University of Applied Sciences and Arts Northwestern Switzerland
School of Engineering

Wood Burning Appliances

Paving the Way for a Next-Generation (Particulate Matter) Emission Measurement Method

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Overview of the Consortium

- European consortium led by Swiss institutes (Oekozentrum & FHNW)
- Goal: Modernize emission measurements for wood burning appliances
- 49 European experts, 29 Institutions:
  Universities, Research Centers, Notified Bodies (certified test facilities),
  Manufacturers, Environmental Agencies
- 3 Workshops held in 2023 → Position Paper
- Next Step: Start a European project to define and validate a NGEMM

Supported by:

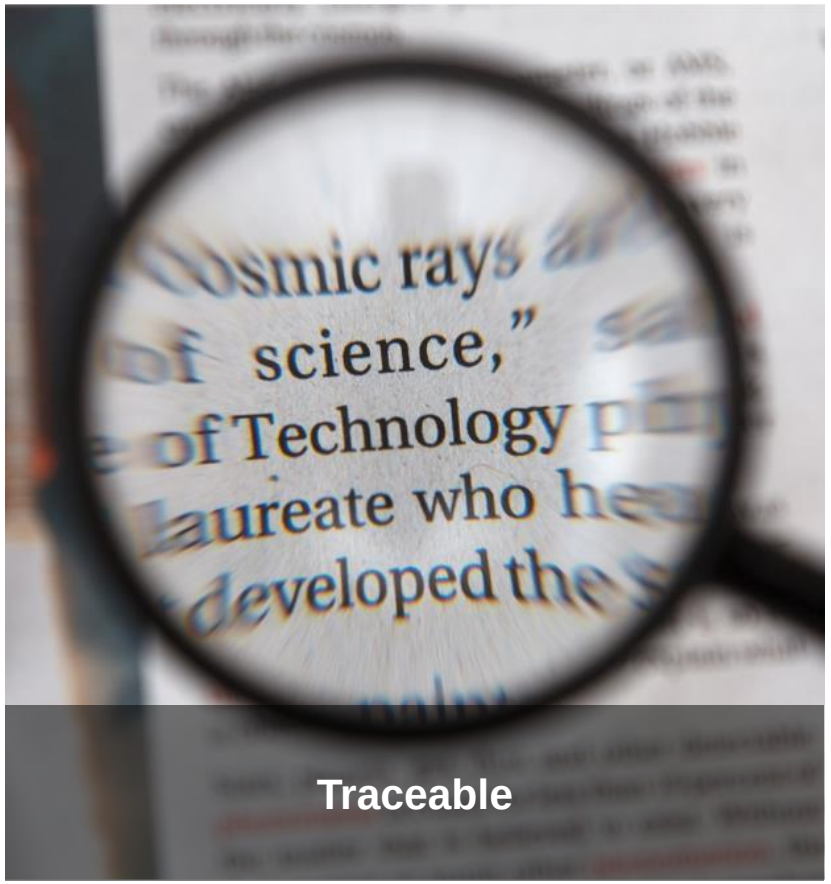
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU
Office fédéral de l'environnement OFEV
Ufficio federale dell'ambiente UFAM
Uffizi federal d'ambient UFAM

Biomass Combustion with Future

Focus of NGEMM

Other Requirements for a NGEMM



What about PMP?

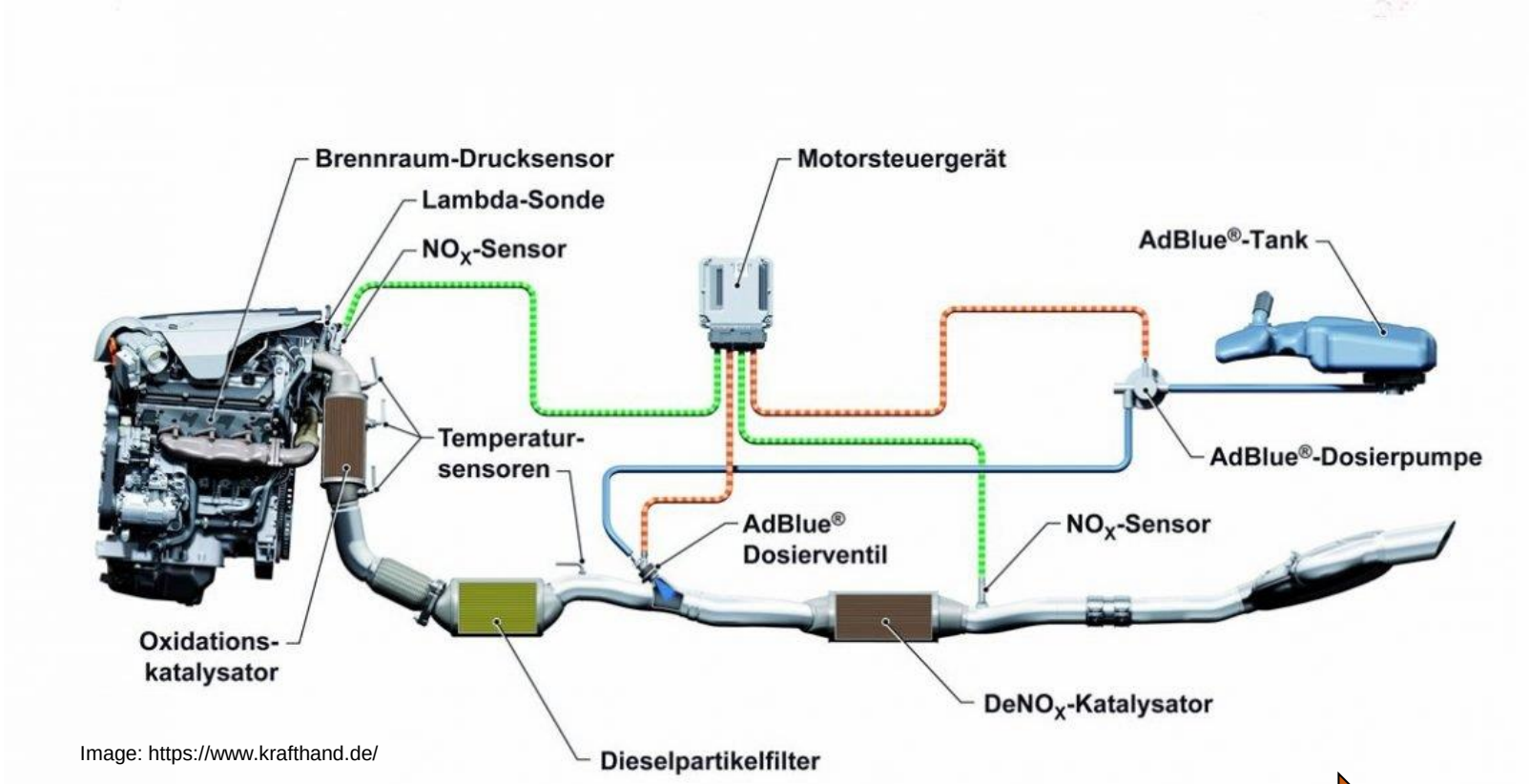


Image: https://www.krafthand.de/

~0.04 seconds

versus

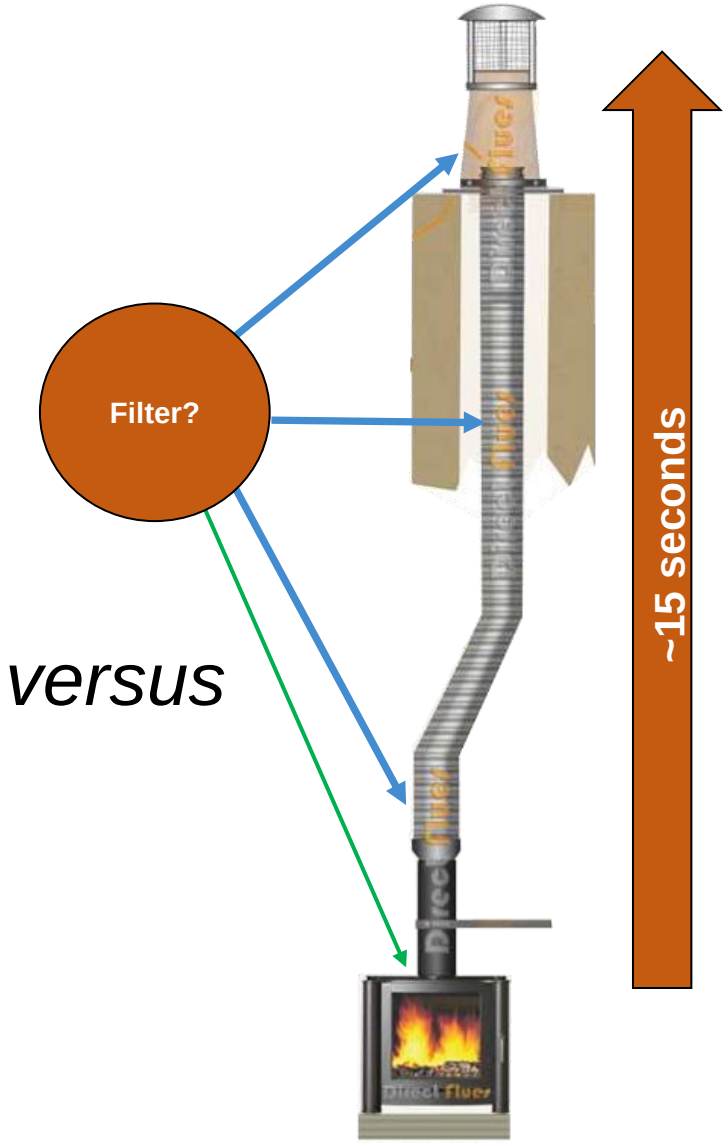
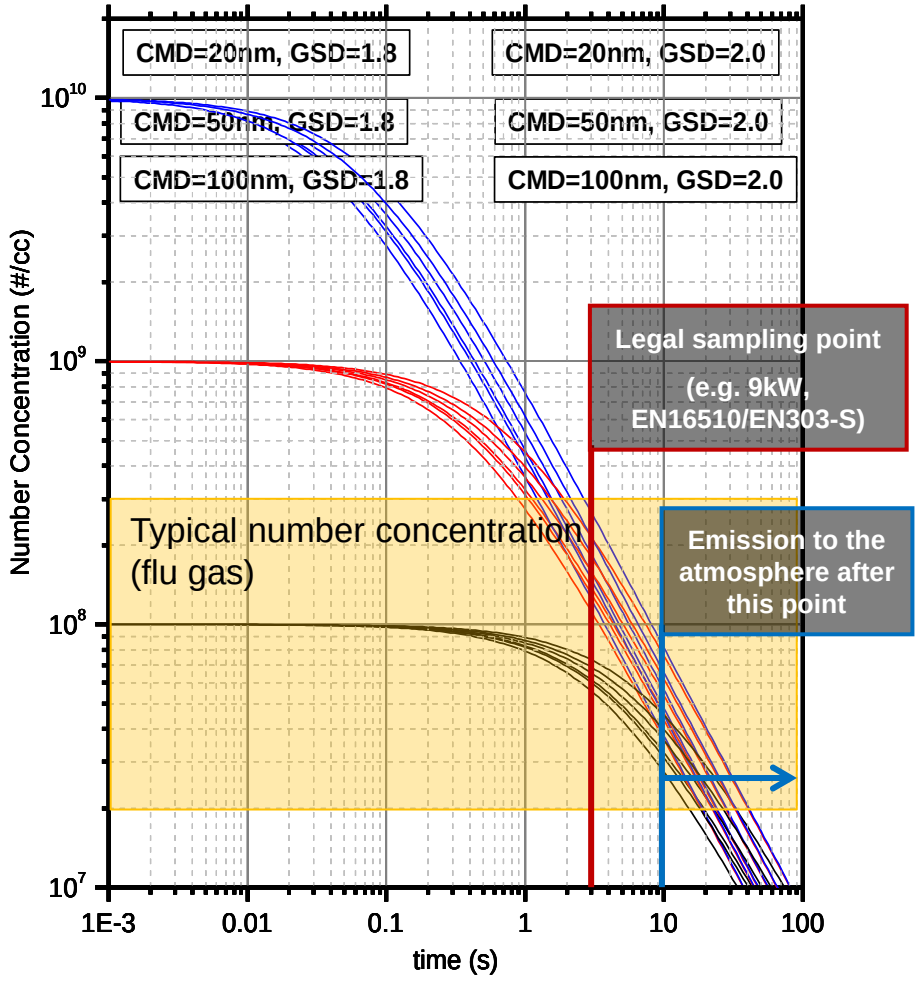


Image adapted from: http://directflues.co.uk

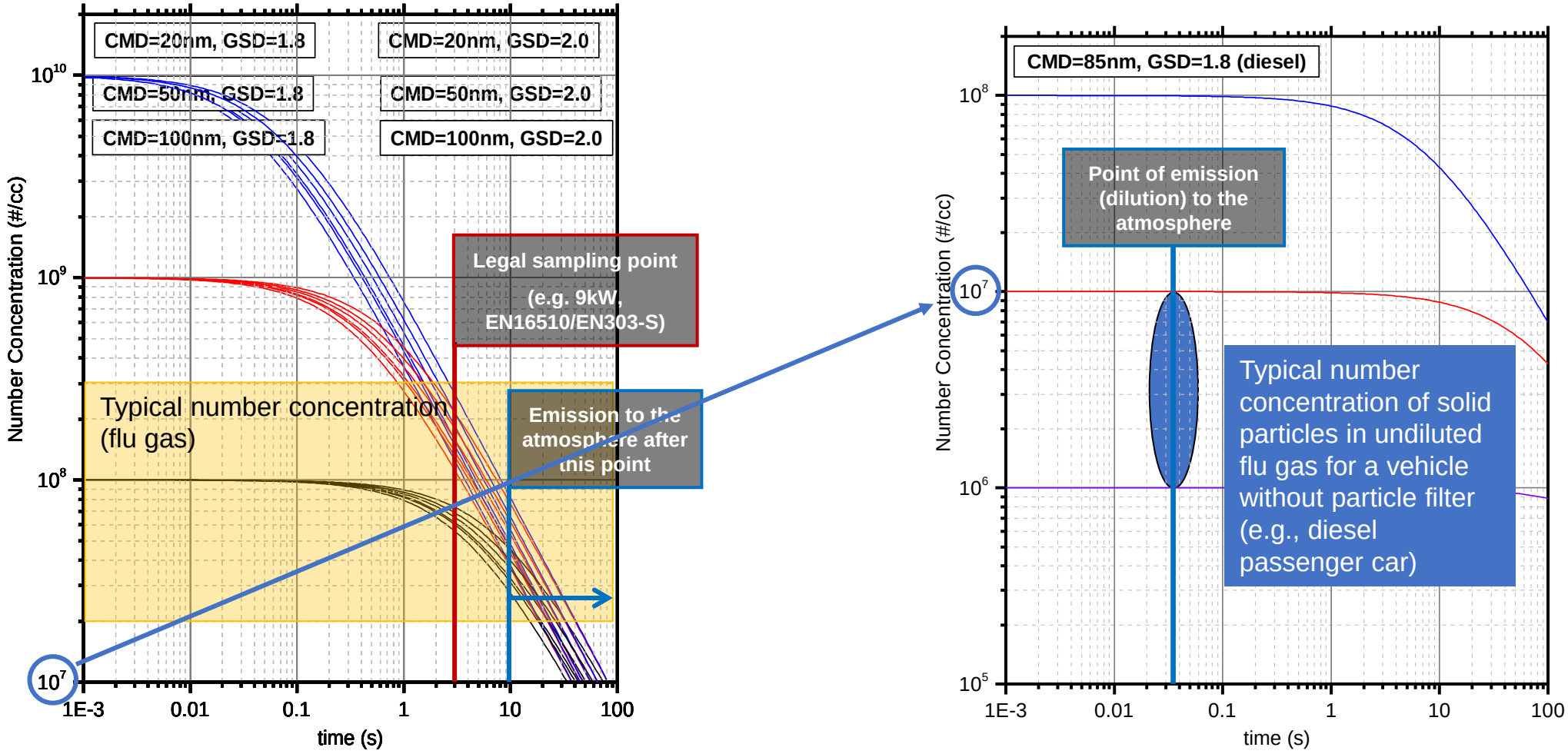
Number Concentration: Theoretical Background



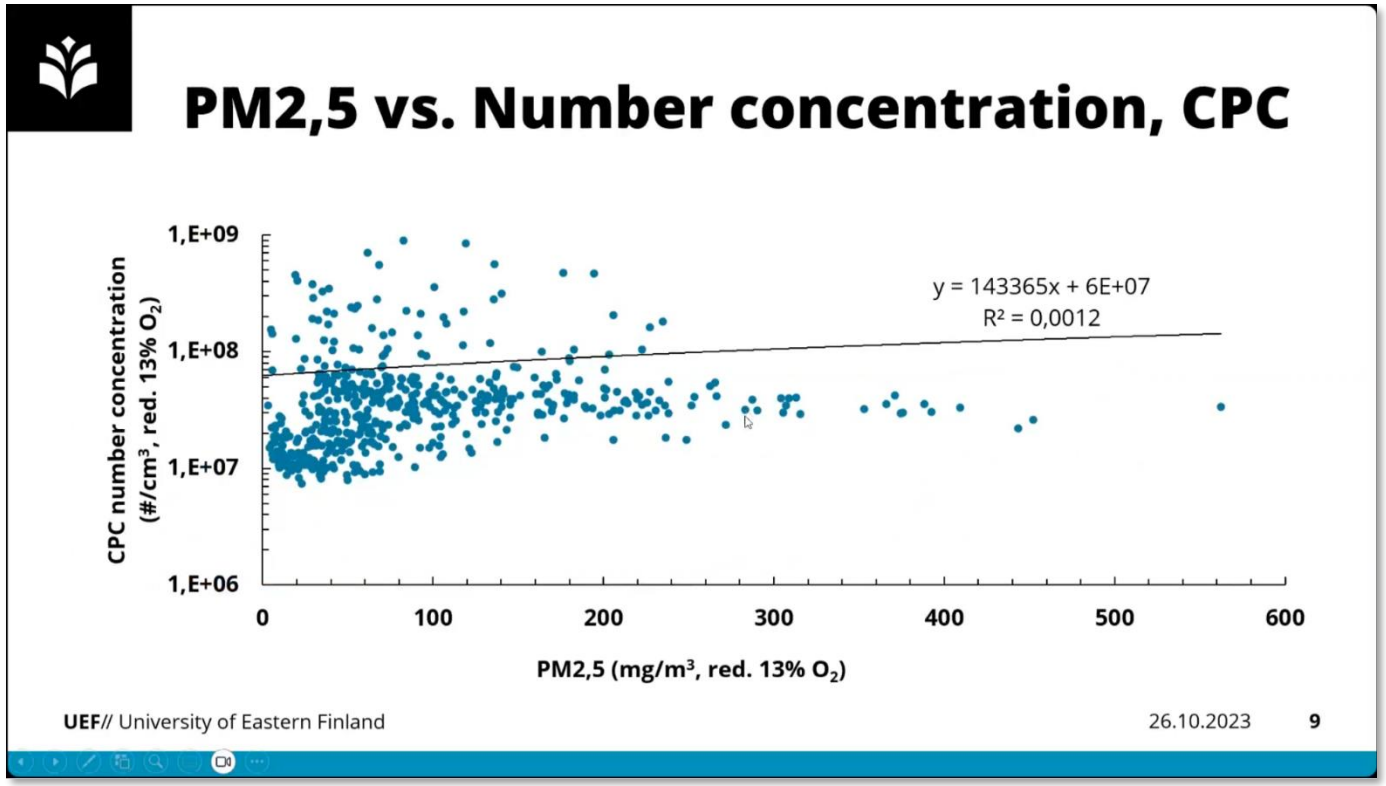
- Number concentration in wood burning is not a good parameter for emissions measurement (coagulation*)
- No relation with the quality of the combustion
  - Even clean oil boilers (mass emissions M≈1 mg/m^3_{STP} @ 3% O_2) have number concentrations N~10^7 #/cc.
- Not an indicator for health and climate impact (more in other slides)
- Does not promote the use of BAT:
  - Opens a door to certify high emission stoves
  - Promote the placement of filters as close as possible to the end of the stack → **No integrated solutions**

* Examples for room temperature. Coagulation faster at real flu gas temperatures. Based on log-normal distributions.
CMD: Count Mean Diameter; GSD: Geometrical Standard Deviation

Number Concentration: Theoretical Background



Number Concentration: Test Bench Experiments



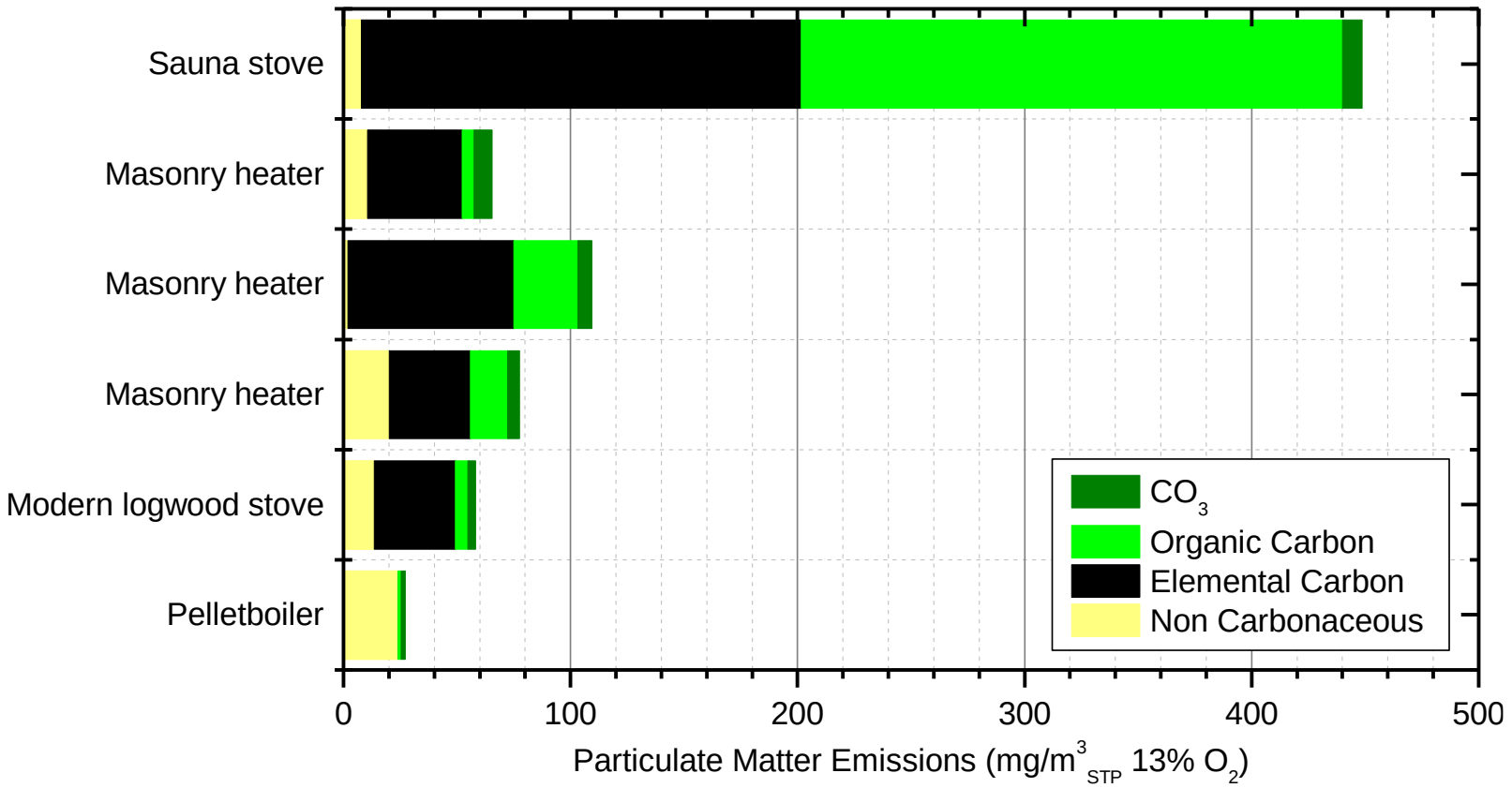
Source: Juho Louhisalmi @ 2nd International Real-LIFE Emission Workshop on Small-Scale Combustion

SIMO Database

University of Eastern Finland

- 352 combustion cycles
- 50 different appliances
  - Sauna stoves, wood stoves, masonry heaters, and cooking stoves
  - Mainly new and modern appliances

Wood Burning as a Pollution Source



Metrics based on **mass, surface or number fail to capture the diversity of emissions**.

Graphic adapted from: Lamberg et al. / Atm. Env. 45 (2011) 7635-7643

Focus on Carbonaceous Particles (Wood Combustion)

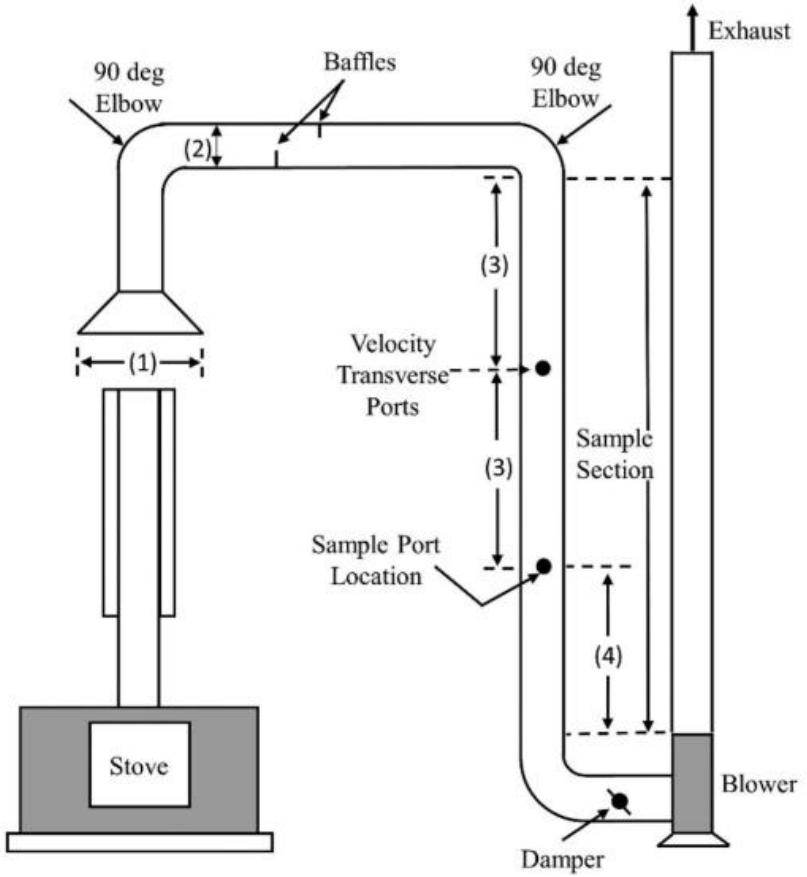
- Health relevant
- Contribute to climate change [a]
  - Effect mostly from elemental carbon (EC; soot)
  - Organic carbon (OC) contributes 14%
- Source apportionment (Switzerland)
  - OC concentrations at least as high as EC[b]
  - Winter smog episodes: OC ten times more than EC[c]
  - Secondary organic aerosol: ~ same concentration as primary organics[d]

[a] Kirchstetter, 2012: 10.5194/acp-12-6067-2012; [b] Gianini, 2012: 10.1016/j.atmosenv.2012.02.036
[c] Zotter, 2014: 10.5194/acp-14-13551-2014; [d] Daellenbach, 2017: 10.5194/acp-17-13265-2017

“Condensables”

- ☑ Somewhat related to organic aerosol in the atmosphere (after cooling/dilution)
- ☑ May be related to secondary organic aerosol potential

- ☒ No universal definition
  - Definition via measurement method



Secondary Organic Aerosols

Dekati® Oxidation Flow Reactor DOFR™

☑ Secondary aerosol formation is relevant for health and environmental impacts

☒ Lack of experience

- Has never been used for, e.g., type approval testing.

☒ In the past very expensive

Summary

Current Standard (Gravimetric PM + Organics through FID)	X	X
Number Concentration	X	X
Carbonaceous Particles	✓	✓
Condensables	✓	?
Secondary Organic Aerosol	✓	?

The Proposed Method

Current Standard

Conditioning (180°C)

Hot Filter

FID

PTD + Filter

Condensables

Comparison to Current Method

New Concept

SOA Reactor

Production of Condensables

Quantification of Carbon TC (EC, BC, OC)

Focus on Carbon

Quantification of TC ~1000x more precise than the total mass emission limit

Primary and Secondary

ESP: Electrostatic Precipitator
PTD: Porous Tube Diluter
FID: Flame Ionization Detector
SOA: Secondary organic Aerosol
TC/EC/BC/OC: Total/Elemental/Black/Organic Carbon

Thank you for your attention

PAUL SCHERRER INSTITUT

Wood burning in Roveredo Switzerland

LABOR FÜR ATMOSPHÄREN-CHEMIE

Wood is used as fuel for 75% of the domestic heating installations in Roveredo Switzerland[1]

OC/TC = 82% (18% EC)
91% of OC from Wood Burning

[1](Alfarra *et al.*, 2007 Environ. Sci. Technol)

Total Carbon and Oxidation Reactors

- The TCA-8 from Aerosol d.o.o. measures total carbon semi-online.
- Two sampling heads to avoid measurement downtime
- Limit of detection 0.4 µg-C sampled on the filter

- FHNW development for semi-online Total Carbon measurements (FATCAT)
- Limit of detection 0.1 µg-C sampled on the filter
- Has already been tested with wood burning emissions

Dekati® Oxidation Flow Reactor DOFR™

Based on the limit of detection, our systems will be able to detect Total Carbon concentrations as low as TC=35 µg-C/m^3_{STP} *

* Assuming sampling duration of 30 minutes, 1:10 dilution and 1 lpm sampling flow

FHNW, Organic Coating Unit (OCU)

Keller et al. 2022 (OCU): https://doi.org/10.1080/02786826.2022.2110448
Keller et al. 2023 (FATCAT): https://doi.org/10.5194/ar-2023-11