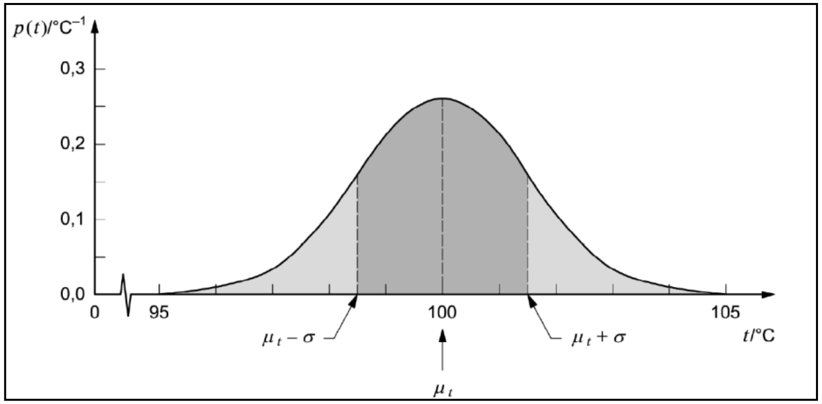
Measuring range

correlated / independent

Reynold's number



temperature



$$s^2(q_k)=\frac{1}{n-1}\sum_{j=1}^{n}\left(q_j-\bar{q}\right)^2$$

Corrosive fluids

viscosity

Uncertainty for activity data: tiers (1)

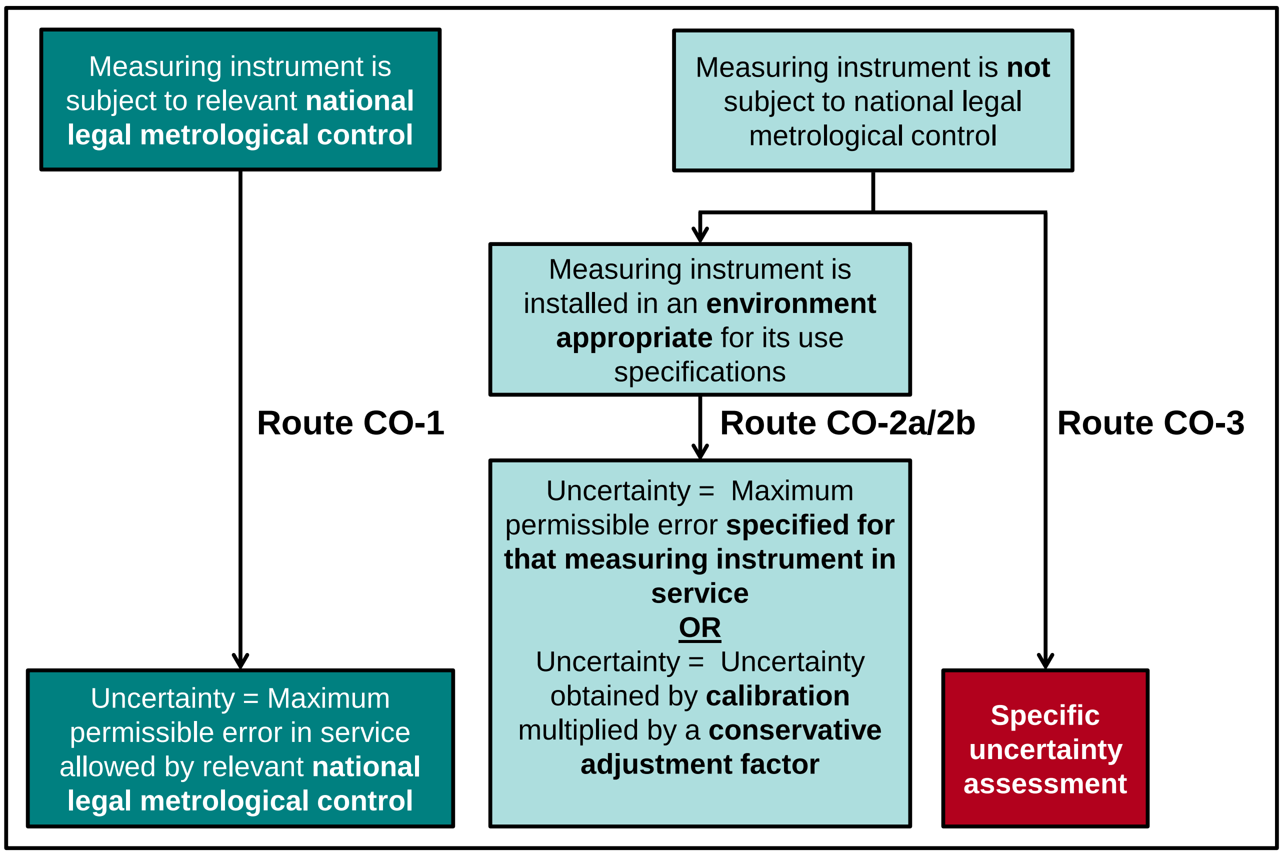
- *Article 12(1)(a) requires the operator to* ***submit to CA an uncertainty assessment*** *as supporting document to the MP*
  - Article 28(2):
    "[..] When carrying out the assessment, the operator shall take into account the fact that the stated values used to define tier uncertainty thresholds in Annex II refer to the ***uncertainty over the full reporting period*** *[..]."*
  - Annex II(1) MRR:
    "The uncertainty thresholds shall be interpreted as ***maximum permissible uncertainties*** *for the determination of source streams* ***over a reporting period****"*
  - Reporting period = **one calendar year** (1st Jan – 31st Dec)
- *Main principle for quality requirements of activity data: The larger the installation (emissions), the lower the permissible uncertainty*

Uncertainty for activity data: tiers (2)

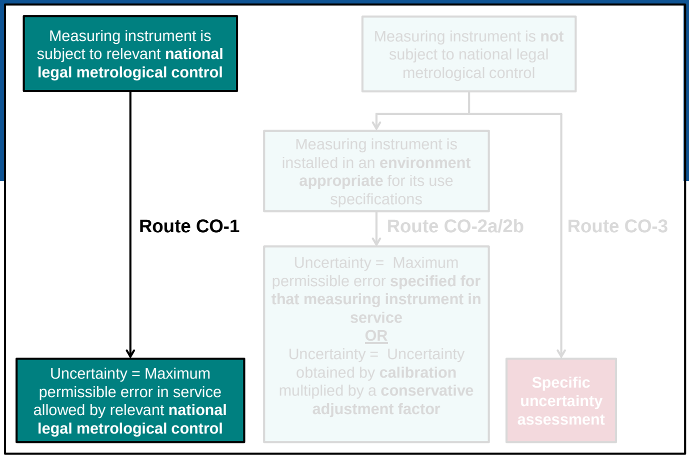
- ***"Over full reporting period"*** *implies that also ongoing QA/QC measures in service are of relevance:*
  - **Art 28(1)(b):** operator to ensure at least once per year, and after each calibration of MIs, that the **calibration results multiplied by a conservative adjustment factor** based on an appropriate time series of previous calibrations for taking into account the effect of uncertainty in service, are compared with the relevant uncertainty thresholds.
  - **Art 58(3)(a): Quality assurance** to be laid down in written procedures → summary of this procedure part of the monitoring plan
  - **Art. 59(1):** 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."

➢ *Uncertainty assessment has to take into account QA/QC in service*

Operator's own control (Art. 28 MRR)



Source: EC Guidance Document 4

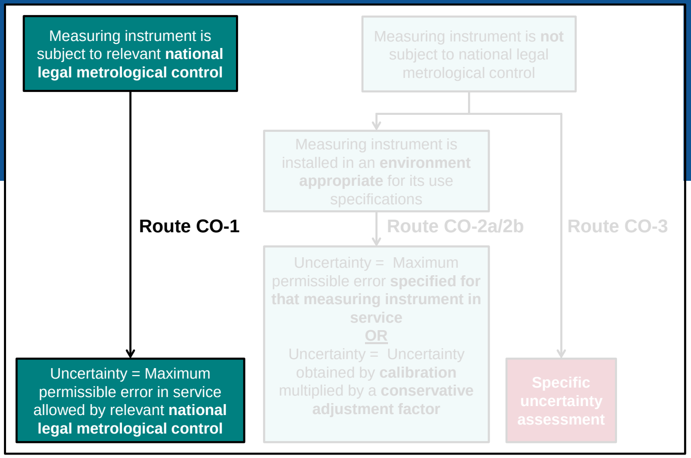


Route CO-1

Measuring instrument (MI) is subject to relevant national legal metrological control (NLMC)

- *Simplification avoids double regulation and administrative burden*
- *MI subject to relevant NLMC usually and regularly checked and calibrated by a governmental authority or by an entrusted accredited body*
- *NLMC usually applicable where market transactions (trades) require the reference to accepted standards (traceability)*

> ➢ ***Overall uncertainty = Maximum permissible error in service (MPES from relevant NLMC)***

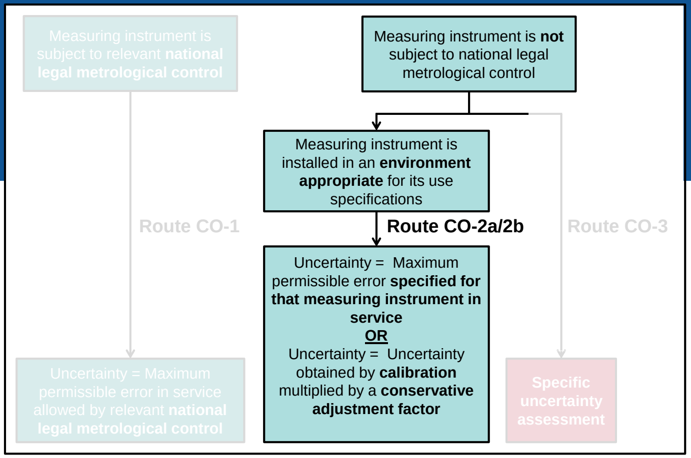


Route CO-1

How to demonstrate evidence?

- *The most appropriate evidence for being under NLMC is a **certificate of the latest (metrological) verification / (re-)calibration** of the instrument*
- *Alternatively, evidence (e.g. a picture) can be provided of the **legal metrology label affixed** to the MI*

Route CO-2a and CO-2b



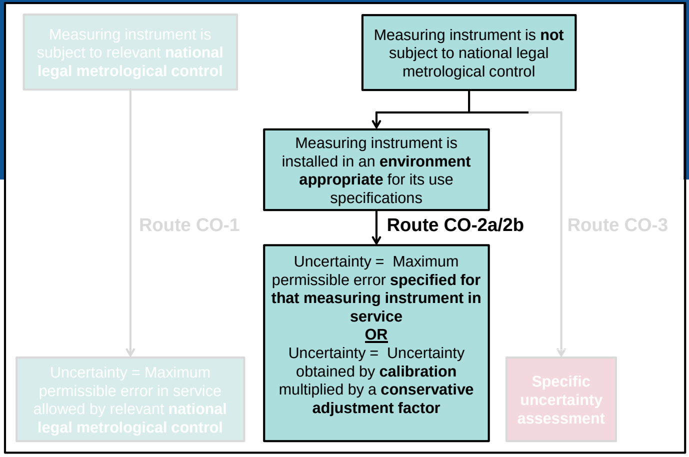
- *Two further simplifications applicable if MI is installed in an* ***environment appropriate for its use specifications***
- ***What is such an environment?***
  - Guidance Document 4 lists **4 steps** that have to be met
  - Only if <u>all</u> 4 steps are met → MI regarded as installed in an environment appropriate for its use specifications

Appropriate environment

- ***Step 1: Operating conditions*** *regarding* ***relevant influencing parameters*** *(e.g. flow rate range, medium, T, p,..) and* ***maximum permissible deviations*** *for those* ***are available***
  - Alternative: manufacturer declares that MI complies with an international standard (CEN, ISO, OIML, ‘CE’ labelling,..), laying down operating conditions regarding influencing parameters.
- ***Step 2: Operating conditions under step 1 are met***
  - Evidence could be provided by e.g. **making a checklist** of each relevant influencing parameter
  - Evidence should be provided that the MI is installed appropriately

Appropriate environment

- ***Step 3: Perform quality assured calibration procedures***
  - Regular calibration should be carried out in accordance with Art. 59(1) using appropriate standards (CEN, ISO, ..) and performed by an institute accredited to EN ISO/IEC 17025
  - Frequency of calibration: based on e.g. manufacturer's specifications, time-series analysis of previous calibrations,..
  - If calibration is performed by non-accredited institute, operator has to provide evidence of suitability and that the calibration is performed using the instrument manufacturer's recommended procedure and the results comply with the manufacturer's specifications
- ***Step 4: Further quality assurance procedures***
  - Maintain written procedures for effective control system (Art. 58(3): QA/QC of MIs, corrective action,..)
  - Include such procedures in quality/environmental management systems (e.g. EN ISO 9001, EN ISO 14001, EMAS,..), if applicable

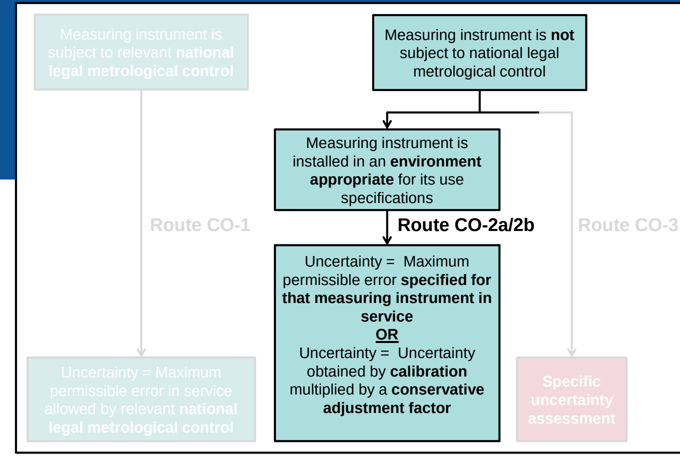


Route CO-2a

- *<u>Only if all</u> of the 4 steps are met, it may be assumed that:*
  - manufacturer's specifications,
  - specifications from legal metrological control, and
  - guidance documents such as the Commission's guidance (Annex II of Guidance Document 4 provides conservative values for uncertainty ranges of common measuring instruments and additional operating conditions)
- *are **suitable sources for the maximum permissible error in service***

> ***Overall uncertainty = Maximum permissible error in service (MPES from suitable source)***

European Commission



Route CO-2b

- *<u>Only if all</u> of the 4 steps are met, it may be assumed that:*
  - the **expanded uncertainty from calibration**, multiplied by
  - a **conservative adjustment factor** (e.g. 2) to take into account any further errors in service
- *can be used as the overall uncertainty*
- *Note: calibration is <u>not</u> a "one-point" check*
  → in best-case scenario carried out by an accredited body using appropriate standards (CEN, ISO or follow principles in e.g. EA 4/02 - Guidance to Expression of Uncertainty of Measurement in Calibration)

> ***Overall uncertainty =***
> ***Uncertainty from calibration ×***
> ***conservative adjustment factor***

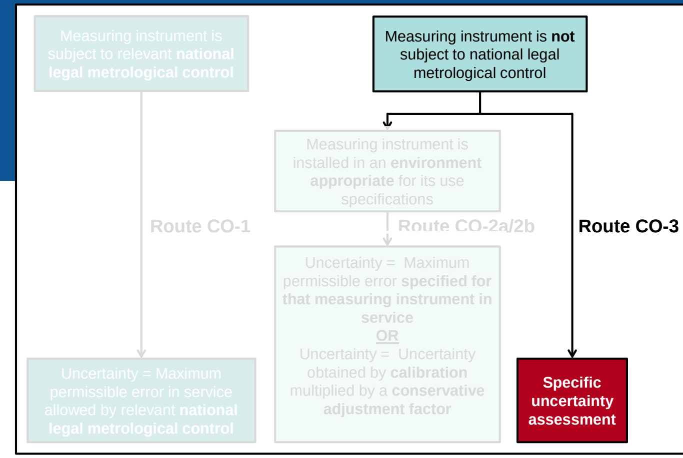
Climate Action

Appropriate environment (cnt‘d)

Note on NLMC

- *Also in the case of Route CO-1 the MI has to be installed in such appropriate environment*
- *It is just assumed that **if relevant NLMC is available** (e.g. it lays down MPES valid between re-calibration intervals), **the 4 steps are typically met** by complying with the provisions set out under NLMC*
- *If there is **no relevant NLMC** (e.g. it does not regulate anything that happens after putting MI into use, like the MID does), the 4 steps are no longer automatically met → **use another Route***

European Commission

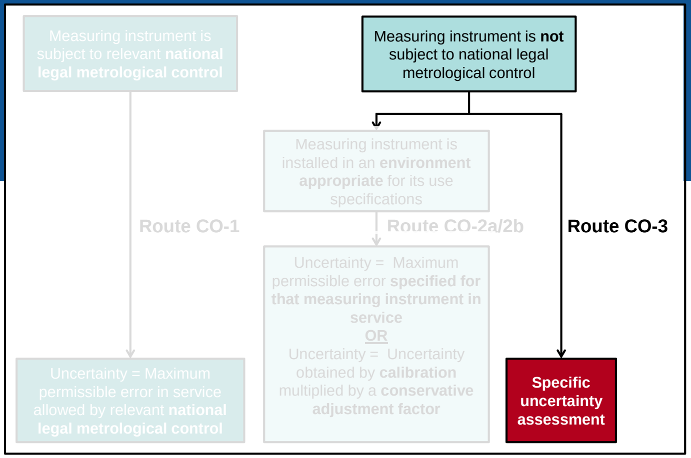


Route CO-3

- ***MI <u>not</u> installed in an environment appropriate for its use specifications**, or this cannot be demonstrated → carry out specific uncertainty assessment (e.g. using GUM – Guidance to Expression of Uncertainty in Measurement)*
- *Operator is always entitled to carry out a specific uncertainty assessment, e.g. if the operator is of the opinion that this provides more reliable results (or where none of the simplification routes are possible)*
- ***Important note:** "specific uncertainty assessment" does not necessarily mean that this assessment has to be completely started from new → use uncertainties gathered from simplification routes as starting points – where appropriate – for further calculations, e.g. via uncertainty propagation*

> ***No simplification route applies:***
> ***Carry out specific uncertainty assessment***

Climate Action



Route CO-3

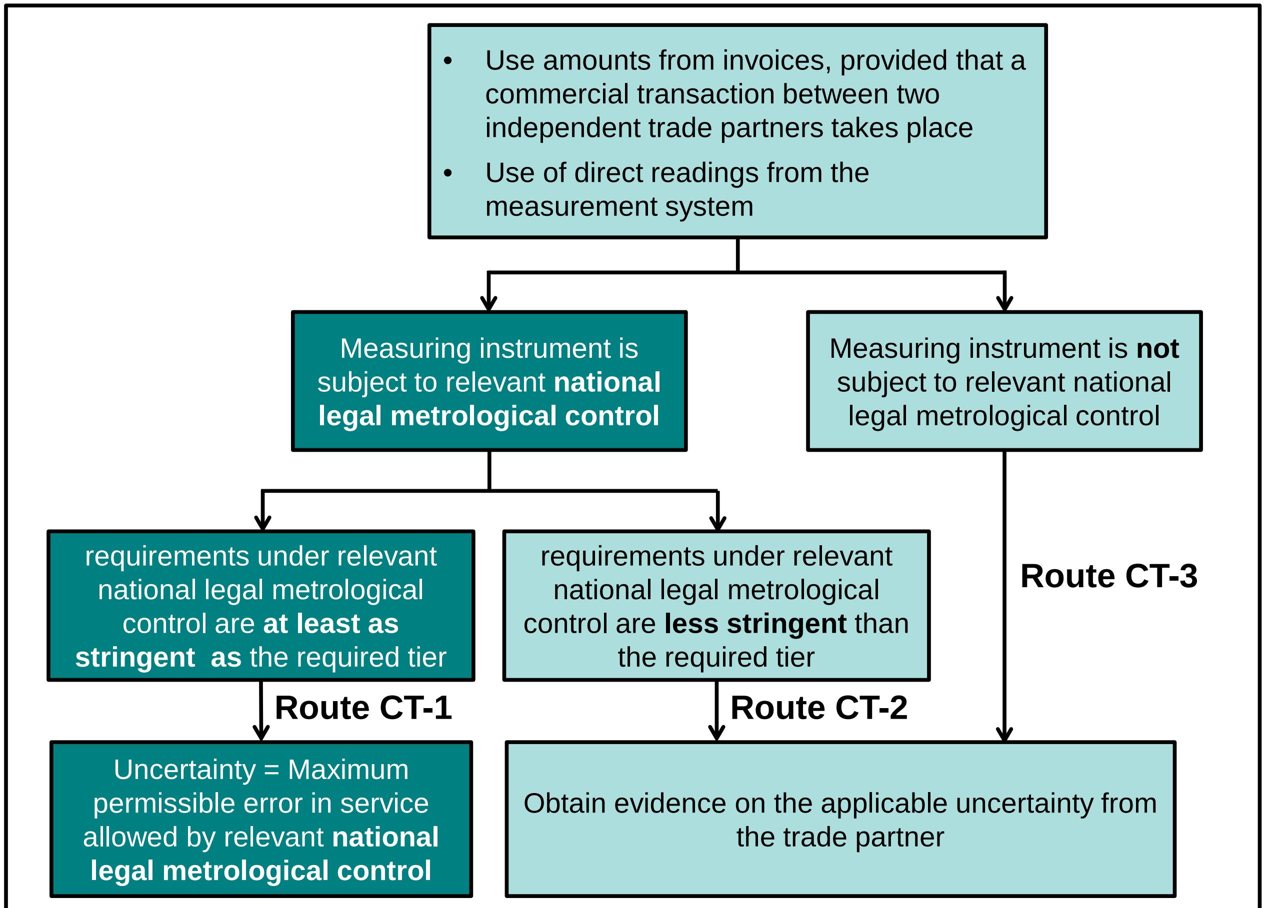
How to demonstrate evidence to CA

- *In principle the **uncertainty assessment shall comprise***
  - the specified uncertainty of the applied measuring instrument
  - the uncertainty associated with the calibration
  - any additional uncertainties connected to how the MI is used in practice

- ***Starting point might be uncertainties obtained from Routes 1 or 2**, where applicable, taking into consideration further possible influences*

- ***Possible further influences** on the uncertainty include:*
  - Deviation from working range
  - Different uncertainties subject to load or flow rate
  - Atmospheric conditions (wind, temperature, humidity, corroding substances,..)
  - Operation conditions (adhesion, density, viscosity, irregular flow rate,..)
  - Installation conditions (bending, vibration, wave)
  - Using the instrument for other medium than the one it is designed for
  - Long-term stability and calibration intervals
  - Etc.

MI under trading partner's control (Art. 29)



Source: EC Guidance Document 4

Routes CT

Condition:

- *Operator must confirm that those instruments allow the operator to comply with at least as high a tier, give more reliable results and are less prone to control risks compared to using own instruments*
- *General assumption is that NLMC is applicable due to commercial relationship (Route CT-1, similar to Route CO-1)*
  - Use max. permissible error in service (MPES) under NLMC for uncertainty
  - If MPES too high for required tier → operator shall obtain evidence on uncertainty from trade partner
- *Operator may also directly read from trading partner's instrument, where this is possible*
  - Responsibility for maintenance and calibration "outsourced" but operator still required to exert control measures (Art. 58(3)(f) and 64)

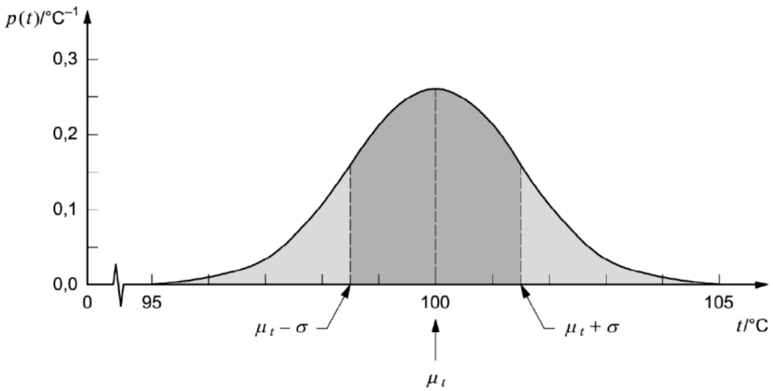
> ***MI under trading partner's control instead of own MI: only use if it allows to comply with at least as high a tier, gives more reliable results and is less prone to control risks***

Derogations

- *What if none of the Routes provides evidence that the required tier can be met?*

> *Carry out **corrective action**, e.g. install a measurement system that meets the required tier, **OR***
>
> *Provide evidence that meeting the required tier is **technically infeasible** or would incur **unreasonable costs***

Any questions so far?



Climate Action

Propagation of uncertainties

Why and when is this needed?

- *The measurand, the particular "output" quantity (Y) subject to measurement, is often not directly measured*
  → e.g. not just one MI involved in determination of AD
- *Instead, "input" quantities (X_i) are measured on which the "output" quantity depends*

How is this done?

- *Express mathematical function:*

$$Y = f(X_1, X_2, .., X_n)$$

- **Example**: Electrical resistance of a resistor not directly measured but calculated from measuring voltage and current

$$R = f(V, I) = \frac{V}{I}$$

Climate Action

Uncorrelated input quantities

$$U_Y = \sqrt{(\frac{\partial Y}{\partial X_1} \cdot U_{X_1})^2 + (\frac{\partial Y}{\partial X_2} \cdot U_{X_2})^2 + \ldots + (\frac{\partial Y}{\partial X_n} \cdot U_{X_n})^2}$$

- *Propagation of uncertainty of a sum*

Example: total fuel oil consumption of two boilers, each equipped with one flow meter (F1, F2)

F1: 10,000 t (standard uncertainty: 1%)
F2: 7,500 t (standard uncertainty : 3%)

$$u_{total} = \frac{\sqrt{(U_1)^2 + (U_2)^2}}{|x_1 + x_2|} = \frac{\sqrt{(100)^2 + (225)^2}}{17{,}500} = 1.4\%$$

$$\Rightarrow u_{95\%}(k=2) = 2.8\%$$

- *Propagation of uncertainty of a product*

Example: determination of mass from volume and density

Volume: standard uncertainty 1.5%
Density: standard uncertainty 3%

$$\frac{U_m}{m} = u_m = \sqrt{u_v{}^2 + u_\rho{}^2} = \sqrt{1.5\%^2 + 3\%^2} = 3.35\%$$

$$\Rightarrow u_{95\%}(k=2) = 6.7\%$$

Correlated input quantities

$$U_Y = \left(\left|\frac{\partial Y}{\partial X_1}\right| \cdot U_{X_1}\right) + \left(\left|\frac{\partial Y}{\partial X_2}\right| \cdot U_{X_2}\right) + \ldots + \left(\left|\frac{\partial Y}{\partial X_n}\right| \cdot U_{X_n}\right)$$

- *Propagation of uncertainty of a sum*

Example: purchased limestone weighed on the same truck scale (weighing bridge)

Weighing bridge: standard uncertainty: 0,5%
100 deliveries about 10t each

$$u_{total} = \frac{U_1 + U_2 + \ldots + U_n}{\left|x_1 + x_2 + \ldots + x_n\right|} = \frac{100 \cdot 0.05}{1{,}000} = 0.5\%$$

$$\Rightarrow u_{95\%}(k = 2) = 1\%$$

- *Propagation of uncertainty of a product*

Example: loss on ignition of clay → material before and after ignition weighed on the same scale

$$u_{total} = u_1 + u_2$$

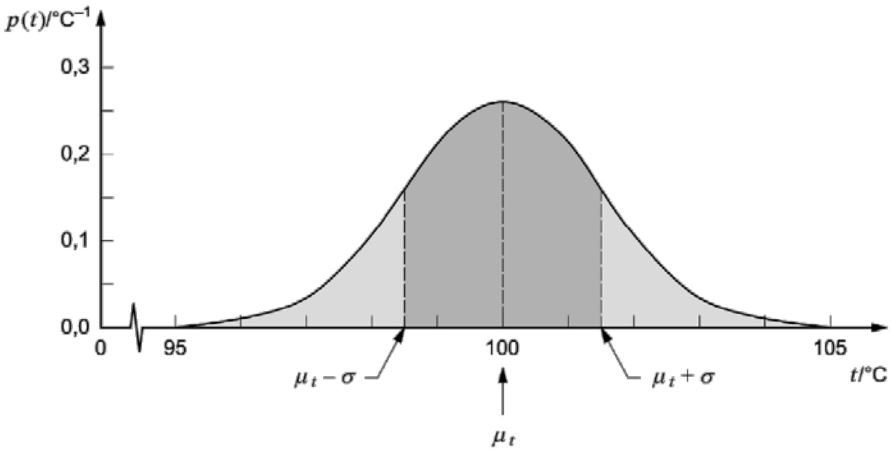
Step-by-step approach

- **Step 1:** Express mathematical relationship "input↔output quantities"
  - e.g. $\mathbf{Q = P - E + (S_{begin} - S_{end})}$ (see batch metering) or $\mathbf{Q = Q_1 + Q_2}$
- **Step 2:** Determine <u>standard</u> uncertainty for each input quantity
  - Route 1: MPES from NLMC
  - Route 2a: MPES from manufacturer's specification, NLMC, OIML,..
  - Route 2b: Calibration x conservative adjustment factor
  - Route 3: Full uncertainty assessment for the input quantity
- **Step 3:** Check for any correlation between e.g. P, S, Q_1,..
- **Step 4:** Combine uncertainties (propagation laws) → obtain $\mathbf{u_Q}$
- **Step 5:** Calculate expanded uncertainty (coverage factor k =2; 95%)

Climate Action

Type of distributions

Normal



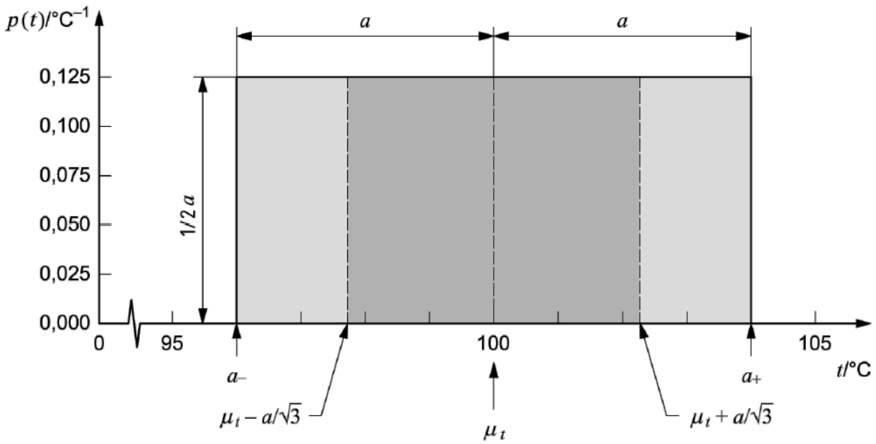
Standard uncertainty

u (standard deviation)

Typical occurrences

- Calibration reports
- Manufacturer's specifications
- Combined uncertainties

Rectangular



Standard uncertainty

$$u = \frac{a}{\sqrt{3}}$$

Typical occurrences

- Maximum permissible errors
- Tolerances
- Reference book values

Example: Clay in ceramics plant

- ***Specific information***
  - Clay is gathered from the clay pit directly by the operator
  - Operator transports the clay from the pit to the installation on trucks
  - Trucks weighed on a weighing bridge owned by the operator
  - <u>No commercial transaction</u> → not subject to NLMC
  - Measurement instrument is used in an <u>environment appropriate for its use specifications</u> ("<u>Route CO-2a</u>")

- *See more details in Guidance Document 4a*

Example – Step-by-step approach

- **Step 1:** Mathematical relationship $\mathbf{Q = P - E + (S_{begin} - S_{end})}$
- **Step 2:** Determine <u>standard</u> uncertainty for each input quantity
  - Route 2a: MPES from manufacturer's specification for **P** (e.g. ±1%)
    → MPES usually rectangular distribution → convert to standard uncertainty
    $$u_{Pi} = \left(\frac{\boldsymbol{MPES}}{\sqrt{3}}\right)$$
  - Route 3: (Simplified) uncertainty assessment for $\mathbf{S_{begin,\ end}}$ (e.g. standard u ±5%)
- **Step 3:** Check for any correlation between input quantities
  (e.g. all $\mathbf{P_i}$ correlated because they are measured on the same instrument)
- **Step 4:** Combine uncertainties $$u_Q = \frac{\sqrt{\mathbf{2} \cdot (\boldsymbol{U_S})^2 + (\boldsymbol{U_P})^2}}{\boldsymbol{Q}}$$
- **Step 5:** Calculate expanded uncertainty $\mathbf{u_{(95\%,\ k=2)} = 2 * u_Q}$

Example: Clay in ceramics plant

Suppose:

- *Annual total amount of clay consumed (P) = 125,000t*
- *Average stock levels (S_{begin} = S_{end}) = 10,000t*

$$u_Q = \frac{\sqrt{2 \cdot (10,000 \cdot 5\%)^2 + \left(125,000 \cdot \frac{1\%}{\sqrt{3}}\right)^2}}{125,000} = 0.8\%$$

- *Expanded uncertainty $u_{(95\%,\ k=2)}$ = 2*0.8% = **1.6 %***

Climate Action

Example: Clay in ceramics plant

Evidence for complying with all four steps:

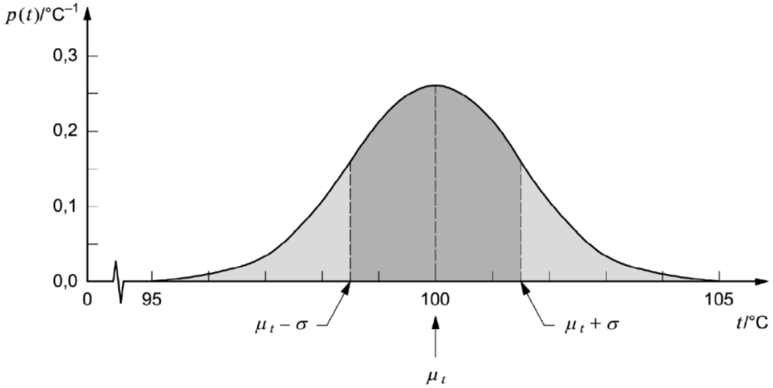
“Step 1”: *see manufacturer’s specification (“MPES ± 1.0%”) in the weighing bridge’s operating manual*

“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	✓
Measurement range	2 - 50 tonnes	10 - 35 tonnes	✓
Wind speed	< 20 m/s	< 15 m/s	✓
Calibration interval	Every two years	Every year	✓

“Steps 3 and 4”:
e.g. <See attached the latest calibration certificates for the truck weighing bridge WB-XYZ123 and quality management procedure>

Any questions so far?



Climate Action

Fall-back approaches

Fall-back approach

- ***Art 22 MRR***
- *Applicable if achieving **at least tier 1** for at least one major or minor source stream is **technically not feasible** or would incur **unreasonable costs***
- *In such case "any" estimation method is allowed, provided **overall emissions uncertainty** is:*
  - Less than **7.5% for category A** installation
  - Less than **5.0% for category B** installation
  - Less than **2.5% for category C** installation
- *Justification for the approach and a **full uncertainty analysis (GUM)** are required with every annual emission report and the improvement reports*

Fall-back approach – example

- *Installation category A*
- *Uncertainty of the determination of the emissions for the whole installation must not exceed 7.5%*

$$Em_{total} = Em_{NG} + Em_{FB}$$

- *Em_{total} .. total emissions of the installation*
- *Em_{NG} ... emissions resulting from natural gas burning (2%; 35,000 t CO_2)*
- *Em_{FB} ... emissions resulting from the source stream monitored by a fall-back approach (18%; 12,000 t CO_2)*

$$u_{total} = \frac{\sqrt{(2.0\% \cdot 35{,}000)^2 + (18\% \cdot 12{,}000)^2}}{\left|35{,}000 + 12{,}000\right|} = 4.8\%$$

Measurement-based approaches

Measurement-based methodology

- *Section 3 of the MRR*
- ***Continuous emissions measurement systems (CEMS)***
- ***Requires two elements:***
  - Measurement of the GHG concentration
  - Volumetric flow of the gas stream
- *Extensive **QA/QC measures** required*
  - Application EN 14181, EN 15259, etc.
  - Pass Quality Assurance Levels
    QAL 1, 2, 3 and Annual Surveillance Test (AST)
- *Corroborating calculations*

CEMS – Overview of requirements

	QAL1	QAL2	QAL3	AST
When?	Before installation of the CEMS	Installation and calibration	During operation	Starting one year after QAL2
Frequency	Once	At least every five years	Continuously	Annually
Who?	Operator	Accredited laboratory	Operator	Accredited laboratory
Relevant standards	EN 14181, EN ISO 14956, EN 15267-3	EN 14181, EN 15259	EN 14181	EN 14181, EN 15259

CEMS – QA / QC requirements

- ***QAL 1**: Procedure used to demonstrate the potential suitability of the CEMS before it is installed (EN ISO 14956, EN 15267-3)*
- ***QAL 2**: Obtain uncertainty from the calibration function against a standard reference method (recommended standard for flue gas flow: EN 16911-2)*

> ➢ ***Uncertainty obtained by QAL2 (incl. flue gas flow) to be compared to tier requirements in the Regulation***
>
> $$u_{av\ hourly\ emissions} = \sqrt{u_{GHG\ concentration}^{2} + u_{flue\ gas\ flow}^{2}}$$

- ***QAL 3**: Ongoing quality control using control charts (e.g. Shewart, CUSUM), determine appropriate maintenance interval and action limits (ref. QAL1)*
- ***Annual Surveillance Test** (AST): "mini"-QAL 2; confirm that CEMS functions correctly and calibration function valid*
- *Further readings: see **EC Guidance Document 7***

Questions?

Where to find more information?

Regulation No. 601/2012 (MRR)
http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1462274244220&uri=CELEX:02012R0601-20140730

Guidance Documents on European Commission's website
http://ec.europa.eu/clima/policies/ets/monitoring/documentation_en.htm
in particular Guidance Documents 4 and 4a

Annex II - Presentations:

Checking Compliance with the tier requirements:

by Member States Representatives

- Practical approach to checking operators' uncertainty assessments
- Common difficulties and limitations
- Required time effort and expertise (e.g. use of external consultants)
- Best practice examples: What kind of checks are performed?
- Best practice examples: What kind of evidence is requested from operators?

Nederlandse Emissieautoriteit
Dutch Emissions Authority

Uncertainty assessment

Alex Pijnenburg
Coordinator EU-ETS

Approach

Uncertainty: important for NEa

- One of the key elements of monitoring
  ➔ a few % more can make a large difference

- One of the elements with the most mistakes
  ➔ Lack of understanding of the basics

In NL uncertainty assessments of <u>all</u> installations are assessed

- Before approval of the monitoring plan
- When changes are notified
- Pragmatic/practical approach where possible

Requirements by NEa

Activity data

- Sources of uncertainties listed for different measurement devices.
  (e.g. calibration certificate, specifications, ISO 5168)

- Error propagation calculation checked

- Evidence documents (certificates) not always requested to submit to competent authority (only on request for information purposes).

  ➔ Limits for assessing evidence "behind the desk"
  ➔ More effective to evaluate evidence documents on site (by verifier and NEa-inspectors)
  ➔ Assess effectiveness operators procedures and Q-systems on measurements instruments

Expertise

In House

- Training course by Dutch Metrological institute
- Specific guidance document including aspects National metrology.
- Getting more experienced each year (“the hard way”)

External

- Permitting phase 3: contract with Dutch Metrological institute for support
- On going: support from engineering consultancy if needed

Uncertainty Assessment Check Compliance with Tier Requirements

Annette Prendergast
Emissions Trading Unit
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Overview of Situation in Ireland

- 44 out of 99 stationary installations are required to submit an Uncertainty Assessment.
- 55 installations with low emissions are required to submit evidence that they can achieve the required tier such as current calibration certificates for meters or confirmation that legal metrology meters used.
- We have no Fall Back methods applied in Ireland.
- All uncertainty Assessments are examined in detail by the team. Time taken depends on the complexity and the quality of information submitted. Less than an hour for simple uncertainty assessments up to a day for complex assessments.

Uncertainty Assessment

- Detailed checks are performed on calculations to ensure correct formula are applied. Back-up data which justifies uncertainty assumptions is checked.
- Commission Guidance on Uncertainty Assessment and Commission Examples are used for Guidance.
- Types of Legal Metrology meters include: Weighbridges for solid/ liquid fuels/ materials, beltweighers for solid fuels/materials, truck meters for liquid fuels.
- Types of non legal meteorology meters include; Gas and liquid meters (turbine, vortex, orifice plate, ultrasonic, Coriolis, rotor), level indicators, weigh scales, various methods for stock determination, draught surveys.

Evidence Requested from operators

- Evidence is assessed during agreement of the monitoring plan. Evidence is also checked during site visits by interview of relevant personnel and examination of calibration and maintenance procedures, schedules and records.
- For Legal Metrology Meters:
- Do the calibration certs match the installed meters, serial nos. detailed in plan. Have the legal metrology meters been validated in the current year/2 year period. Is the maximum permissible error in service within the required uncertainty level for the tier.

Evidence Requested from operators

- For Non –Legal Metrology Meters;
- Current calibration certificate for the meter and temperature, pressure equipment where relevant. Does this match meters listed in plan.
- Evidence of manufacturers recommended MPES and operating conditions (temperature, measurement range, pressure, wind speed, turbulence etc)
- Evidence that such conditions are met.
- Procedure for the installation, operation, maintenance and calibration of meters.
- Evidence that such procedures are followed.

Additional evidence in specific cases

- Sampling /analysis plan for determination of moisture content of raw material, method uncertainty.
- Uncertainly associated with, pressure change and molecular weight determination (e.g. use of orifice meters for gaseous fuels).Sampling/ analysis plan, calibration, operation maintenance of gas chromatograph, is the sampling and analysis method 17025 accredited.
- Are the calibration gases supplied by accredited lab and are they in date.

Conclusions and Recommendations

- Detailed uncertainty assessment takes time and effort. In addition to desk based analysis a site visit can be beneficial to gather required information.
- Commission Guidance document and example document can be used as a guide.
- Simple excel calculation spreadsheets could be developed as an outcome to this training to include formulas for example for Independent uncertainties of a product (temperature and pressure correction for volume measurement),Independent uncertainties of a sum, correlated uncertainties of a sum and of a product etc.

M&R Training Event on Uncertainty Assessment

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CONTENTS

1. Practical approach to check operators' uncertainty assessments

2. Common difficulties and limitations

3. Possible ways forward

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1. Practical approach to check operators' uncertainty assessments

CA checks the uncertainty assessments of all the operators (exception for < 25 kt)

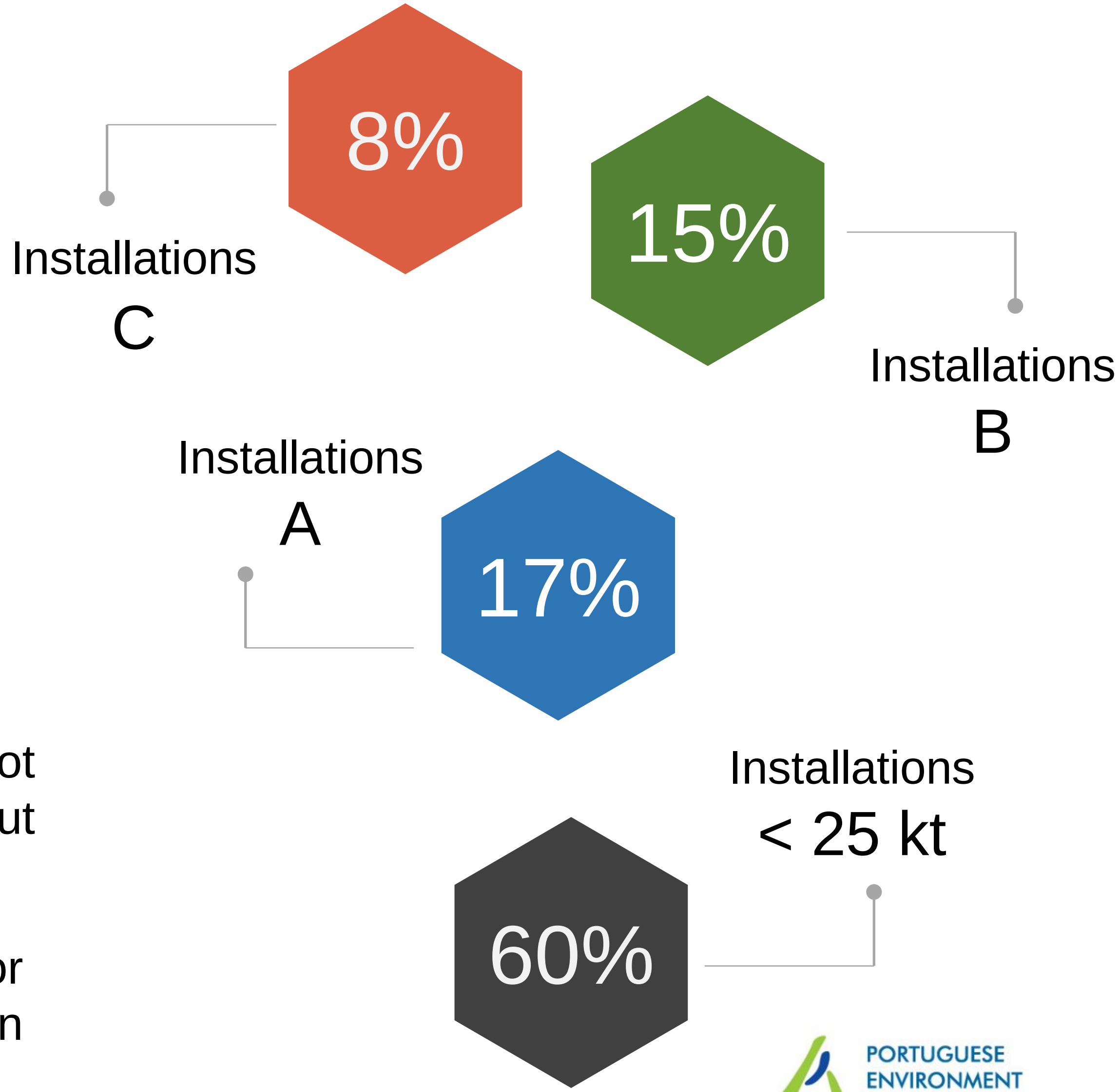
CA checks the verification reports for any recommendation concerning uncertainty assessment

CA checks which route the operator followed and if the formulas used are correct according to EC's Guidance doc. n.º4

Main Topics:

Natural gas meters – did the operator considered not only the uncertainty of the volume measurement, but also the temperature and pressure measurements?

Other fuels and materials – did the operator considered the uncertainty related to the stock (when applicable)?



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2. Common difficulties and limitations

National metrological legislation is disperse and it´s not always clear what is the maximum permissible error in service (since it results from the combination of several parameters)

Difficult for CA to assess if the MPES meets the tier requirement

Operators tend to submit a full uncertainty assessment, not always with the same formula that are presented in the guidance doc.

Difficult for CA to assess it since there are no uncertainty experts in the team

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3. Possible ways forward

In line with the spirit of simplification, this could be a great opportunity to think on pragmatic approaches on uncertainty assessment for phase IV

In cases where the amount of fuel consumed is determined based on invoices, with national metrological control and there is an independent relation between the operator and the supplier -> could we derogate the need for an uncertainty assessment?

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M&R Training on „Uncertainty Assessment“

Checking Compliance with the tier requirements

Lisa Buchner

German Emissions Trading Authority, 2016-05-31, Brussels

Situation in DE (only category B and C installations)

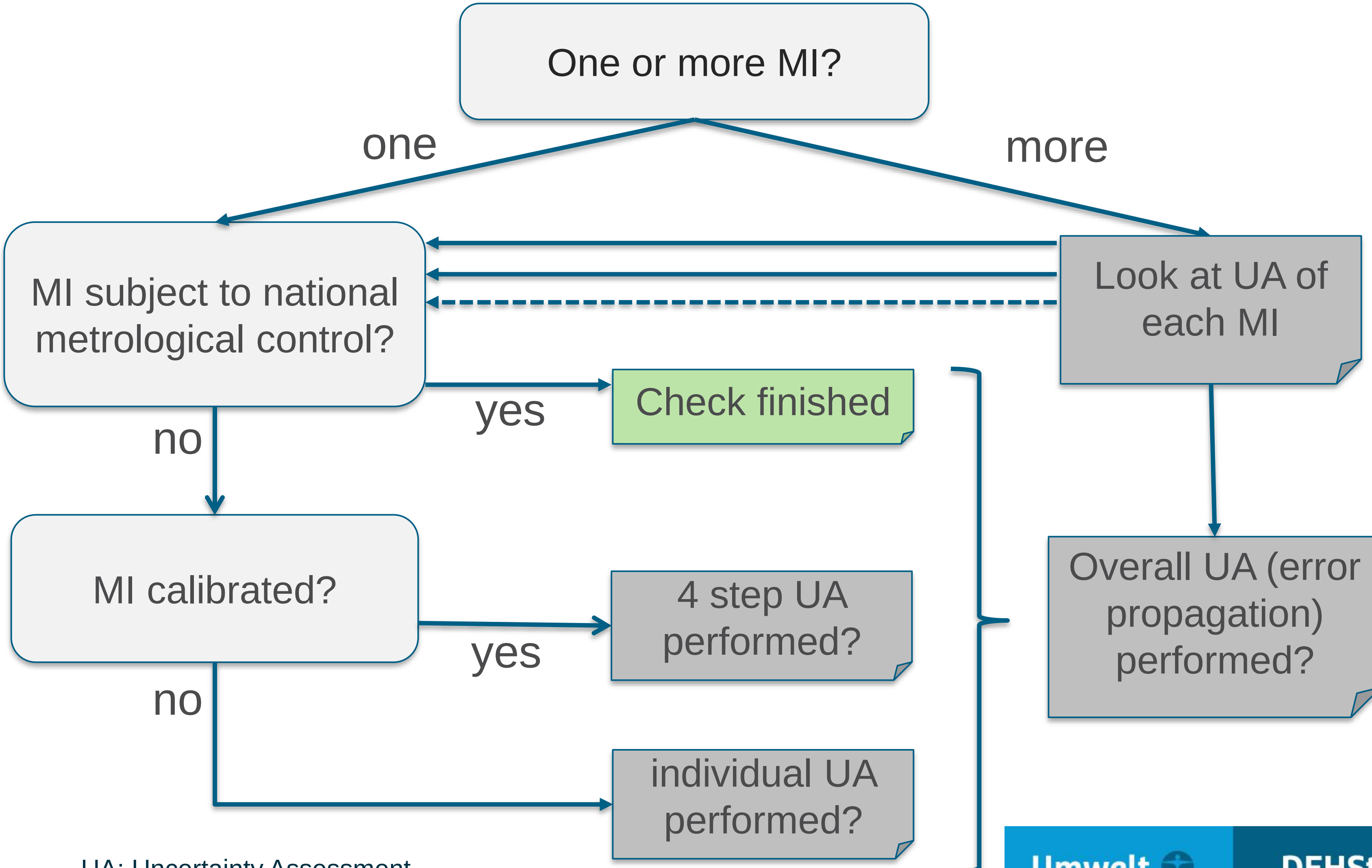
- Number of installations: ~ 550 (29%)
- Emission of installations: ~ 440 Mio. t CO_2/a (96%)
- Number of source streams: 4,250 (49%), thereof
  1,650 major, 750 minor, 1,850 de-minimis
- Number of measuring instruments (MI) for major and minor source streams:

Minor/major source streams	Number of MI subject to national metrological control	Number of MI not subject to national metrological control
Minor	~ 900	~ 750
Major	~ 2900	~ 2650

Umwelt Bundesamt

DEHSt
Deutsche Emissionshandelsstelle

Practical approach to check uncertainty assessment



UA: Uncertainty Assessment
MI: Measuring Instrument

Example for an insufficient evidence

Information in operator's MP

- source stream ethylene: 800,000 t CO2/a
- calibrated coriolis mass flow meter
- calibration certificate (08.06.2004): measuring uncertainty < 1.5%
- next calibration in August 2012
- tier 4 can be met safely

Checking uncertainty assessment

- MI not subject to nat. metrological contr. → 4 step approach necessary
- measuring uncertainty = max. deviation of **flow rate** obtained during calibration

Step 1 Application limits and maximum deviations for all relevant influencing parameters → missing

Step 2 Evidence that application limits are met → missing

Step 3 Information on who is carrying out the calibration → missing

Step 4 Information on quality management system → missing

Thank you for your attention!

[Lisa Buchner]

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Uncertainty on MW measured with online gaschromatograph

- Typical application: determination of activity data (mass flow) of gaseous fuels (natural gas, process gases in refineries, steel plants or chemical plants)
- Mass flowrate, measured with a venturimeter or orificemeter is:

$$F_M = C \cdot d_0^2 \cdot \sqrt{\Delta p * MW * \frac{p}{T}}$$

- Uncertainty analysis on mass flowrate is:

$$U_M = 0.5 * \sqrt{U_{\Delta p}^2 + U_T^2 + U_P^2 + U_{MW}^2}$$

- How to find U_{MW} ?
- *Note: Also in case of volumetric flowrate (Nm³/h or Am³/h) of gaseous fuels measured with an orifice type meter U_{MW} must be calculated*
- *Example*: An on line gaschromatograph determines the composition (MW) of a gas source stream with 9 components

Input 1: Reference used to validate

INPUT							
				References			
Name of component	Molecular weight	Caloric value	C-factor	Reference 1		Reference 2	
				Composition	Uncert	Composition	Uncert
2015	(Mw_i)	MJ/Nm³	mol C/mol comp	x_i (mol%)	(%)	x_i (mol%)	(%)
						Since	1/06/2015
hydrogen	2,016	10,835	0	51,21	2	51,25	2
methane	16,032	35,963	1	4,005	2	4	2
ethane	30,048	64,632	2	37	2	37	2
propane	44,064	93,935	3	2,002	2	2	2
butane	58,08	122,805	4	0,6	2	0,6	2
pentane	72,096	141,558	5	0,3976	2	0,4	2
benzene	78,048	142,403	6	0,2952	1	0,3	1
CO2	44	0	1	0,4989	2	0,5	2
nitrogen	28	0	0	4,011	2	4	2
COMP-10	0	0	0	0	0	0	0
COMP-11	0	0	0	0	0	0	0
COMP-12	0	0	0	0	0	0	0
COMP-13	0	0	0	0	0	0	0
COMP-14	0	0	0	0	0	0	0
COMP-15	0	0	0	0	0	0	0

Input 2: Validation data

Number	Components	hydrogen	methane	ethane	propane	butane	pentane	benzene	CO2	nitrogen	SuM
Reference		**51,21**	**4,005**	**37**	**2,002**	**0,6**	**0,3976**	**0,2952**	**0,4989**	**4,011**	100,00
#	**Check date**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
1	**1/02/2015**	51	3,85	37,5	2	0,6	0,41	0,25	0,56	3,9	**100,07**
2	**1/05/2015**	51,5	3,7	36,9	2	0,65	0,38	0,26	0,53	4,2	**100,12**
3	**1/08/2015**	52	3,9	36,8	2	0,66	0,4	0,24	0,55	4,2	**100,75**
4	**1/02/2016**	51,5	3,7	36,9	2	0,65	0,38	0,26	0,53	4,2	**100,12**
5	**1/09/2016**	52	3,9	36,8	2	0,66	0,4	0,24	0,55	4,2	**100,75**
6	**1/05/2016**	51,5	3,7	36,9	2	0,65	0,38	0,26	0,53	4,2	**100,12**
7	**1/07/2016**	51,5	3,7	36,9	2	0,65	0,38	0,26	0,53	4,2	**100,12**
8											**0**
9											**0**
10											**0**

Results

Check Ref1 Σx =	OK	
Check Ref2 Σx =	OK	
Average MW=	15,87	kg/kmol
Uncert. on MW=	1,60	%
Average C-fact=	2,51	kg/kg
Uncert. on C-fact=	0,18	%
Aver. Emission factor	51,62	kg CO2/GJ
Uncert. on Emissionfact=	0,44	%

<u>Further information:</u>
Related example (gaseous fuels - orifice meter) is part of the discussion group session.

Annex III: Case Studies and Model Answers (Suggested Approaches)

- **Example 1:** Fuel oil delivered on trucks
- **Example 2:** Petcoke
- **Example 3:** Backward calculations for cement clinker
- **Example 4:** Calibration of an ultrasonic meter
- **Example 5:** Calibrated belt weigher
- **Example 6:** Tar delivered on ships
- **Example 7:** Draft survey
- **Example 8:** Natural gas meter with electronic volume converter
- **Example 9:** Split source stream partly exported to non-ETS installations
- **Example 10:** Online gas analysers

Disclaimer: *Each example (except Example 10 which is informative as it stands) is accompanied by a 'model' answer (approach) that aims to facilitate understanding for participants and to illustrate at least one possible solution for each case. Each answer recognises the simplifications provided by the M&R Regulation in order to carry out an uncertainty assessment with proportionate effort. As a consequence, it is not claimed that these 'model' answers show the only correct solution(s). Other approaches might be technically and scientifically correct as well and fully in line with the requirements in the M&R Regulation for carrying out an uncertainty assessment.*

Example 1:

Fuel oil delivered on trucks from many different suppliers

The overall annual consumption of gasoil is calculated from the aggregated deliveries with tank trucks (see Art. 27 (1) b) MRR):

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

where:

P ....Purchased quantity of fuel oil over the whole year
E ....Exported quantity of fuel oil the whole year
S_{begin}.......Stock level reading of fuel oil at the beginning of the year
S_{end}.........Stock level reading of fuel oil at the end of the year

- The trucks are equipped with flow meters on the truck subject to national legal metrological control
  - Maximum Permissible Error in Service: 1.0%.
  - Each truck delivery: 25,000 litres of fuel oil.
  - Number of truck deliveries per year: 50
- Fuel oil is stored in tanks on-site:
  - Storage capacity of 30,000 litres
  - Uncertainty of level reading (k=1): 2.5%

1. How should the overall expanded uncertainty of the amount of fuel oil be calculated?

2. Is there any information missing for calculating annual activity data of the fuel oil consumption and associated uncertainties?

3. What further supporting evidence would you request from the operator?

Approach Example 1:

Fuel oil delivered on trucks from many different suppliers

ad 1)

In total, there are 50 truck deliveries per year, each with a typical load of 25,000 litres of fuel oil. Each delivery is measured by the flow meter on each truck. Deliveries each have an uncertainty (MPES) of 1.0% and can be treated as uncorrelated input quantities to determine P, the annual quantity of purchased fuel oil.

How should the calculations be done if the type of uncertainty distribution is known?

As a first step, the MPES, which usually of a rectangular distribution, has to be converted to normal distribution by dividing by the square root of 3:

$$u_{Pi} = \frac{MPES}{\sqrt{3}} = \frac{1.0\%}{\sqrt{3}}$$

The uncertainty related to the stock level reading is the same for both readings (beginning and end of the year). As the difference between S_{begin} and S_{end} may not be predictable, S_{begin}-S_{end} can be assumed as zero. However, the uncertainty related to both readings must not be omitted.

Subsequently, in accordance with the example 7 in section 8.3 of guidance document 4, the following equation can be used to determine the uncertainty:[1]

$$u_Q = \frac{\sqrt{2 \cdot (U_S)^2 + n \cdot (U_{Pi})^2}}{P}$$

where:

u_Q........total (relative) uncertainty associated of Q (i.e. total annual quantity of fuel oil consumed)

$U_{S,\,Pi}$.... (absolute) uncertainty of the stock level reading or quantity provided by one truck

$$u_{Q(k=1)} = \frac{\sqrt{2 \cdot (30{,}000 \cdot 2.5\%)^2 + 50 \cdot (25{,}000 \cdot \frac{1.0\%}{\sqrt{3}})^2}}{50 * 25{,}000} = 0.12\%$$

expanded uncertainty (95%): $u_{Q(k=2)} = 2 \cdot 0.12\% = 0.24\%$

What should be done if the type of uncertainty distribution is <u>not</u> known?

In this case the overall expanded uncertainty may be calculated as follows:

$$u_{Q(k=2)} = \frac{\sqrt{2 \cdot (30{,}000 \cdot 5.0\%)^2 + 50 \cdot (25{,}000 \cdot 1.0\%)^2}}{50 * 25{,}000} = 0.22\%$$

ad 2)

So far, we have only calculated uncertainty related to the annual amount of fuel oil consumed, expressed as litres. However, for the multiplication with NCV and EF for the determination of annual emissions, the annual quantity needs to be expressed as tonnes.

[1] Note that this equation is only valid if all individual measurements are uncorrelated. However, in reality there might be a considerable correlation, in particular if only a small number of different trucks are used.

Therefore, the operator has to describe in the monitoring plan how the density of the fuel oil is determined and how associated uncertainties are being assessed. For instance, if the density of a mixed sample from samples drawn from each fuel oil delivery is determined with an uncertainty (k=1) of 2%, the annual uncertainty of the quantity in tonnes would be as follows[2]:

$$u_{Q(tonnes)} = \sqrt{u_{Q(Volume)}^2 + u_{density}^2} = \sqrt{0.12\%^2 \ + 2\%^2} \ = 2\% \ \rightarrow u_{Q(k=2)} = 4\%$$

As can be seen, despite the very good uncertainty achieved for the volume-based quantity, the mass-based uncertainty is considerably higher in comparison. This is almost exclusively caused by the uncertainty related to the determination of the density. Therefore, if the operator has to achieve a higher tier, the uncertainty associated with the determination of the density would have to be improved, e.g. by measuring the density of each truck delivery.

ad 3)

In principle, the operator should obtain copies of (metrological) verification certificates for the flow meters from each supplier. It may be reasonable for an operator to suggest the seeking of certificates only from a smaller number of suppliers which would still leave enough margin to prove that the overall uncertainty is well below the next tier threshold. How many certificates are sought with a year and how it is ensured that track is kept appropriately, may best be addressed by an appropriate procedure which would be part of the monitoring plan and subject to the CA´s approval, provided that the sampling of the selection is done in a representative way, e.g. randomly.

In addition to that, the operator should provide you with further information of how he determined the uncertainty of the stock readings. However, with storage facilities capable of containing only less than 5 % of the annual quantity of fuel oil (30,000/1,250,000), Art. 28(2) of the MRR would also allow to exclude stock level readings from the uncertainty assessment in the first place.

[2] assuming measurements of volume and density are not correlated to any significant extent.

Example 2:

Uncertainty Associated with Measurement of Petcoke Activity Data

Petcoke usage in an installation is determined by aggregation of metering of quantities separately delivered taking into account relevant stock changes (see Art. 27 (1) b) MRR), using the following formula:

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

where:

P ....Purchased quantity over the whole year
E ....Exported quantity of petcoke over the whole year
S_{begin}.......Stock of petcoke at the beginning of the year
S_{end}.........Stock of petcoke at the end of the year

The weighbridge (scale interval 25 kg) used for the purchased amount of petcoke delivered on trucks is subject to Legal Metrological Control.

- Maximum Permissible Error: +/- 1.5 scale intervals.
- Truck deliveries per year: 95
- Typical load on each truck: 30t (=total purchased amount of 2,850t)
- No export of petcoke.

Stock measurements are carried out at year end to determine closing stock / opening stock. There is a maximum surveyors uncertainty of 1-1.5%. A value of 1.5% is chosen as a worst case scenario.

For the weighbridge (25kg scale interval; typical load of 30t), an adjustment factor of x 2 is applied for converting the MPE (+/- 1.5 scale intervals) to MPE “in service”.

$$MPES = \frac{1.5 \cdot 25kg \cdot 2}{30{,}000kg} = 0.25\%$$

The operator follows the example provided in MRR Guidance Document 4, section 8.3, and provides you with the following calculation of the overall uncertainty:

$$u_{petcoke,(k=2)} = \frac{\sqrt{2 \cdot (1{,}300 \cdot 1.5\%)^2 + 95 \cdot (30 \cdot 0.25\%)^2}}{2{,}850} = 0.97\%$$

1. Do you agree with the way the operator calculated the overall uncertainty?

2. What further supporting evidence would your request from the operator?

Approach Example 2:

Uncertainty Associated with Measurement of Petcoke Activity Data

ad 1)

The general outline of the uncertainty assessment seems to be reasonable. However, the operator failed to provide you with one very important information: what coverage factor is used for the uncertainty assessment.

Without further information, the term “uncertainty” is commonly understood as the “standard” uncertainty, i.e. the uncertainty related to the coverage factor of 1 implying a confidence level of only 68%.

For instance, if the uncertainty related to the stock surveyors of 1.5% only corresponds to the 68% confidence level (k=1), the whole calculation of the overall uncertainty would only correspond to the coverage of k=1 and would need to multiplied by 2 to obtain the uncertainty at the 95% level.

Moreover, the operator assumed that individual measurements are uncorrelated. However, in reality this may not be the case as the same weighbridge is used for all measurements. In the absence of further information on correlation it would be the more conservative approach to assume correlation between measurements.

How should the calculations be done if the type of uncertainty distribution is known?

Furthermore, a minor incorrectness (minor only in this specific case due to the figures provided) concerns the use of the MPES for the weighing bridge. If this was the sole MI used for determination annual quantities the use of MPES without further adjustment would be allowed by the MRR. However, this is not the case because also stock changes are factored in as well. Where an MPES is combined with other uncertainties it would, as a first step, have to be appreciated that an MPES most commonly exhibits a rectangular distribution and needs to be converted into a standard uncertainty (k=1) prior to combination. This is achieved by dividing the MPES by the square root of 3.

$$MPES = \frac{0.25\%}{\sqrt{3}}$$

When taking this into account and suppose the uncertainty related to the stock levels is indeed only the standard uncertainty, the correct calculation should look as follows:

$$u_{petcoke,(k=1)} = \frac{\sqrt{2 \cdot (1{,}300 \cdot 1.5\%)^2 + (2{,}850 \cdot \frac{0.25\%}{\sqrt{3}})^2}}{2{,}850} = \frac{\sqrt{760.5 + 16.9}}{2{,}850} = 0.98\%$$

$$u_{petcoke,(k=2)} = 2 \cdot 0.98\% = 1.96\%$$

Two things can be seen:

- Firstly, if the uncertainty related to the stock levels only denotes the standard uncertainty, the highest tier would no longer be achieved because the overall uncertainty at the 95% confidence level is above 1.5%.
- Secondly, as stated above, the treatment of the MPES only plays a minor role due to the high stock levels (1,300t) compared to the quantities purchased (2,850).

What should be done if the type of uncertainty distribution is <u>not</u> known?

In this case the overall expanded uncertainty may be calculated as follows:

$$u_{petcoke,(k=2)} = \frac{\sqrt{2 \cdot (1{,}300 \cdot 3.0\%)^2 + (2{,}850 \cdot 0.25\%)^2}}{2{,}850} = \frac{\sqrt{1{,}521 + 50.7}}{2{,}850} = 1.95\%$$

ad 2)

Further supplementary evidence to be requested from the operator for uncertainty of the weighbridge may include e.g. certificate of the latest (metrological) verification or a picture of the affixed legal metrology label.

However, for the reasons given above, this is not the main source of the overall uncertainty. Instead, the surveyors are. Therefore, the operator should provide sound and robust evidence for the uncertainty provided on meters used including their uncertainties and how they were obtained (calibration, manufacturer’s specification, “Steps 1 to 4” under Routes CO-2a/2b,..)

Example 3:

Cement clinker production

The activity data of the cement clinker is determined based on method B and aggregation of metering of quantities separately delivered taking into account relevant stock changes (see Art. 27 (1) b) MRR). However, the amount of clinker is not measured directly but back-calculated from cement production.

Information from the operator's Monitoring Plan:

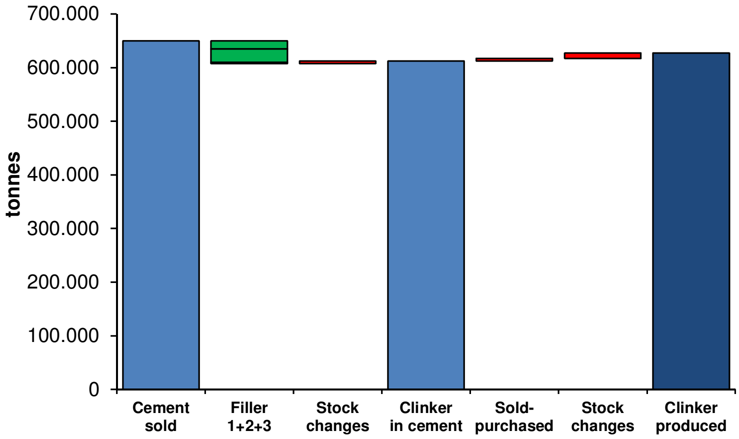
The operator uses the following calculation steps to determine the amount of clinker produced:

I: $\mathbf{Clinker_{produced}} = \mathbf{Clinker_{in\ cement}} + Clinker_{sold} + Clinker\ stock_{close} - (Clinker\ stock_{open} + Clinker_{purchased})$

II: $\mathbf{Clinker_{in\ cement}} = \mathbf{Cement_{produced}} - (Filler_1 + Filler_2 + Filler_3)$

III: $\mathbf{Cement_{produced}} = Cement_{sold} + Cement\ stock_{close} - Cement\ stock_{open}$

$Clinker_{sold}$	5,000t
$Clinker\ stock_{close}$	80,000t
$Clinker\ stock_{open}$	70,000t
$Clinker_{purchased}$	0t
$Filler_1$	15,000t
$Filler_2$	25,000t
$Filler_3$	2,500t
$Cement_{sold}$	650,000t
$Cement\ stock_{close}$	35,000t
$Cement\ stock_{open}$	30,000t



All on-site weighbridges are Class III non-automatic weighing instruments with a 20kg scale interval and are subject to Legal Metrology control. In accordance with the Legal Metrology Regulations, a Maximum Permissible Error of +/- 1.5 scale intervals is allowed. Typical load is 45t. Weighbridges are used for:

- $Clinker_{sold}$
- $Clinker_{purchased}$
- $Cement_{sold}$
- $Filler_{1,\ 2\ and\ 3}$

The measurement of stock changes for clinker, cement stocks by the stock surveyors has an estimated uncertainty (k=2) of +/- 5%.

1. How should the overall expanded uncertainty of the amount of clinker produced be calculated?

2. What further supporting evidence would your request from the operator?

Approach Example 3:

Cement clinker production

ad 1)

For weighbridges (20kg scale interval; typical load of 45t), an adjustment factor of x 2 is applied for converting the MPE (+/- 1.5 scale intervals) to MPE "in service".

$$MPES = \frac{1.5 \cdot 20kg \cdot 2}{45{,}000kg} = 0.14\%$$

Parameter	Quantity	Relative uncertainty(k=2)
$\text{Clinker}_{\text{sold}}$	5,000t	0.14%
$\text{Clinker stock}_{\text{close}}$	80,000t	5%
$\text{Clinker stock}_{\text{open}}$	70,000t	5%
$\text{Clinker}_{\text{purchased}}$	0t	0.14%
Filler_1	15,000t	0.14%
Filler_2	25,000t	0.14%
Filler_3	2,500t	0.14%
$\text{Cement}_{\text{sold}}$	650,000t	0.14%
$\text{Cement stock}_{\text{close}}$	35,000t	5%
$\text{Cement stock}_{\text{open}}$	30,000t	5%

III: **$\text{Cement}_{\text{produced}}$** = $\text{Cement}_{\text{sold}}$ +$\text{Cement stock}_{\text{close}}$ – $\text{Cement stock}_{\text{open}}$

$$u_{cement\ produced} = \frac{\sqrt{(650{,}000 \cdot 0.14\%)^2 + (35{,}000 \cdot 5\%)^2 + (30{,}000 \cdot 5\%)^2}}{650{,}000 + 35{,}000 - 30{,}000} = 0.38\%$$

II: **$\text{Clinker}_{\text{in cement}}$** = **$\text{Cement}_{\text{produced}}$** – ($\text{Filler}_1$ + Filler_2 + Filler_3)

$$u_{clinker\ in\ cement} = \frac{\sqrt{(655{,}000 \cdot 0.38\%)^2 + (15{,}000 \cdot 0.14\%)^2 + (25{,}000 \cdot 0.14\%)^2 + (2{,}500 \cdot 0.14\%)^2}}{655{,}000 - 15{,}000 - 25{,}000 - 2{,}500} = 0.40\%$$

I: **$\text{Clinker}_{\text{produced}}$** = **$\text{Clinker}_{\text{in cement}}$** + $\text{Clinker}_{\text{sold}}$ + $\text{Clinker stock}_{\text{close}}$ – ($\text{Clinker stock}_{\text{open}}$ + $\text{Clinker}_{\text{purchased}}$)

$$u_{clinker\ produced} = \frac{\sqrt{(612{,}500 \cdot 0.40\%)^2 + (5{,}000 \cdot 0.14\%)^2 + (80{,}000 \cdot 5\%)^2 + (70{,}000 \cdot 5\%)^2 + 0}}{612{,}500 + 5{,}000 + 80{,}000 - 70{,}000 - 0} = 0.93\%$$

ad 2)

Further supplementary evidence to be requested from operator for uncertainty of the weighbridges may include e.g. certificates of the latest (metrological) verification or pictures of the affixed legal metrology label. In addition to that, the operator should provide you with further evidence of how he determined the uncertainty of 5% for the stock surveyors (*Note that even if only an uncertainty of 8% could be demonstrated for the stock surveyors, the overall uncertainty would still be below the 1.5% threshold, thus in compliance with the highest tier*)

Example 4:
Ultrasonic meter with 4 signal paths

Information from the operator's Monitoring Plan:

Natural gas is determined by an ultrasonic meter with 4 signal paths. The expanded uncertainty obtained during calibration of the ultrasonic meter is 0.2% (calibration is performed by an ISO 17025 accredited institution).
Information from the manufacturer's specification of the ultrasonic meter are shown in following table:

No	Influencing parameter	Manufacturer's specification	Maximum deviation (expanded uncertainty)
1	Range of flow rate	$Q_{b,max}$ = 1000 m^3/h Q_t = 100 m^3/h Q_{min} = 10 m^3/h	1 % Q_{max}… Q_t 2 % Q_t … Q_{min}[1]
2	Medium's temperature	T_{min}= -10 °C T_{max} = 35 °C	0.5 % Deviation compared to reference conditions
3	Medium's pressure	p_{max} = 10 bar p_{min} = 0.9 bar	0.5 % Deviation compared to reference conditions
4	Medium's type	Air, natural gas	0.3 % Deviation compared to reference conditions
5	Intake turbulence	10-D straight pipe section (after a sharp bend or a tee)	0.35 % Deviation compared to reference conditions
6	Ambient conditions: temperature range	T_{amb} -10… + 55 °C	< 0.2 % Deviation compared to reference conditions above Q_t
7	Long-term stability	Re-calibration (5-year cycle recommended)	< 0.5 %

<u>Question:</u> How should the operator perform an uncertainty assessment of the ultrasonic meter?

[1] Q_{min} = minimum flowrate, Q_{max} = maximum flowrate, Q_t = transitional flowrate

Example 4 - Approach:

Operator's description of measures for adhering to manufacturer's specifications

No	Influencing parameter	Manufacturer's specification	Maximum deviation	Operator's description of measures for adhering to manufacturer's specifications
1	Range of flow rate	$Q_{b,max}$ = 1000 m^3/h Q_t = 100 m^3/h Q_{min} = 10 m^3 /h	1 % Q_{max}… Q_t 2 % Q_t … Q_{min}	Average flow rate exceeding Q_t
2	Medium's temperature	T_{min}= -10 °C T_{max} = 35 °C	0.5 % Deviation compared to reference conditions	The medium is transported in a buried pipeline. The pipeline is thermally insulated between the measuring device and the point where the pipeline leaves the earth.
3	Medium's pressure	p_{max} = 10 bar p_{min} = 0.9 bar	0.5 % Deviation compared to reference conditions	Safety valves guarantee that the pressure remains within specifications.
4	Medium's type	Air, natural gas	0.3 % Deviation compared to reference conditions	Only natural gas is used.
5	Intake turbulence	10-D straight pipe section (after a sharp bend or a tee)	0.35 % Deviation compared to reference conditions	The measuring instrument is installed after a 15-D straight pipe length downstream. The diameter of the inlet pipe is 1 % greater than the diameter of the measuring instrument.
6	Ambient conditions: temperature range	T_{amb} -10… + 55 °C	< 0.2 % Deviation compared to reference conditions above Q_t	The measuring instrument is installed in an unheated insulated container that is equipped with a fan to the environment when the temperature within the container should rise above 35 °C.
7	Long-term stability	Re-calibration (5-year cycle recommended)	< 0.5 %	Requirement which is integrated in the operator's quality management

COM Gudiance Nr. 4 approach (route CO-2b):
$$\boldsymbol{U_{total}} = \mathbf{0.2\%} * \mathbf{2} = \mathbf{0.4\%}$$

Germany's approach:
$$\boldsymbol{U_{total}} = \sqrt{\mathbf{1^2 + 0.5^2 + 0.5^2 + 0.3^2 + 0.35^2 + 0.2^2 + 0.5^2}} = \mathbf{1.42\%}$$

Example 5:
Belt weigher not subject to national metrological control

Information stated by the operator in the Monitoring Plan for your approval:

- **Estimated emissions from the source stream: 90,000 t CO_2/a**

- **Specification of measuring instrument:**
  - Operator's own measuring instrument
  - Type of measuring instrument: „belt weigher"
  - Measuring range: 0-40 t/h
  - Typical use range: 27 t/h

- **Specification of quality assurance:**
  - Calibrated measuring instrument (*not subject to national metrological control*)
  - Measuring instrument's uncertainty: 1.10%
  - Interval of checking: 3 years
  - Previous date of checking: January 2015
  - Description of quality assurance and uncertainty assessment: see checking protocols 2013 and 2015

1) What information is missing or unclear?
2) Which information can be gained from the checking protocols (e.g. by comparing 2013 and 2015 results)?
3) What should the operator be asked to do/justify?

Checking protocol 2013, page 1

schenck process

Checking protocol

General Information

Date:	05.04.2013	weigher specification:	
inspector:	xxxx	costumer	xxx
		name of weigher	xxx
		type of weigher	belt weigher
		Serial number **(mech.)**	xxx
		evaluation instrument	xxx
		serial number **(electr.)**	xxx
		manufacturer	Schenck Process GmbH Pallaswiesenstraße 100 64293 Darmstadt

Signatur, Stempel

Schenck Process GmbH
Pallaswiesenstraße 100
64293 Darmstadt

Dynamic check at actual state

measured belt speed [V]		0.93400 m/s
length of bridge [L]		4 m
reference weight [Q]		10 kg
current feed rate		8.40 t/h
theoretical feed rate	$P = \frac{Q \cdot v}{L} 3{,}6$	8.41 t/h
error [actual - target, or target]		-0.07 %

Checking via material control at actual state

number of weighing	1	2	3
reference weighing [t]	1.000		
correction factor	1.053		
meter [t]	0.974		
difference [t] [ACTUAL-TARGET]	0.026		
measurement uncertainty [or traget]	-2.60%		
average measurement uncertainty	-2.60%		

Checking protocol 2013, page 2

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Checking protocol

General Information

Date	05.04.2013
Inspector	xxxx

Signatur, Stempel

Schenck Process GmbH
Pallaswiesenstraße 100
64293 Darmstadt
Germany

weigher specification:

costumer	xxx
name of weigher	xxx
type of weigher	belt weigher
Serial number (mech.)	xxx
evaluation instrument	xxx
serial number (electr.)	xxx
manufacturer	Schenck Process GmbH Pallaswiesenstraße 100 64293 Darmstadt

Überprüfung der Mechanik / Mechanical check

	insufficient	sufficient	good	note
cleanliness		X		
position of load cell			X	
running characteristic of belt			X	
belt tenion		X		
running performance of nearby rolls			X	
alignment of roll stations	X			
status of speed sensor			X	
status of wiper				

Taring Control

	error
after cleaning	2.34%
after adjustment	0.00%

Adjustment via material control

number of weighing	1	2	3	4	5
reference weighing [t]	1.002	1.001	1.002	1.002	
correction factor	1.0527	1.0427	1.0340		
meter [t]	1.022	1.015	1.006	1.008	
difference [t] [ACTUAL-TARGET]	0.02	0.01	0.00	0.01	
adjusted yes/no	yes	yes	no	no	
new correction factor					
error [target]	2.00%	1.40%	0.40%	0.60%	
average error	1.10%				

Notes

Checking protocol 2015, page 1

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Checking protocol

General information

Date	19.01.2015	weigher specification:	
inspector	xxx	costumer	xxx
		name of weigher	xxx
		type of weigher	belt weigher
		serial number (mech.)	xxx
		evaluation instrument	xxx
		serial number (electr.)	xxx
		manufacturer	Schenck Process GmbH Pallaswiesenstraße 100 64293 Darmstadt

Signatur, Stempel

Schenck Process GmbH
Pallaswie
64293
Germany

Statische Überprüfung im Ist-Zustand / Static check at actual state

correction factor	1.054
tara error (relative deviation from zero point)	- 3.74%

recommended correction factor from weight control

measurement number	1	2	3	4	5
correction factor	1.000	1.000	1.000	1.000	1.000

average	1.000
+/- standard deviation	0.000
total	1.000

	Abweichung Parameter	Abweichung Messwert zum Sollwert
Tara	-3,74% - 0,00%	direkte Auswirkung auf den Messwert
	-3,74%	-3,74%
Correction Factor	1,000 ÷ 1,054	1 ÷ 94,88% - 1
	94,88%	5,40%
Measurement uncertainty (deviation tara + deviation correction factor)		1,66%

Check via material control at actual state

number of weighing	1	2	3
reference weighing [kg]	500.00		
correction factor	1.054		
meter [kg]	440.00		
difference [kg] [ACTUAL-TARGET]	60.00		
measurement uncertainty [or target]	12.00%		
average measurement uncertainty	12.00%		

senstraße01

Checking protocol 2015, page 2

PASS

schenck process

Checking protocol

Allgemeine Daten

Prüfdatum	19.01.2015	weigher specification:	
inspector	xxx	costumer	xxx
		name of weigher	xxx
Signatur, Stempel		type of weigher	belt weigher
Schenck Process GmbH		serial number (mech.)	xxx
Pallaswiesenstraße 100		evaluation instrument	xxx
64293 Darmstadt		serial number (electr.)	xxx
Germany		manufacturer	Schenck Process GmbH Pallaswiesenstraße 100 64293 Darmstadt

Überprüfung der Mechanik / Mechanical check

	insufficient	sufficient	good	note
cleanliness			X	
position of load cell			X	
running characteristic of beld		X		
belt tension		X		
running performance of nearby rolls			X	
alignment of roll stations			X	
status of speed sensor			X	
status of wiper				
Plattenband: Zustand der Schienen, Schienenüberg.				

Tarierung durch Tarakontrolle / Taring control

	error
Nach Reinigung /after cleaning	-3.74%
Nach Justage /after adjustment	0.01%

Justierung mit Prüfgewichten / adjustment via reference weights

	correction factor	reference weight	error
Nach Reinigung /after cleaning			
Nach Justage /after adjustment			

Justierung durch Materialkontrolle / adjustment via material control

number of weighing	1	2	3	4	5
reference weighing [kg]	1002.00	1001.00	1005.00	1002.00	
correction factor	1.054	1.054	1.054	1.054	
meter [kg]	1002.00	998.00	1002.00	999.00	
difference [kg] [ACUTAL-TARGET]	0.00	-3.00	-3.00	-3.00	
adjusted yes/no?					
new correction factor					
error [or tagret]	0.00%	-0.30%	-0.30%	-0.30%	
average error	-0.22%				

Bemerkungen /Notes

There was no need for adjusting the correction factor. While changing the belt weigher's rolls, the position of the rolls has to be checked.

Example 5 - Approach:

Ad 1)
According to the checking protocols the quality assurance of the belt weigher is carried out both by comparison measurement and by checking the load cells and the belt speed.
A calibration of a belt weigher is performed by a comparison measurement of a defined source stream amount on an officially (metrological) verified measuring instrument. The checking of the load cell (e.g. through placing or hanging weights or roller chains) and of the belt speed via test equipment, is not a “real” calibration, because the influence of the belt itself is not considered when checking the load cell (belt is lifted from the load cell).

From the protocols it is not clear which method (calibration with reference measuring instrument or checking load cell and belt speed) is the primary method for quality assurance.

Ad 2)
In the checking protocol 2013 the set correction factor is not identical with the correction factor at actual state in the protocol 2015. This indicates that between 2013 and 2015 a change of the correction factor was carried out. However the operator stated that no other checks were performed until now in the 3rd trading period.

In order to determine the uncertainty associated with long-term stability (drift) of the belt weigher (most important influencing parameter), the results during a check have to be documented both before and after the checking.
After checking the belt weigher in 2013, a deviation of 0.4-0.6% was documented. In 2015 the belt weigher showed a deviation of 12% at actual state after two years of operation. Due to only one check via material control performed, no further reliable data is available. However it is clear, that the required tier of 1.5% cannot be met with 12% deviation.

Ad 3) CA’s request:

- The operator should be required to deliver an explanation on the primary method for quality assurance of the belt weigher
- To reduce the drift, the operator should be required to raise his frequency of checking by dividing in half the interval of checking
- The operator should be required to justify, why the error remained undetected despite quality assurance measures.

Example 6:

Steel production – tar on ships

A steel producer produces tar which is exported to consumers by ships. The amount of tar leaving the installations is part of the mass balance applied by the operator and is one of the outgoing source streams.

The quantity of the tar is measured by radar tank gauge technology. This technology measures the distance from a single point to the surface of the tar in the tank. With an internal algorithm the volume of the tar can be measured. This volume needs then to be converted into a mass by a measurement of the density which is determined by analysis of tar samples.

- Amount of tar exported per year: 90,000m^3
- Average density of the tar: 0.83t/m^3

The amount of tar exported is calculated as follows:

Total amount of tar (t) = Volume of tar (m^3)* · ρ (t/m^3)

The uncertainties related to the measurements are:

- Standard uncertainty (i.e. k=1) of this source stream: 0.75%
- Uncertainty (k=1) of the pycnometer[1] used for the density: 1%

The operators follow the solution example 1 of Guidance Document 4 of the Commission:

$$\frac{U_Y}{Y} = u_Y = \sqrt{\frac{(X_2 \cdot U_{X_1})^2 + (X_1 \cdot U_{X_2})^2}{X_1^2 \cdot X_2^2}} = \sqrt{\left(\frac{U_{X_1}}{X_1}\right)^2 + \left(\frac{U_{X_2}}{X_2}\right)^2} = \sqrt{{u_{X_1}}^2 + {u_{X_2}}^2}$$

1. Does the operator comply with the highest tier (1.5%)?

2. What further supporting evidence would your request from the operator?

[1] The operator provided evidence by submitting the latest calibration certificate of the pycnometer and multiplying the result by a conservative estimation factor of 2.

Approach Example 6:

Steel production – tar on ships

ad 1)

With the use of the formula in Guidance Document 4 the operator would obtain the following overall uncertainty:

$$u_{mass,(k=1)} = \sqrt{0.75\%^2 + 1\%^2} = 1.25\%$$

$$u_{mass,(k=2)} = 2 \cdot 1.25\% = 2.5\%$$

As a result, the operator does not achieve the highest tier and would have either to improve the measurement quality or demonstrate technical infeasibility or unreasonable costs.

It has to be noted though that this approach is only applicable if uncertainties associated with the determination of volume and density are independent (i.e. uncorrelated). If both volume and density are measured at the same temperature, this approach seems reasonable. However, volume and density are strongly negatively correlated via temperature, i.e. higher temperatures lead to volume expansion but at the same time to a lower density.

Although, despite this correlation, it has to be born in mind that temperature is just *one* of the influencing parameters on the overall uncertainty. This means that while both *values* being correlated the *uncertainties* associated with the radar tank gauge and the pycnometer may not. For instance, if the uncertainty of the radar tank gauge is largely attributable to its drift or other source of uncertainty and to the temperature only to negligible extent. In such a case, small deviations in temperature would only have small impact on the measurement's uncertainty.

Furthermore, as volume and density are negatively correlated (0 ≥ correlation coefficient ≥ -1), uncertainties would outweigh each other to some extent (see for instance formula (16) in the GUM). Therefore, in contrast to a positive correlation with a correlation coefficient of 1 (see example 6 in GD4), assuming independence (i.e. uncorrelated input quantities) would provide the more conservative results (i.e. higher uncertainty) for this case anyway.

Nevertheless, the operator should be required to explain the measurements in more detail, e.g. whether they are conducted in accordance with appropriate standards and whether the usual temperature during measurement is covered by the uncertainties provided and within allowed ranges. This information may be supported if the operator can demonstrate that the temperature-induced thermal expansion has only a negligible effect compared to the other sources of uncertainties. The latter would be particularly helpful if density measurements are not carried out at different temperatures, e.g. in a laboratory under controlled climatic conditions. Furthermore, the operator should demonstrate that sampling for analysis of the density is done representatively, e.g. by providing a suitable sampling plan.

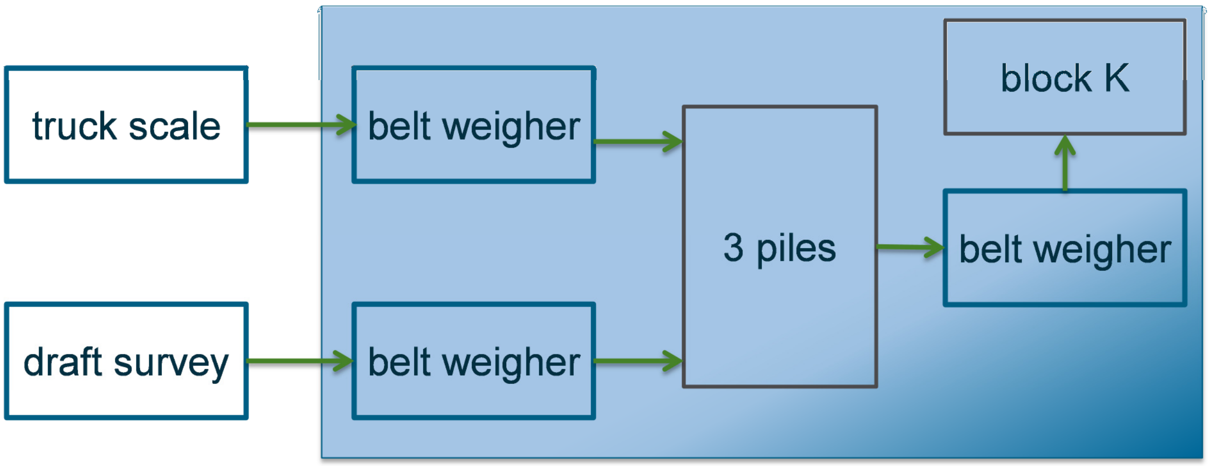
ad 2)

Since the tar exported on ships is presumably sold to third parties the radar tank gauge may be subject to legal metrological control. If this is the case, the operator should provide evidence for the MPES of the radar tank gauge e.g. certificates of the latest (metrological) verification or pictures of the affixed legal metrology label. Where this is not available or no relevant legal metrological control is in place, the operator would have to demonstrate other sound and robust evidence for the uncertainty, e.g. calibration, manufacturer's specifications, "Steps 1 to 4" under Routes CO-2a/2b,..

Example 7:
Aggregation of metering of quantities delivered and consideration of relevant stock changes

The activity data of a solid source stream is determined based on aggregation of metering of quantities separately delivered taking into account relevant stock changes: (see Art. 27 (1) b) MRR)

Information from the operator's Monitoring Plan:



Uncertainties of measuring instruments

- **truck scale (subject to national metrological control):**
  - Maximum permissible error in service: U_1 = 1.0%
- **draft survey[1] (subject to national metrological control):**
  - Maximum permissible error in service: U_2 = 1.0%
- **measuring system for stock changes (belt weighers)**
  - Overall expanded uncertainty of the measuring system: U_3 = 7.5%

Amounts determined by measuring instruments:

- **truck scale:**
  - x_1 = 0.5 Mio. t
- **draft survey:**
  - x_2 = 1.5 Mio. t
- **measuring system for stock changes (belt weighers)**
  - x_3 = 150,000 t

<u>Question:</u> How to calculate the overall uncertainty associated with the determination of the source stream's activity data?

[1] A draft survey is a calculation of the weight of cargo loaded or unloaded to or from a ship from measurements of changes in its displacement (Archimedes' principle)

Example 7 - Approach:

Determination of the overall uncertainty:

1) **Simplified approach (assumption of Gaussian distribution for all errors)**
   ➔ no conversion to standard uncertainty necessary to calculate the combined uncertainty at 95 percentile

$$\boldsymbol{U_{total}} = \frac{\sqrt{(\boldsymbol{U_1} * \boldsymbol{x_1})^2 + (\boldsymbol{U_2} * \boldsymbol{x_2})^2 + (\boldsymbol{U_3} * \boldsymbol{x_3})^2}}{|\boldsymbol{x_1} + \boldsymbol{x_2} + \boldsymbol{x_3}|}$$

$$\boldsymbol{U_{total}} = \frac{\sqrt{(\mathbf{1\%} * \mathbf{500,000})^2 + (\mathbf{1\%} * \mathbf{1,500,000})^2 + \mathbf{2} * (\mathbf{7.5\%} * \mathbf{150,000})^2}}{|\mathbf{500,000} + \mathbf{1,500,000} + \mathbf{150,000}|}$$

expanded uncertainty: $\boldsymbol{u_{total,k=2}} =$ **1.0%**

2) **Approach according to GUM**

As a first step, the MPES (for truck scale and draft survey), which are usually of a rectangular distribution, have to be converted to a standard uncertainty by dividing by the square root of 3:

$$u_{Pi} = \frac{MPES}{\sqrt{3}} = \frac{1.0\%}{\sqrt{3}}$$

Subsequently, with an expanded uncertainty of 7.5% (for the belt weighers) for stock changes, a standard uncertainty has to be calculated by dividing 7.5% (expanded uncertainty) by the factor 2 (because of Gaussian distribution) to 3.75%. Furthermore, uncertainties associated with stock level readings have to be taken into account for both, reading at the beginning and at the end of the year (indicated by a multiplier of 2).

$$\boldsymbol{u_{total}} = \frac{\sqrt{(\frac{\mathbf{1\%}}{\sqrt{\mathbf{3}}} * \mathbf{500,000})^2 + (\frac{\mathbf{1\%}}{\sqrt{\mathbf{3}}} * \mathbf{1,500,000})^2 + \mathbf{2} \cdot (\mathbf{3.75\%} * \mathbf{150,000})^2}}{|\mathbf{500,000} + \mathbf{1,500,000} + \mathbf{150,000}|} = \mathbf{0.56\%}$$

expanded uncertainty: $\boldsymbol{u_{total,\ k=2}} = \mathbf{2} \cdot \mathbf{0.56\%} = \mathbf{1.12\%}$

Example 8:

Gas meter with electronic volume converter

An operator measures the activity data of natural gas using a gas flow meter which the manufacturer declared to be in conformity with OIML R 137, accuracy class 1. Since the flow meter only measures actual volume, it is equipped with an electronic volume converter (EVC) to convert actual volume measured to reference conditions.

- MPES of the gas meter for the usual flow range: ±2%
- Expanded uncertainty (k=2) of the EVC[1]: 0.5%

The operator suggests to calculate the overall uncertainty by considering these two parameters via the propagation rule for independent uncertainties of a product:

$$u_{overall} = \sqrt{u_1^2 + u_2^2}$$

What is the overall uncertainty associated with the natural gas activity data?

[1] This is the uncertainty provided in manufacturer's specification. In addition to that the operator provided you with evidence that steps 1 to 4 of Route CO-2a are satisfied.

Approach Example 8:

Gas meter with electronic volume converter

How should the calculations be done if the type of uncertainty distribution is known?

In order to combine uncertainties the MPES for the gas flow meter is divided by the square root of 3 to account for the rectangular distribution of the MPES. The resulting standard uncertainty (k=1) of the gas flow meter is combined with the standard uncertainty of the EVC using the formula suggested by the operator:

$$u_{natural\ gas,(k=1)} = \sqrt{\left(\frac{2\%}{\sqrt{3}}\right)^2 + 0.25\%^2} = 1.18\%$$

Finally, in order to obtain the overall uncertainty at the 95% confidence level, a coverage factor of two is applied to the combined uncertainty above:

expanded uncertainty: $u_{natural\ gas,(k=2)} = 2 \cdot 1.18\% = 2.36\%$

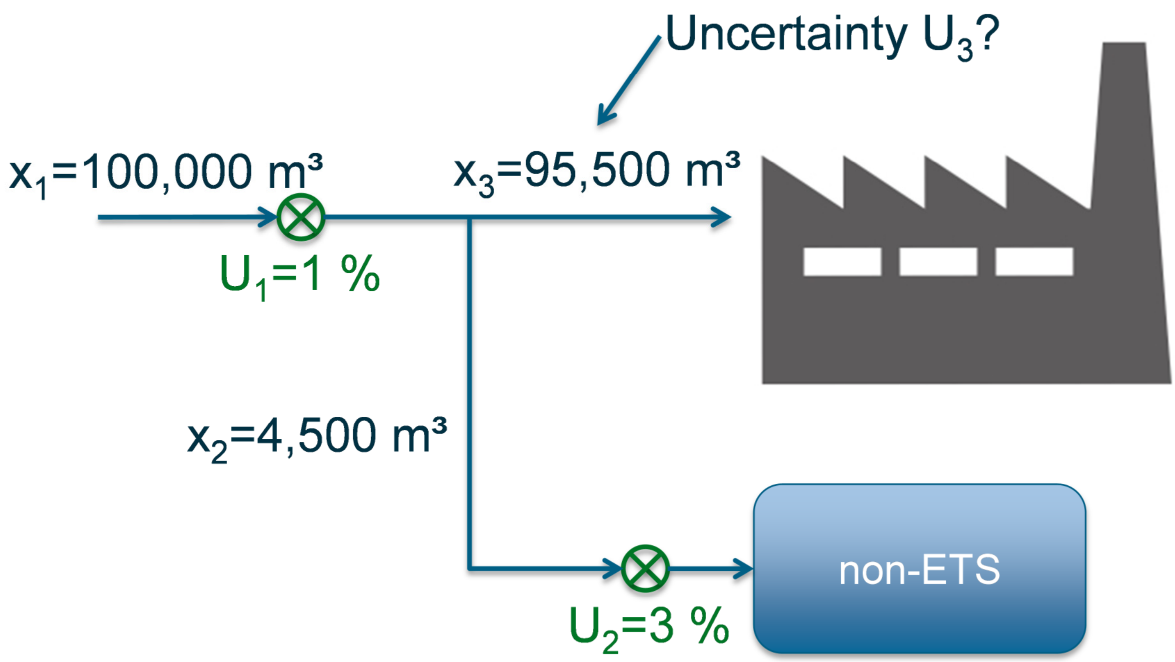
What should be done if the type of uncertainty distribution is <u>not</u> known?

In this case the overall expanded uncertainty may be calculated as follows:

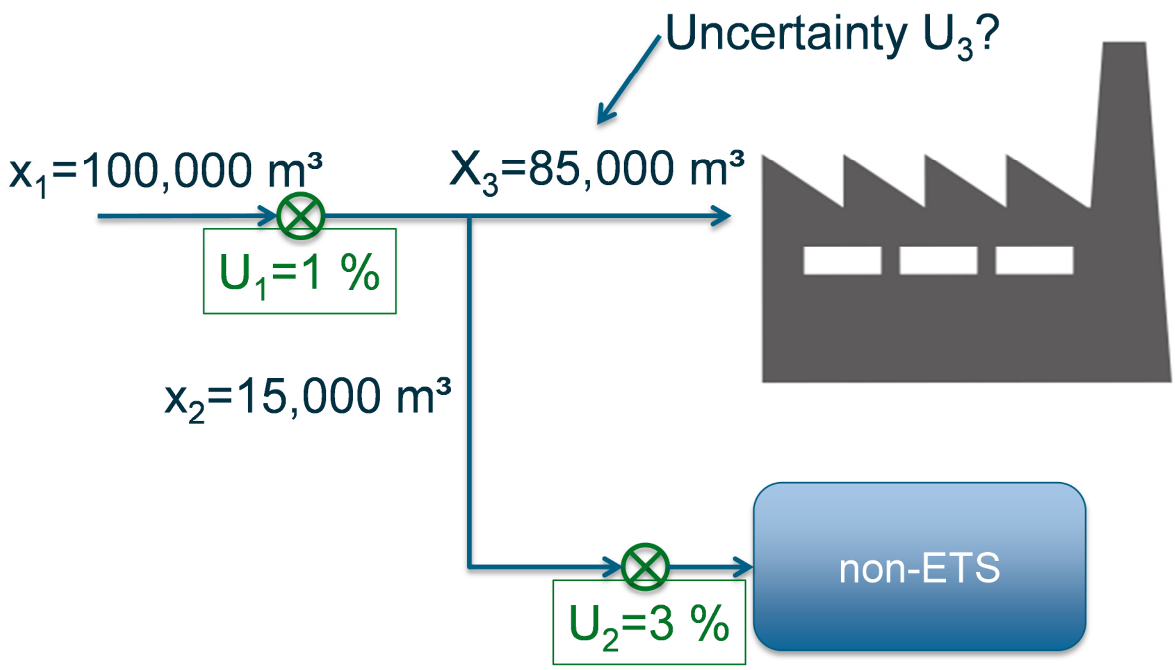
$$u_{natural\ gas,(k=2)} = \sqrt{2\%^2 + 0.5\%^2} = 2.06\%$$

Example 9:
Determination of activity data where a part of the source stream is used in a non-ETS installation

Case 1:



Case 2:

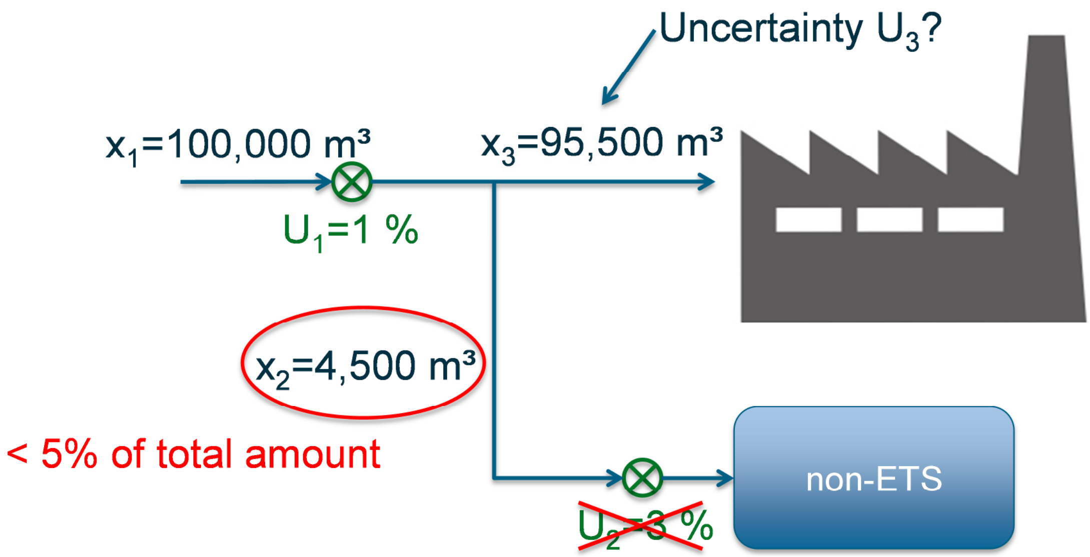


<u>Question</u>: How to calculate the overall uncertainty associated with the determination of the source stream's activity data (x_3) in the particular cases?

Example 9 - Approach:

$$U_3 = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2}}{|x_1 + (-x_2)|}$$

Case 1:



$$U_3 = U_1 = 1\%$$

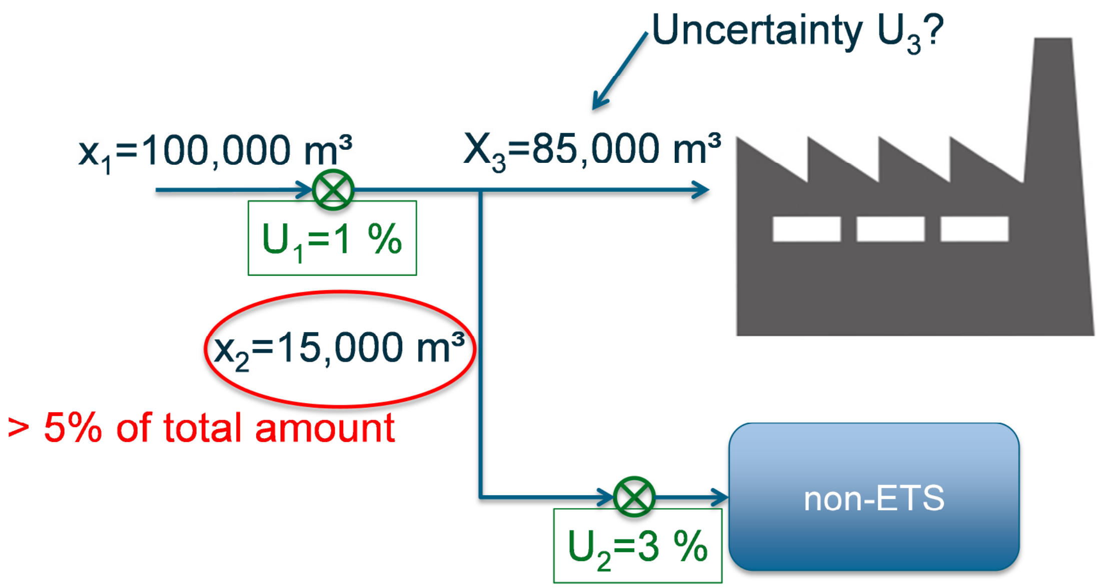
<u>Explanation:</u> The simplification is not regulated in the MRR. It is a proposal to simplify the uncertainty assessment for operators in analogy to Art. 28 (2) MRR (uncertainty related to stock changes). The uncertainty related to parts of a large source stream doesn't have to be included in the uncertainty assessment when they represent less than 5% of the total amount of the source stream.

The added value of not taking into account the deducted quantity less than 5% is that the operator doesn't have to assess the uncertainty associated with the determination of the deducted quantity. This reduces the burden on the operator and the CA if e.g. the measuring instrument used for the deducted quantity is not subject to national metrological control and a more detailed uncertainty assessment would have to be performed for this measuring instrument.

This approach allows to keep up the concept of accuracy as the influence of the uncertainty contribution of the deducted quantity <5% on the overall uncertainty is negligible and at the same time the administrative burden on operators (perform uncertainty assessment for deducted quantity) and CA (check uncertainty assessment) is reduced.

According to chapter 6.5 of the Air quality Guidelines for estimating measurement uncertainty (EN ISO 20988) an additional contribution of 5 % could be neglected. The standard applies the general recommendations of the Guide to the Expression of Uncertainty in Measurement (GUM).

Case 2:



$$\boldsymbol{U_3} = \frac{\sqrt{(\mathbf{1}\% * \mathbf{100{,}000})^2 + (\mathbf{3}\% * \mathbf{15{,}000})^2}}{|\mathbf{100{,}000} - \mathbf{15{,}000})|} = \mathbf{1.3}\%$$

Example 10:

Gaseous fuels – uncertainty of orifice meters

Orifice meters are, amongst others (turbine, vortex, ultrasonic…), common measuring instruments used for the determination of activity data of gaseous fuels such as natural gas or other process gases used in e.g. refineries, steel plants or chemical plants. The measurement principle is based on Bernoulli's principle by establishing a relation between a measured differential pressure and the volumetric gas flow. The appropriate use of orifice meter is covered by ISO standard 5167[1].

The mass flow rate (F_M) is the product of the volumetric flow rate (F_V) and the fuel density (ρ). In case of gaseous fuels the density is influenced by temperature, pressure and composition of the gas. If these parameters are not constant one has to take them into account in the uncertainty assessment.

$$F_M = C \cdot d_0^2 \cdot \sqrt{\Delta p * MW * \frac{p}{T}}$$

By means of propagation of uncertainties, the combined uncertainty associated with the mass flow is determined by the following mathematical relationship[2]:

Composition	**Uncertainty**
Constant	$U_M = 0.5 * \sqrt{U_V^2 + U_T^2 + U_P^2}$
Variable	$U_M = 0.5 * \sqrt{U_V^2 + U_T^2 + U_P^2 + U_{MW}^2}$

C ....a constant taking into account the discharge coefficient, expansion coefficient and several other parameters that are nearly constant, hence negligible

d_0............diameter of the orifice plate opening

U_M ....uncertainty on quantity F_M of fuel consumed in a year (in %)

U_V...........uncertainty on orifice meter (also applicable to all other Δp-meters such as orifices, dall tubes, annubar, venturi's, etc. or speed in case of turbine-, vortex-, ultrasonic meters and others) (%)

U_T...........uncertainty of the temperature of a gaseous fuel at the metering point (%)

U_P...........uncertainty of the pressure of a gaseous fuel at the metering point (in %)

U_{MW} ....uncertainty of the averaged molecular weight of a gaseous fuel (%).

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[1] ISO 5167 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full

[2] *Note*: Following the principles in ISO 5167, several other parameters are influencing the flow rate's uncertainty as well, e.g. the discharge coefficient, expansion coefficient, etc. However, as these uncertainties are in general small and negligible compared to the other sources of uncertainty, they are omitted here.

Determination of the uncertainty of the composition (U_{MW}):

In case the molecular weight is measured with an on-line gas analyser such as a gas chromatograph, an excel-tool was developed in cooperation between several operators and the VBBV for calculation of U_{MW} (see presentation by Xavier Martens in the session: “How to check compliance”).

The correct operation of a gas chromatograph must be checked regularly (weekly, monthly,..). For this purpose, a reference with known composition is fed to the analyser and the deviation to the reference is noted for each component. This action is called ‘validation. The output is U_{MW}.

This tool is now in use by almost all Flemish chemical companies and refineries to their satisfaction.