State-of-the-art of small-scale biomass combustion with respect to fine particulate emissions
Country report from Austria

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Contents

- Residential heating systems in Austria
- The Austrian state-of-the-art of biomass based residential heating systems
- Emissions from residential biomass heating systems
- Conclusions and recommendations

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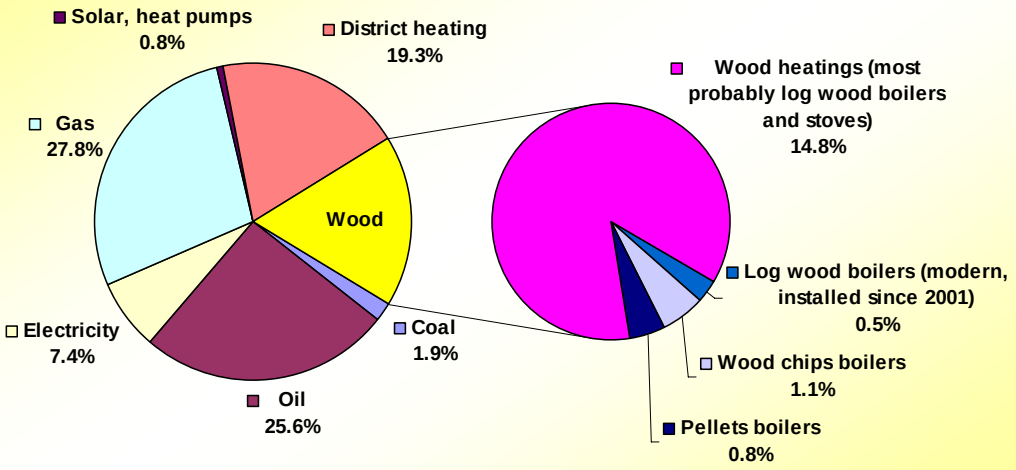
Main heating systems in Austrian households in 2004



Total number of households: 3.4 million (2004)

Sources: Statistik Austria, 2007

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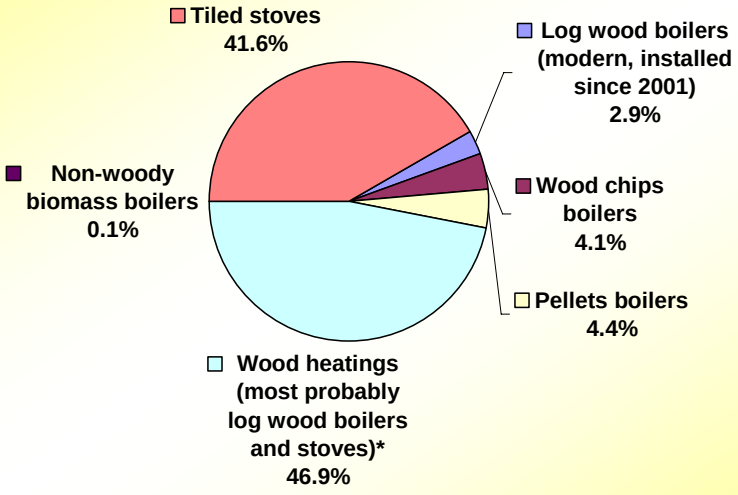
Main and secondary heating systems based on solid biomass in Austria in 2006



Total number: 1.08 million (2006)

Sources: Statistik Austria, 2007; Haneder et al., 2007

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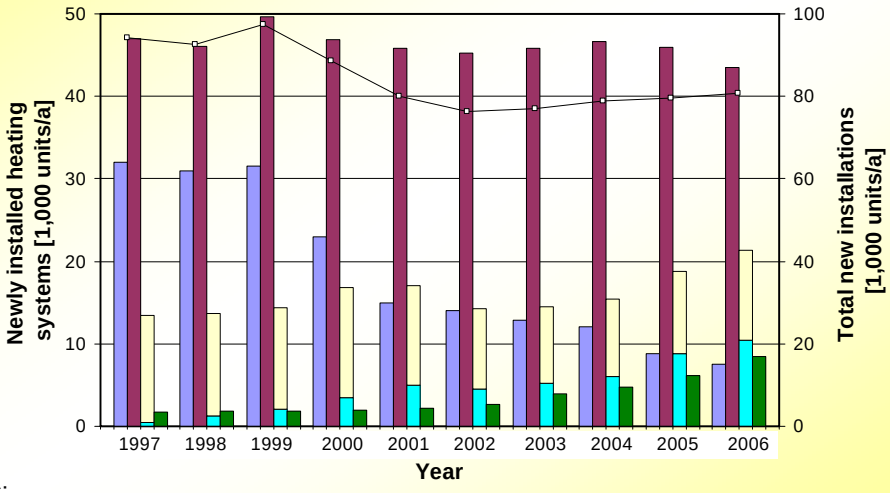
Annual installations of central heating systems in Austria



Sources:
Regionalenergie Steiermark, 2007

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Biomass based residential heating technologies – overview and classification

- **Biomass fuels**
  - **Wood fuels**
    - **Manually fed systems**
      - **Stoves**
        - logwood
        - briquettes
      - **Boilers**
        - logwood
        - briquettes
      - **Tiled stoves**
        - logwood
        - briquettes
    - **Automatically fed systems**
      - **Tiled stoves**
        - pellets
      - **Stoves**
        - pellets
      - **Boilers**
        - pellets
        - wood chips
  - **Non-wood fuels**
    - **Automatically fed systems**
      - **Boilers**
        - straw pellets
        - corn
        - miscanthus

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Tiled stoves

- Manually fed (logwood, briquettes) and automatically fed (pellets)
- Usually in batch operation and especially suitable for cold climates with slow temperature changes
- Constructed of pre-fabricated heavy stone plates or purely of stones according to defined guidelines
- During combustion the heat generated is stored in the stove and after the fire is extinguished, the heat is released to the surrounding during a considerable period of time (usually about 12 hrs)
- Flat bottom (no grate)
- To be de-ashed with shovels
- No air staging
- Capacity range: usually 10 to 15 kW

Source: ÖKV, 2007

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Stoves

- Manually fed (logwood, briquettes) and automatically fed (pellets)
- Simple design
- Firebox walls typically lined with chamotte or fire resistant material
- Sometimes removable iron grates are inserted, and an ash box is placed below the grate
- Release of useful heat by radiation and/or convection to surroundings
- Combustion air is normally supplied as primary and secondary air and is controlled by usually manually and sometimes automatically driven valves
- Capacity range: usually between 7 and 12 kW

Source: Rika, 2007

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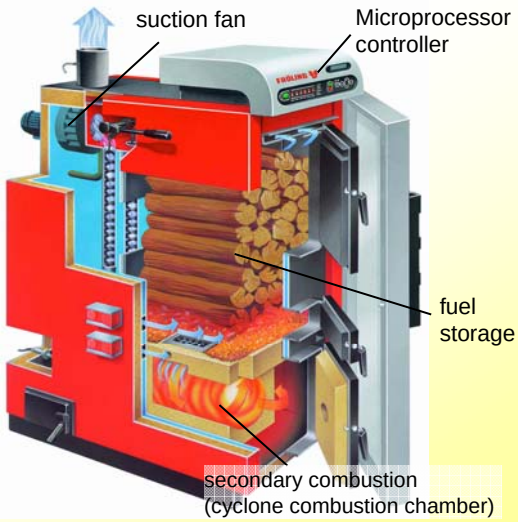
Logwood boilers

- Manually fed
- Types
  - over-fire boilers
  - downdraft boilers
- Over-fire boilers
  - simple and cheap
  - but normally high emissions of unburned hydrocarbons (especially at partial load operation)
- Downdraft boilers
  - more stable combustion than in over-fire boilers
  - air staging (primary and secondary combustion zone with separate air feed)
- Capacity range: usually 15 to 70 kW



Downdraft logwood boiler

Source: Fröhling (A)

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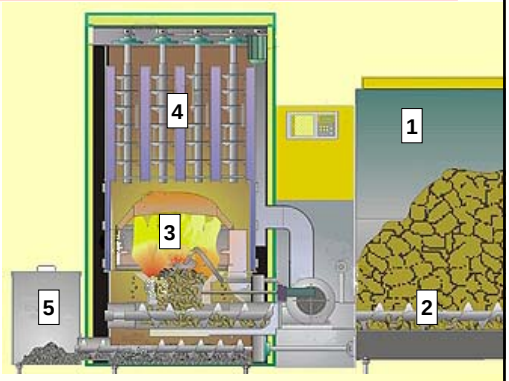
Wood chip boilers

- Proven automatic fuel feeding with burn-back protection
- Fully automatic operation (only ash box emptying needed)
- Micro-processor controlled (load and combustion control)
- Typically vertical fire tube boilers with automatic or semi-automatic boiler cleaning
- Application in domestic heating and micro grids as well as larger buildings (schools, hotels, etc.)
- Air staging (primary and secondary combustion zone with separate air feed)
- Capacity range: usually 15 to 500 kW



1… storage container
2… feeding screw
3… combustion chamber with radiation plate
4… heat exchanger with turbolators and cleaning system
5… ash container

Source: KWB (A)

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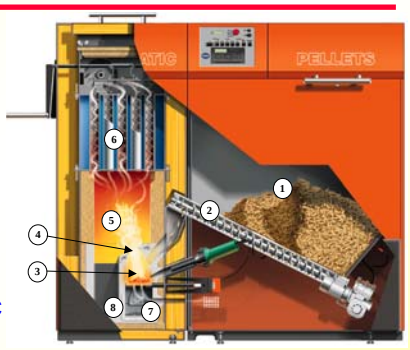
Pellet boilers

- Automatic fuel feeding (flexible or inflexible screw conveyors, pneumatic systems, agitators or combinations) with burn-back protection
- Fully automatic operation (only ash box emptying once or twice a year)
- Micro-processor controlled (automated load and combustion control)
- Typically vertical fire tube boilers with automatic or semi-automatic boiler cleaning
- Pellet boilers with flue gas condensation units already available
- Air staging (primary and secondary combustion zone with separate air feed)
- Capacity range: 8 to 300 kW (usual capacities in Austria)



1 …. fuel container
2 …. stoker screw
3 …. primary combustion chamber
4 …. secondary air addition
5 …. secondary combustion chamber
6 …. heat exchanger with cleaning device
7 …. bottom ash container
8 …. fly ash container

Source: Guntamatic (A)

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Current state-of-the-art – measures for technology improvement and emission reduction

- **During recent years permanent R&D have significantly improved the performance and user friendliness of small-scale combustion technologies**
- **Improvements were realised by the optimisation of:**
  - **air staging**
  - **burner design**
  - **furnace design**
  - **control systems**
  - **reduction of auxiliary energy**
- **Increasing activities to support new furnace designs by CFD (computational fluid dynamics) simulations**

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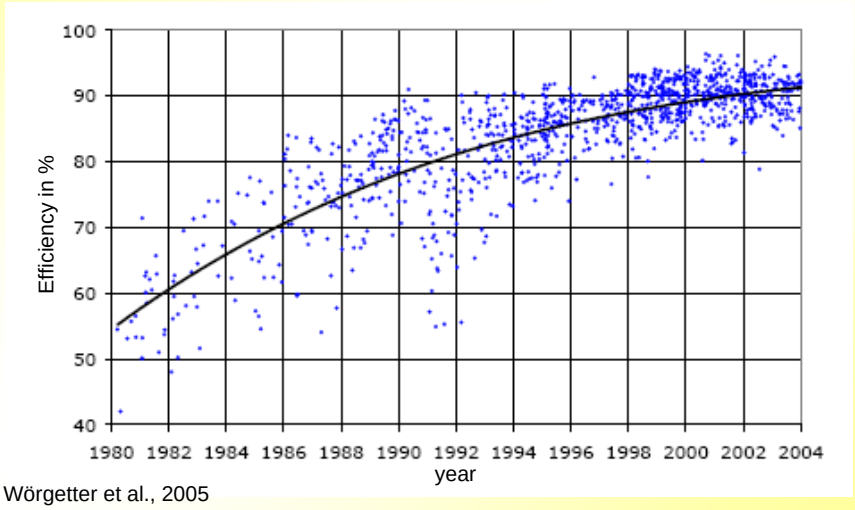
Improvement of small-scale combustion systems with respect to efficiencies (example)

Modern log wood boilers achieve efficiencies of more than 90% (compared to approximately 55% in the early 1980´s)



Source: Wörgetter et al., 2005

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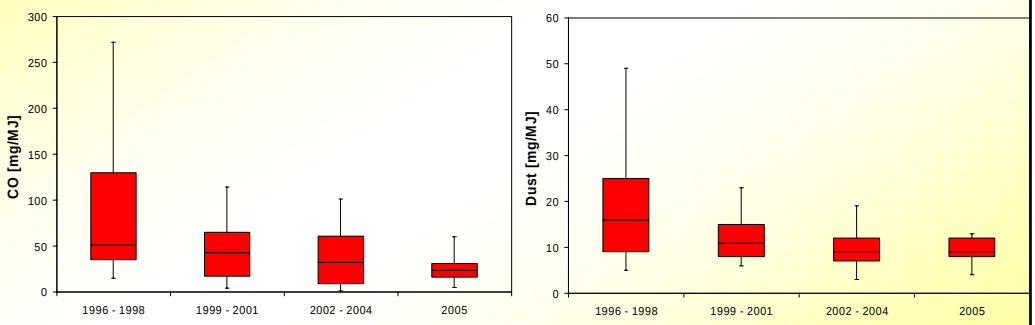
Improvement of small-scale combustion systems with respect to emissions (example)

CO and total dust emissions - comparison between old and new pellet furnaces



Sources: Jungmeier et al., 1999; BLT Wieselburg, 2006, results from test stand measurements

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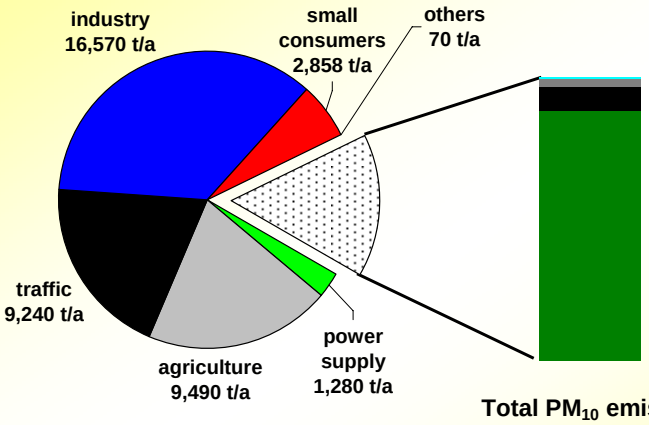
PM_{10} emission sources in Austria (2004)



small consumers residential heating

natural gas	33 t/a
fuel oil	215 t/a
coal	595 t/a
wood	6,369 t/a
total	7,212 t/a

Total PM_{10} emissions: 46,720 t/a

Contribution of residential heating: 15.4%

Contribution of biomass based residential heating: 13.6%

Sources: Statistik Austria, 2007

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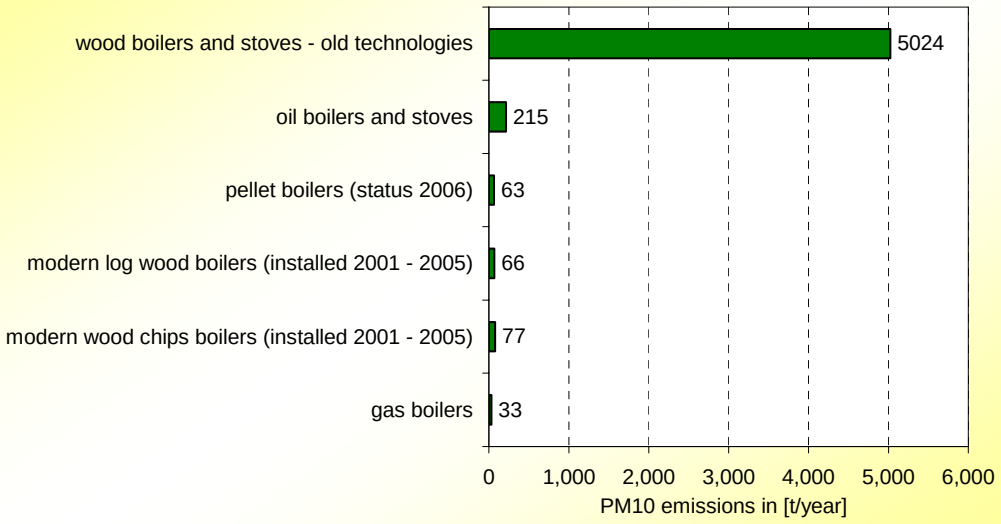
PM_{10} emissions from residential heating systems in Austria



Source: Schwarz, 2007

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PM emission factors for old residential heating systems

Actually applied emission factors for small-scale combustion units in Austria – total dust

combustion unit	fuel	emission factor dust [mg/MJ]
stove [1)]	wood	148
stove [1)]	coal	153
stove [2)]	fuel oil extra light	< 0.5
boiler [1)]	wood	90
boiler [1)]	coal	94
boiler [2)]	fuel oil extra light	< 0.5
boiler [2)]	fuel oil light	2

Explanations: 1) related to small-scale combustion plants existing in Austria in 1997/98
2) related to small-scale combustion plants existing in Austria in 1993-1995

Source: Umweltbundesamt, 2004

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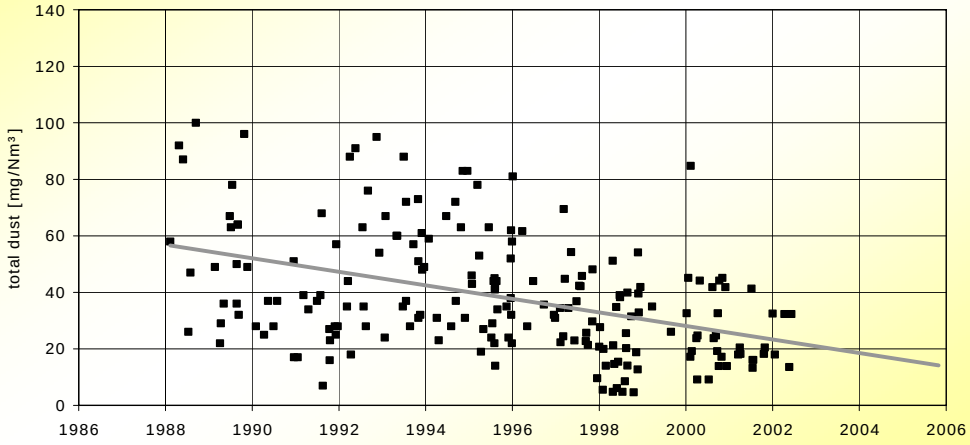
Technological improvement of residential heating systems during the last 2 decades (I)

Total dust emissions of wood chips boilers – test stand measurements (type tests) between 1988 and 2005



Explanations: concentrations in mg/Nm³ related to dry flue gas and 13% O2
Sources: [Wörgetter et al., 2005]

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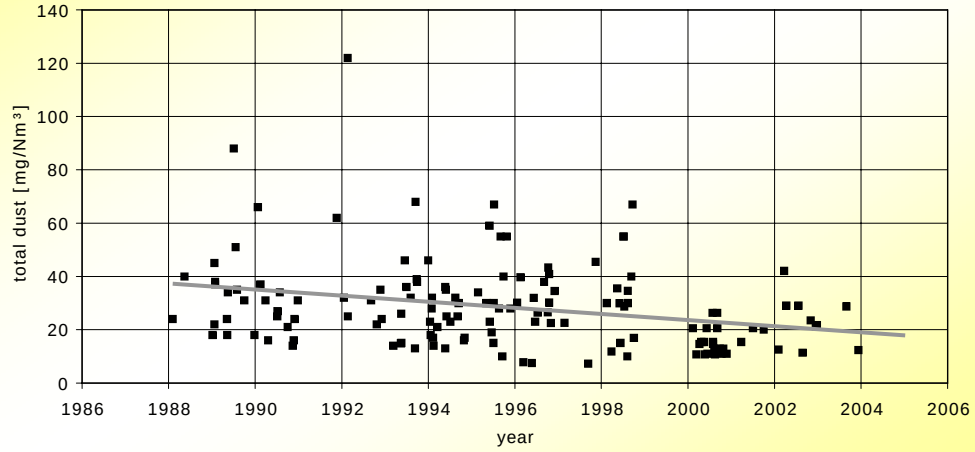
Technological improvement of residential heating systems during the last 2 decades (II)

Total dust emissions of log wood boilers – test stand measurements (type tests) between 1988 and 2005



Explanations: concentrations in mg/Nm³ related to dry flue gas and 13% O2

Sources: [Wörgetter et al., 2005]

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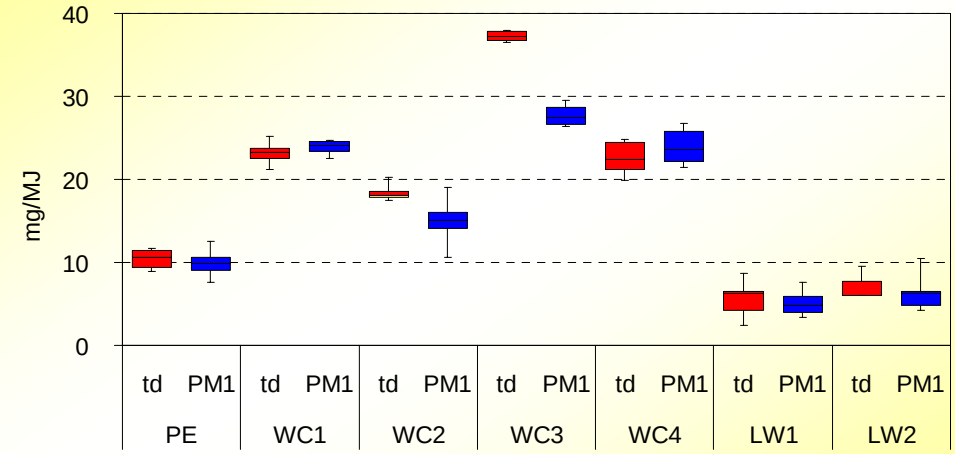
Modern small-scale biomass boilers – total dust and PM_1 emissions at full load operation



Explanations: td … total dust; Pe … pellet furnace; WC … wood chip furnace; LW … log wood furnace; results from measurements performed with a total dust sampling equipment (dust) as well as a Berner-type low-pressure impactor (PM_1)

Source: Obernberger et al., 2007

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PM-emissions from state-of-the-art small-scale biomass combustion systems

- Average total dust emissions during stable full and partial load operation (related to dry flue gas and 13 vol% O_2):
  - log wood boilers: < 6.7 mg/MJ (10 mg/Nm³)
  - pellet boilers: < 13.3 mg/MJ (20 mg/Nm³)
  - wood chip boilers: < 33.3 mg/MJ (60 mg/Nm³)
  - tiled stoves: < 53.6 mg/MJ (83 mg/Nm³)
- Usually, more than 90% of the total dust emissions are related to PM10.
- Considering all relevant operation modes including start-up, load changes and shut down the following PM_{10} emission factors can be recommended for modern residential biomass heating systems
  - log wood boilers: 20 mg/MJ
  - pellet boilers: 20 mg/MJ (if softwood pellets are applied)
  - wood chip boilers: 20-50 mg/MJ (depending on the K-content of the fuel)

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Conclusions and recommendations (I)

- In Austria 17.2% of the main heating systems (about 580.000 systems) are based on biomass combustion.
- In total (main and secondary heating systems) about 1.08 million small-scale biomass combustion appliances are installed.
- Logwood combustion in tiled stoves, stoves and boilers holds a share of approximately 88.5% of all biomass based heating systems. Old systems are thereby dominating.
- During the last decade about 15,000 to 22,000 new small-scale biomass heating plants have been installed per year.
- There is a broad variety of different modern boilers and stoves for logwood, pellets and wood chips combustion available in Austria.
- The technological performance of these systems has steadily strongly been improved during the last decades.

Conclusions and recommendations (II)

- Residential heating contributes with approximately 15.4% to the PM_{10} emissions in Austria (status: 2004).
- Biomass combustion is the main PM_{10} source of the residential heating sector (88% of the PM_{10} emissions).
- This is mainly due to the high number of old systems in operation.
- While old biomass boilers and stoves show PM_{10} emission factors of 90 mg/MJ respectively 148 mg/MJ, the emission factors for state-of-the-art automated systems are in the range of 20 to 50 mg/MJ.
- Therefore, it must be recommended to support the substitution of old biomass combustion systems by modern automated systems in order to considerably reduce PM_{10} emissions from residential heating in a CO_2-neutral and sustainable way.

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Conclusions and recommendations (III)

- The further technological development of small-scale biomass boilers aims at “zero emissions systems” (<5 mg/MJ PM_{10}) to be achieved by appropriate primary and secondary measures.
- The combustion of agricultural biomass fuels in small-scale biomass combustion systems is not recommended due to considerably larger fine particulate emissions.

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Acknowledgement

BIOMASS - PM Project

ERA-NET Bioenergy project Biomass-PM
Clean biomass combustion in residential heating
particulate measurements, sampling, and physicochemical and toxicological characterisation

FFG

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