State-of-the-art and assessment of filter technologies for residential biomass combustion systems

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Objectives (I)

- **Within IEA Bioenergy Task32 "Biomass Combustion and Co-firing" a survey on the present state-of-the-art of particle precipitation devices for residential biomass combustion systems (nominal boiler capacity <50 kW) in the Task32 member countries has been performed.**

- **Main objectives:**
  - **collection and compilation of data**
  - **assessment of particle precipitation devices regarding applicability, availability and technical performance**

- **The work mainly focused on technologies which are already available on the market or which are close to market introduction.**

- **A literature survey as well as data available from filter manufacturers, data from national projects of the Task32 member countries and data from the ongoing ERANET project "Future Biotec", formed the basis of this survey.**

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Objectives (II)

- Evaluation of 12 electrostatic precipitators, 2 catalytic converters, 2 ceramic filters and 3 flue gas condensers from Austria, Finland, Germany, Liechtenstein, The Netherlands, Norway and Switzerland.
- In addition, the situation of particulate emissions in general as well as of dust emission limits for residential biomass combustion in the IEA Bioenergy Task32 member countries was summarized.
- Furthermore, information concerning standards and specific problems of dust emission measurements are given.
- The results of the survey have been summarised in a report. The final report can be downloaded from the IEA Bioenergy Task 32 homepage (http://www.ieabcc.nl/).

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Background – general issues

- The contribution of residential biomass combustion to the total PM emissions of the residential heating sector exceeds in some European countries 80%.
- Intense R&D activities regarding the development of particle precipitation devices are especially ongoing in Austria, Germany and Switzerland at present.
- Significant differences exist regarding the present dust emission limit values for small-scale combustion systems in the IEA Bioenergy Task32 member countries (from no limits up to quite strict regulations).
- There are no dedicated PM_1 emission limit values existing for biomass fired combustion systems in the IEA Bioenergy Task32 member countries.
- Stricter emission limits accelerate the technological development and the market introduction of particle precipitation devices.

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Background – dust emission measurements (I)

- There is no common international approach regarding PM emission measurements (usually gravimetric methods).
- A common European method to determine PM emissions has started within CEN (standardisation groups CEN/TC 57 and CEN/TC 295) during the last years, but no European Technical Specification or European standard has been achieved so far.
- Moreover, also for the determination of dust precipitation efficiencies of filters no common international approach exists so far. However, a standard test method for determining the collecting efficiency of a particle precipitator is currently being elaborated in Germany within VDI Guideline 33999.

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Background – dust emission measurements (II)

General aspects regarding measurements at ESP units

- The influence of charged particles on particle losses in sampling lines is not fully understood yet
  → more investigations are needed
- Filters at chimney top cannot be evaluated in the field concerning precipitation efficiency.
  → appropriate test stand tests are needed.
- At test stand measurements the field operation conditions of a specific filter have to be considered:
  - Position of the filter
    (directly coupled to the stove/boiler vs. chimney top)
    → position has strong influence on flue gas temperature and organic aerosol formation
  - Temperature history between filter inlet/outlet
    (due to possible condensation of gaseous organic species)
  - Parallel measurements before and after filter

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Results of technologies evaluated – electrostatic precipitators (I)

- The ESP technology seems to be the most promising technological approach. Up to now a few number of ESPs for residential biomass combustion systems have been introduced into the market and some ESPs can be expected to enter the market soon.

- Mean total dust precipitation efficiencies of 50 to 90% can be achieved. The particle precipitation efficiency strongly depends on the fuel utilised and the combustion technology (old/new system).

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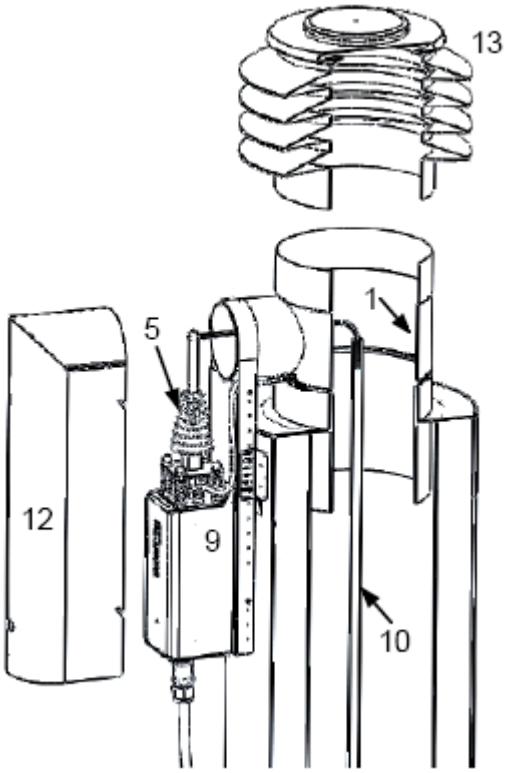
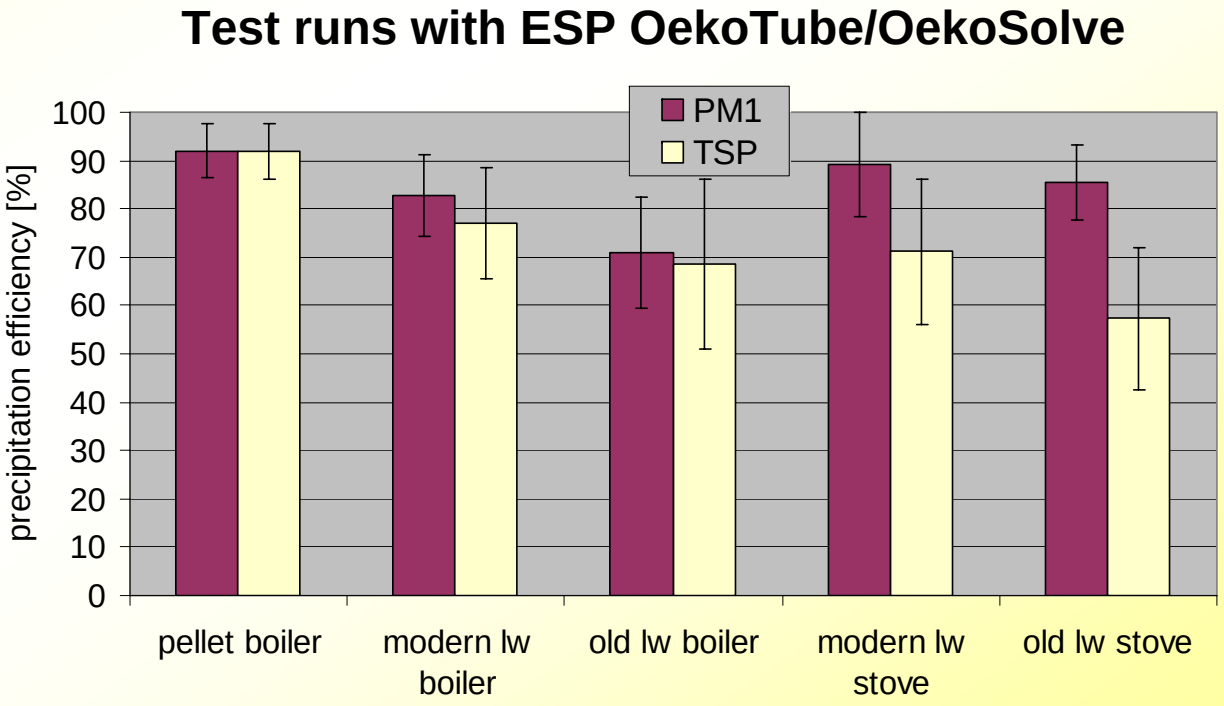
Results of technologies evaluated – electrostatic precipitators (II)



1 ... metal tube
5 ... insulator
9 ... electronic circuit
10 ... electrode
12 ... ESP cover
13 ... chimney hood
source: http://www.oekotube.ch/, 2010

➢ Influence of different biomass combustion systems on the precipitation efficiency



Explanations: Test runs performed with ESP Oekotube with a modern pellet boiler (21 kW), an old and a modern logwood boiler (20 kW) and an old and a modern logwood stove (8 kW); lw … logwood

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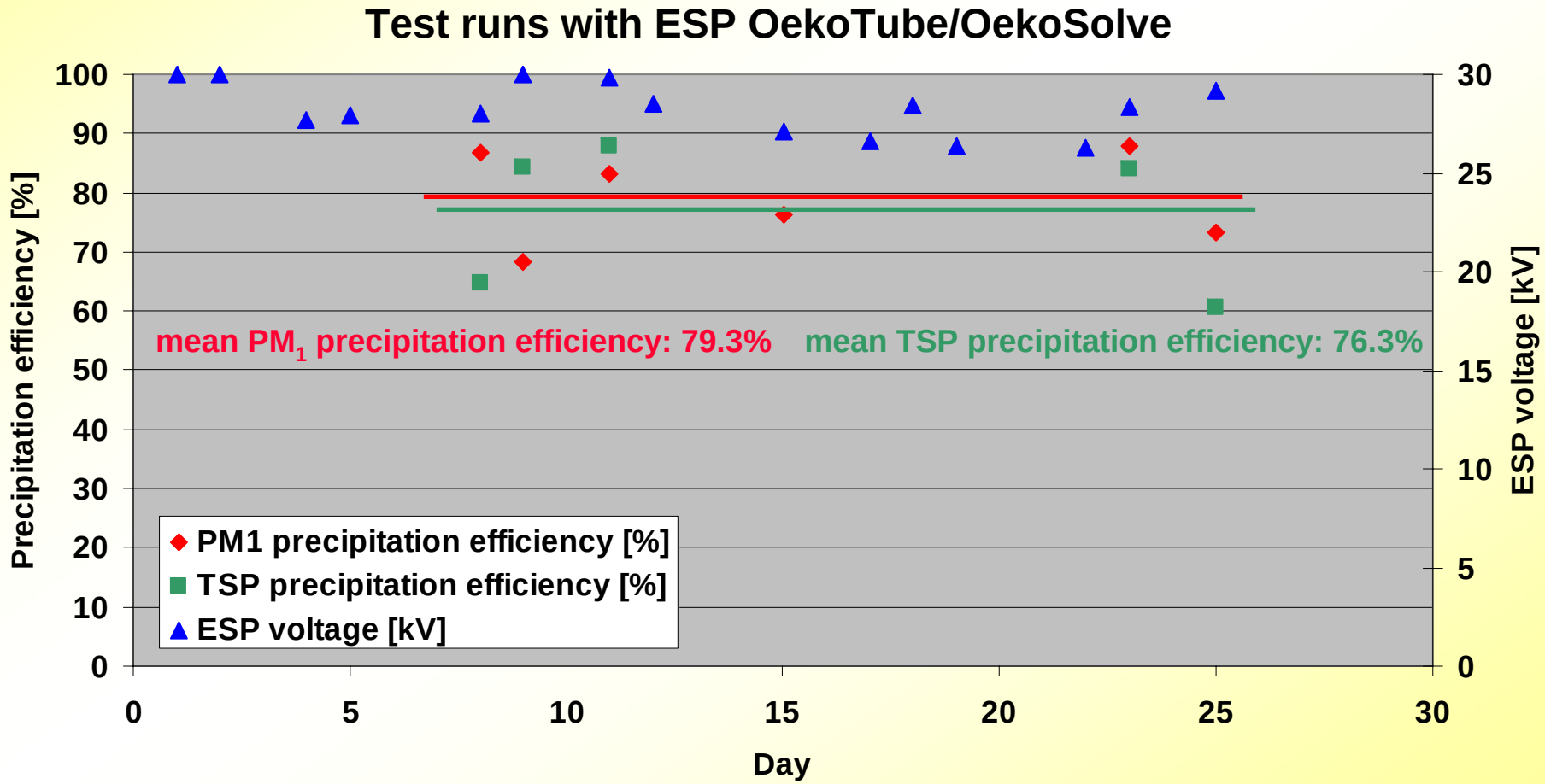
Results of technologies evaluated – electrostatic precipitators (III)

➢ Influence of the duration of operation time on the performance of the filter (pre-evaluation of availability)



Explanations: Test runs performed with ESP Oekotube with a modern logwood boiler (20 kW) under poor combustion conditions

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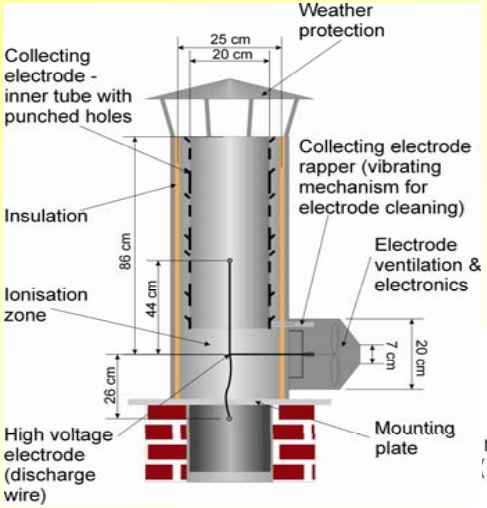
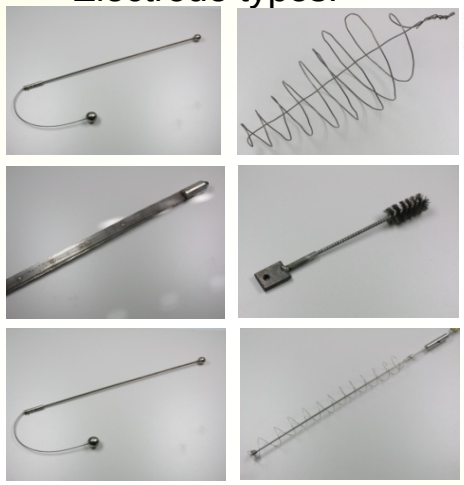
Results of technologies evaluated – electrostatic precipitators (IV)

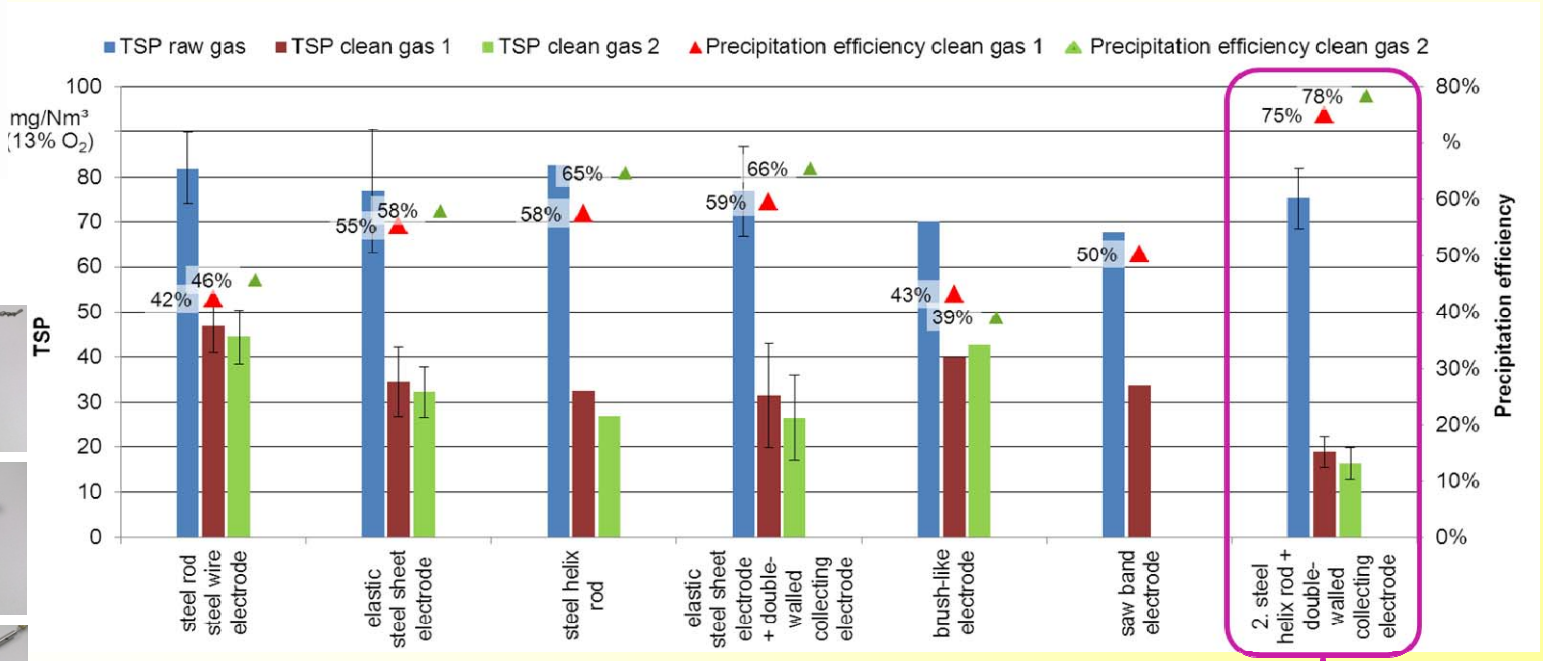


- **Relevant influencing parameters on the precipitation efficiency:**
  - Highest voltage and long electrodes achieved the best precipitation results

Electrode types:



Test runs with ESP RuffKat/Ruff Tech



22 kV

Explanations: Operation conditions: 15 kW, 14 kV; source: TFZ Straubing

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Results of technologies evaluated – electrostatic precipitators (V)

- **The ESP is installed in the flue gas pipe between furnace and chimney (left) or is mounted on top of the chimney (right).**

ESP CAROLA/Karlsruhe Institute of Technology (Germany)

ESP OekoTube/OekoSolve (Liechtenstein)

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Results of technologies evaluated – electrostatic precipitators (VI)

- Power consumption of ESPs: 10 to 100 W (mostly 10-30 W);
- Investment costs of ESPs: 1000 to 3000 €, excl. VAT (mostly 1,200-1,500 €)
- The national and technical safety standards have to be fulfilled (e.g. temperature resistance, lightning protection,...)
- Performance evaluation over longer periods relevant in order to be able to evaluate weak points and maintenance aspects
- An efficient and periodic cleaning of the ESP is of relevance - is done automatically (brush, vibration) or manually (e.g. by the chimney sweep)
- Furthermore, an approved control and monitoring system for the ESP is needed.

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Results of technologies evaluated – electrostatic precipitators (VI)

- Sufficient data concerning the applicability and availability of the devices investigated, especially regarding old systems, are in many cases not available.

- Ongoing and future projects are focusing on these issues as they will be crucial for a broad market introduction of a specific technology.

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Results of technologies evaluated – ceramic filters and catalytic converters

- Up to now no promising results have been achieved with catalytic converters for wood boilers and stoves. Due to the high flue gas temperatures required for catalytic oxidation, these devices are typically not available during start-up where typically the highest emissions occur.
- Catalytic converters should preferable be installed in the post-combustion chamber, where temperatures are sufficiently high to burn absorbed carbonaceous particles.
- In general, no information regarding deactivation of catalysts and the cleaning procedure of the converter are available.
- The tested ceramic filters are installed in the upper part of the combustion chamber of chimney stoves. Thus, an evaluation of the filter itself is not possible. Comparisons with TSP emissions of other modern high technology stoves show no relevant differences regarding TSP emissions. Therefore, the precipitation efficiency seems not to be very high.
- The pressure drop of a ceramic filter or catalytic converter may negatively influence the combustion behaviour of natural draft systems.

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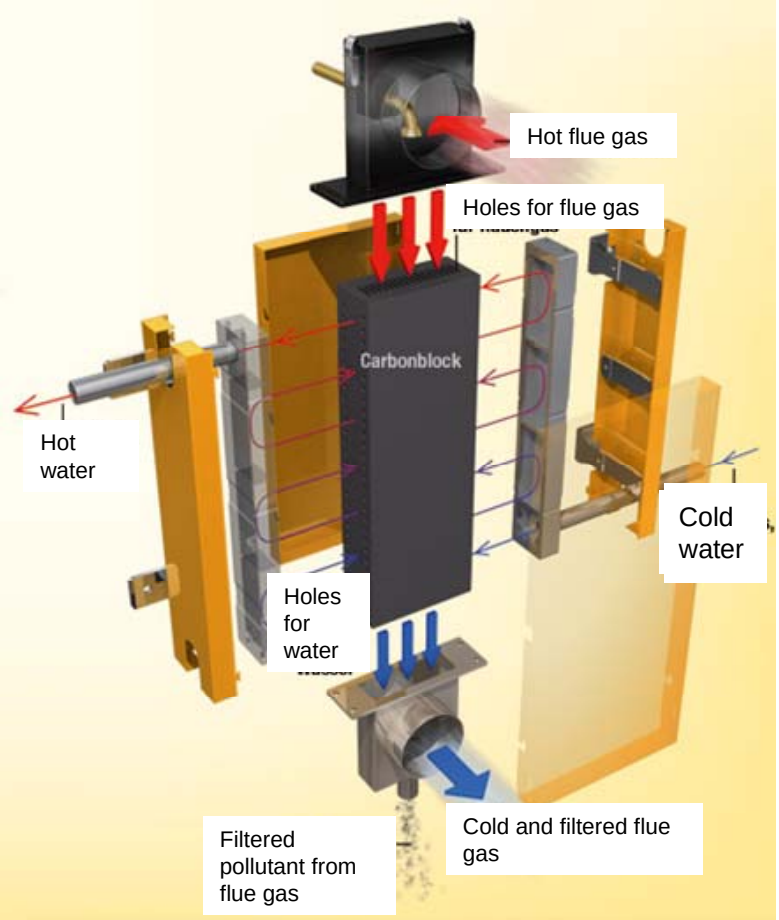
Results of technologies evaluated – condensing heat exchangers

- The precipitation efficiency of conventional condensing heat exchangers (Öko-Carbonizer (Germany), ÖkoFEN (Austria)) is rather low (typically 10-20%).
- The main application of these systems is to increase the thermal efficiency of the boiler rather than to reduce particulate emissions.
- A specially developed high temperature condensing heat exchanger (UEF/Finland) can achieve higher particle precipitation efficiencies. This technology is still in the R&D phase.



Öko-Carbonizer - Bschor (Germany)

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Conclusions and recommendations (I)

- In general particle precipitation devices are secondary measures and therefore could especially be attractive for old systems which show the highest particulate emissions.
- But these systems also show the most difficult framework conditions in terms of PM load, burnout quality of the particles and stickiness of particles.
- Therefore, the applicability of filters for old systems where really great particle reduction potentials are given should be a special focus of future work.
- A second possible application for filters are stoves as the burnout quality of batch combustion systems with natural draft is not as good as of continuously operated systems. For stove filters which are directly implemented in the chimney or on top of the chimney are of special interest.

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Conclusions and recommendations (II)

- The ESP technology seems to be the most promising technological approach for residential biomass combustion systems.
- For modern biomass boilers the main focus should be on the reduction of particulate emissions by primary measures.
- There is no common international approach regarding PM emission measurements and a common European method for the determination of filter efficiencies available so far is urgently needed.
- In order to really introduce new residential filters in the market, the filters must be well tested and reliable. Furthermore, the filters must operate automatically over a whole heating period and must work efficiently.
- Besides the technological requirements, which still have to be proven for most applications, also legal and financial incentives will be needed to really achieve an effective market introduction.

Thanks for your attention!

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