Technology development of boilers for domestic heating with wood fuels – implications for dust emissions and their toxicological relevance

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Abstract

Considerable amounts of wood are used throughout Europe for domestic heating purposes. The combustion of wood in typical conventional stoves and boilers causes significant amounts of dust, hydrocarbons and carbon monoxide.

Systematic improvements of combustion technologies during the last two decades have led to a dramatic reduction of emissions. CO emissions of state of the art wood boiler technology are three orders of magnitude lower than of conventional logwood stoves or boilers. Emissions of unburned hydrocarbons have been reduced by more than two orders of magnitude and are generally below the detection limits of measuring equipment. Dust emissions of modern wood boilers – particularly of pellet boilers offer a dust reduction of 92 – 98 % compared to conventional wood combustion.

The paper describes the steps of technical development that have led to the massive reduction of emissions of modern wood combustion technology. It gives a brief overview of market development and market penetration of these technologies. Due to the technologies applied in modern wood boilers and pellet stoves not only dust quantities but also dust qualities have changed considerably. Typical chemical composition of dust from electronically controlled state of the art wood combustion contains less then 1 % of soot. The main components of fine dust emissions are KCl, K_2SO_4 and $CaCO_3$. Consequently the toxicological evaluation of dusts from modern wood combustion devices differs significantly from fine dusts for example from diesel engines or conventional wood combustion. Recent toxicological tests have demonstrated this difference.

The paper concludes, that the accelerated replacement of outdated wood combustion devices by modern wood combustion technology, particularly pellet boilers and stoves offers significant reductions of dust emissions without compromising other policy targets such as the reduction of greenhouse gas emissions, the increased use of renewable energy and the socioeconomic development of rural areas.

Key words: Wood combustion, pellets, toxicity, policies

The relevance of wood combustion for fine dust emissions

Austria is a country of significant forest resources and wide spread traditional use of fire wood for heating. Fire wood is often used in simple logwood boilers or wood stoves characterised by high emissions of unburned hydrocarbons and dust. As a consequence 13 % of fine dust emissions in Austria are caused by wood combustion in conventional boilers and stoves [1].

The quantification of fine dust emissions of wood boilers and stoves is based on the measurements of field emissions realized by Spitzer et al. [2]. These measurements were carried out in the mid 1990ies – that is before the introduction of modern pellet boilers. The included only conventional logwood boilers with an average age of 20 years. The emission factors determined by Spitzer et.al are as follows:

	NOX kg/TJ	TOC kg/TJ	CO kg/TJ	Dust kg/TJ
Stoves	106 ± 35	664 ± 412	4463 ± 1562	148 ± 68
Boilers	107 ± 29	448 ± 112	4303 ± 775	90 ± 15

Table 1

State of the art wood combustion technology

In Austria research in wood combustion technology started in the early 1980ies, as a consequence of new emission regulations for wood boilers, introduced by the province of Styria. The new regulations required emissions that were significantly lower than achieved by conventional equipment. The new regulations also required the type approval of new wood boilers introduced into the market. Prior to market introduction every new wood boiler had to pass a test in a certified test laboratory to make sure it complied with emission regulations.

Significant public R&D funds were made available to support research to improve wood combustion. Figure 1 shows how the reduction of emissions proceeded through the last two decades. Every dot represents the test value of CO emissions of a newly introduced boiler model – either logwood, wood chip or pellet boiler as measured in the BLT testing laboratory. Within 20 years it was possible to reduce CO emissions by three orders of magnitude for all three types of boilers.

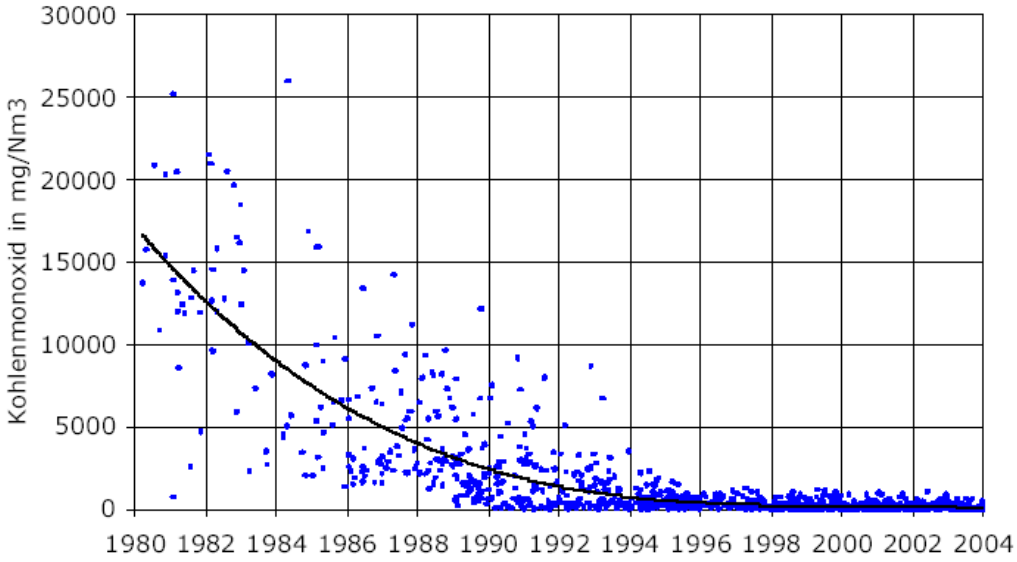

Figure 1

Table 2 shows the average emissions of logwood boilers, wood chip boilers and pellet boilers tested by the certified testing laboratory BLT in Austria. The differences compared to the values of Table 1 are remarkable. Lowest dust emissions are achieved by pellet boilers.

	NO_X kg/TJ	TOC kg/TJ	CO kg/TJ	Dust kg/TJ
Logwood boilers	85	3	65	14
Woodchip boilers	101	< 1	18	18
Pelletboilers	81	< 1	31	11

Table 2

The improvements of emission values evident from figure 1 and table 2 are based on continued and significant R&D efforts over a time period of about 25 years. Modern wood boilers apply a number of technical principles that lead to complete combustion: staged combustion – wood is first gasified and the resulting gases are burned in a separate part of the combustion chamber. This principle leads to slow air flow in the gasification zone which minimises uptake of dust particles. High temperatures, high turbulence and sufficient residence time of flue gases in the oxidation zone of the combustion chamber facilitate complete combustion. Modern wood boilers are equipped with electronic sensors regulating combustion air supply in such a way that complete combustion is achieved and excess air is minimized, in order to achieve high efficiencies. These principles are applied both in state of the art logwood, woodchip and pellet boilers.

In terms of stoves only pellet stoves offer a similar quality of combustion – logwood or chip stoves generally do not achieve comparably low emissions.

Dust emission of pellet boilers in field tests

In 2006 the Austrian Bioenergy Centre conducted a series of emission tests under normal operating conditions in the field. Pellet boilers of different design were measured both in full load and part load operation. The results of these field tests

were that dust emissions did not exceed 13,3 kg/TJ [3]. This means that dust emissions in operation under field conditions did not different significantly from the results at the test stand. This result is related to the fact that electronic controls are constantly optimizing combustion parameters, under field conditions in the same way as under test stand conditions.

Overall dust emissions from domestic combustion of wood fuels in Austria

Figure 3 compares the overall emissions of domestic heating systems in Austria [4]. It is obvious that wood heating systems applying conventional technology contribute significantly to dust emissions. Compared to these the emission of pellet boilers, modern logwood boilers and wood chip boilers are very low. Of course market dissemination of these boilers is still small as current replacement rates are relatively low. Significant market share changes need decades which means that emission reductions due to ongoing technical developments will further reduce fine dust contributions.

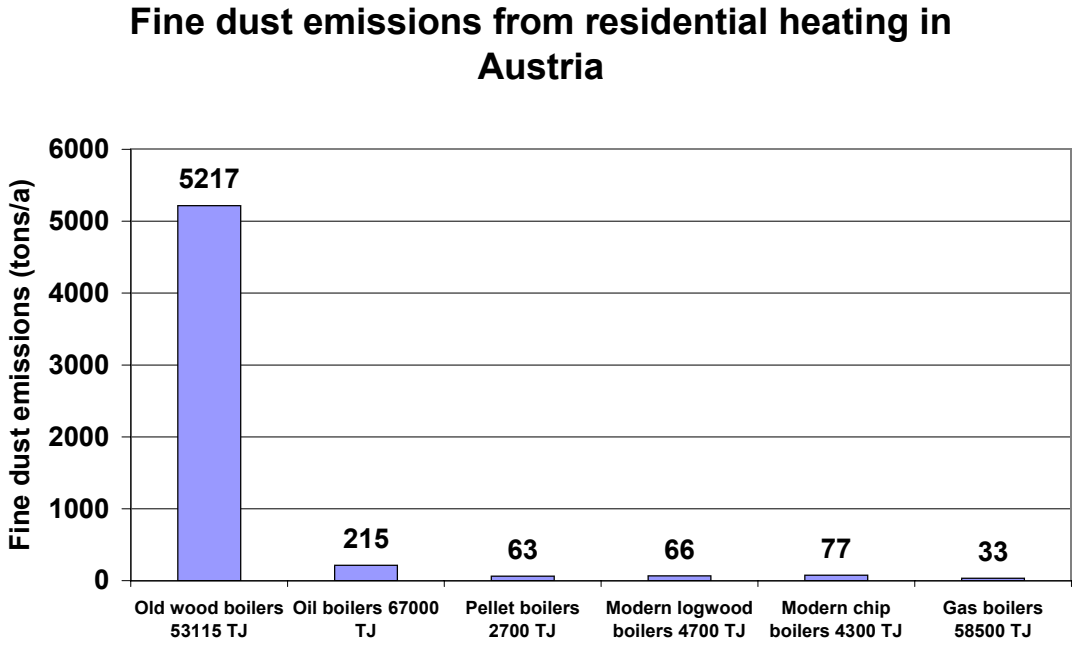

Figure 2

Toxicological evaluation of fine dust emissions from advanced wood combustion technology

Due to the highly developed and electronically controlled combustion technology fine dust emitted by advanced wood boilers contains less than 1 % of soot. Emissions are mostly $CaCO_3$, KCl and K_2SO_4. The later two substances are water soluble. Recent studies have tried to compare the toxicity of emission of fine dust from advanced wood combustion with the toxicity of other fine dust particles such as soot from diesel engines [5]. Figure 3 shows the corresponding test results: the cell survival rate of cells exposed to wood dust was significantly higher than of cells exposed to diesel dust. The authors conclude that the toxicity of diesel dust can be considered to be at least 5 times higher than from wood dust.

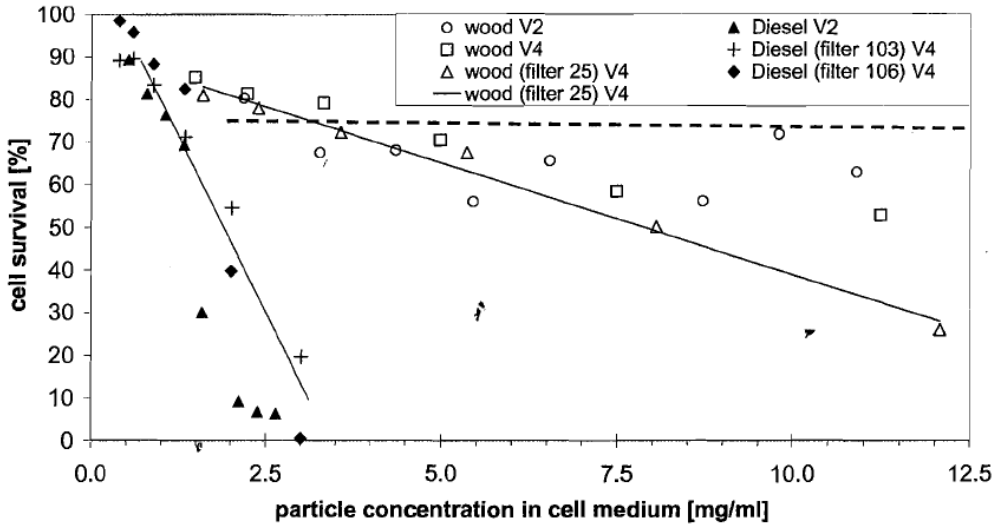

Figure 3

Conclusions

Massive quality differences exist in current European wood boiler and stove markets. State of the art wood boilers are available from Austrian, German, Danish and Swedish companies. Boiler manufactures of most other countries have not realised similar technical improvements. A meaningful policy to reduce dust emissions would be to implement strict requirements for the market introduction of wood boilers forcing producers to improve designs towards best available technologies.

This would not only imply significant emission reductions but also substantial improvements of efficiency, as modern wood boilers achieve efficiencies of over 90% while conventional devices hardly exceed 50 % efficiency.

The utilization of wood fuels in Europe is of considerable interest both for energy policies which are oriented towards reducing the dependence on fossil fuels and of policies to reduce greenhouse gas emissions. It is also of considerable socioeconomic significance as the production and utilisation of wood creates employment in rural areas throughout Europe. By replacing conventional wood heating devices with best available wood combustion technology a massive reduction of fine dust emissions can be achieved without compromising the goals of climate protection, energy policies and the target of socioeconomic development of rural areas.

References

[1] Anderl M.:
Emissionstrends 1990 – 2004 – Ein Überblick über die österreichischen Verursacher von Luftschafstoffen mit Datenstand 2006
Umweltbundesamt, Wien (2006)

[2] Spitzer J.; Enzinger P., Fankhauser G., Fritz W., Gloja F. und Stiglbrunner R.:
Emissionsfaktoren für feste Brennstoffe.

Joanneum Research Report, Graz (1998)

[3].Brunner T., Bärnthaler G., Obernberger I.:
Fine particulate emissions from state of the art pellet furnaces. Proceedings of the Second World Conference on Pellets, Jönköping (2006)

[4] Schwarz M.: Argumentationsleitfaden Feinstaub. Austrian Bioenergy Centre Wieselburg (2007)

[5] Nussbaumer T., Klippel N., Oser M.:
Health relevance of aerosols from biomass combustion in comparison to diesel soot indicated by cytotoxity tests, 14th European Biomass Conference, Paris (2005)