Bioenergy Research Group

Lucerne University of Applied Sciences and Arts

HOCHSCHULE LUZERN

Wood combustion for energy in buildings

LABOR FÜR ATMOSPHÄREN-CHEMIE

PAUL SCHERRER INSTITUT

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1 Introduction

Wood combustion contributes with 3.8% to the Swiss energy supply and has a potential to increase up to 7.3%. Life cycle analyses show that heat and power from wood are effective to replace fossil fuels [1].

On the other hand, wood combustion contributes to air pollution with adverse health effects [2]. Consequently, there is a target conflict between air pollution and wood as a renewable energy source (**Fig.1**).

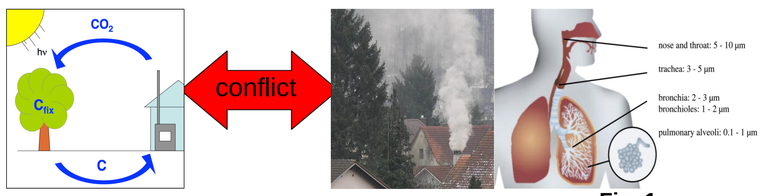

Fig. 1

In addition, investigations in ambient air reveal that the contribution of biomass to organic particulate matter is not only due to primary particles emitted at the source and accounted for by emission limit values, but also due to secondary organic aerosol (SOA) formed from volatile organic compounds (VOC) [3].

2 Target

Within the framework of the **National Research Programme "Energy Turnaround" (NRP 70)** the initial target of the **joint project between LUAS and LAC** is to deepen the knowledge

1. on the pollutant formation in wood combustion
2. on the conversion of pollutants in the atmosphere and specifically the formation of SOA, and
3. on the impact of wood combustion on ambient air quality and human health.

Further, the influences of the combustion technology, the fuel type and the operation of the device shall be identified. Based on these findings, the final target is to develop measures to reduce the impact of wood combustion on ambient air by:

1. Identification of best technologies and operation conditions.
2. Development of target-oriented air pollution strategies.
3. Definition of requirements for combustion design, control strategies and fuel properties.

Finally the findings of this project should enable to overcome the barriers that hinder a stronger implementation of wood as a renewable energy resource.

4 Research Plan

To identify the influence of combustion type and fuel, tests are carried out with log wood, wood pellets, and wood chips (**Fig. 2**) with the following combustion devices:

- Log wood stoves with conventional combustion (8 kW, **Fig. 3**)
- Log wood stoves with 2-stage combustion (**Fig.4**)
- Log wood boiler with 2-stage combustion (**Fig.5**)
- Pellet stove with 1-stage combustion (**Fig.6**)
- Pellet boiler with 2-stage combustion (15 kW, **Fig.7**)
- Semi-industrial moving grate boiler with multi-sector grate (150 kW, **Fig.8**).

Fig. 2

Further, influences of operation type, combustion phase, and flue gas cleaning (before vs. after electrostatic precipitator (ESP)) are tested.

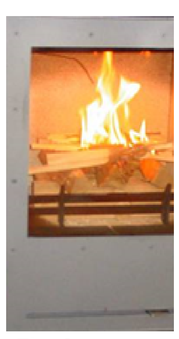

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

During the first campaign in 2015 the following combustion devices and conditions were tested:

1. Pellet boiler (**Fig.7**), optimum (λ_{opt}), lack (λ--) and excess of combustion air (λ_{++}) operation.
2. Moving grate boiler (**Fig.8**), operated with wood chips at 30% and 100% heat output.
3. Log wood stove (**Fig.3**), entire burning cycle (start/reload, flaming, burn out).

3 Experimental Setup

Experiments are performed in the LUAS combustion laboratory (**Fig. 9**). The setup **(Fig. 11)** enables investigation of SOA formation (via exposure to UV light and OH radicals) with the Potential Aerosol Mass Chamber (PAM) by LAC (**Fig. 10**) and an on-line characterization of the following species in the flue gas:

- Gas phase: O_2, NO, CO, CO_2, CH_4, volatile organic compounds (VOC), NMVOC (VOC minus CH_4)
- Particle phase: total PM, particle number concentration and size distribution (with SMPS), organic matter as well as NH_4^+, NO_3^-, Cl^- and SO_4^{2-} (by Aerosol Mass Spectrometry) and black carbon (with aethalometer)

In addition, two novel methods for **health indicators** of flue gases are applied:

1. On-line detector developed by LAC for reactive oxidative species (ROS) analysis.
2. Analysis of cell toxicity by a novel sampling method in cooperation with the Aerospace Biomedical Science and Technology Centre at LUAS (presented in oral session 6B by P. Zotter).

Fig. 9 Laboratory of the Bioenergy Research Group at LUAS

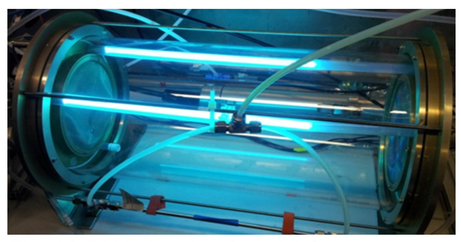

Fig. 10 PAM chamber from LAC

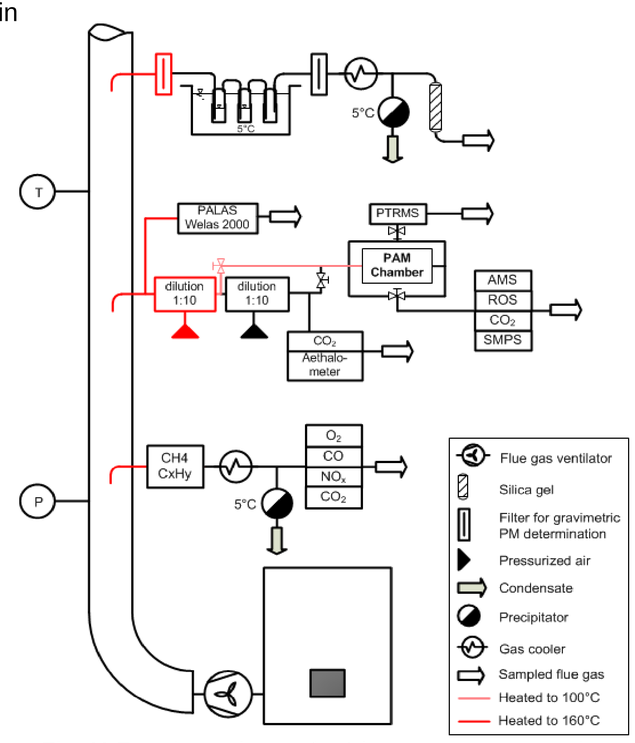

Fig. 11 Experimental setup for 1st measurement campaign

3 Results

Preliminary results from the 1st measurement campaign are shown in **Fig. 12** and the provisional conclusions are as follows (further information are given in oral session 4 by D. Bhattu and in poster 78):

- The log wood stove reveals highest emissions and variability of NMVOC, primary organic aerosol (POA) and BC and exhibits a strong influence on the operation.
- Automated devices (pellet and moving grate boiler) emit low organic but higher inorganic PM which, however, can be separated in ESPs.
- Non-ideal conditions in pellet boiler (λ-- and λ_{++}) and moving grate boiler (start up and boiler shutdown) also result in high NMVOC, POA, BC and SOA.
- NMVOC is related to SOA formation and might be used as a SOA indicator.
- SOA can significantly exceed POA.
- SOA formation also occurs at low POA.
- ROS significantly increases with SOA (more information on poster 78).

→An estimation of contribution and impact of wood combustion to ambient PM based on primary PM in flue gas is not sufficient.

→The contribution of wood energy to the Swiss energy supply with even reduced impact on air quality is possible, however, only if automated boilers with well operated ESPs are introduced and if in parallel measures to reduce mal-operation of manual combustion devices are implemented.

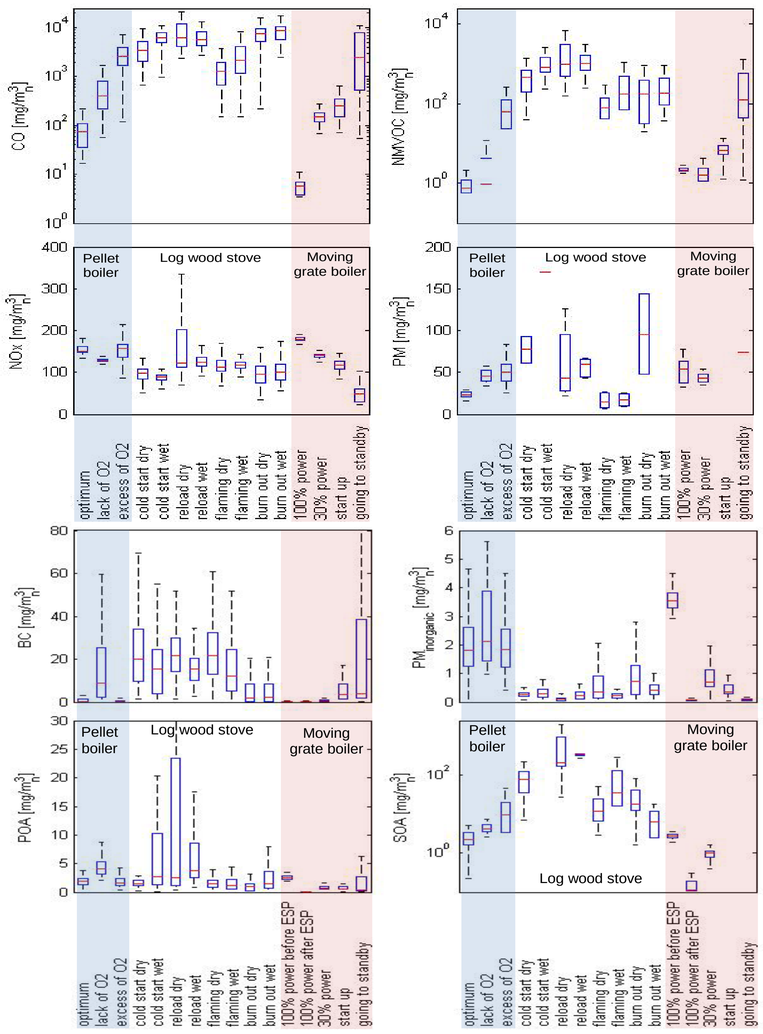

Fig. 12 Comparison of emission and SOA

Literature

[1] Nussbaumer T., Schweiz Z Forstwes, 12 2013, 389–397
[2] WHO: Air Quality Guidelines for PM, O_3, NO_2 and SO_2, Geneva, 2006
[3] Heringa, M., et al., Atmos. Chem. Phys., 2011, 11 (12), 5945–5957

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