The Real-Life Emissions project has received funding from the European Union under grant agreement n° LIFE 20 PRE/FI/000006

Suggestion for short-term and long-term sampling and testing protocols and methods

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Juho Louhisalmi

University of Eastern Finland

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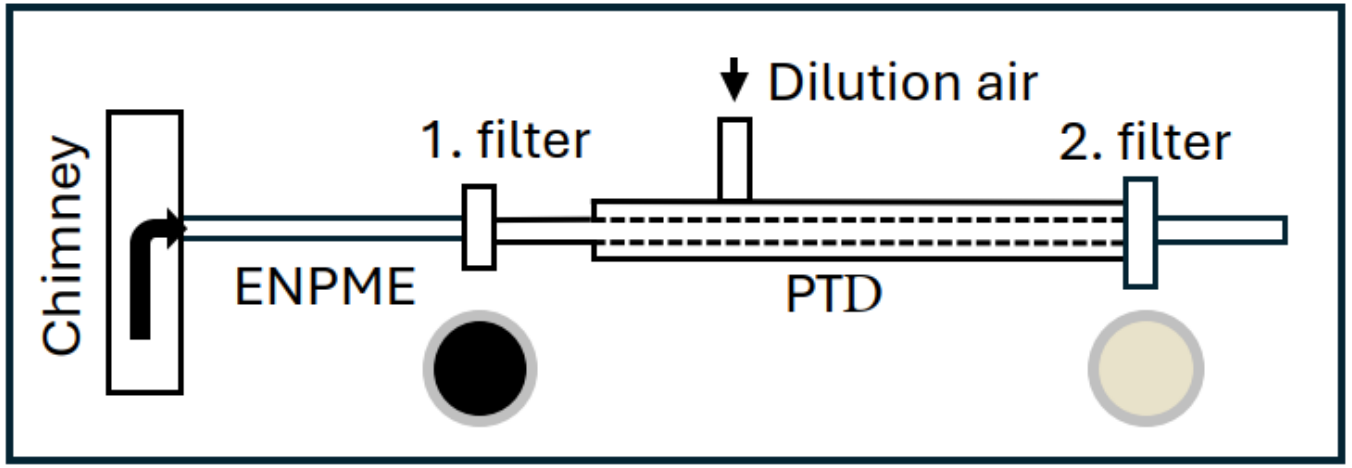
Short-term method: General requirements

- Capable of measuring relevant parameters regarding human health and environment
  - Able to measure condensable particles
- Ability to differentiate the performance of tested appliances
  - Comprehensive testing protocol that includes various types of combustion

Short-term method: Restricted emission parameters

- Same as in Ecodesign regulation and in EN16510:2022 standard
  - Organic gaseous compounds, OGC
  - Carbon monoxide, CO
  - Nitrogen oxides, NOx
  - Particulate matter including condensable particles, PM. NOVEL METHOD

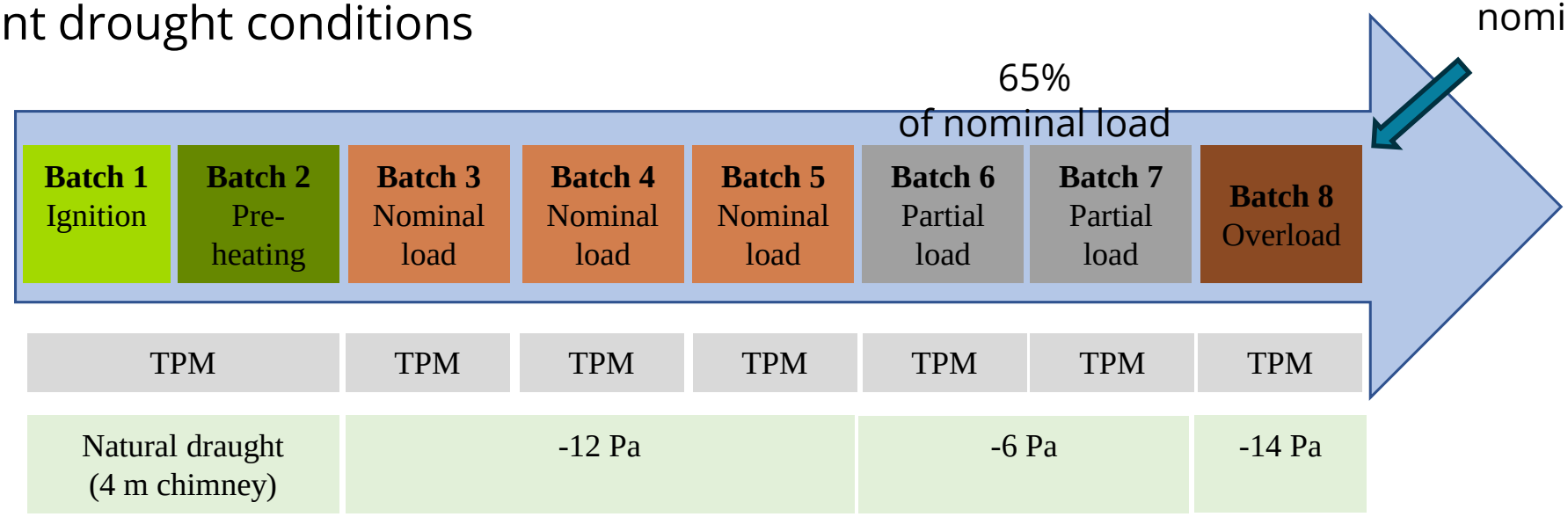
FOCUS on PM in this project



Short-term method: testing protocol

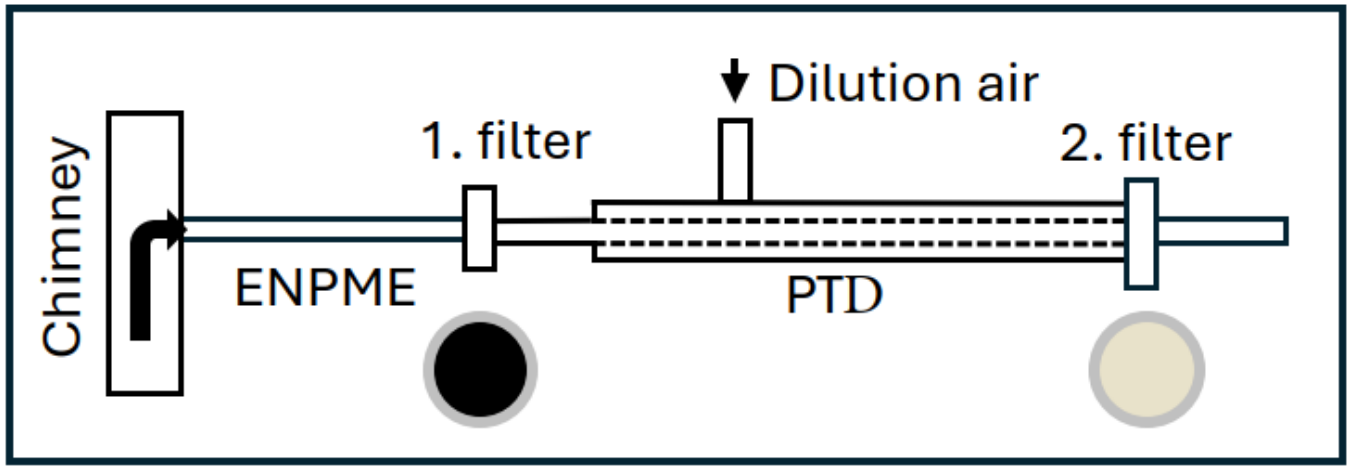
- Type testing protocols typically focus on the nominal load
- Protocols should reflect real-life use of each appliance type
  - This project focuses on wood stoves, but a similar approach should be applied to other appliance types, such as slow heat release appliances, cookers, and sauna stoves
- The real-LIFE test protocol includes four combustion phases and different drought conditions

The most efficient phase of heating cycle!



Short-term method: Novel two stage PM sampling method

- Extended ENPME: ENPME + porous tube diluter + second filter for condensable particles
  - First stage: ENPME sampling as described in EN16510:2022 standard
    - Flow rate: 10 lpm (0 °C, 1 atm)
    - Filter collection temperature: 180 ± 10 °C



- Second stage: dilution of the remaining sample in porous tube diluter (PTD) and collection of particles on a second filter
  - Sample cools down and new particles are formed
  - Dilution ration: 1:8
  - Dilution air: purified and at ambient temperature
  - Determination of dilution ratio with CO_2 is recommended
- **Total PM concentration is the sum of first and second filter concentrations**

Short-term method: advantages and disadvantages

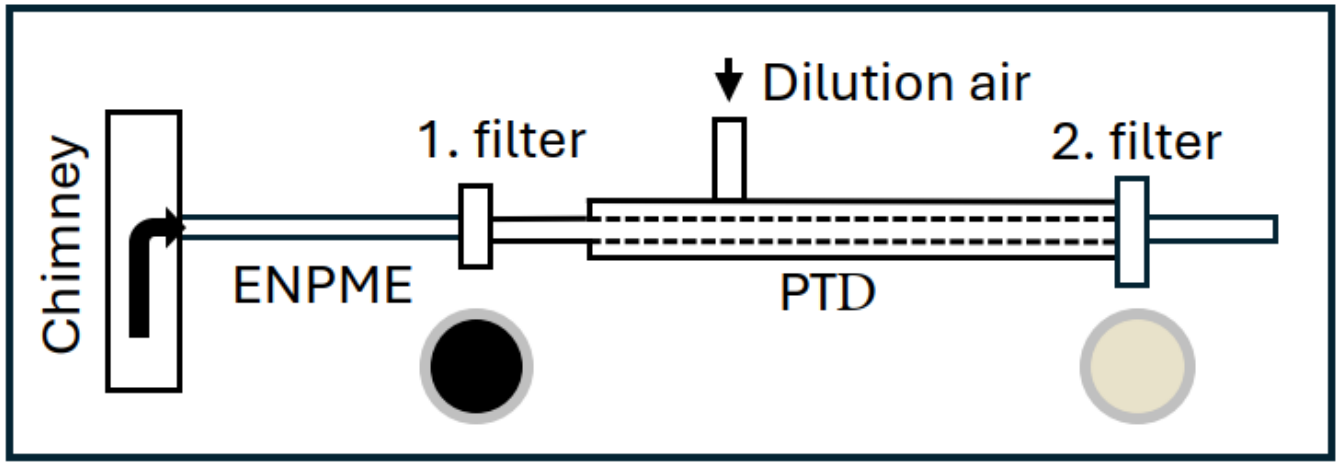
+ Based on a standard method
+ Significantly smaller than methods like dilution tunnel (DT)
+ Capable of measuring condensable particles
+ Promising preliminary data

– Two filters needed for PM determination
– Needs upgrades for lab equipment
– No clear cut-off size

→Random large particles cause deviation

→This makes it difficult to use the data for emission inventories

– A validation project is required!
  - PTD spesifications
    - Optimal dilution ratio (DR) for new particle formation
    - Temperature of the second filter (approximately 40 °C in this project)
  - More research concerning the nucleation



Long-term method: General requirements

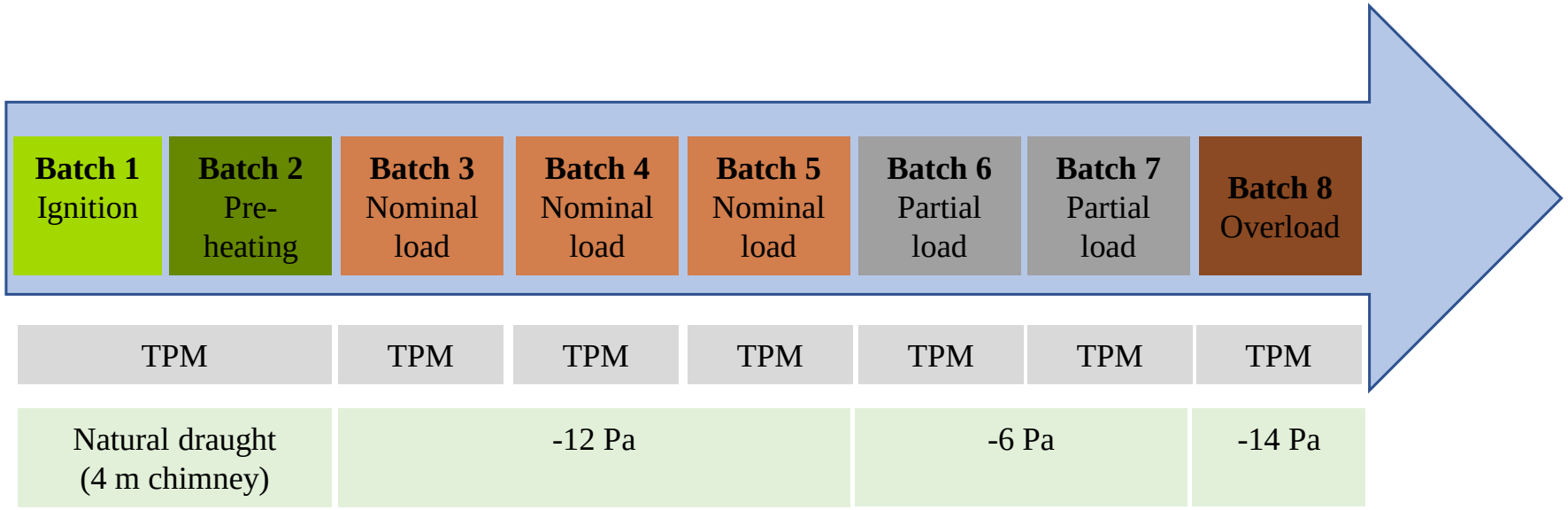
- Method for quantification of health and environment-relevant emissions, product development and type testing
- Ability to differentiate the performance of tested appliances
- Produce data that can be easily used in emission inventories and climate modeling
- Reliable and simple to use
- Expandable for secondary organic aerosol (SOA) measurements

Long-term method: Restricted emission parameters

- Most important parameters:
  - Fine particle mass concentration (PM2.5)
  - Black carbon or elemental carbon concentration (BC or EC)
  - Polycyclic aromatic hydrocarbons (PAHs)
  - Volatile organic compounds (VOCs)
  - Secondary organic aerosol (SOA) potential
- Supportive and indicative parameters:
  - Lung deposition surface area (LDSA)
  - Particulate size distribution (PSD)
  - Particulate number concentration (PN)
  - Ulrafine particle number conenctration (UFP)
  - Carbon monoxide (CO)
  - Nitrogen oxides (NO_x)
  - Organic gaseous compounds (OGC)

Long-term method: testing protocol

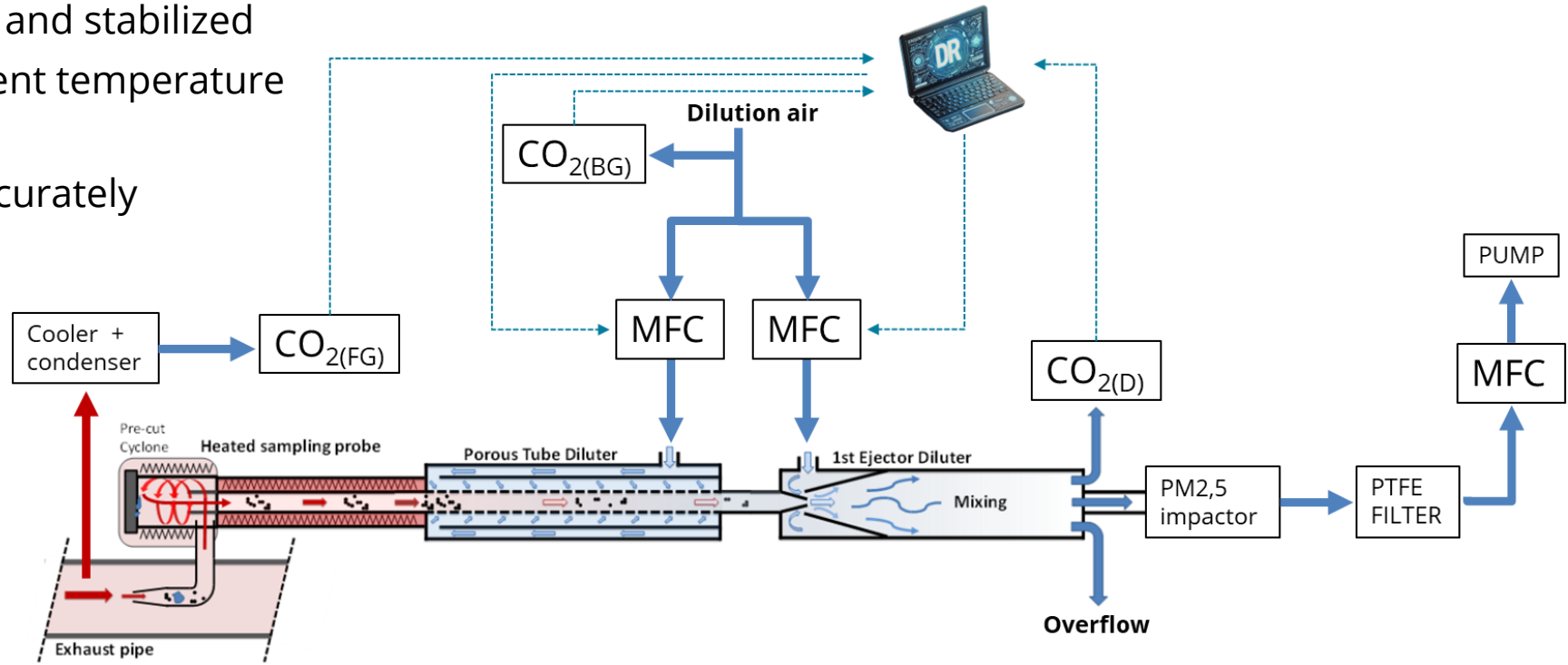
- Same as in short-term method
- Protocols should reflect real-life use of each appliance type
- The real-LIFE test protocol includes four combustion phases and different drought conditions



Long-term method: sampling method

- Sampling method: two-stage partial flow dilution system using a porous tube diluter (PTD) and an ejector diluter (ED)
  - After dilution, sample is cooled and stabilized
  - Filter collection occurs at ambient temperature
    - Condensables are included
  - PM2.5 concentration can be accurately measured with single filter

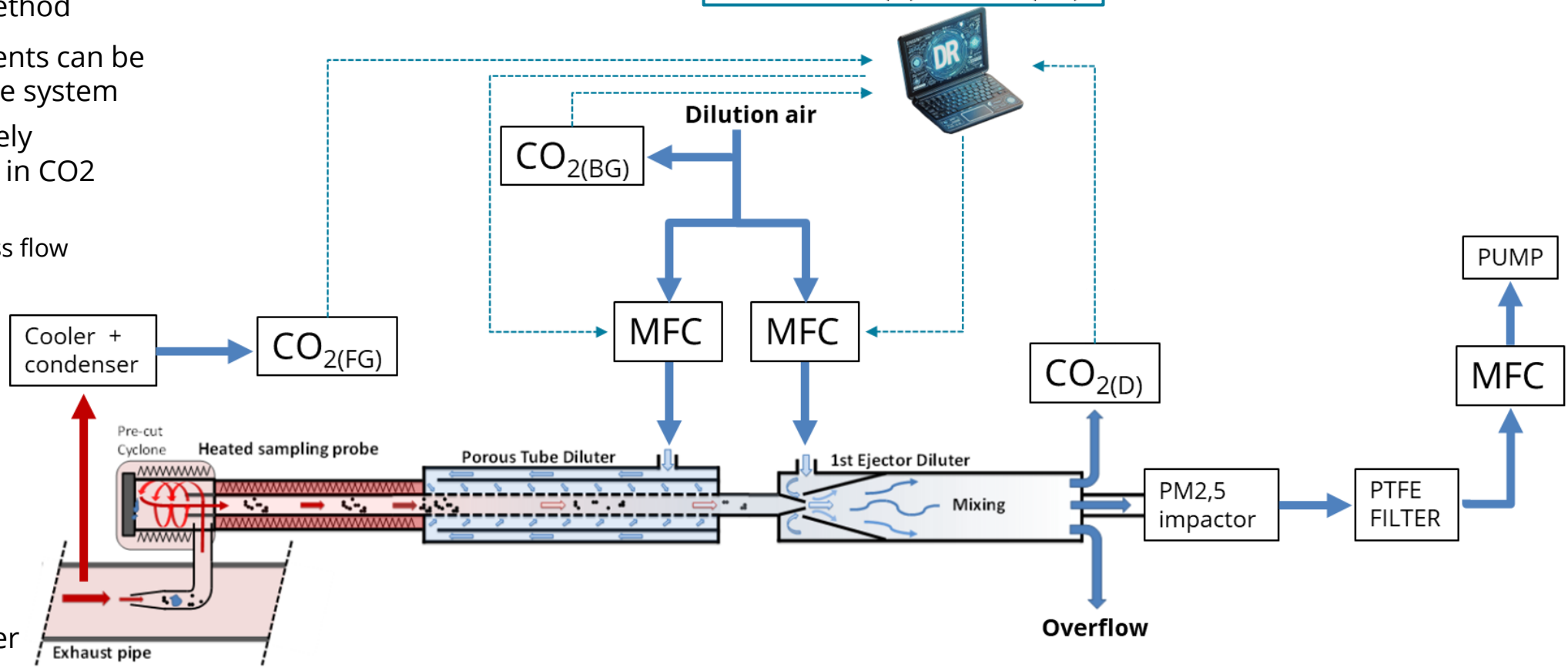
$$DR = \frac{CO_{2(FG)} - CO_{2(BG)}}{CO_{2(D)} - CO_{2(BG)}}$$



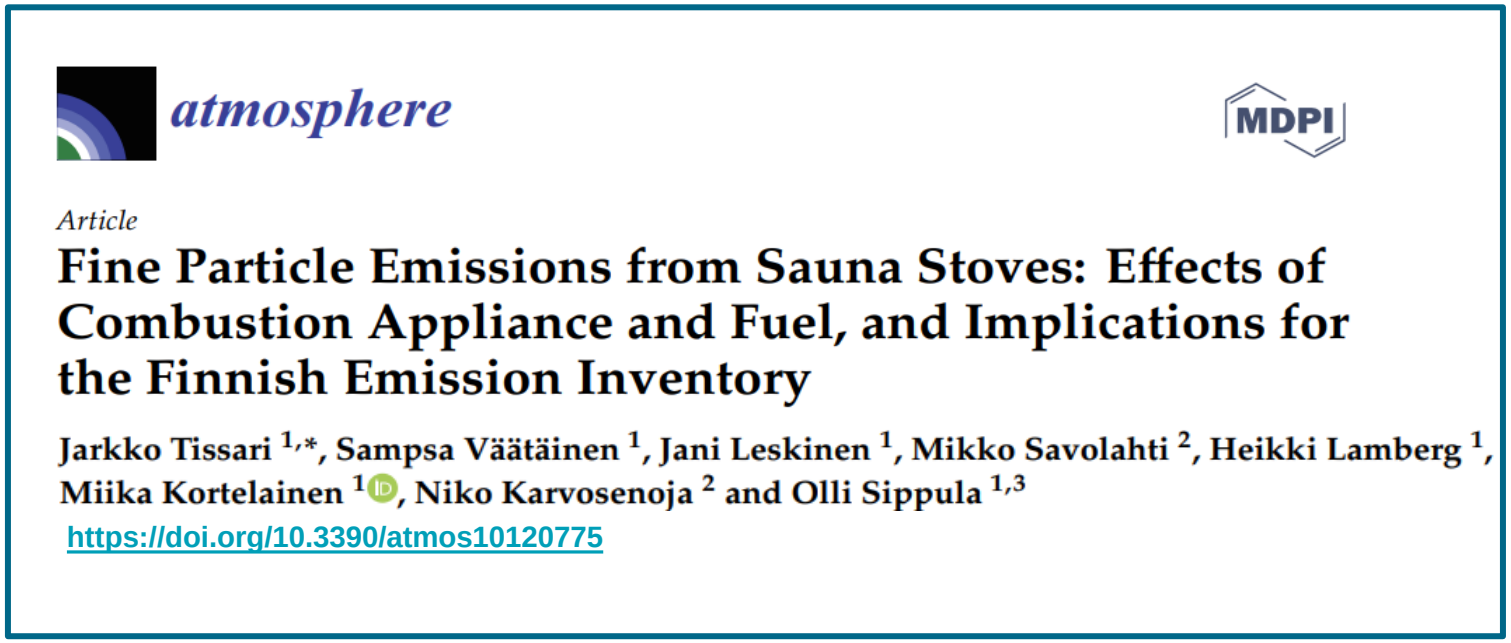
Long-term method: Key points from PTD+ED method

- The porous tube diluter minimizes particle losses
- The ejector tube diluter ensures good mixing and stable sample flow
- Moderate dilution ratios and a large nozzle in the ejector diluter ensures good function of the method
- Online aerosol instruments can be easily integrated into the system
- Dilution ratio is accurately determined by changes in CO2 concentrations
  - Adjustable with mass flow controllers (MFC)
  - Can be automated

$$DR = \frac{CO_{2(FG)} - CO_{2(BG)}}{CO_{2(D)} - CO_{2(BG)}}$$



More information about the method and emission calculations



atmosphere

MDPI

Article

Fine Particle Emissions from Sauna Stoves: Effects of Combustion Appliance and Fuel, and Implications for the Finnish Emission Inventory

Jarkko Tissari [1,*], Sampsa Väätäinen [1], Jani Leskinen [1], Mikko Savolahti [2], Heikki Lamberg [1], Miika Kortelainen [1], Niko Karvosenoja [2] and Olli Sippula [1,3]

https://doi.org/10.3390/atmos10120775

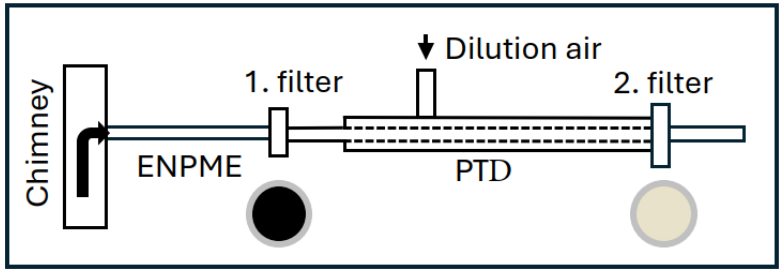
Long term method: advantages and disadvantages

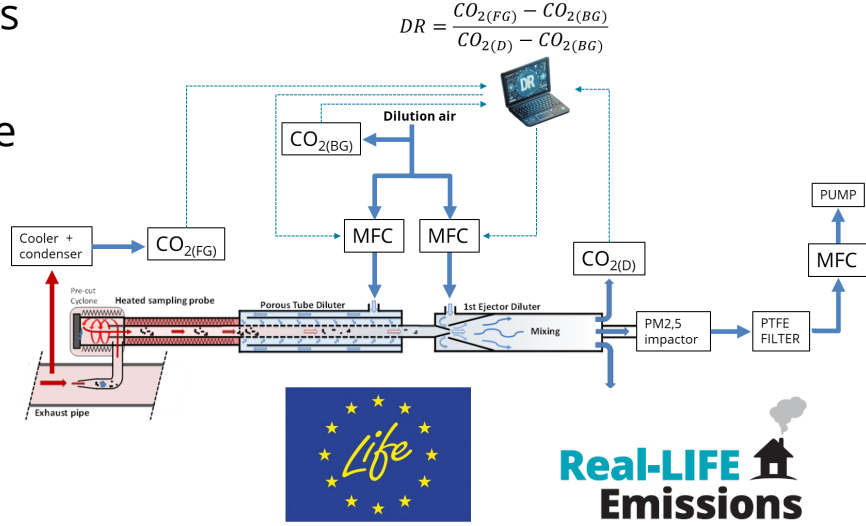
+ The system is compact, user-friendly and adjustable
+ Its effectiveness is well-documented in numerous publications
+ A particulate size cutting impactor can be used → Data is compatible with emission inventories
+ SOA reactor can be directly added after dilution

– Not a commercial product yet and there are no producer
– More complex than ENPME or DT methods, but can be automated to be user-friendly
– More expensive, but saves working hours and resources
– Needs extensive upgrade for lab insturmentation
– Extensive instrumentation requires more education
– Need for external laboratory for PAH analysis

Summary

- Short-term method: Extended ENPME method
  - PM is determined from two successive filters
  - Capable of measuring condensable particles
  - Based on the standardized ENPME method
  - Currently in the research phase and requires a validation project. Not ready for type testing
- Long-term method: PTD+ED
  - PM2.5 measured from diluted flue gas at ambient temperature → includes condensable particles
  - Dilution ratio is calculated from CO_2 concentrations, and DR control can be automated
  - Allows the use of online aerosol instruments including an SOA reactor
- Protocol should reflect realistic appliance use, including different combustion phases





Thank you for your attention

Juho Louhisalmi
University of Eastern Finland
Department of Environmental and Biological Sciences
Fine Particle and Aerosol Technology Laboratory
juho.louhisalmi@uef.fi