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

Summary of the 2nd International Real-LIFE Emissions Workshop on Small-scale Combustion

The Real-LIFE Emissions project consortium organized the second international workshop in Straubing, Germany on 26th October 2023. The workshop emphasized the **test protocols** and **total particle measurement (TPM) determination methods** for small-scale solid fuel combustion appliances. The workshop brought scientists, combustion appliance manufacturers, regulators, and experts in the field together to discuss current issues and solutions for residential combustion emissions, sampling methods, and protocols.

The workshop had two sessions: Session 1 discussed the test protocols for small-scale solid-fuel combustion units. The project partners presented their results, experiences, and knowledge on the impact of test protocols on emission formation based on the completed experiments and literature reviews. In session 2, we discussed TPM determination from small-scale solid fuel combustion appliances. The project partners presented their preliminary results from the experiments performed to determine TPM using different sampling methods, including a novel sampling method that is under investigation within the project consortium.

The workshop was held both online and onsite and a lot of discussions were held both at the venue and in the Q&A chat panel. The workshop was able to communicate with the experts in the field and exchange knowledge about the test protocols and sampling methods of small-scale solid fuel combustion emissions between the project members and external experts. A summary of the workshop activities such as presentations, discussions and knowledge exchanges is briefly presented below:

1. In session I, Dr. Kamil Krpec from the Technical University of Ostrava presented existing protocols for stove type testing and more real-life test protocols available on the market. There are plenty of standardized test protocols in use around the world. EN standards provide operational characteristics near to steady-state operation. Typical real-life operation shows higher emissions and lower efficiency in comparison with results from type testing. The choice of test protocol significantly affects the results of determining the appliance characteristics. He concluded that results obtained by different test procedures are not comparable.

2. Claudia Schön from Technology and Support Centre in the Centre of Excellence for Renewable Resources (TFZ), Germany presented a novel test protocol for wood stoves thathas been developed in the Real-LIFE-Emissions project and preliminary results obtained with this protocol. The aim of the novel protocol is to measure gaseous emissions from the whole combustion cycle and particulate emissions from each batch from start to end. Filter change time is limited to 3 minutes. The question of the real-life operation was raised. The suggested protocol has been tested in project partners laboratories in UEF, VSB, INERIS and TFZ. TFZ noted that emissions of overloading are

highly dependent on used wood log sizes: With same wood mass few bigger logs produce much less emissions compared to multiple smaller wood log pieces.

3. Franziska Kausch from SINTEF Energy Research institute, Norway presented results from user influence on emissions and the technical specification of overload in CEN TC 295 work group. Good ignition is possible but hard to repeat so automatization of the air valve will improve the operation. Wood log size is an important factor regarding emissions: too large logs and too full loading usually produce high emissions. No significant differences between wood types except for BC emissions were found. The reason for high emissions in overload situation could be due to the type testing requirements and product development. Combustion appliances may be optimized for type testing and do not work properly with different operational ways, which often is the case with the end user, e.g., overloading the appliance. Even now some appliances work well with different burn rates. It is important that test procedure for type testing includes different burn rates and loadings and appliances work well also in real life conditions.

4. In Session II, Henna Rinta-Kiikka from University of Eastern Finland (UEF) presented results from the effect of dilution ratio and wood species on particulate emissions. Experiments were conducted on SIMO research facility at UEF. No clear correlation between dilution ratio and particulate emissions was found. She concluded that dilution ratio is not an important factor when the particulate emissions are dominated by elemental carbon (EC). That is often the case with modern combustion appliances. Differences in the emissions were found with different wood species, but also even within the same species. This is due to the differences in wood characteristics. E.g., growth speed affects the density of wood. However, the comparison of wood species is very complicated because it is hard to produce similar combustion conditions with each species due to the physical differences between wood species. The results obtained are partly contradicted by the literature.

5. Juho Louhisalmi from University of Eastern Finland (UEF) presented correlations of particulate emissions ($PM_{2,5}$) with other emission components based on database which was collected during recent years in SIMO research facility. The database includes data from multiple different combustion appliances. The correlation between emission components gets worse when emission levels decrease. With high emission levels both particle and gaseous emission are usually high, but it also happens that either gaseous or particulate emission are high, and the other is low. Due to that it is important to measure the gaseous and particulate emission separately. From gaseous organic compound concentrations there is not a reliable possibility to predict the concentration of condensable particulate organic concentrations. Particulate number concentration doesn't correlate with particulate mass concentration. There is always a relatively high concentration of particulate number even when the mass concentration is very low.

6. Claudia Schön from Technology and Support Centre in the Centre of Excellence for Renewable Resources (TFZ), Germany presented a method description and preliminary results from a novel method for TPM determination – Combination of EN-PME and Porous Tube Dilution. The idea of the new approach is to collect the solid total particulate mass (TPM) and condensable particles to separate filters. TPM is collected to first filter which is operated at 180°C according to new EN 16510-2022 standard. The second filter collects the particles that has formed during the dilution and cooling of the sample in the porous tube diluter. Compared to the ENPME method alone this method gives additional information regarding organic particulate emissions which could be used for correcting emission factors that are based on heated filter method. This method has been tested in an intercomparison campaign (ILC) at INERIS in September 2023.

7. The last presentation was delivered by Isaline Fraboulet from The French National Institute for Industrial Environment and Risks (INERIS). She presented INERIS test bench design, gaseous and particulate emission homogeneity results from feasibility study and feedback and preliminary results from the intercomparison of new combination of EN-PME and Porous Tube Dilution method on a test bench at INERIS. Feasibility studies showed that OGC concentrations were homogenous along the full bench. Solid particle concentration was slightly higher in the first sampling ports but gets homogenous between sampling ports 7 to 11 at the end of the bench. These ports were used in interlaboratory comparison (ILC) where Real-LIFE-project partners measured particulate concentrations with their own prototypes of the combination of the EN-PME and porous tube diluter sampling systems. 16 trials were performed during the three-day campaign with different emission levels. The data from ILC is under evaluation.

In addition to the presentations there was also a very good discussion online in the Q & A panel. There was discussion about the definition of real-life operation and emissions regarding small scale solid fuel combustion. Questions about natural versus fixed drought, multiple small or fever bigger logs during overload combustion, used fuel species and number of batches during the combustion test were raised. One attendee noted that real-life operation practices vary between countries. There was new information regarding the situation in the USA: new testing protocols will be proposed during the year 2024. Interest was shown towards the novel EN-PME and porous tube diluter combination method.