SI-traceable inline measurements of water content in biomass at CHP plant

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BIOFMET 2nd Stakeholders' Workshop

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How much water?

Measuring water in solid biofuels

- Solid biofuel = Combustible organic compounds + lot of water (10 – 60 %)
- Organic compounds burn – water don't

1. Inline measurements
2. What is SI traceability?
3. How to measure water content … with traceable results!

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Project motivation

- Biomass is a key building block in sustainable energy supply
- EU aims to increase the use of biomass, reaching at least a 27 % share of renewable energy consumption
- Water content in solid biofuel materials is a key parameter for the characterization
  - Optimal combustion efficiency
  - Fair payment
- Inline water-content measurements
  - Significant advantages over traditional LoD measurements
  - Simplifies the sampling process
  - Calibration is a challenge

Motivation

- Impact
  - ~~€€€€€€€€~~
  - Combustion technique
  - Sampling
- Challenges
  - Heterogeneity with respect to… Sample material, Impurities, Physical parameters (size), Water content
- CHP plants burning solid biofuel
  - Green: CO_2 neutral
  - Backup for solar and wind power

What are the options?

- Relevant for all part of the value chain:
  - Producers
  - Distributers
  - Consumers

Options

1. LoD (Loss on Drying) + Sampling
2. Moisture measurement device (+ less sampling)

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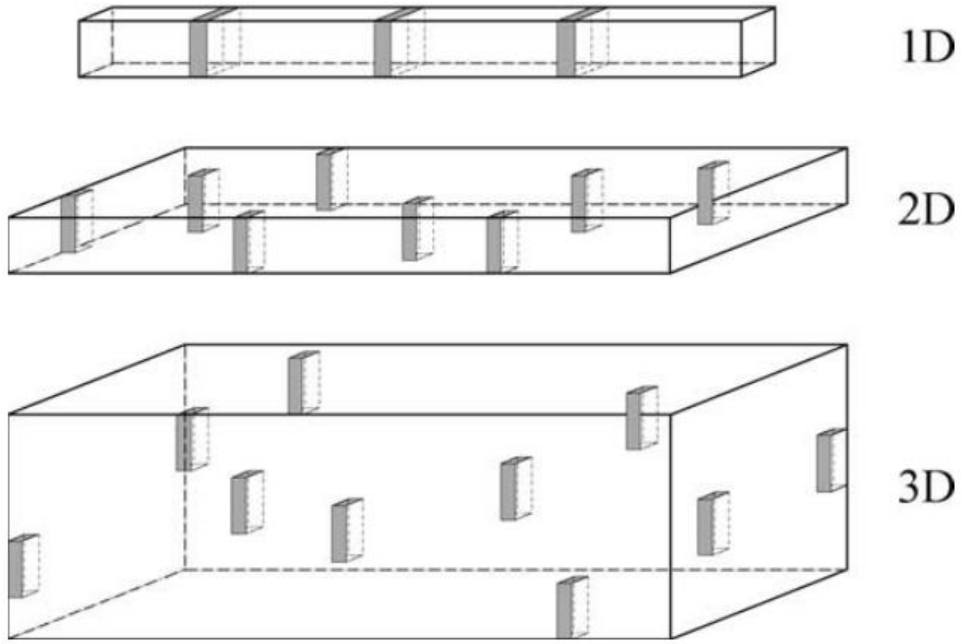
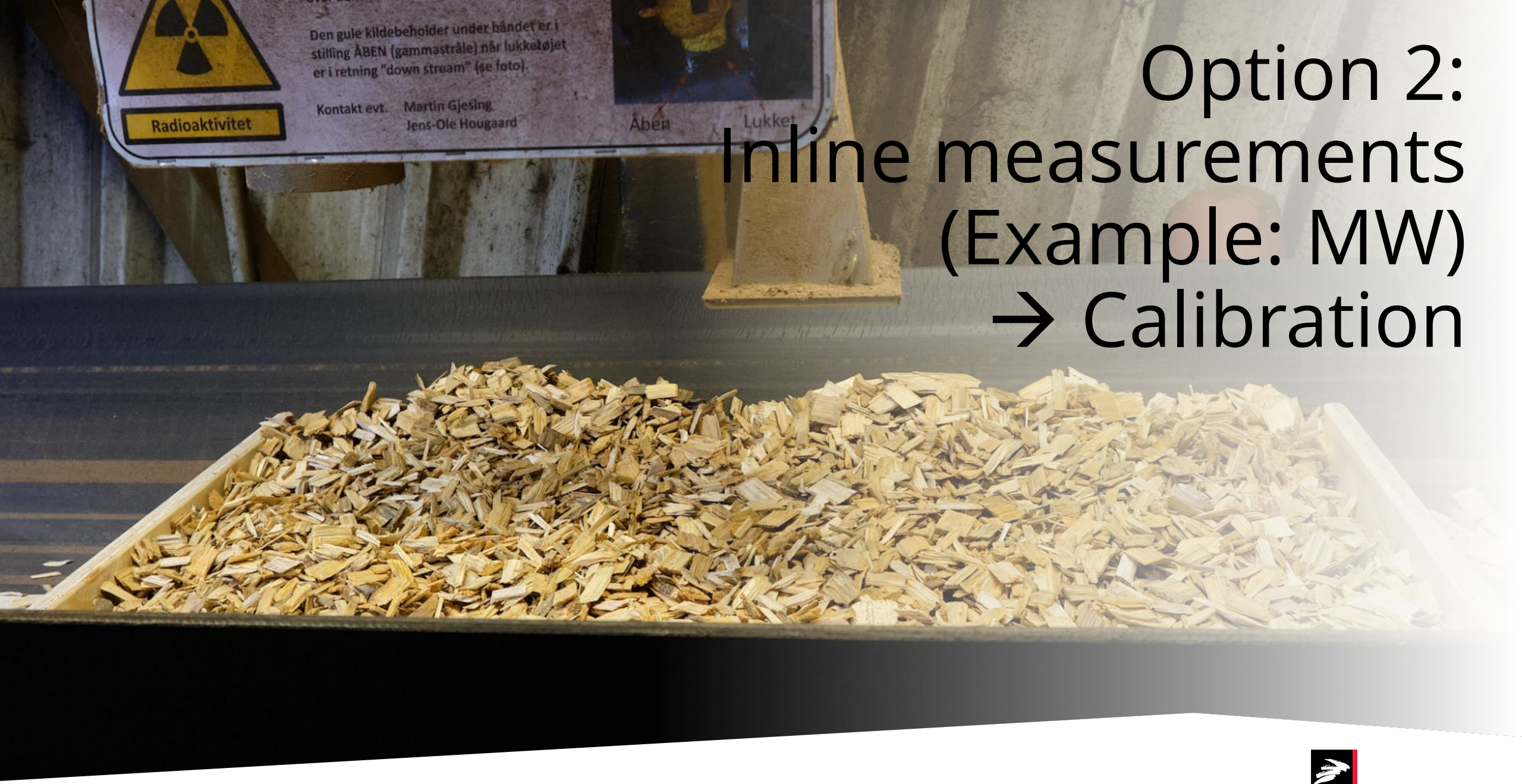
Option 1: "Traditional" procedure

- LoD (Loss on Drying) + Sampling

- Where does the uncertainty come from?
  - Sampling: 80 %
  - Handling: 15 %
  - Measurement (LoD): 5 %
  - Source: 1) Finish VVT report, 2) Similar results by DTI

- Sampling dimensions: 3D → 2D → 1D → 0D
  - Aim for 1D (*e.g. belt*) or 0D (*entire lot*)





Option 2: Inline measurements (Example: MW) → Calibration

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Option 2: Online moisture measuring

- Moisture measurement device (+ less sampling)
- Where does the uncertainty come from?
  - Sampling: small
  - Handling: small
  - Measurement (device): larger
  - Calibration (larger)
- Key question: Is it possible to get similar accuracy using electronic device instead of LoD for moisture measurements?

- Sampling ←→ Calibration

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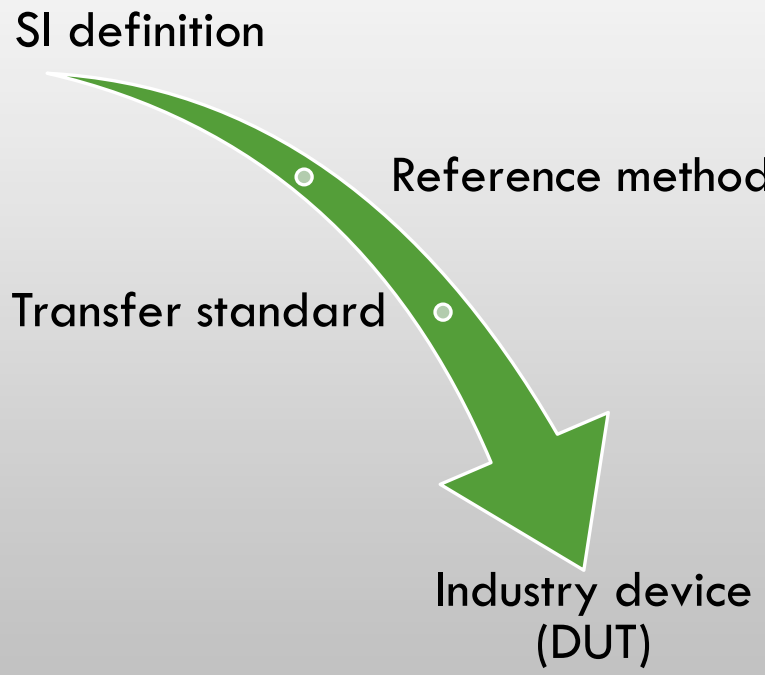
Traceability ➔ accurate measurements in industry



- Definition of metrological traceability:
  - Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

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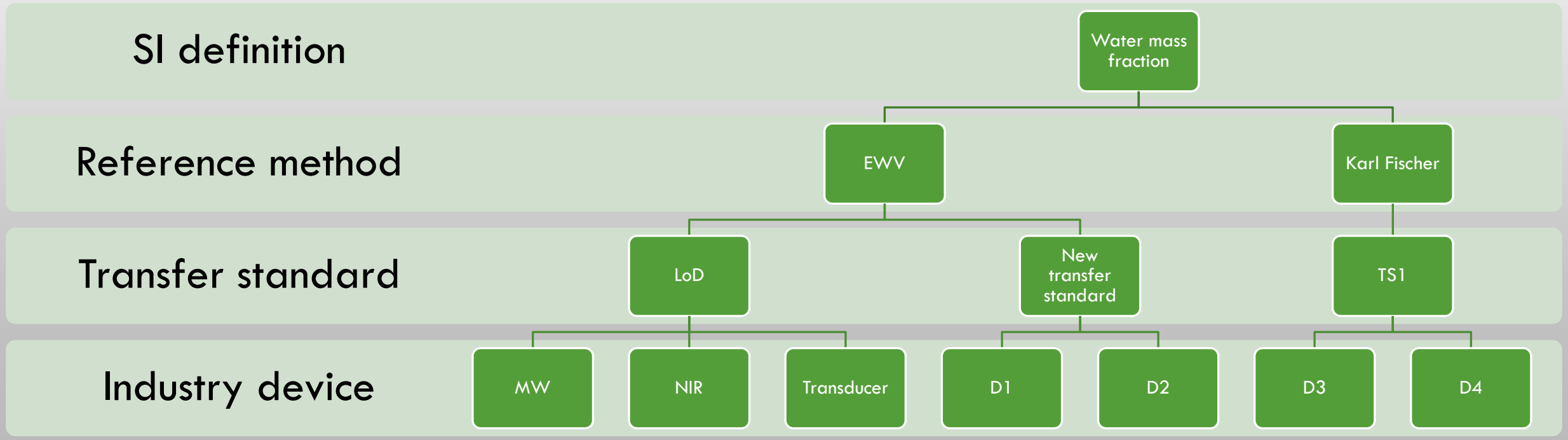
Traceability ➔ accurate measurements in industry



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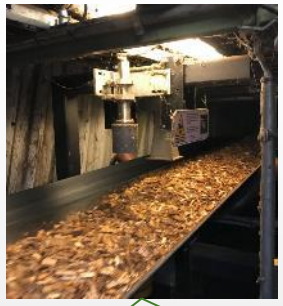
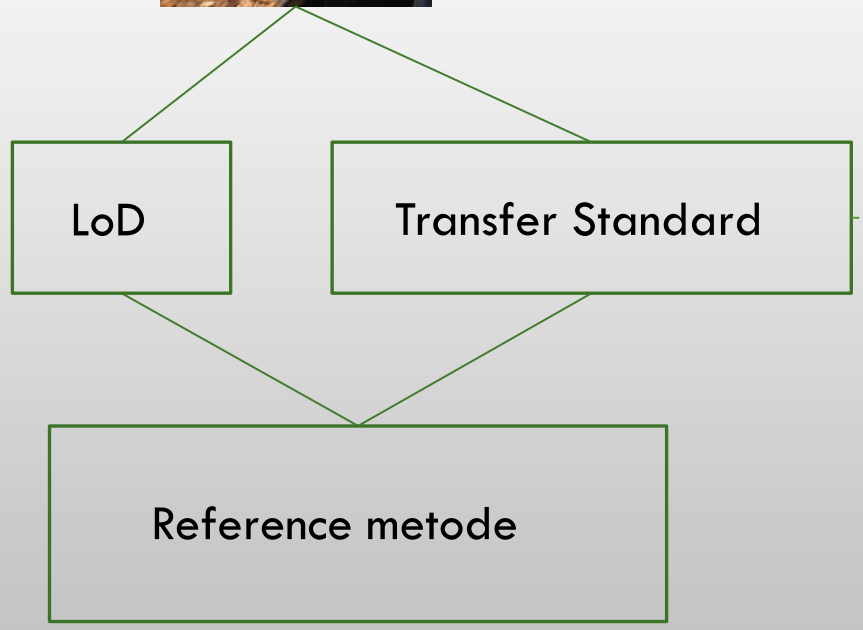
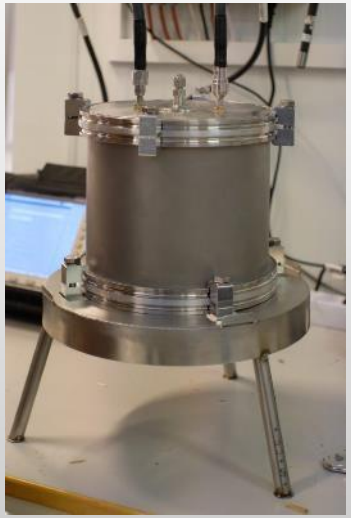


Verdo CHP Bertold MW / X-ray.
How to calibrate it?

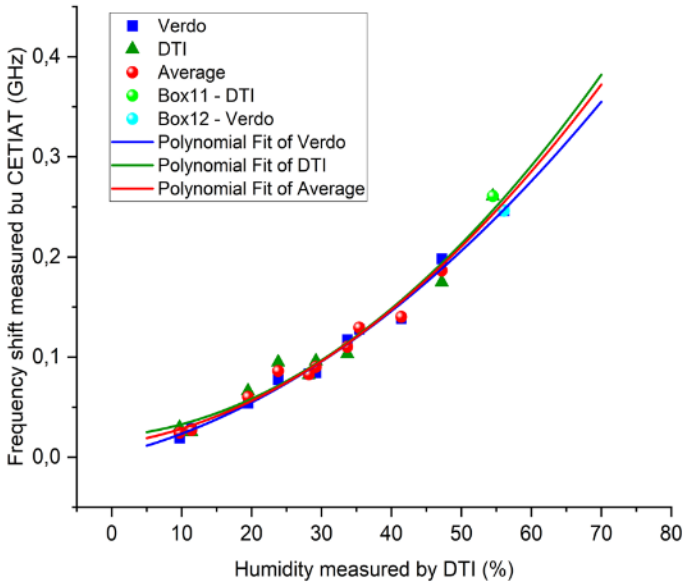




Providing Traceability to Industry

Example of transfer standard (CETIAT)

- Chamber (resonant cavity) has been constructed and is currently tested and metrologically characterized
- Calibrated and tested in industry

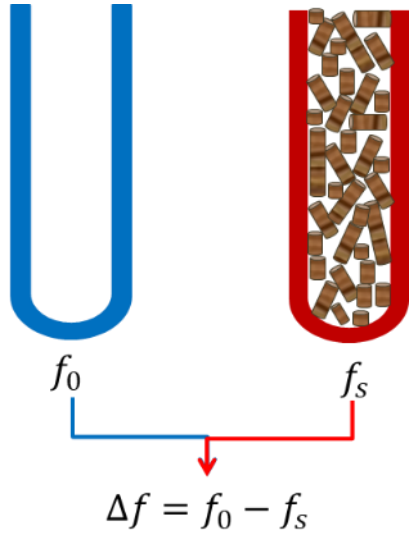


Box Nr.	Reference value (DTI) (%)	Estimated value from curve (%)
11	54,5	57,97
12	56,1	55,93

Box Nr.	Reference value (DTI) (%)	Estimated value from curve (%)
11	54,5	56,30
12	56,1	54,45

Box Nr.	Reference value (DTI) (%)	Estimated value from curve (%)
11	54,5	56,89
12	56,1	54,97

Equation	y = Intercept + B1*x^1 + B2*x^2		
Plot	Verdo	DTI	Average
Intercept	0,0018 ± 0,0118	0,0206 ± 0,0240	0,0125 ± 0,0153
B1	0,0017 ± 7,9964E-4	5,7607E-4 ± 0,0017	0,0010 ± 0,0010
B2	4,80E-5 ± 1,22E-5	6,55E-5 ± 2,62E-5	5,90E-5 ± 1,49E-5
Residual Sum of Squares	5,5299E-4	0,0015	0,00108
R-Square (COD)	0,9884	0,9658	0,9836
Adj. R-Square	0,9855	0,9544	0,9799



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Reference methods for water in solids

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Requirements to reference methods

- SI definition: Water mass fraction, WMF

$$WMF = \frac{m_{water}}{m_{sample}}$$

- Mass of sample, m_{sample}: Easy
- Mass of water, m_{water}: Require method specific to water

- Example I: Coulometric Karl Fischer titration (cKF)
- Example II: Evolved Water Vapour (EWV)

Loss on Drying not specific to water → **NOT** a reference method

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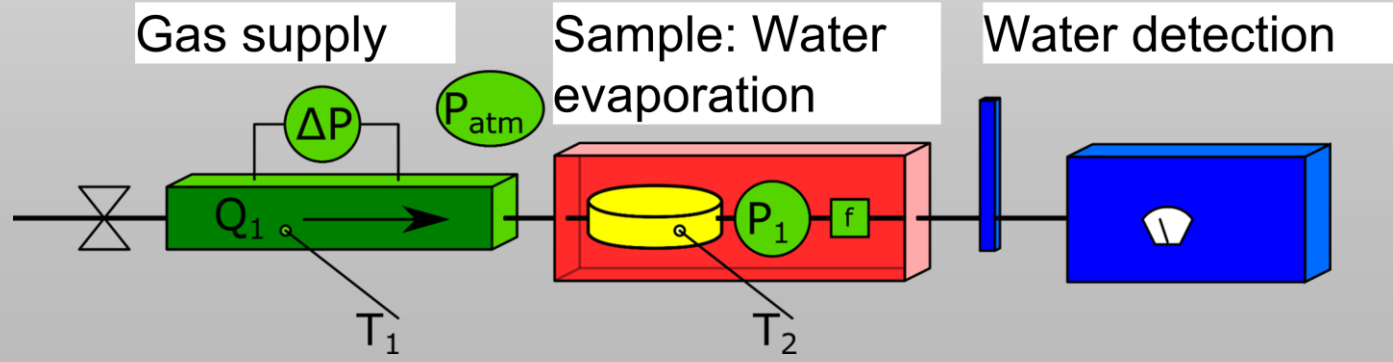
EWV: Implementation

Evolved Water Vapour

- **EVW using dew-point temperature (EVW-DP) (DTI)**
  - Water = $\int [flow][water\ content]dt$
  - Measure water vapor evolved from sample
- EVW using coulometric Karl Fischer titration (vap-C-KFT) (CETIAT)
- **EVW using P_2O_5 sensor (CETIAT)**
- EVW-freeze (VTT)
  - Water collected by freezing



- *BIOFMET: Validated by laboratory intercomparison*

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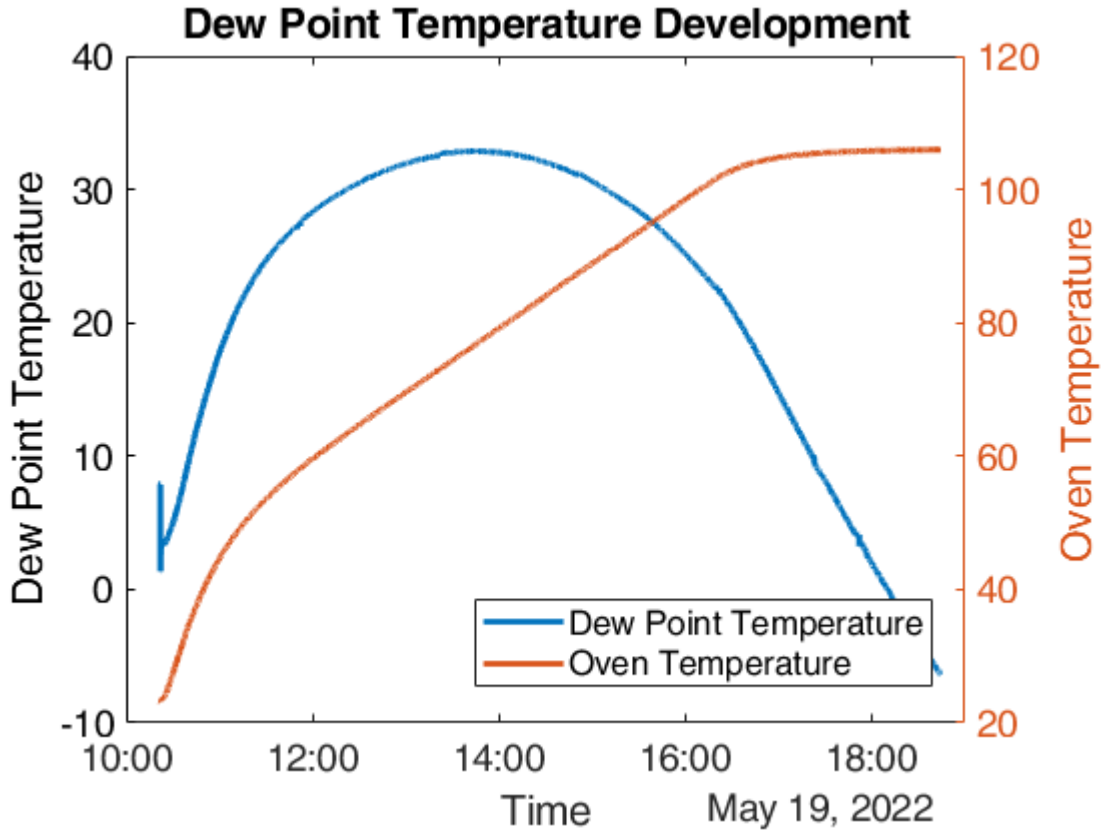
Data from EWV-DP

- Water vapour is monitored
- Temperature is gradually increased to 105 °C
- Test ends when measured dew point is below -10 °C, corresponding to 0.1 g/h



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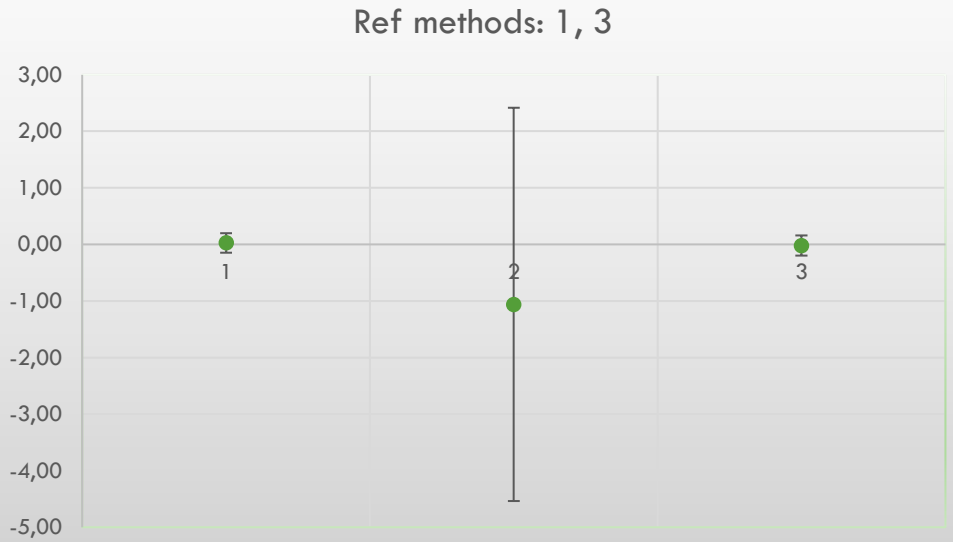
Validation: Lab intercomparison



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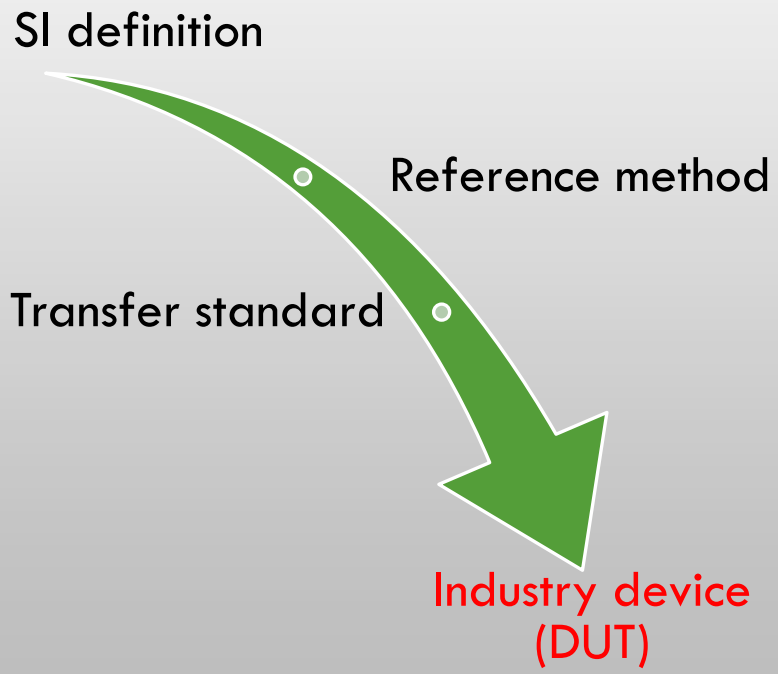
Moving traceability to industry



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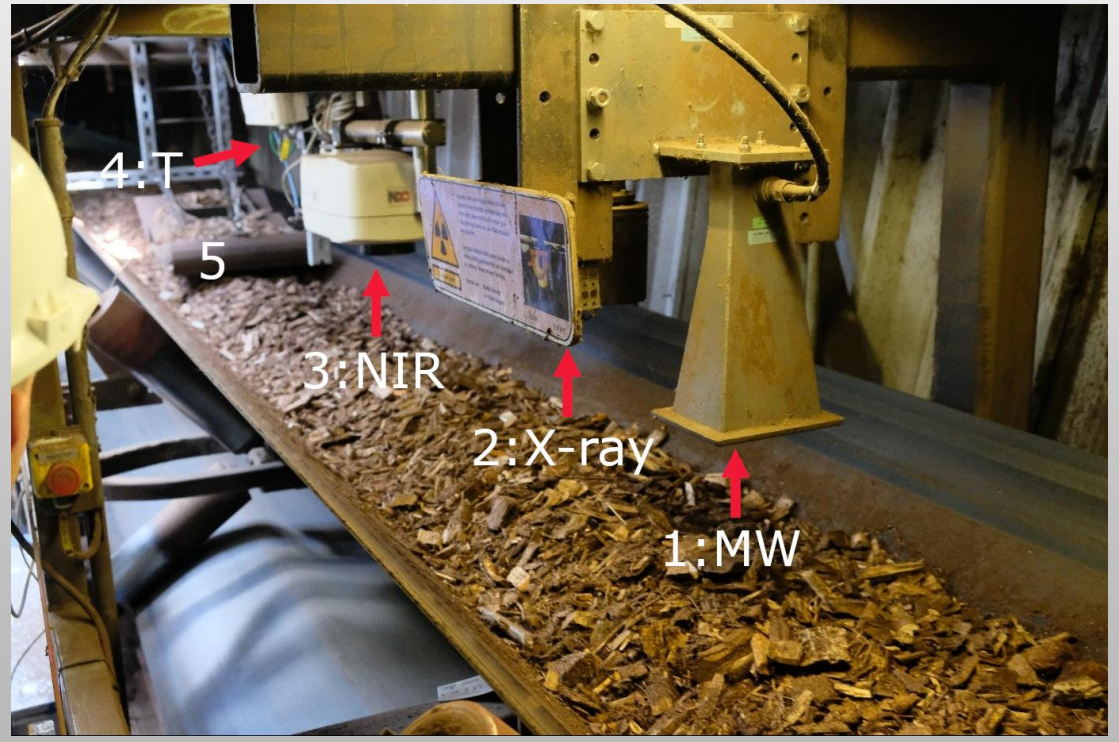
Example of devices in industry
DUT = Device Under Test



- MW: MicroWave equipment
- NIR: Near InfraRed
- MT: Moisture transducer
- …

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Calibration/adjustment: Requirements

1. Transfer standard
   - Transfer standard and DUT measurement on equivalent sample material

   →Remember this during installation!

   →Sampling may be required
2. Sample material
   - Must cover entire measurement range

   →No extrapolation
   - Special sample material may be prepared

   → Control moisture content!

Sample material

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Sample material

- Challenge: Woodchips are inhomogeneous
  - Chemical / physical
- Selected material
  - "White" woodchips, no bark etc.
  - Small chips → packing
  - Mixture of Picea Abies (Norway Spruce, Épicéa commun) and Picea Sitchensis (Sitka Spruce, Épicéa de Sitka).
- Water mass fraction 10 % to 60 %
  - Pre-dried at 40 °C to 10 % water fraction
  - Mixed …
  - Re-humidified (12 fractions)

SEE POSTER

Calibration

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Measurements using MW (DUT) at site

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Reference measurements: Method

- DTI reference provides values
  - Evolved water vapour using dewpoint temperature
- Homogeneity: LoD (Loss on Drying) on two subsamples
  - Both before ref. measurements
- Stability: LoD on two subsamples
  - Before and after ref. measurements

- Problem: Biological activity

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Reference measurements: Results

#	Box	Phase	Att.	Load	Ref	u ref	u hom	u stab	u (k=1)
1	10	-86.13	2.21	10.36	11.26%	0.14%	0.26%	0.94%	1.0%
2	9	-90.28	1.9	9.98	9.53%	0.13%	0.26%	0.94%	1.0%
3	8	-73.31	5.15	10.41	19.40%	0.24%	0.26%	0.94%	1.0%
4	7	-71.06	4.93	10.19	24.09%	0.28%	0.26%	0.94%	1.0%
6	5	-54.61	9.4	10.71	28.80%	0.42%	0.26%	0.94%	1.1%
7	4	76.1	7.78	11.94	35.85%	0.39%	0.26%	0.94%	1.1%
8	3	71.37	7.38	10.74	34.09%	0.39%	0.26%	0.94%	1.0%
9	2	119	15.52	11.62	43.94%	0.48%	0.26%	0.94%	1.1%
10	1	9.87	15.38	11.37	48.53%	0.52%	0.26%	0.94%	1.1%
11	blank	1.29	0.19	7.88					
12	11	145.86	17.66	11.4	56.10%	0.57%	0.26%	0.94%	1.1%
13	12	22.95	20.4	11.51	56.97%	0.61%	0.26%	0.94%	1.1%

$$M = a \cdot \frac{phaseshift}{load} + b \cdot \frac{attenuation}{load} + c$$

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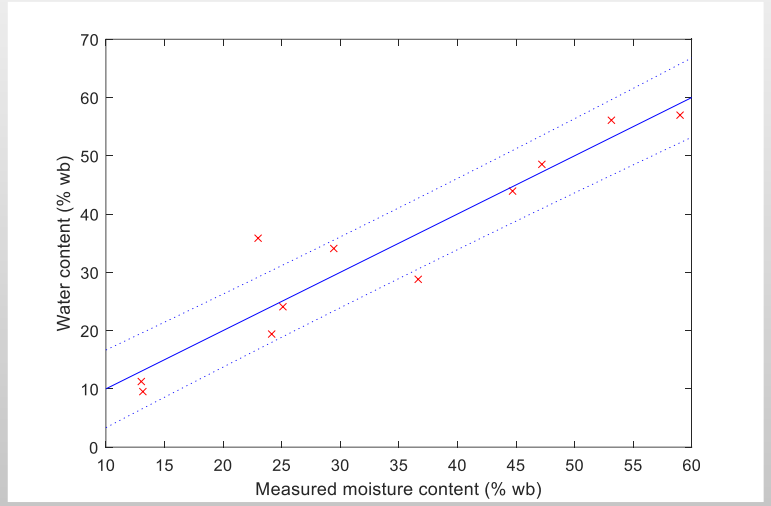
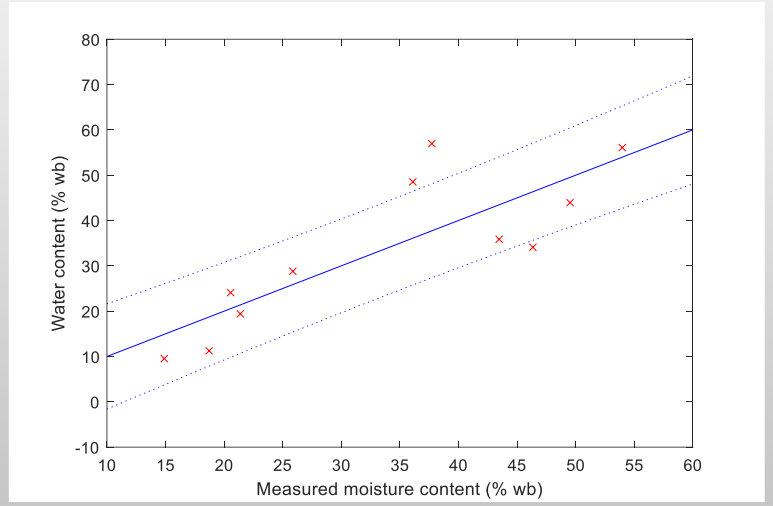
Calibration results

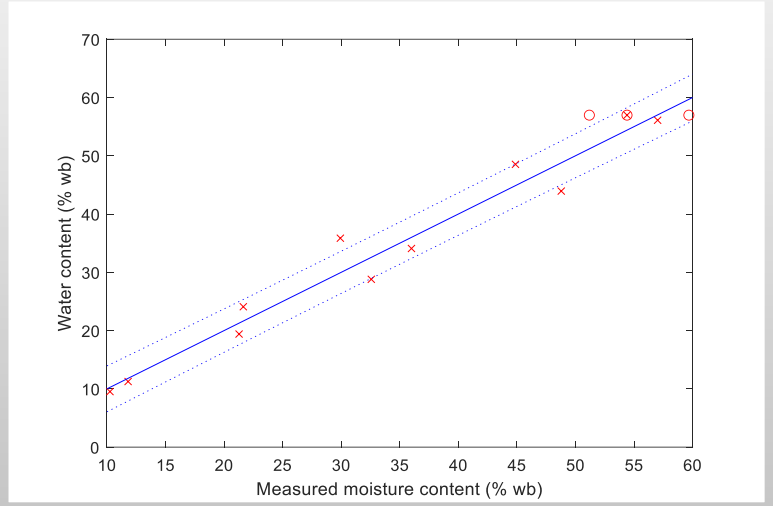
Phase



Attenuation



Combined



Method	$\boldsymbol{u(cal)}$, standard calibrations uncertainty ($\boldsymbol{k = 1}$)	$\boldsymbol{U(cal)}$, expanded calibrations uncertainty ($\boldsymbol{k = 2}$)
Phase	3.3 %	6.6 %
Attenuation	2.1 %	4.2 %
Phase and attenuation	1.5 %	3.1 %

Conclusion outlook

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Conclusion & Outlook

- Calibration of online MW system performed
  - Water-fraction range: 10 – 60 %
  - Accuracy: 3.1 % absolute
- Improvements
  - Handling sample material at site
  - Load sensor
  - Storage of sample material
  - Test of different types of sample material

Support

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Thanks!

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Thank you for your attention!

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