

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

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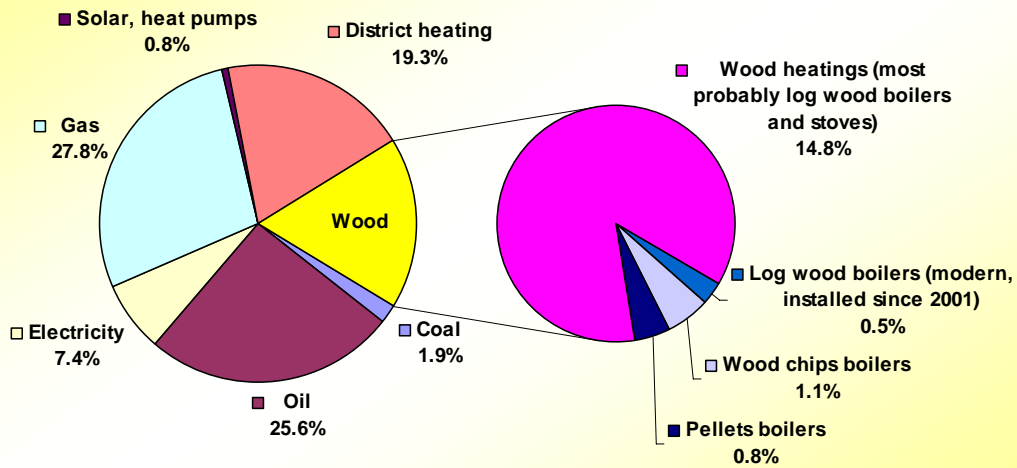
## Contents

- 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)

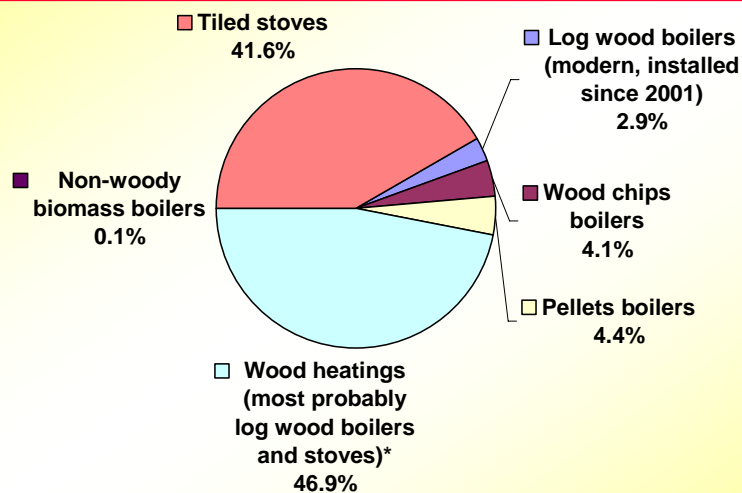
Sources: Statistik Austria, 2007

3



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



Total number: 1.08 million (2006)

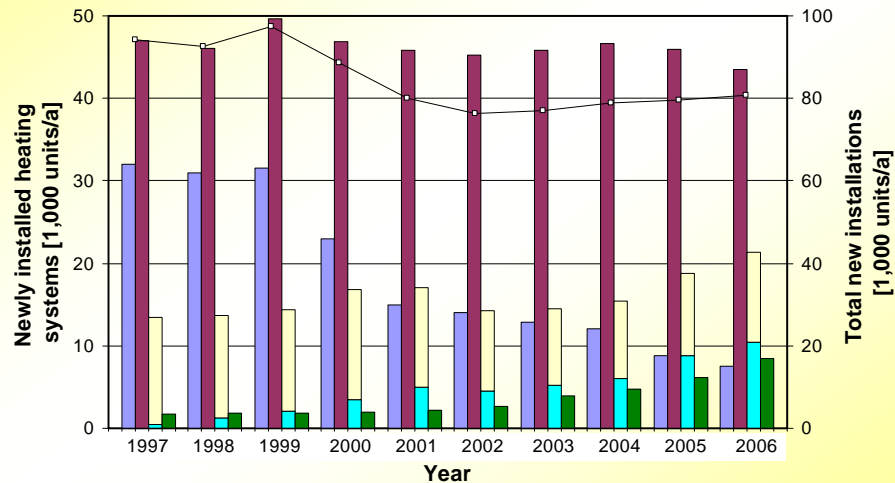
Sources: Statistik Austria, 2007; Haneder et al., 2007

4



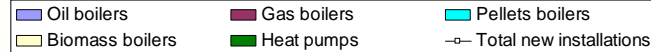
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## Annual installations of central heating systems in Austria



Sources:

Regionalenergie  
Steiermark, 2007

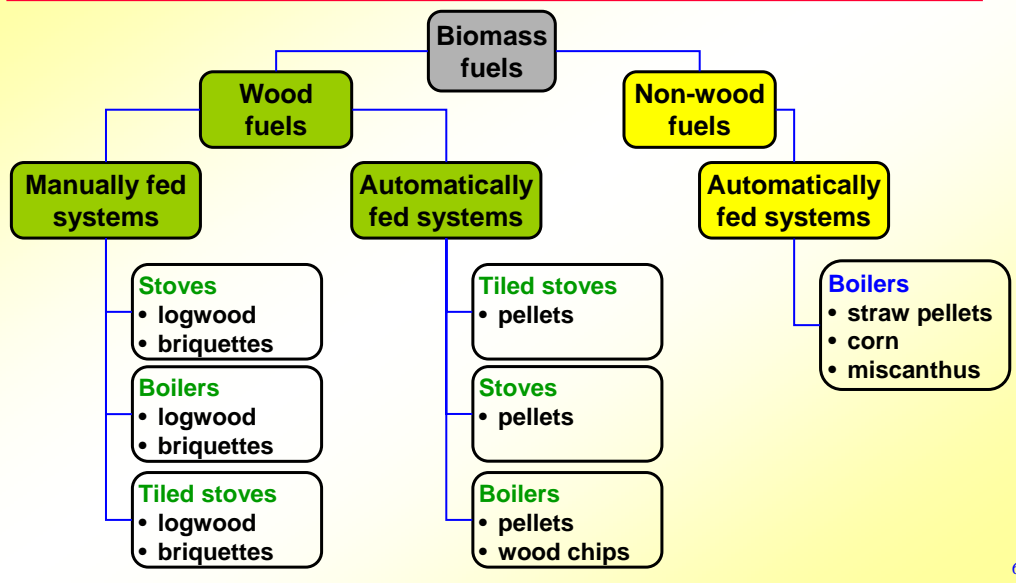


5



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## Biomass based residential heating technologies – overview and classification



6



## 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

7



## 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

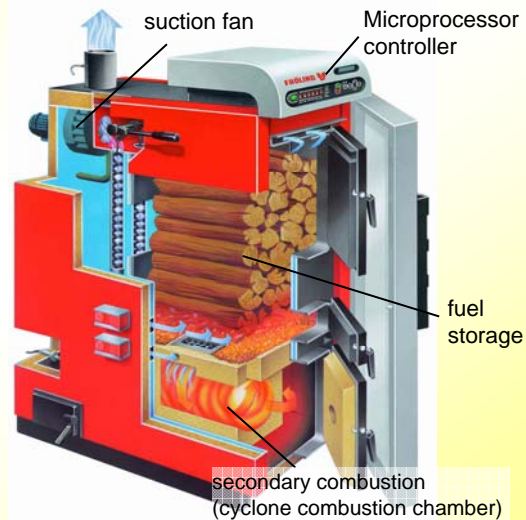
8



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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)

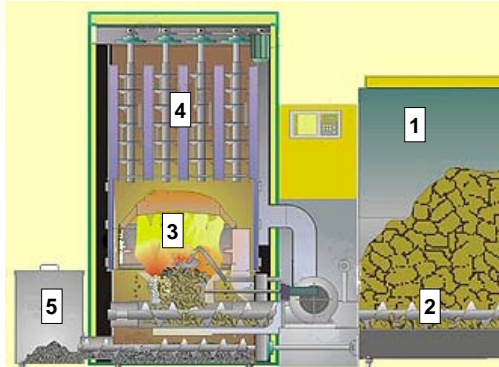
9



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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



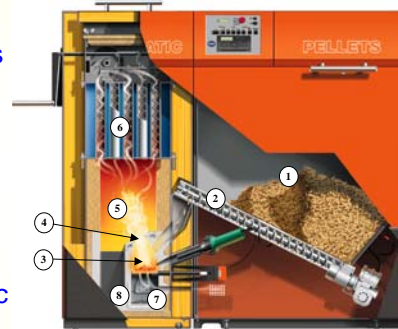
- 1... storage container
- 2... feeding screw
- 3... combustion chamber with radiation plate
- 4... heat exchanger with turbulators and cleaning system
- 5... ash container

Source: KWB (A)

10

## 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)

11

## Current state-of-the-art – measures for technology improve- ment 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

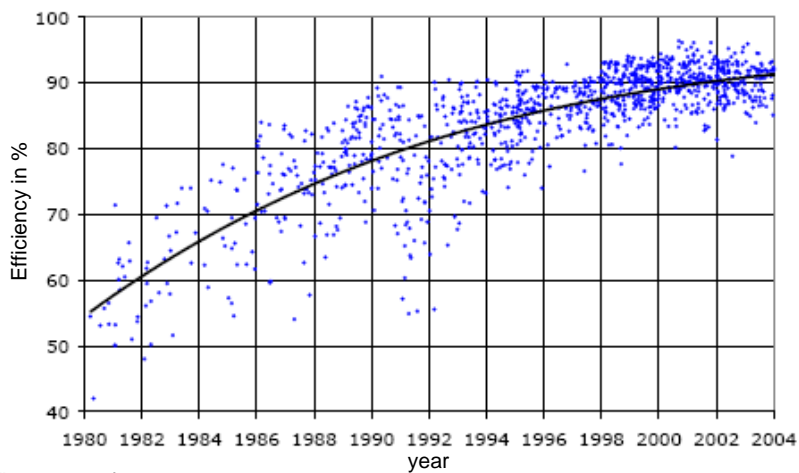
12



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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

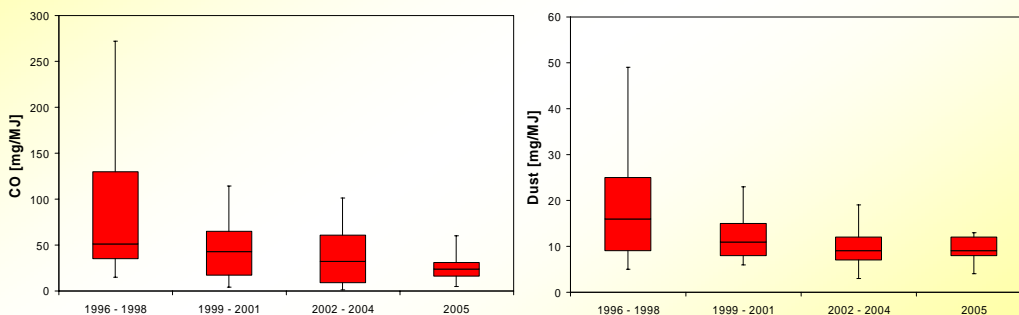
13



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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



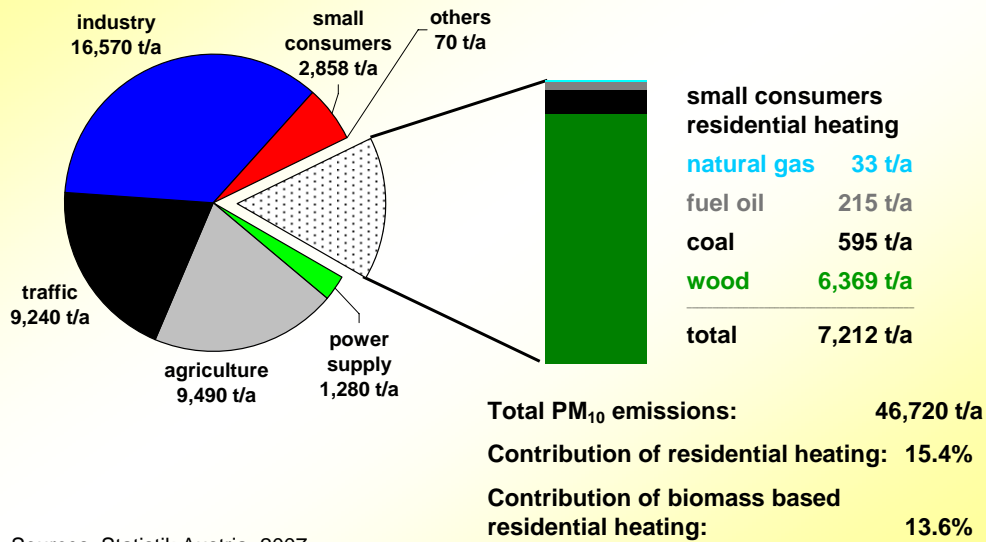
Sources: Jungmeier et al., 1999; BLT Wieselburg, 2006, results from test stand measurements

14



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## PM<sub>10</sub> emission sources in Austria (2004)

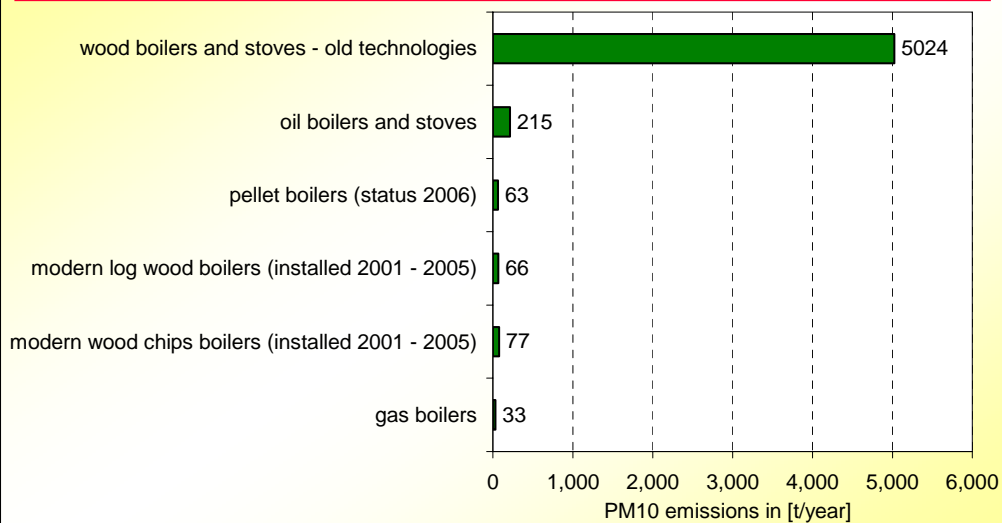


15



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## PM<sub>10</sub> emissions from residential heating systems in Austria



Source: Schwarz, 2007

16



## 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 <sup>1)</sup>	wood	148
stove <sup>1)</sup>	coal	153
stove <sup>2)</sup>	fuel oil extra light	< 0.5
boiler <sup>1)</sup>	wood	90
boiler <sup>1)</sup>	coal	94
boiler <sup>2)</sup>	fuel oil extra light	< 0.5
boiler <sup>2)</sup>	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

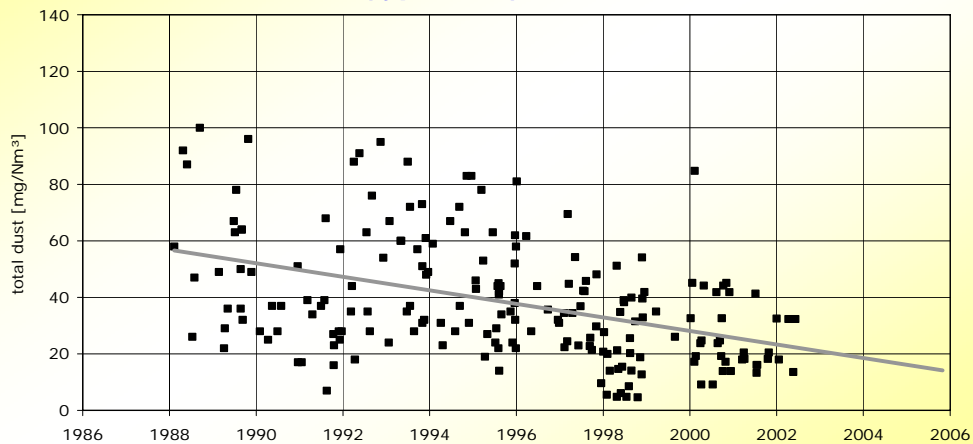
Source: Umweltbundesamt, 2004

17



## 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/Nm<sup>3</sup> related to dry flue gas and 13% O<sub>2</sub>

Sources: [Wörgetter et al., 2005]

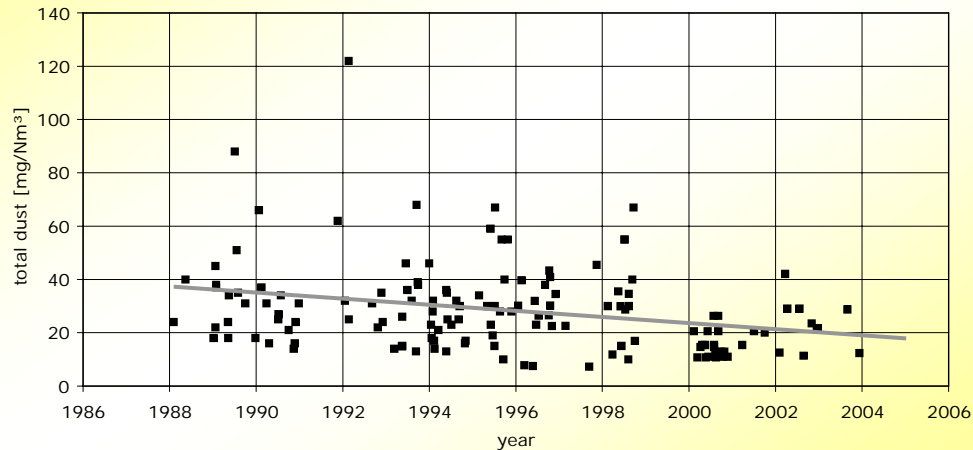
18



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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/Nm<sup>3</sup> related to dry flue gas and 13% O<sub>2</sub>

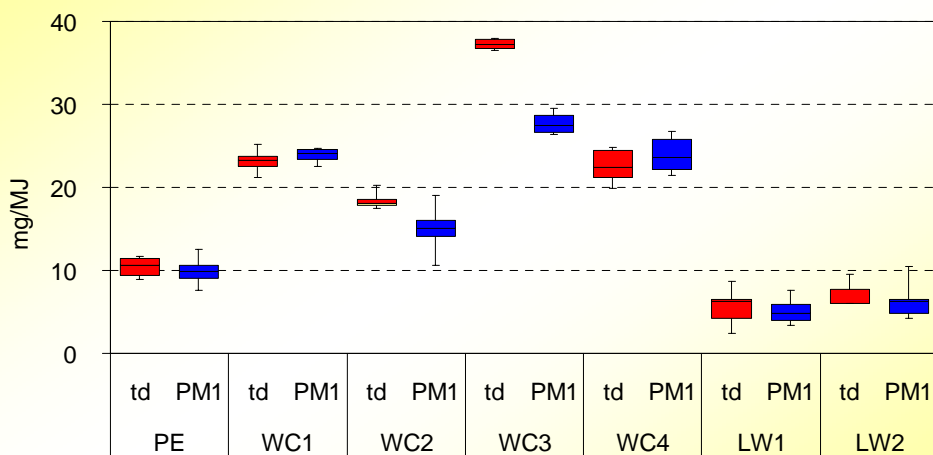
Sources: [Wörgetter et al., 2005]

19



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## Modern small-scale biomass boilers – total dust and PM<sub>1</sub> 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<sub>1</sub>)

Source: Obernberger et al., 2007

20



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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<sub>2</sub>):**
  - log wood boilers: < 6.7 mg/MJ (10 mg/Nm<sup>3</sup>)
  - pellet boilers: < 13.3 mg/MJ (20 mg/Nm<sup>3</sup>)
  - wood chip boilers: < 33.3 mg/MJ (60 mg/Nm<sup>3</sup>)
  - tiled stoves: < 53.6 mg/MJ (83 mg/Nm<sup>3</sup>)
  
- **Usually, more than 90% of the total dust emissions are related to PM<sub>10</sub>.**
  
- **Considering all relevant operation modes including start-up, load changes and shut down the following PM<sub>10</sub> 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)

21



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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.**

22



## 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.

23



## 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.

24



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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



## Energiesysteme der Zukunft

eine Initiative des Bundesministeriums für Verkehr, Innovation und Technologie (BMVIT)

25



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**Thank you for your attention**

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26