Residential Wood Combustion

IEA Bioenergy Task 32 Workshop as part of the
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Workshop Report

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Summary

This workshop organized by IEA Bioenergy Task 32 covered highly relevant topics for residential wood combustion: direct-heating and central-heating technologies as well as operational performance and certification methods for high quality products. Additionally, the invited experts highlighted recent developments and future perspectives of advanced control concepts and secondary emission abatement technologies.

The workshop was held on January 23 as part of the 6th Central European Biomass Conference (CEBC) in Graz, Austria.

The first part of the workshop focused on local space heaters (stoves). Guidelines for the optimal design of efficient and clean stoves were discussed as well as the factors influencing the behaviour of users. As a special highlight at the end of the first part, the new Blue Angel (D) quality label for stoves was presented to the public for the first time. This certification programme does not rely on existing standards as before, but prescribes its own test procedure with particularly high practical relevance.

In the second workshop part, current developments in the field of domestic biomass boilers were presented. In addition to technical combustion concepts for greater fuel flexibility, work on additives for biomass combustion systems was also presented. Reduction of emissions by secondary measures and the experiences with the use of separators in domestic boilers in practice were the contents of the presentation by a representative of a Swiss company, which has been developing and marketing electrostatic separators for small combustion systems for many years. Finally, another Austrian contribution summarized the advantages of completely new control concepts for small-scale furnaces.

Link to workshop presentations: https://task32.ieabioenergy.com/ieaevent/iea-workshop-residential-wood-combustion/

Introduction to biomass combustion and pollutant reduction in wood stoves and boilers

Thomas Nussbaumer, Verenum, Switzerland

Biomass furnaces emit particles (salts, unburned fuel, coke, soot and liquid particles) and gaseous substances (VOC, CO) as well as products from complete combustion (CO_2, H_2O, NO_X). The emissions depend on the technology, the quality of the fuel and the operating conditions. The differences between the results of standardized tests on ovens and small boilers with the "real life" emissions are considerable, but a fixed ratio cannot be specified. Investigations in this regard were carried out in the EU-funded beReal project. Emission-reducing secondary measures such as exhaust gas catalytic converters installed between the combustion chamber and heat exchangers and electrostatic precipitators are under development.

General requirements for low emissions are:

- Low-emission lighting and suitable fuels
- A two-stage combustion with suitable combustion air regulation
- Optional electrostatic separation
- Heat storage in the central heating system

Residential biomass combustion significantly contributes to air pollution. However, technological improvements known as primary and secondary measures are able to reduce emissions significantly. It is very challenging to achieve the performance of test bench measurements in real operation. Therefore, fully automatic appliances are advantageous. Useful accompanying measures are training courses for installers and operators as well as recurring inspections.

Technical guidelines for design of low emission stoves

Morten Gottlieb Jespersen, Danish Technological Institute, Denmark

This presentation gives an overview of the most important technical aspects in the development and design process of low emission stoves. Emission reduction measures which are directly related to the combustion process and therefore prevent the formation of particles are known as primary measures. The presentation includes valuable information on such measures like combustion chamber geometry, window design and combustion air staging as well as important other aspects like computational fluid dynamics (CFD) analysis as support tool, user behaviour and automation.

In the second part of the presentation a short overview on secondary measures, removing already formed emission components from the flue gas, is given.

Influence of user behaviour on emissions from firewood stoves

Robert Mack, TFZ Straubing, Germany

The operator of firewood stoves and its influence on the emissions of particulate and gaseous compounds is in the focus of this presentation. Beside interesting findings about factors influencing the emission behaviour also general recommendations for a low-emission operation are given. Some of the main findings were:

- The generally assumed advantages of "top-down" ignition could not be confirmed.
- Good ignition aids and the right ignition material reduce emissions during a cold start significantly.
- Incorrect air settings increase emissions dramatically.
- Fuels with a water content of over 30% increase emissions up to five times.
- Reloading the next fuel batch late requires opening the primary air; automatic regulations are desirable.
- Good operating instructions are essential for clean and efficient combustion. It is the responsibility of the manufacturer to provide instructions for clean and efficient operation.

The new Blue Angel ecolabel certification method for firewood stoves

Ingo Hartmann, Deutsches Biomasseforschungszentrum (DBFZ), Germany

The “Blue Angel” is the environmental label of the German Federal Government and for over 40 years facilitates sustainable purchase decisions. In this presentation the first version of the "Blue Angel" – labelling scheme for firewood stoves is presented.

Different to other existing quality labelling schemes the new Blue Angel certification introduces a new testing method which differs from the methods in the respective harmonized testing standards. The focus of the new method is on real-life operation; therefore, the testing procedure and measurement methods were adopted to emulate field operation.

The presentation gave an overview of the new methods and the requirements for products to get the new firewood stove Blue Angel label.

GrateAdvance - Advanced adjustable grate solutions for future fuel flexible biomass combustion technologies

Elisabeth Wopienka, BEST Bioenergy and Sustainable Technologies, Austria

This contribution dealt with a method for upscaling a screw burner for ash-rich solid biofuels from 35 to 150 kW. The investigations were carried out in the frame of the ERA-net project "GrateAdvance". The main challenge was to transfer existing knowledge about slagging and emissions based on lab-scale experiments to larger outputs.

The consortium consisted of researchers from Austria (Bioenergy2020 +, TU Graz), Switzerland (Verenum, University of Lucerne) and Sweden (Lulea University, Umea University). The fuels investigated included bamboo pellets, grain husks, miscanthus, hay, pruning, contaminated corn, olive pits and milling residues.

Fuel improvements using kaolin as additive to pellets and chopped materials in residential boilers

Hans Hartmann, TFZ Straubing, Germany

Kaolin as an additive to solid biomass fuels has been reported to positively influence the particle formation and the slagging properties during biomass combustion. The aim of the work presented was to check whether the addition of kaolin additives to pellets made from willow wood, cereal straw, grass and sunflower husks can confirm these earlier findings. The main results were:

- The addition of kaolin significantly reduces particle and CO emissions.
- Adding kaolin separately to the boiler is less effective.
- The addition of kaolin can increase sulphur dioxide and hydrochloric acid emissions (which poses be a problem for chlorine and sulphur-rich fuels).
- When mixing agricultural fuels with poplar wood, additives alone are not enough to comply with the PM emission limits.
- The mixture with softwood (> 75%) reduces the formation of slag in wheat straw.
- The addition of kaolin can largely reduce problems caused by slag.

Electrostatic precipitators for residential combustion technology – State of the art and future perspectives

Daniel Jud, ÖkoSolve AG, Switzerland

The Swiss company Ökosolv AG develops and produces fine particle filters for wood firing. The electrostatic separators can be used in boilers and stoves for pellets, wood chips and wood logs. They usually are installed outside at the chimney top outside the building, but also individual solutions are possible. ÖkoSolv has been dealing with the topic since 2006, and the first precipitator

for a 40kW system was installed in 2008. The advantages are the high separation efficiency for fine particles, the low flow resistance and the low operating costs. The assembly at the outlet of the chimney is easy and fits to all common chimney types. The filter is cleaned from below by the chimney sweep during the regular chimney sweeping.

The field operation performance has been investigated together with Verenum, a Swiss engineering company for research and development which performed measurements at 7 pants over two heating seasons. The types of appliance included were tiled stoves (slow heat release), fireplaces, classic firewood stoves and pellet stoves. The average separation efficiency was 74% and the availability (operational time) of the separators were 84 to 100%. Similar results were obtained in another study in Austria.

Advanced control concepts for biomass-based residential heating

Markus Gölles, BEST Bioenergy and Sustainable Technologies, Austria

Optimizing the control of biomass boilers is challenging due to the complexity of the process itself and the wide range of combustion technologies each with different requirements. In addition, the interaction of the boiler with the heat distribution (or storage) system needs to be considered. Even the integration of weather forecasts in the control concept is possible. This presentation gave an overview of advance control concepts which have been recently developed by BEST Research in Austria in cooperation with different industry partners:

Log wood firing:

The goals of the development of log firing are compliance with the optimal residual oxygen content in the exhaust gas and the desired flow temperature. Therefore, following parameters can be controlled:

- the negative pressure at the boiler outlet by changing the speed of the fan,
- the primary and secondary air volume through the flap position,
- and the flow rate by changing the pump speed

The control method recently developed shortens the start-up phases and reduces the fluctuations in the residual oxygen content and, consequently, the emissions of pollutants. Further improvements are possible through energy management measures. The developed control system uses data from the weather forecast and also considers the operator behaviour through a self-learning process.

Furnaces with automatic fuel supply:

The control concept aims at maintaining good combustion conditions (residual oxygen, air ratio) and to ensure the required water flow temperature. The following parameters can be controlled:

- the fuel mass flow,
- the volume of primary and secondary air by regulating the speed of the fan,
- and the flow temperature by changing the pump speed.

The new control system decouples the flow temperature from the fuel mass flow and ensures optimum combustion. The flow temperature remains constant, the fluctuations in the residual oxygen levels are low. The self-learning model predictive control considers weather forecast data and optimizes all settings every 15-minutes. The developed control concept was validated for two years in a 2.5MW boiler in a district heating system: the fuel consumption could be reduced by 3.8%, the CO emissions by 200 mg/m^3 and the particle emissions by almost 20%.

Presentations

All presentations from the workshop are available in the events-section of the task website (https://task32.ieabioenergy.com/ieaevent/iea-workshop-residential-wood-combustion/).