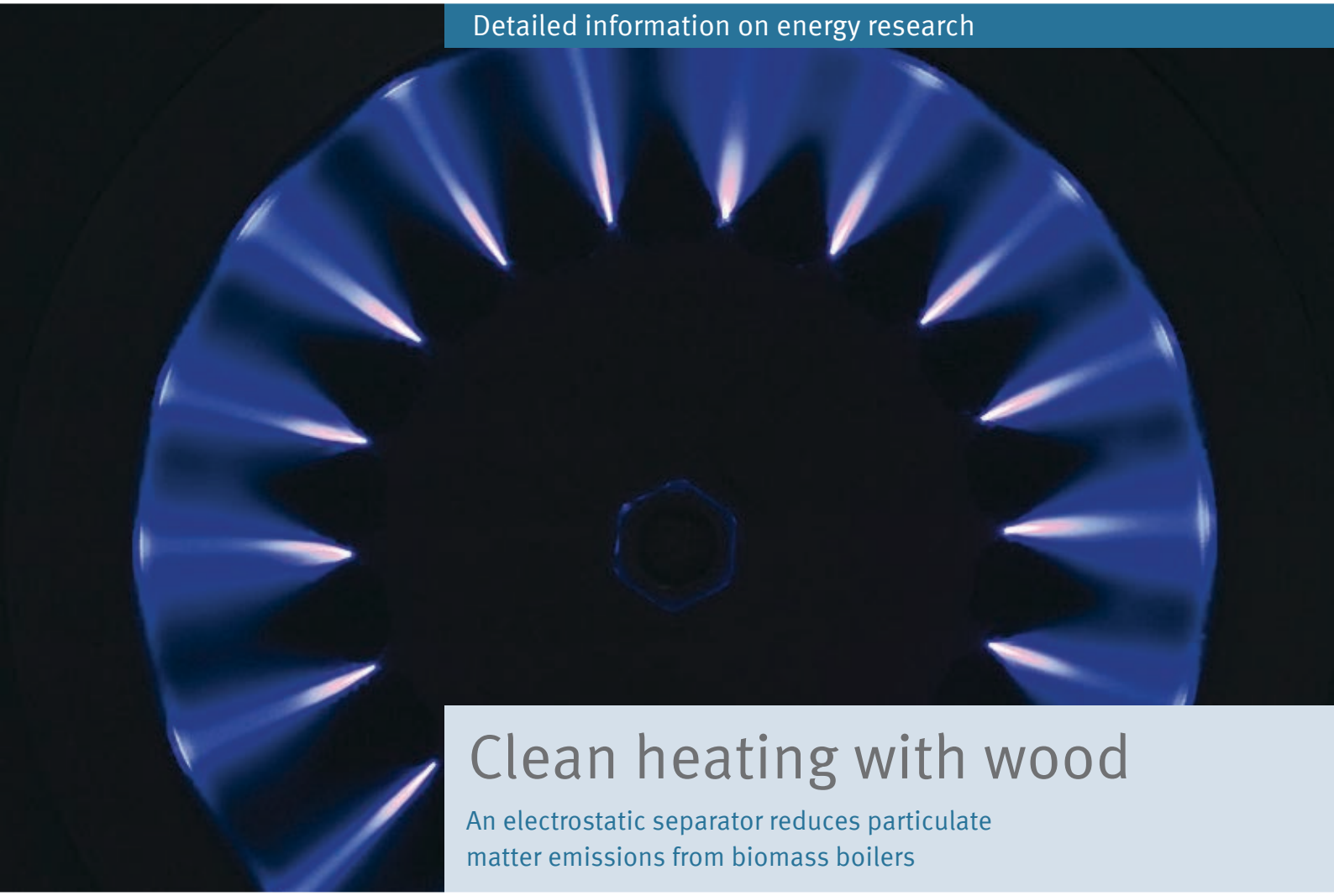
Projektinfo **06**/2016

Detailed information on energy research



Clean heating with wood

An electrostatic separator reduces particulate matter emissions from biomass boilers

BINE Information Service

Despite considerable advances in firing technology, harmful particulate matter is produced when wood is combusted. Electrostatic separators, however, filter up to 90 per cent of particulate emissions from biomass boilers. These therefore enable wood burners to use a wider range of fuel and still meet the tightened requirements of Germany's 1st Ordinance on the Implementation of the Federal Immission Control Act. The major advantage: Both new and old heating plants can benefit from the new system.

Heating with wooden logs, briquettes, chips or pellets is becoming increasingly popular. In addition to the fuel costs, users are particularly motivated by the environmental aspects. If the fuel stems from sustainable forestry and is available without long transport routes, it causes on balance only a fraction of the carbon dioxide emissions produced by comparable gas- or oil-fired combustion systems. However, wood burners also emit harmful particulate matter. In the winter time, their particulate emissions often exceed those produced by vehicular traffic. Therefore since 2015, the 1st Ordinance on the Implementation of the Federal Immission Control Act (1. BImSchV) has stipulated more stringent limit values (second limit level) for emissions of particulate matter and carbon monoxide from biomass-fired boiler systems. In a research project jointly conducted with HDG Bavaria GmbH and CCA-Carola Clean Air, researchers at Karlsruhe Institute of Technology (KIT) have therefore developed an electrostatic filter that ensures that dust emissions are reduced below the new limits.

„We previously evaluated chimney sweep measurement reports for a sample of 94 wood chip burners," says Dr Hanns-Rudolf Paur, director of the research project, in explaining the initial situation (Fig. 1). „Although almost all the systems were within the limits permitted at that time, only 10 per cent of the systems would

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have complied with the currently applicable requirements.“ In accordance with the year of manufacture, the second limit level of the 1st Ordinance on the Implementation of the Federal Immission Control Act stipulates different transition periods for biomass-fired boilers with thermal outputs between 4 and 1,000 kW. There is already a considerable need for flue gas purification. According to the Fachagentur Nachwachsende Rohstoffe (Agency for Renewable Resources), about 850,000 wood-fired boiler systems are currently operated in Germany. In principle, particulate emissions can be minimised during the wood combustion by optimising the combustion and fuel quality and through the post combustion of carbon-containing dusts. In practice, however, fluctuating fuel compositions limit the success of these measures. For many wood chip and wood log boilers, it will therefore be necessary to install particle separators that have separation efficiencies ranging between 70 and 90 per cent. Modern filter technology makes it possible to use a wider range of fuel and will play a significant role when the utilisation of thermal biomass takes on increasing importance as part of the energy transition.

Electrically charging and separating particles

The separator is installed directly in the flue gas path between the boiler and chimney. It consists of ionisation and separation chambers, through which the flue gas successively flows (Fig. 2). In the ionisation chamber, a corona discharge on a high voltage electrode (Fig. 4) ensures that the particles in the flue gas are electrically charged. The flue gas then enters the tubular separation chamber and flows along a spiral, grounded steel brush. The particles are discharged to the bristles and then precipitate. The flue gas cleaned in this manner then passes into the chimney.

The steel brush rotates at periodic intervals over a scraping edge and thus cleans the walls of the collector chamber and its bristles. The dust falls into an ash pan. Almost all that needs to be done in maintenance terms is to empty the ash pan. Paur sees particular advantages in the dry cleaning: „This therefore makes it easier to install and only dry dust is produced. No official approval is required in order to dispose of soot-containing cleaning water. „Thanks to the regular cleaning of the electrodes, the efficiency is maintained even under difficult combustion conditions.

With a corresponding chimney design, the filter can be operated without blowers. The structural principle enables the separator to be integrated downstream of the boiler or directly in it. Since no additional openings in the separator are required, it is structurally impossible for toxic fumes to escape into the building.

Depending on the system size, the corona discharge and the motor for the automatic brush cleaning system consume between 40 and 100 watts.

On the test rig

The electrostatic fine particle separator was operated on test rigs and in field trials for over 30,000 hours. For the service life investigations and quality control, the researchers at the KIT site are operating a test rig with a 100-kW wood chip boiler. It produces at full load a flue gas volume of 350 m³ per hour. This is fed at a temperature of between 150 and 200 °C into the measurement test section designed in accordance with the German VDI Guideline 2066. Here up to three separators can be tested in parallel. Particle and gas gauges as well as temperature and pressure sensors provide readings from the flue gas stream upstream and downstream of the separator.

„Combining the optimum combustion technology used in our boilers with the separator ensures that the limits of the 1st Ordinance on the Implementation of the Federal Immission Control Act are securely met even with varying fuel qualities,“ emphasises Martin Ecker, Managing Director of HDG Bavaria GmbH.

In numerous design experiments, the researchers optimised the mechanical and electrical interfaces so that in particular, by making structural adjustments, the separator was able to be connected to the boiler in the most

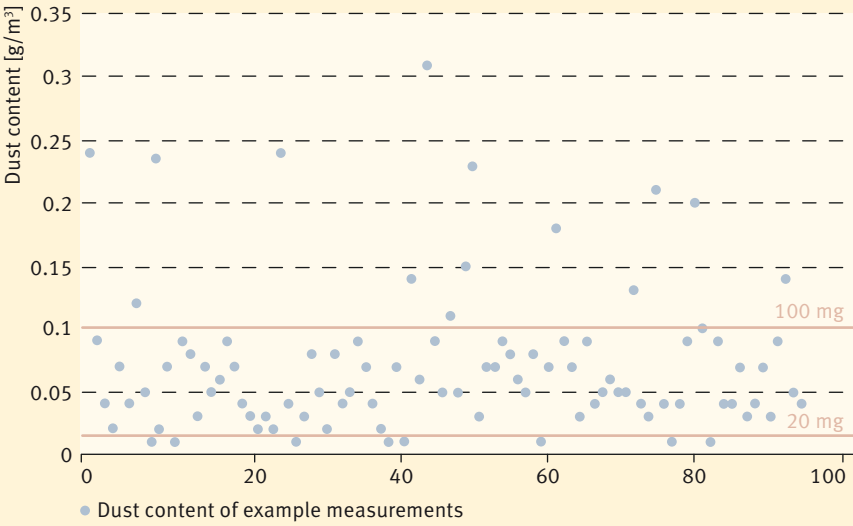
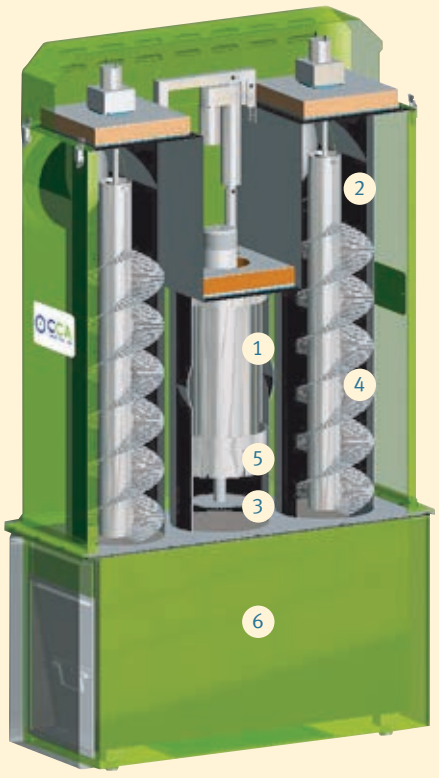


Fig. 1 *Dust content in the flue gas with recurring chimney sweep measurements made on 94 wood chip boilers*



1 *Ionisation chamber*
2 *Collector chamber*
3 *Corona electrode*
4 *Steel brush*
5 *Cleaning unit*
6 *Ash pan*

Fig. 2 *Structure of the flue gas cleaning system*

Fig. 3 *A 100-kW fine dust filter in the field trial*

The market is growing

Thanks to modern combustion technology, manufacturers of biomass heating systems have already significantly reduced the particulate emissions. However, in order to permanently meet the second limit level of the 1st Ordinance on the Implementation of the Federal Immission Control Act, these primary-side optimisations are not sufficient. Secondary measures are required. Therefore the market for separation systems is growing in Germany. For the thermal output range covered by the 1st Ordinance on the Implementation of the Federal Immission Control Actbetween 4 and 1,000 kW, a market volume of approximately 40,000 boiler systems per year is expected, which will need to be partly equipped with separators. In terms of the export possibilities within Europe, the researchers believe that Italy and Austria have considerable potential because relevant boiler manufacturers are located there.

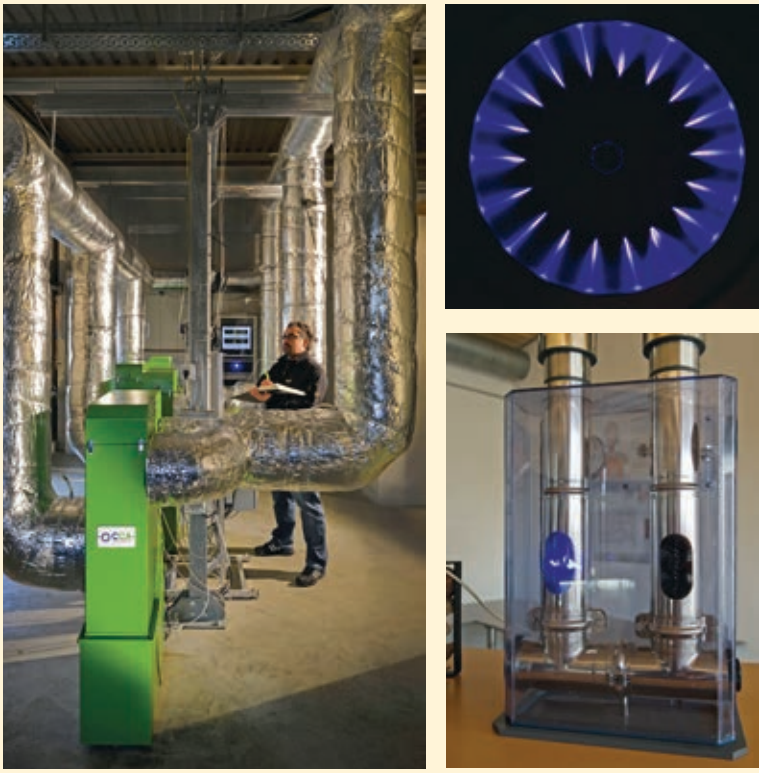


Fig. 4 *Left: Separator prototypes in test operation*
Top right: Corona discharge at the high voltage electrode
Bottom right: Separator in the model with the ionizer and brush for the collector

cost-effective manner. The optimal design was identified using several prototypes with various boiler-separator combinations.

Alternative separator technologies

Separators are already particularly used for larger plants. These operate according to different principles. A simple, inexpensive form of flue gas filtration is offered by cyclone separators. With these the flue gas is tangentially fed into a pipe, the cyclone, which causes the gas flow to rotate. The cyclone tapers toward the outlet side. Because the angular momentum is maintained, the rotational speed increases as the pipe cross-section decreases. The centrifugal forces push the dust particles outwards towards the casing where they are separated. This technique is used in bagless vacuum cleaners. Cyclones, however, only achieve low separation rates with the very fine particles produced by optimised wood chip boilers. Another disadvantage in terms of the energy consumption is the high pressure loss.

With fabric filters, clean gas values ranging from 2 to 20 mg/m³ dust can be achieved depending on the filter material. Sticky soot particles cause, however, unstable filter operation, which requires elaborate and additional technical measures. Necessary fire protection measures increase the investment costs and the pressure loss that is inherent to the principle increases the operating costs.

The first electrostatic separators for small firing systems have now appeared on the market. These are dry electrostatic separators that come with and without integrated cleaning systems. In particular these differ from the system presented here in terms of the type of cleaning. This is where the researchers see an advantage: „The self-cleaning ensures a longer service life and good separation rates in the long term," confirms Paur.

From research project to product

The research was funded as part of the „Energy Efficient Utilisation of Biomass" programme run by the German Federal Ministry for Economic Affairs and Energy. In 2012 this led to the founding of a company that further developed the separation technology to market maturity. Following numerous tests, the German Institute for Building Technology (DIBt) granted national technical approval for the patented separator in the summer of 2015. The testing was also monitored by the Technischer Überwachungsverein (German Technical Inspectorate (TÜV)). Among other things this confirmed the high separation efficiency, electrical safety and soot fire resistance. The separator is the first dry particle separator with fully automatic cleaning to be approved for the German market for wood-fired boiler systems in the 50-200 kW thermal output range. The newly founded company, CCA – Carola Clean Air GmbH, is now producing electrostatic particle separators for domestic and industrial systems with thermal outputs between 25 and 1,000 kW.

Small particles cause big problems

Although better combustion systems and filter technology in industry and transport have greatly reduced air pollution caused by dust since the 1980s, the use of energy has remained a major source of particulate emissions. For instance, the increased burning of biomass in heating systems without filter systems is a particular cause of concern among environmental physicians.

The chemical composition and particle size play a decisive role in how dust affects human health. The World Health Organisation (WHO) points out that particulate matter reduces the average life expectancy in Germany by 10.2 months.
Larger particles are deposited primarily in the nasopharyngeal area and the upper bronchi. Ultrafine particles (‹100 nm) can even penetrate deep into the human respiratory tract and even sometimes into the bloodstream. On average they remain for a year in the alveoli and cause inflammation, DNA damage and vasoconstriction.

Therefore, environmental legislation makes a distinction in accordance with the particle size: for the coarsest fraction (PM10 to 10 µm), the daily limit is 50 µg/m³. This must not be exceeded by more than 35 times a year. The permissible annual mean is 40 µg/m³. Many large cities are currently struggling to comply with these provisions. For smaller particles (PM2.5), the average annual limit is 25 µg/m³ and, from 2020, 20 µg/m³. The WHO even only classifies concentrations below 10 µg/m³ as harmless!

The relationships between the emission of particles, the time they reside in the human body and their biological effects are the subject of intensive investigations. By means of epidemiological studies and animal testing, researchers are investigating systemic effects such as cardiovascular disease. They are also making increasing use of cell cultures. These enable them to verify changes in the metabolic processes in cells at a very early stage.

A study published in 2016 investigated the reasons for people dying in Hong Kong. Particulate matter in the metropolitan area increased the risk of death from cancer in the liver, pancreas or gallbladder by 35 per cent. With women, the risk of dying from breast cancer was even 80 per cent greater. The researchers therefore conclude that particulate matter has to be reduced in major cities worldwide as soon and as much as possible.

Project participants

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- **Development of the Carola particle separator:** CCA – Carola Clean Air GmbH, Eggenstein-Leopoldshafen, Germany, Dr Hans-Peter Rheinheimer (CCA), rheinheimer@carola-clean-air.com

Links and literature (in German)

- Paur, H.-R.; Ecker, M.; Reinheimer, H.-P.: Elektrostatischer Feinstpartikelabscheider zur flexiblen Anpassung an Biomassekessel. Abschlussbericht. FKZ 03KB083A/B/C. Karlsruher Institut für Technologie (KIT). Institut für Technische Chemie (Hrsg.); HDG-Bavaria GmbH, Massing im Rottal (Hrsg.); CCA-Carola Clean Air GmbH, Eggenstein-Leopoldshafen (Hrsg.). August 2015

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