UNECE Convention on Long-range Transboundary Air Pollution **June 2010**
Subgroup on Small Combustion Installations
under EGTEI

Options for limit values for emissions of dust from small combustion installations < 50 MWth

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1 Introduction

Small combustion installations are important sources of particulate emissions. However this source category is not yet included in the draft technical annexes to the revised Gothenburg Protocol. At its 45th session the Working Group on Strategies and Review (WGSR) therefore invited the Expert Group on Techno-economic Issues (EGTEI) to explore the possibility of establishing emission limit values (ELVs) for dust for small combustion installations (SCI), i.e. installations with a thermal input < 50 MW, with a special focus on wood combustion. At its 16th meeting EGTEI has delegated this task to a newly designated subgroup on SCI.

According to the terminology defined in the draft technical annexes to the revised Gothenburg protocol as adopted by EGTEI for other source categories, options for emission limit values (ELV) have been defined in a three tier approach:

- Option 1: ELV1 is a demanding but technically feasible option with the objective of achieving a high level of reduction. The ELV1 is based on a value between the lower and upper BAT AEL[1] (where it is available),
- Option 2: ELV2, while technically demanding, pays greater attention to the costs of the measures for achieving reduction. The ELV2 is a value based on the upper BAT AEL (where it is available),
- Option 3: ELV3 represents current [good] practices based on the legislation of a number of Parties to the Convention.

Since no official BAT reference documents (BREF) have been published so far for SCI, information on best practice and achievable emission levels has been compiled in a technical background report (Nussbaumer 2010).

2 Particulate emissions from small combustion installations

Figure 1 shows PM2.5 emissions in the GAINS Europe[2] area for the years 2000, 2005 and 2020. In 2005 SCI emitted 837 kt of PM2.5, thus having a share of 25% in total PM2.5 emissions of 3299 kt, which is higher than the share of large combustion plants.

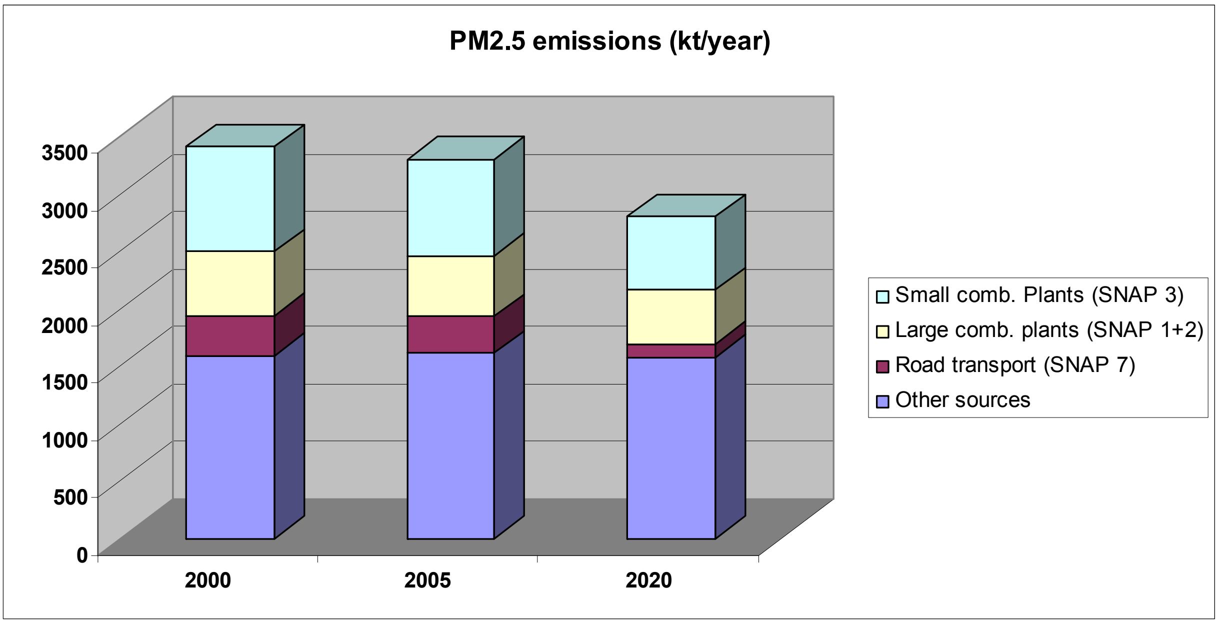


Fig. 1: PM2.5 emissions in the GAINS Europe area

[1] BAT AEL = BAT associated emission level
[2] GAINS emissions data provided courtesy IIASA. Detailed data are shown in annex 1.

As shown in fig. 2 PM2.5 emissions from SCI mainly stem from biomass combustion (73%).

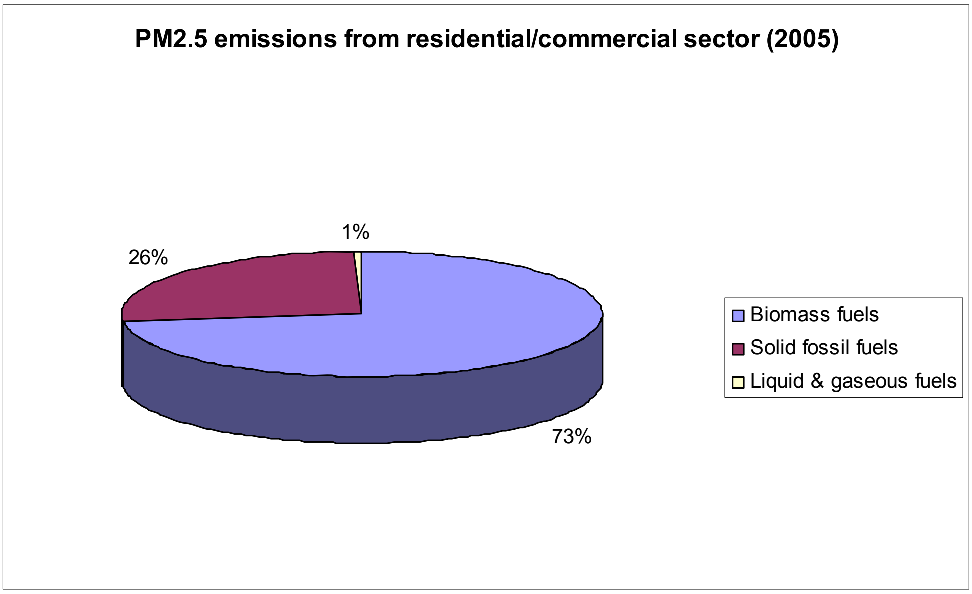


Fig. 2: PM2.5 emissions from the residential/commercial sector in the GAINS Europe area (2005)

Fig. 3 shows that about 97% of PM2.5 emissions from biomass combustion in SCI are emitted by small-scale domestic appliances: fireplaces, stoves (typically < 15 kW) and manually fed single house boilers (< 50 kW). Automatic single house boilers and medium size boilers (manually or automatically fed) are contributing relatively small shares to PM2.5 emissions.

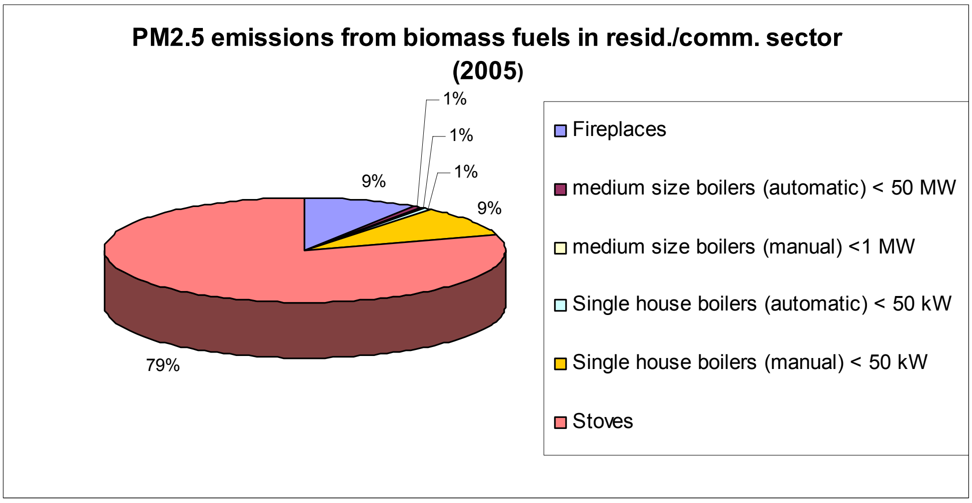


Fig. 3: PM2.5 emissions from biomass combustion in the residential/commercial sector in the GAINS Europe area (2005)

Black carbon (BC) is a relevant component of dust emissions from SCI and an important short-lived climate forcer. In 2005 approximately 25% of PM2.5 emissions from SCI in the GAINS Europe area were BC emissions corresponding to 209 kt and making up a share of 36% of total BC emissions of 588 kt. As shown in fig. 4 BC emissions from SCI mainly stem from biomass fuel combustion (68%).

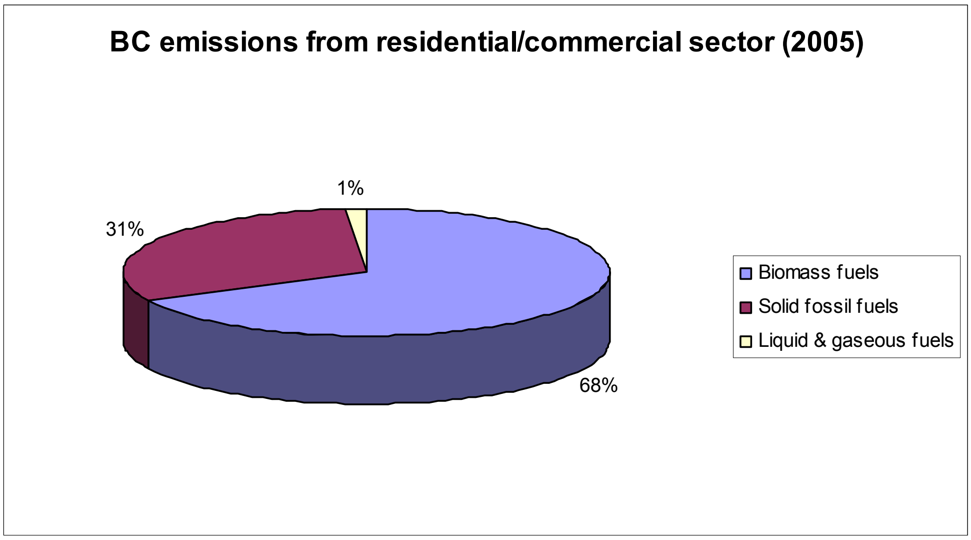


Fig. 4: BC emissions from the residential/commercial sector in the GAINS Europe area (2005)

Like PM2.5 emissions, BC emissions from biomass combustion in SCI are also mainly caused by small-scale domestic appliances (fig. 5)

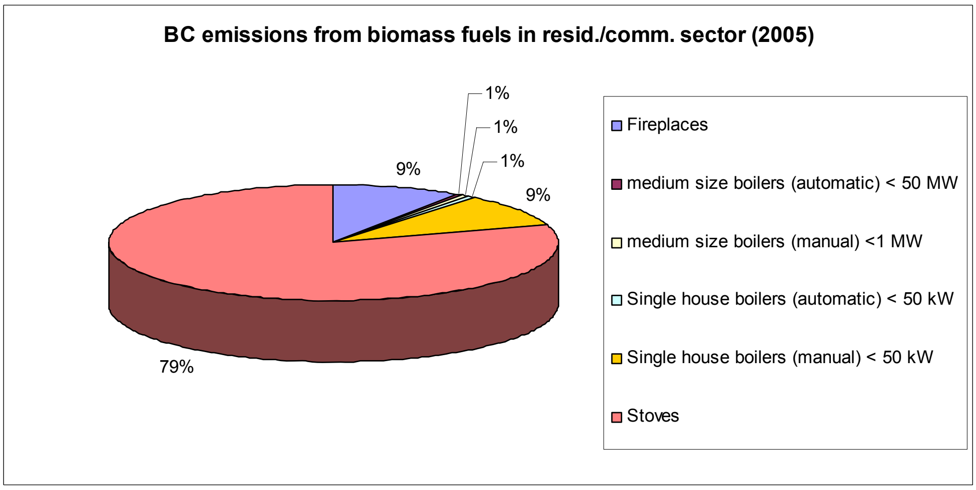


Fig. 5: BC emissions from biomass combustion in the residential/commercial sector in the GAINS Europe area (2005)

Conclusions:

- Small combustion installations (< 50 MW) are significant contributors to PM2.5 and BC emissions.
- Biomass is the most relevant fuel category in this source category; consequently this report puts a focus on regulations for biomass and especially wood combustion.
- Small-scale domestic appliances (typically < 50 kW) are by far the most relevant subcategory concerning PM2.5 and BC emissions.

3 Combustion and dust abatement techniques

3.1 State-of-the-art of biomass combustion

Biomass combustion is widely applied in small and medium scale appliances. Small-scale appliances (typically < 50 kW) are mainly used for residential heating. For this purpose, manually operated stoves and boilers are commonly used. As an alternative to manually operated devices, pellet boilers and pellet stoves are available. For medium-scale appliances up to 10 MW or more, automatic boilers are available and widely applied. The state-of-the-art of biomass combustion and achievable emission levels have been compiled in a technical background report (Nussbaumer 2010) and are summarized below.

For **log wood boilers**, the technical standard has been significantly improved in the past 30 years by the application of the two-stage combustion principle with primary and secondary air, which is injected with mechanical ventilation and followed by a hot combustion chamber. This allows improvements in efficiency and a reduction of pollutant emissions, such as CO, which is often used as an indicator for the carbon burnout, as well as VOC and also carbonaceous particulate matter, which originates from soot and organic condensables. However, to ensure good combustion conditions in practice, operation at low load needs to be avoided. For this purpose, the application of a heat storage tank is needed. The use of log wood boilers without heat storage tanks and/or with simple combustion technology can lead to excessive pollutant formation.

For **wood stoves**, ideal operation is essential to avoid high-pollutant emissions in practice, such as ignition of the wood from the top instead of ignition from the bottom and use of small batches of small dry logs. As for boilers, throttling the combustion air to achieve low heat loads needs to be strictly avoided. Since the ideal type of operation is related to frequent adding of small logs, wood stoves are often non-ideally operated. Consequently, residential wood combustion is a relevant source of PM including soot and condensables.

In some countries, **open fireplaces and inset appliances** are widely in use. Modern inset appliances are available with combustion design similar to wood stoves thus enabling similar efficiencies and emission levels. Beside these, simple open fireplaces and simple closed fireplaces are most common today, which achieve very low heating efficiencies and do not enable an efficient energy utilisation of wood. In addition, they exhibit significantly higher PM emission than well designed and operated wood stoves and wood boilers. However, there is only a limited risk of operation at throttled air which in case of boilers or stoves can lead to excessively high emissions.

> Biomass combustion is related to three basic types of particles:
>
> - Inorganic particles, basically salts, are formed from minerals (i.e., ash constituents) in the fuel. These particles are dominant at near-complete combustion.
> - Condensable organic compounds (COC) which are formed in different processes during incomplete combustion:
>   - At low temperature VOC or COC are formed by pyrolysis with characteristic compounds depending on residence time, heating rate, temperature and other operation parameters.
>   - At moderate temperatures and local lack of oxygen, organic compounds can be converted to secondary tars, which appear as condensables.
> - Soot (found as black carbon in the atmosphere) is formed from organic precursors in zones of high temperatures and lack of oxygen, where volatiles and primary tars react to secondary tars and form polyaromatic hydrocarbons, which consequently can form soot particles by further agglomeration and release of hydrogen.
>
> Incomplete combustion is often found in manual combustion where soot or condensables can be the dominant part of the total particulate matter released to the atmosphere. Due to the different temperature regimes and the different influence of the residence time for soot and COC formation, usually either one of the two particle types dominates the particle ensemble. In automatic combustion, nearly complete combustion can be achieved and hence salts are dominant as particles. However, during start-up, and in phases of inappropriate operation, condensables or soot can also be emitted from automatic plants.

To reduce PM emissions from residential wood combustion, **small-scale electrostatic precipitators (ESP)** and other particle separation technologies are under development and in the market implementation phase. These separators are often based on a design which is simplified compared to industrial applications for cost reasons. In some cases, high separation efficiencies of up to more than 90% are reported, while for other applications, moderate separation efficiencies in the order of only 50% are expected. In addition, the reduction potential in practice especially for soot and condensable organic compounds is uncertain for most applications and hence further experiences are needed.

As an alternative to manually operated devices, **pellet boilers and pellet stoves** are applied. Thanks to automatic feeding and small fuel size, improved combustion conditions can be achieved in practical operation. Consequently, pellet combustion instead of manual stoves or badly operated boilers allows a reduction of PM emissions. However, pellet boilers and stoves are often operated with high excess air and frequent automatic ignition or glow bed maintenance resulting in increased emissions. Due to this, there is still a certain potential of improvement, which is, however, of lower priority than the improvements needed to reduce PM resulting from inappropriate operation of manual wood combustion devices.

For medium scale applications up to 10 MW, **automatic boilers** for wood chips, bark and similar fuels are widely applied. Thanks to high combustion temperature, such plants exhibit usually low emissions of uncombusted gaseous and solid carbon emitted as PM, while relevant emissions of inhalable particles result from ash constituents in the fuel during such conditions emitted mainly as salts. For plants greater than 200 kW, or certainly for plants greater than a few MW, depending on national emission limits, efficient particle removal mostly by ESP and in some cases by fabric filters is commonly applied thus enabling low PM levels in the clean gas when properly operated. Cyclones are often used as a first stage gas cleaning device in industrial application or when national legislation is less stringent. However, they exhibit a very poor separation efficiency for particles smaller than 5 microns. Besides, boilers for heating purposes are often operated at part-load or with periodic on/off operation. During such operation modes, the particle removal is often ineffective. Therefore system integration, boiler management, and combustion control need to be improved in future to ensure high availability of the particle separation. For applications greater than 10 MW, biomass is mostly used for steam generation in combined heat and power production plants. Thanks to nearly continuous operation and efficient flue gas cleaning, PM emissions from such applications are usually on a low level.

3.2 Best practice emission levels

Wide ranges of PM emission factors have been reported for biomass combustion (Nussbaumer 2010). Emission factors from modern manual wood combustion devices exhibit ranges from less than 20 mg/MJ under ideal conditions, to more than 1'000 mg/MJ under poor combustion conditions[3]. Emission factors of medium and large scale applications mainly depend on secondary particle removal equipment. Emissions factors may also depend on measurement and sampling standards or protocols (see chapter 4.1), especially for natural draught appliances with incomplete combustion. In the following context only emissions of solid particles collected by out-stack filtration on heated filters are considered.

1. For wood stoves, wide ranges are found due to different operation conditions. While low emissions of less than 25 mg/MJ are possible by utilisation of small logs of dry wood being added in small batches and igniting the fuel from the top, excessive PM emissions of up to more than 1 000 mg/MJ can occur due to smoldering conditions at reduced load and throttled air supply or due to inappropriate fuel such as wet wood. Consequently, high priority should be given to avoiding inappropriate operation.
2. Closed inset appliances with advanced design are available today with comparable combustion characteristics as wood stoves. However, closed inset appliances with simple design as well as open fireplaces typically exhibit higher emissions than well designed and operated stoves and boilers. Nevertheless, the risk of operation at throttled air is smaller than for wood stoves and boilers, where correct operation and - in the case of wood boiler - equipment with a heat storage tank is crucial.
3. For residential wood boilers, the type of combustion design influences the PM emission. Modern wood boilers with forced downdraft combustion and electronic combustion control achieve low PM emissions of less than 20 mg/MJ if properly operated, i.e. full load operation and appropriate fuel, while old-type boilers with updraft combustion exhibit significantly higher emissions. However, for all types of wood boilers, excessive PM emissions of more than 1 000 mg/MJ can occur if the boiler is operated without heat storage tank resulting in throttled operation. Consequently, heat storage tanks are highly recommended or should be mandatory for log wood boilers.
4. For pellet boilers and stoves, typical particle emissions of approx. 30 mg/MJ are reported with a relatively narrow variation from 10 to 60 mg/MJ. In average, PM emissions under typical operation conditions are expected to be lower than in manually operated combustion devices since variations are less emphasized. It should be noted that the market for pellets is growing and therefore the production of pellets with higher ash content may increase. The use of such pellets in small-scale equipment without particle removal will result in higher emissions, i.e. an expected increase of a factor of 3 to 5 in PM and NO_X emissions for agricultural pellets instead of wood pellets. Domestic

[3] conversion of emission factor to concentration: 1 mg/MJ = approx. 1.5 mg/m^3 at 13% O2

scale applications should be restricted for high quality wood pellets with low ash content, while pellets with increased ash content should be reserved for applications in larger plants which are equipped with flue gas cleaning.

5. For automatic combustion plants, the emission factors without electrostatic precipitator (ESP) or fabric filter – but with a multicyclone - are relatively high, typically around 100 mg/MJ. Thanks to high temperature and sufficient oxygen availabilty at good conditions, these PM emissions are mainly attributed to inorganic particles, except if due to inappropriate boiler operation or bad furnace design, incomplete combustion occurs. Clean gas emissions from automatic boilers usually depend on the type of flue gas cleaning applied, which depends on national or local emission standards. In many European countries, emission limit values for such applications have recently been made stricter. The situation of typical PM emissions will change in many countries in the near future, since particle removal allows clean gas emissions of easily less than 30 mg/MJ e.g. by simple ESP[4] or safely less than 10 mg/MJ, e.g. by application of advanced ESP[5] or fabric filter.

Table 1 summarizes achievable best-practice PM emission levels of various appliance types for biomass combustion.

Appliance type	**Abatement technology**	**Achievable PM emission level** **mg/MJ**	**Achievable PM emission level** **mg/m_n^3 at 13% O_2**
Open fireplaces		50 - 100	75 - 150
Wood stoves and closed inset appliances		15 - 25	20 - 40
Log wood boilers (with heat storage tank)		10 - 20	15 -30
Pellet stoves & boilers		10 - 20	15 - 30
Automatic combustion plants	multicyclone	50 - 100	75 - 150[6]
	simple ESP	15 - 35	20 - 50
	improved ESP	5 - 15	< 10 - 20
	fabric filter	< 5	< 10

Table 1: Achievable best-practice PM emission levels of various appliance types for biomass combustion under ideal conditions. The emission levels give approximate ranges as rounded values, therefore the ranges indicated as mg/MJ resp. mg/m_n^3 may not correspond exactly to one another.

3.3 Cost of dust abatement techniques

A survey on availability and cost of ESP and fabric filters for automatic biomass boilers in Switzerland has shown that ESP and fabric filter technology is available and proven for boilers with a thermal capacity of 500 kW to 2 MW (Nussbaumer 2007). ESP technology exhibits higher investment cost while fabric filters exhibit higher operation cost. The total additional cost are similar and result in an increase of the heat production cost of approx. 6% to 12% for fuel prices and capital cost in Switzerland (table 2). Applications down to 100 kW boilers are possible, however with sharply increasing cost for installations below 500 kW (fig. 6), which can lead to an uneconomic situation for biomass compared to fossil fuels. It is however noted that there is a cost reduction potential for technology < 500 kW.

[4] e.g. 1-stage ESP with limited dimensions
[5] usually multi-stage ESP
[6] with a restriction for straw combustion due to large fraction of fine particles

Heat Output	Light fuel oil	Wood w/o precipitation	Wood with electrostatic precipitator		Wood with fabric filter	
	[Ct./kWh]	[Ct./kWh]	[Ct./kWh]	[%]	[Ct./kWh]	[%]
100 kW	11.0	12.5	16.3	30	16.0	28
200 kW	10.0	11.0	13.3	21	12.8	17
500 kW	9.1	9.5	10.6	12	10.3	9
1 MW	8.6	7.6	8.2	8	8.1	7
2 MW	8.2	6.6	7.1	6	7.0	6

Table 2: Heat production cost for light fuel oil and for wood with and without particle removal and cost increase (in %) resulting from particle precipitation. Fuel prices: 3 Euro Ct./kWh for wood and 6 Euro Ct./kWh for light fuel oil. Interest rate: 5% p.a. (Nussbaumer 2007)

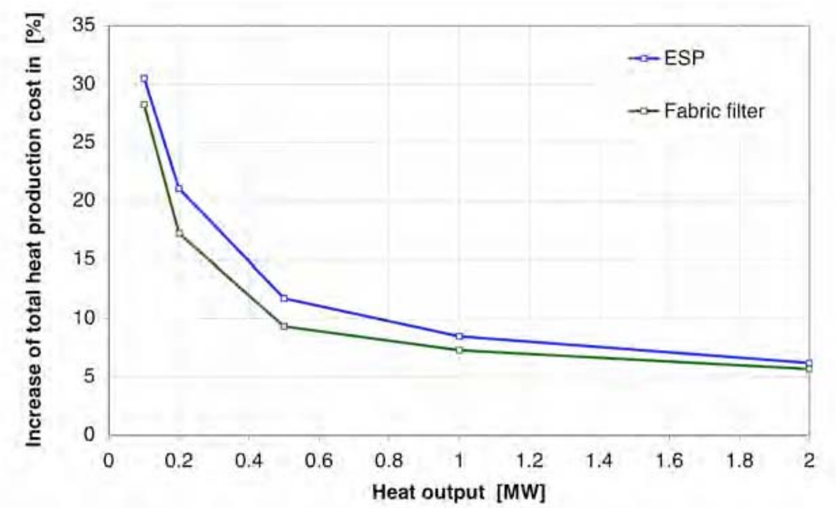


Fig. 6: Increase of the heat production cost (%) caused by application of an ESP or fabric filter (Nussbaumer 2010)

A Finnish study has reviewed measures for reducing PM emissions in Finland including domestic combustion (Karvosenoja 2007). Table 3 summarizes the abatement options and cost considered for domestic biomass boilers.

Boiler type	**Em. factor without ESP (mg/MJ)**	**ESP removal efficiency (%)**	**Em. factor after ESP (mg/MJ)**	**Unit cost (€/ton PM2.5)**	**Unit cost (€/TJ)**
Manually fed log wood boiler with accumulator tank	100	90	10	3700	333
Manually fed log wood boiler without accumulator tank	800	95	40	419	318
Automatic wood chip boiler	60	85	9	6960	355
Automatic pellet boiler	30	80	6	15300	368

Table 3: Finnish data on cost and efficiency of ESP for residential boilers (Karvosenoja 2007)

4 Current regulations

4.1 Measurement and sampling standards

Several countries have adopted emission measurement standards or protocols showing different approaches. Thus it can be difficult to compare regulations between countries. The differences in measurement procedure concern test cycles (for example whether to include start-up emissions) and emission measurement procedures. The differences in measurement procedure depend on whether the procedure only looks at filterable material collected directly out-stack on heated filters (e.g. at 160° according to the German standard VDI 2006) or whether it includes sampling of condensable organic compounds by collection in impinger traps (e.g. US EPA method 5H) or by condensation in a dilution chamber (e.g. Norwegian standard NS 3058-2). Differences between procedures are especially relevant for manually fed small-scale appliances with natural draught where products of incomplete combustion form a major contribution to PM emissions. They are less relevant for appliances with near-complete combustion, e.g. automatic combustion installations (cf. chapter 3.1). This issue has been discussed in more detail in the technical background report (Nussbaumer 2010).

In 2009 the standard CEN/TS 15883 "Residential solid fuel burning appliances: emission test methods" has been published, containing methods for the measurement of total hydrocarbons (THC) and NO_x. Concerning particle measurement the standard mentions three European methods (Austria/Germany, Norway and UK), leaving free choice.

4.2 Product standards

A number of countries are enforcing emission controls to small combustion appliances. For residential appliances, these are generally applied under ‘type approval’ arrangements under which the manufacturer undertakes tests on an example appliance to assess compliance with product standards. Table 4 lists European EN standards for residential solid fuel appliances and for independent boilers with a nominal heat output of up to 300 kW.

The standards include minimum requirements for efficiency, construction and safety of appliances. Some standards are setting limits on the emission of CO and total hydrocarbons (THC). Low emission of CO and THCs are associated with optimized burning rates and thus low emissions of PM, especially low shares originating from soot (black carbon) and condensable organic compounds (COC). Since measuring PM is far more expensive than measuring CO, it is more cost-effective to set a limit value for CO and THCs. Only EN 303-5, the independent boiler standard, includes PM emissions criteria (table 5). However EN 303-5 is not a harmonized standard and the standard indicates that national requirements in several member states differ from the standard in terms of PM measurement protocols and permitted emissions.

EN 303-5[7]	Heating boilers for solid fuels, hand and automatically stocked, nominal heat output of up to 300 kW - Terminology, requirements, testing and marking
EN 12809	Residential independent boilers fired by solid fuel - Nominal heat output up to 50 kW - Requirements and test methods.
EN 12815	Residential cookers fired by solid fuel - Requirements and test methods.
EN 13229	Inset appliances including open fires fired by solid fuels - Requirements and test methods.
EN 13240	Room heaters fired by solid fuel - Requirements and test methods.
EN 14785	Residential space heating appliances fired by wood pellets - Requirements and test methods.
EN 15250	Slow heat release appliances fired publication by solid fuel - Requirements and test methods
EN 15270	Pellet burners for small heating boilers - Definitions, requirements, testing, marking
EN 155544	One-off tiled/mortared stoves - Dimensioning

Table 4: European EN standards for residential solid fuel appliances and boilers with nominal heat output of up to 300 kW

[7] EN 303-5 is currently under revision. Future boiler size range may be up to 500 kW.

Stoking	Nominal heat output	Emission limit, mg.m^{-3} dry at STP (0°C, 101.3 kPa) and 10% O_2		
	kW	Class 1	Class 2	Class 3
Manual	≤50	200	180	150
	>50 to 150	200	180	150
	>150 to 300	200	180	150
Automatic	≤50	200	180	150
	>50 to 150	200	180	150
	>150 to 300	200	180	150

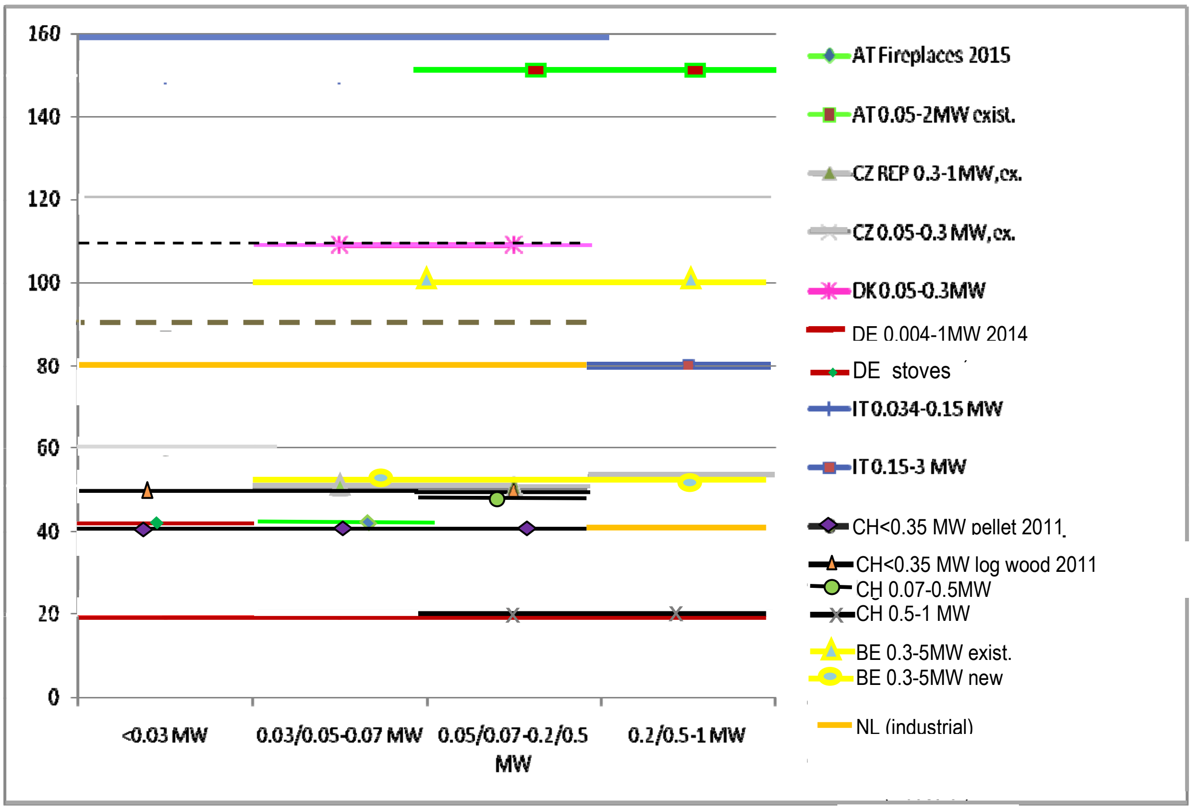
Table 5: PM emission criteria of EN 303-5 for wood combustion appliances

In this context it has to be considered that the European Commission is preparing an implementing measure for solid fuel small combustion installations under Directive 2009/125/EC on establishing a framework for setting Eco-design requirements for energy- related products. The directive does not introduce directly binding requirements for specific products, but does define conditions and criteria for setting requirements regarding environmentally relevant product characteristics (such as energy efficiency or pollutant emissions) and allows them to be improved quickly and efficiently. Requirements for solid fuel small combustion installations will presumably be set within an EC regulation.

4.3 National emission limit values

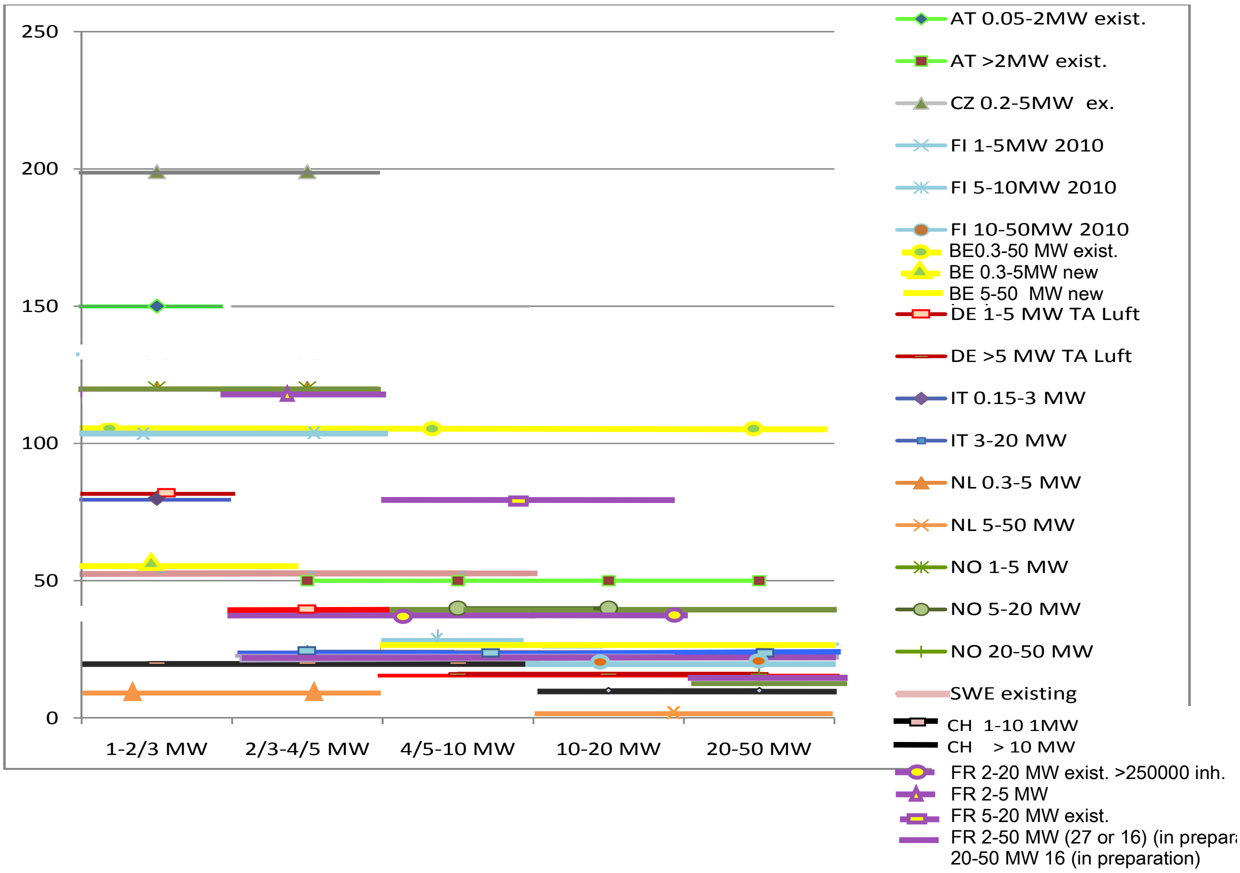
An overview (fig. 7 and 8) of national limit values for dust emissions from combustion installations < 50 MW has been compiled with a view to defining option 3 of ELVs representing current good practices based on the legislation of a number of Parties to the Convention. Values are given with relation to an O_2 reference content of 13%. Conversion of limit values to different oxygen reference contents is shown in annex 2.

Fig. 7 shows a relatively broad range of 20 – 150 mg/m_n^3 for installations with a thermal input < 1MW. Fig. 8 shows an ever broader range of 10 – 200 mg/ m_n^3 for installations with a thermal input from 1 – 5 MW, while in the category 10 – 50 the range narrows down to 3 – 50 mg/ m_n^3.



P_{fuel} < 1 MW, wood combustion PM emission limit values [mg/Nm³] at 13% O_2	<0.03 MW	0.03/0.05 … 0.05/0.07 MW	0.05/0.07-0.2/0.5 MW	0.2/0.5-1 MW
AT Fireplaces, wood pellets, from 2015		40		
AT 0.05-2MW, wood fuels existing			150	150
BE 0.3-5MW, existing		106	106	106
BE 0.3-5 MW, new		53	53	53
CZ REP 0.3-1MW, existing	51	51	51	
CZ 0.05-0.3 MW, existing				53
DK, wood, 0.05-0.3MW		109	109	
DE Stoves (roomheaters), type test from 2014	40			
DE combustion installations (boilers) 0,004 -1 MW from 2014 regular control	20	20	20	20
IT 0.035-0.15 MW	160	160	160	
IT 0.15-3 MW				80
CH < 0.35MW pellet stoves/boilers, from 2011 (type approval)	40	40	40	
CH <0.35MW log wood boilers, from 2011 (type approval)	50	50	50	
CH 0.07-0.5 MW, autom., from 2012			50	
CH 0.5-1MW				20
NL < 0.5 MW (industrial)	80	80	80	
NL 0.5 – 1 MW (industrial)				40
EN 303-5 (Manual/Automatic)	Dust at 13% O2	In the graph shown as:		
Biomass < 300 kW	109	- black dashed line		
Fossil fuel < 50 kW	90	- brown dashed line		

Fig. 7: National PM emission limit values for combustion installations <1 MW



P_{fuel} **1-50MW, wood combustion,** PM emission limit values [mg/Nm3] at 13% O2	1/2 -3 MW	2/3...4/5 MW	4/5-10 MW	10-20 MW	20-50 MW
AT 0.05-2MW existing	150				
AT >2MW existing		50	50	50	50
BE 0.3 - 50 MW existing	106	106	106	106	106
BE 0.3 – 50 MW new	53	53	27	27	27
CZ 0.2-5MW existing	199	199			
FI 1-5MW from 2010	106	106			
FI 5-10MW from 2010			27		
FI 10-50MW from 2010				21	21
FR > 2 MW existing installations	40[1]/120	40[1]/120	40[1]/80	40[1]/80	
FR > 2 MW new installations	40[1]/120	40[1]/120	40[1]/80	40[1]/80	27
FR 2-50MW in preparation	16 or 27	16 or 27	16 or 27	16 or 27	16
DE 1-5 MW TA Luft	80	40			
DE >5 MW TA Luft			16	16	16
IT 0.15-3 MW	80				
IT 3-20 MW		24	24	24	24
NL 1-5MW	10.6	10.6			
NL 5-50 MW			2.7	2.7	2.7
NO 1-5 MW	120	120			
NO 5-20 MW			40	40	
NO 20-50 MW					16
SWE existing	53	53	53		
CH 1-10MW	16	16	16		
CH >10MW				8	8

[1] FR: City centres > 250000 inhabitants

Fig. 8: National PM emission limit values for combustion installations 1-50 MW

4.4 Ecolabels

There are a number of ecolabel schemes in Europe that specify performance criteria that are typically stricter than the minimum efficiency requirements of the EN product standards or national regulations. A number of these ecolabel schemes recognize the importance of PM emission and include criteria for assessment. Table 6 provides a summary of ecolabelling criteria for biomass combustion with selected weblinks to further information.

Ecolabel	Country	ELV		Comment
		NO_x	PM	
Blue Angel	Germany	X	X	Includes efficiency and limit values for wood pellet stoves and wood pellet boilers http://www.blauer-engel.de/en/index.php
Nordic Swan	Sweden, Norway, Denmark & Finland	(X)	X	Includes efficiency, PM and VOC limit values for various residential roomheater types and NOx, PM and VOC limits for boilers <300 kW http://www.svanen.nu/Default.aspx?tabName=StartPage
EFA	European association of fireplace roomheaters		X	Higher efficiencies than product Standards and also PM ELVs for various residential manufacturers www.efa-europe.com
Umweltzeichen 37	Austria	X	X	Higher efficiency and more stringent emission criteria than legislative limits for boilers and roomheaters
Flamme Verte	France		X	Differs from other ecolabelling schemes in that criteria show an annual improvement. Efficiency and CO criteria set for roomheaters, additional PM and VOC ELVs for boilers http://www.flammeverte.org
DINplus	Germany	X	X	VOC limit also set and also covers certification of pellet fuels http://www.dincertco.de/en/about_us/our_marks_of_conformity/quality_mark.html
P marking	Sweden		X	Efficiency and PM ELVs for pellet boilers, pellet stoves and wood-fired roomheaters
Quality label for wood combustion appliances	Switzerland		X	Efficiency criteria based on EN standards, PM and CO ELVs according to Swiss regulations. http://www.holzenergie.ch/holzenergie/qualitaetssicherung/qualitaetssiegel.html

Table 6: Ecolabels for biomass combustion (from EP UK 2009)

4.5 Fuel specification

Fuel specification is very important in terms of emissions from wood combustion in residential appliances. Work to establish CEN standards for a range of biomass fuels is in progress, codifying fuel qualities such as size, moisture content and heavy metals content. The two most important technical specifications being developed deal with classification and specification (EN 14961) and quality assurance for solid biofuels (EN 15234). Draft standards exist for wood fuels (wood pellets, wood briquettes, wood chips and log wood).

A number of countries have developed national standards and there are also environmental and quality label schemes (primarily to address use of waste materials and sustainability of wood sources). The European Pellet Centre[8] provides details of the main standards for pellets.

[8] http://www.pelletcentre.info/CMS/site.aspx?p=2550

5 Suggested options for reducing dust emissions from small combustion installations

For the purpose of suggesting options for reducing dust emissions, three categories of installations have been defined according to thermal input.

1. The 1st category includes installations < [300] [500] kW, which are recommended to be regulated by product standards with type approval or ecolabels.
2. The 2nd category includes installations from [50] [70] [100] kW - 1 MW, thus having an overlap with the 1st category.
3. The 3rd category includes installations from 1 – 50 MW.

Suggested options for emission limit values are referring to solid particles collected by outstack filtration on heated filters at 160°C. Countries using other sampling methods may define equivalent ELVs.

5.1 Combustion installations with a thermal input < [300] [500] kW

On the basis of the considerations put forth in chapters 3 and 4 it is suggested to amend the draft Guidance Document (Chapter 7.1) to the revised Gothenburg protocol with the following recommendations:[9]

Emissions from **new** residential combustion stoves and boilers with a thermal input < [300] [500] kW can be reduced by the application of

a) product standards as described in CEN standards (e.g. EN 303-5) and equivalent product standards in the United States and Canada. Countries applying such product standards are allowed to define additional national requirements. Table 7 is recommending options for additional ELVs for dust for wood combustion appliances.

b) ecolabels specifying performance criteria that are typically stricter than the minimum efficiency requirements of the EN product standards or national regulations.

	Suggested ELV for dust (mg/m_n^3)		
	ELV 1[10]	**ELV 2**[11]	**ELV 3**[12]
open / closed fireplaces	40	75	110
wood stoves	40	75	110
log wood boilers (with heat storage tank)	20	40	110
pellet stoves and boilers	20	40	110
Automatic combustion plant	20	60	110

Table 7: Suggested options for limit values for dust emissions released from new small wood combustion installations with a thermal input < [300] [500] kW to be used with product standards

O_2 reference content: 13% [13]

[9] The recommendatory text as been adapted from chapter V.D of the draft Guidance document on best available techniques to control emissions of POPs from stationary sources (ECE/EB/AIR/2009/14)

[10] ELV 1 based on future German regulation (1. BImSchV, tier 2, entry into force after 31.1.2014), except for open fireplaces

[11] ELV 2 based on future Swiss type approval standards (Ordinance on Air Pollution Control, tier 2, entry into force after 1.1.2011)

[12] ELV 3 in analogy to EN 303-5, class 3, values converted from 10% O2 reference content to 13%

[13] There have been split views among experts in the subgroup about the reference oxygen content. Some experts were in favour of a value of 11% for this source category.

Emissions from **existing** residential combustion stoves and boilers can be reduced by the following primary measures:

(a) by public information and awareness programs regarding:

- the proper operation of stoves and boilers;
- the use of untreated wood only;
- the correct seasoning of wood for moisture content;

(b) by establishing a program to promote the replacement of the oldest existing boilers and stoves by modern appliances;

(c) or by establishing an obligation to exchange or retrofit old appliances.

5.2 Combustion installations with a thermal input [50] [70] [100] kW – 1 MW

On the basis of the considerations put forth in chapters 3 and 4 it is suggested to amend the draft technical annex concerning dust ELVs to the revised Gothenburg protocol with the following options for ELVs for combustion installations with a thermal input [50] [70] [100] kW – 1 MW:

		Suggested ELV for dust (mg/m_n^3)		
		ELV 1	**ELV 2**	**ELV 3**
Solid fuels [50][70][100] – 500 kW	New install.	30 simple ESP	50 simple ESP	150 cyclone
	Existing install.	100 cyclone	150 cyclone	150 cyclone
Solid fuels 500 kW – 1 MW	New install.	20 improved ESP, FF	50 simple ESP	150 cyclone
	Existing install.	30 simple ESP	150 cyclone	150 cyclone

Table 8: Suggested options for limit values for dust emissions released from boilers [and process heaters] with a thermal input of [50] [70] [100] kW – 1 MW. Corresponding abatement technologies are also shown for information.

O_2 reference concentration: wood, other solid biomass and peat[14]: 13%[15]
Coal, lignite and other fossil solid fuels: 6%

5.3 Combustion installations with a thermal input 1 – 50 MW

On the basis of the considerations put forth in chapters 3 and 4 it is suggested to amend the draft technical annex concerning dust ELVs to the revised Gothenburg protocol with the following options for ELVs for combustion installations with a thermal input 1 - 50 MW:

[14] With respect to CO2 emissions, peat is regarded as fossil fuel. However, it shows similar combustion behaviour as biomass and hence is considered in the same category as biomass.
[15] There have been split views among experts in the subgroup about the reference oxygen content. Some experts were in favor of a value of 6 resp. 11% for this source category.

		Suggested ELV for dust (mg/m_n^3)		
		ELV1	**ELV2**	**ELV3**
Solid fuels 1 – 5 MW	New install.	10 improved ESP, FF	20 improved ESP, FF	150 cyclone
	Existing install.	20 improved ESP	50 simple ESP	150 cyclone
Solid fuels 5 - 50 MW	New install.	10 improved ESP, FF	20 improved ESP, FF	50 simple ESP
	Existing install.	20 improved ESP, FF	30 simple ESP	50 simple ESP
Liquid fuels 1 – 5 MW	New install.	10 improved ESP, FF	20 improved ESP, FF	150 cyclone
	Existing install.	20 improved ESP	50 simple ESP	150 cyclone
Liquid fuels 5 - 50 MW	New install.	10 improved ESP, FF	20 improved ESP, FF	50 simple ESP
	Existing install.	20 improved ESP, FF	30 simple ESP	50 simple ESP

Table 9: Suggested options for limit values for dust emissions released from boilers [and process heaters] with a thermal input of 1- 50 MW. Corresponding abatement technologies are also shown for information.

O_2 reference concentration: wood, other solid biomass and peat[16]: 11%[17]
Coal, lignite and other fossil solid fuels: 6%
Liquid fuels, incl. liquid biofuels: 3%

6 References

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Nussbaumer 2007 — Nussbaumer T., Techno-economic Assessment of Particle Removal in Automatic Wood Combustion Plants from 100 kW to 2 MW, 15th European Biomass Conference and Exhibition, Berlin, May 2007

Nussbaumer 2010 — Nussbaumer T., Overview on Technologies for Biomass Combustion and Emission levels of Particulate Matter, prepared for the Swiss Federal Office for the Environment and EGTEI, 2010

[16] See footnote 10

[17] There have been split views among experts in the subgroup about the reference oxygen content. Some experts were in favour of a value of 6% for this source category.

Annex 1: PM2.5 and BC emissions in the GAINS UNECE area (2005)

Emissions of PM 2.5 (kt)

	Emissions	Share in UNECE	Share in DOM	Emissions from biofuels	Share in UNECE	Share in DOM
DOM	5.0	0.2%	0.6%	0.7	0.0%	0.1%
DOM_FPLACE	55.3	1.7%	6.6%	55.3	1.7%	9.0%
DOM_MB_A	24.6	0.7%	2.9%	4.0	0.1%	0.6%
DOM_MB_M	48.6	1.5%	5.8%	3.4	0.1%	0.5%
DOM_PIT	0.0	0.0%	0.0%	0.0	0.0%	0.0%
DOM_SHB_A	3.6	0.1%	0.4%	3.5	0.1%	0.6%
DOM_SHB_M	103.1	3.1%	12.3%	57.1	1.7%	9.3%
DOM_STOVE_C	0.3	0.0%	0.0%	0.3	0.0%	0.0%
DOM_STOVE_H	596.9	18.1%	71.3%	488.5	14.8%	79.7%
Total DOM	837.4	25.4%	100.0%	612.7	18.6%	100.0%
Total UNECE area	3299.1			3299.1		

Emissions of BC (kt); UNECE area in 2005

	Emissions	Share in UNECE	Share in DOM	Emissions from biofuels	Share in UNECE	Share in DOM
DOM	3.1	0.5%	1.5%	0.2	0.0%	0.1%
DOM_FPLACE	7.7	1.3%	3.7%	7.7	1.3%	5.5%
DOM_MB_A	0.9	0.1%	0.4%	0.5	0.1%	0.4%
DOM_MB_M	1.3	0.2%	0.6%	0.9	0.2%	0.7%
DOM_PIT	0.0	0.0%	0.0%	0.0	0.0%	0.0%
DOM_SHB_A	1.3	0.2%	0.6%	1.3	0.2%	0.9%
DOM_SHB_M	45.5	7.7%	21.7%	23.0	3.9%	16.2%
DOM_STOVE_C	0.1	0.0%	0.0%	0.1	0.0%	0.1%
DOM_STOVE_H	149.4	25.4%	71.4%	108.0	18.4%	76.2%
Total DOM	209.2	35.6%	100.0%	141.7	24.1%	100.0%
Total UNECE area	587.9			587.9		

Code	Sectors
DOM	Residential and commercial - use of liquid and gaseous fuels
DOM_FPLACE	Fireplaces
DOM_MB_A	Residential and commercial - medium size boilers (automatic) (< 50 MWth - assumed average size 5 MWth unless other info available)
DOM_MB_M	Residential and commercial - medium size boilers (manual) (<1 MWth - assumed average size 0.5 MWth unless other info available)
DOM_PIT	Three stone stove or open pit (not relevant in Europe)
DOM_SHB_A	Single house boilers (automatic loading) (< 50 kW - - assumed average size 20 kWth unless other info available)
DOM_SHB_M	Single house boilers (manual loading) (< 50 kW - assumed average size 10 kWth unless other info available)
DOM_STOVE_C	Cooking stoves
DOM_STOVE_H	Heating stoves

All emissions data for UNECE area in 2005, excluding Armenia, Azerbaijan, Kasachstan, Georgia…
All calculations refer to the current Gothenburg Protocol scenario (May 2010) where recent model version and national energy scenarios (where available) are used

Data are provided courtesy of IIASA

Annex 2: Conversion table for different oxygen reference contents

Values in bold are national ELVs and they have been converted to the other O_2 reference contents[18]. The green shaded values are proposed as ELV options (at 13% O_2)				
13 %	**11 %**	**10 %**	**6 %**	**3 %**
265	332	365	499	**600**
250	313	345	472	566
199	**250**	275	376	452
199	249	274	375	**450**
186	233	256	**350**	291
159	199	219	**300**	360
150	188	207	283	340
133	166	183	**250**	300
120	150	166	**226**	272
110	138	152	208	**250**
109	136	**150**	205	246
106	133	146	**200**	240
100	125	138	189	227
96	120	132	181	218
90	113	124	170	204
88	111	122	166	**200**
80	**100**	110	**150**	180
75	94	103	141	170
66	83	91	**125**	150
64	80	88	121	145
60	75	83	113	136
53	66	73	**100**	120
51	64	**70**	96	115
50	63	69	94	113
40	50	55	**75**	90
30	38	41	57	68
32	40	44	**60**	72
27	33	37	**50**	60
24	**30**	33	45	54
20	25	28	38	45
16	20	22	**30**	36
15	19	21	28	34
11	13	15	**20**	30
10	13	14	19	23
8	**10**	11	15	18
5	6	7	9	11
3	3	4	**5**	6

[18] Concentration at x%O_2 = (Concentration at y%)*(20.9-x)/(20.9-y), x= desired concentration, y=concentration from which conversion is made