



Technical Guidance: Screening assessment for biomass boilers

**Report to the Department of Environment, Food
and Rural Affairs and the Devolved
Administrations**

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Executive summary

The European Union and the United Kingdom Government have set greenhouse gas emission reduction and renewable energy usage targets. The use of biomass to generate energy offers significant potential environmental advantages for the reduction in emissions of greenhouse gases. The UK Energy White Paper, released in May 2007, has acknowledged the role of biomass and its potential contribution to renewable energy in the UK. However, there are concerns, particularly in London, that a significant increase in biomass combustion, particularly of wood fuel, could have a detrimental impact on particulate matter, PM₁₀ and oxides of nitrogen concentrations. This is a particularly sensitive issue in areas where Air Quality Management Areas (AQMAs) are in force.

Local authorities are required to review and assess air quality in their areas against objectives set out in the Government's Air Quality Strategy. Local authorities are then required to declare an AQMA where it is likely that the objectives will not be achieved. Technical Guidance LAQM.TG(03) provides advice on how to assess air quality. The Air Quality Strategy was revised in July 2007 and new Technical Guidance is consequently being prepared in order to support local authorities in their duties. This report provides background information on methods of assessing the impact of biomass combustion appliances on air quality proposed for inclusion in the new Technical Guidance.

Table of contents

1	Introduction	1
2	Air quality objectives	3
3	Individual installations	5
3.1	Introduction	5
3.2	Dispersion modelling	5
3.3	Procedures	11
3.4	An example	14
4	Combined impacts	16
4.1	Introduction	16
4.2	Dispersion modelling	16
4.3	Estimating emissions	16
4.4	Method	19
4.5	Example	21

Appendices

Appendix 1	Emission factors for solid fuel combustion
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1 Introduction

The European Union and the United Kingdom Government have set greenhouse gas emission reduction and renewable energy usage targets. The use of biomass to generate energy offers significant potential environmental advantages for the reduction in emissions of greenhouse gases. The UK Energy White Paper, released in May 2007, has acknowledged the role of biomass and its potential contribution to renewable energy in the UK. However, there are concerns, particularly in London, that a significant increase in biomass combustion, particularly of wood fuel, could have a detrimental impact on particulate matter, PM₁₀ and oxides of nitrogen concentrations. This is a particularly sensitive issue in areas where Air Quality Management Areas (AQMA) are in force.

Local authorities are required to review and assess air quality in their areas against objectives set out in the Government's Air Quality Strategy. Local authorities are then required to declare an AQMA where it is likely that the objectives will not be achieved. Technical Guidance LAQM.TG(03) provides advice on how to assess air quality. The Air Quality Strategy was revised in July 2007 and new Technical Guidance is consequently being prepared in order to support local authorities in their duties. This report provides background information on methods of assessing the impact of biomass combustion appliances on air quality proposed for inclusion in the new Technical Guidance.

The Air Quality Strategy objectives are set out in Section 2.

The report considers biomass combustion for:

- Domestic heating;
- Service sector heating (commercial offices, communication and transport, education, government, health, hotel and catering, retail, sport and leisure, warehouses);
- Industrial combustion < 20 MW net thermal input (process heating, steam generation, electricity generation and combined heat and power).

Larger plant is regulated under the Pollution Prevention and Control (PPC) regime and is not considered here.

Local authorities need to consider:

- whether each separate installation will lead to a local exceedence of the air quality objectives;
- whether several installations will combine to cause an exceedence of air quality objectives over a wider area.

The Air Quality Strategy objectives are set out in Section 2.

Methods for assessing the local impact of individual installations are presented in Section 3. The methods consider whether the discharge stack is sufficiently tall to disperse the emitted pollutants. The methods cover service sector heating and industrial combustion. The height of chimney stacks for domestic appliances with less than 50 kW thermal input is covered by the Building Regulations.

Methods for assessing the combined impact of multiple installations are presented in Section 4.

The methods presented in Sections 3 and 4 are intended to provide an initial screening assessment to determine whether there is a risk of exceeding the objectives. The screening assessment is intended to provide a conservative overestimate of the potential impacts. More detailed assessment is required where the screening methods indicate that there is a risk of exceeding the objectives.

The PPC regime covers a wide range of processes, including various combustion activities with less than 20 MW thermal input. The screening methods presented here are not sufficient on their own to meet the requirements of the PPC regime.

The screening methods set out in this report are intended to assess whether there is a risk that the air quality objectives will not be met. When considering planning applications for new developments, local

Technical Guidance:
Screening assessment for biomass boilers

AEA/ED48673005/R2655 Issue 1

authorities may wish to impose more stringent limits on emissions in order to further protect the health of members of the public or to allow headroom for other future developments in the area.

2 Air quality objectives

Local Authorities are required under the Environment Act to assess air quality in their areas from time to time against air quality objectives set out in the Air Quality Regulations (2000) and the Air Quality (Amendment) Regulations (2002). The objectives are set out in Table 2.1.

Table 2.1. Air quality objectives included in the Air Quality Regulations (2000) and Amendment Regulations (2002) for the purpose of Local Air Quality Management

Pollutant	Air Quality Objective		Date to be achieved by
	Concentration	Measured as	
Benzene			
All authorities	16.25 $\mu\text{g m}^{-3}$	Running annual mean	31.12.2003
Authorities in England and Wales only	5.00 $\mu\text{g m}^{-3}$	Annual mean	31.12.2010
Northern Ireland only	3.25 $\mu\text{g m}^{-3}$	Running annual mean	31.12.2010
1,3-Butadiene	2.25 $\mu\text{g m}^{-3}$	Running annual mean	31.12.2003
Carbon monoxide			
Authorities in England, Wales and Northern Ireland only	10.0 mg m^{-3}	Maximum daily running 8-hour mean	31.12.2003
Authorities in Scotland only	10.0 mg m^{-3}	Running 8-hour mean	31.12.2003
Lead	0.5 $\mu\text{g m}^{-3}$ 0.25 $\mu\text{g m}^{-3}$	Annual mean Annual mean	31.12.2004 31.12.2008
Nitrogen dioxide	200 $\mu\text{g m}^{-3}$ not to be exceeded more than 18 times a year 40 $\mu\text{g m}^{-3}$	1 hour mean Annual mean	31.12.2005 31.12.2005
Particles (PM₁₀) (gravimetric)^{b,c}	50 $\mu\text{g m}^{-3}$ not to be exceeded more than 35 times a year 40 $\mu\text{g m}^{-3}$	24 hour mean Annual mean	31.12.2004 31.12.2004
Sulphur dioxide	350 $\mu\text{g m}^{-3}$ not to be exceeded more than 24 times a year 125 $\mu\text{g m}^{-3}$ not to be exceeded more than 3 times a year 266 $\mu\text{g m}^{-3}$ not to be exceeded more than 35 times a year	1 hour mean 24 hour mean 15 minute mean	31.12.2004 31.12.2004 31.12.2005

b. Measured using the European gravimetric transfer standard sampler or equivalent.

c. These 2010 Air Quality Objectives for PM₁₀ apply in Scotland only, as set out in the Air Quality (Scotland) Amendment Regulations 2002.

Local Authorities are required to declare an Air Quality Management Area where it is likely that these objectives will not be achieved and to prepare an Action Plan to set out the measures to be taken to achieve the objectives.

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007) introduced two further objectives for PM_{2.5}. These are a “cap” of 25 $\mu\text{g m}^{-3}$ to be achieved by 2010 and an exposure reduction target of 15 % reduction in average concentrations at urban background locations. These PM_{2.5} objectives have not yet been set in Regulations.

3 Individual installations

3.1 Introduction

Local Authorities require a simple tool for assessing whether a biomass combustion installation in the range 50 kW to 20 MW thermal will lead to pollutant concentrations exceeding the air quality objectives or will compromise the effectiveness of measures set out in their Action Plans.

Defra provides Technical Guidance (LAQM.TG(03)) for Local Air Quality Management. The Technical Guidance provides some simple nomographs for assessing the air quality impact of industrial sources. It is expected that the nomographs will remain within the revised guidance and they will be applicable to larger biomass combustion installations. However, biomass burners in the range up to about 2MW_{th} are outside the range of application of the Technical Guidance nomographs. Nomographs suitable for application to biomass combustion plant less than 2MW_{th} are developed in this chapter. The Technical Guidance TG(03) has separate nomographs for stacks and for low level sources. For biomass combustion in the range 50 kW-2MW, the required stacks are relatively short and so a single nomograph has been prepared to cover both low-level sources and isolated stacks. The nomographs developed are intended to prevent localised concentration “hot spots”. Individual combustion appliances are unlikely to result in relevant increases in average exposure over widespread areas. Consequently, the exposure reduction target for PM_{2.5} has not been considered in the development of the nomographs.

In some cases in large cities the background concentrations of pollutants already exceed the air quality objectives. In these cases, it will not be possible to install additional combustion plant without further increasing the pollutant concentrations. However, local authorities may choose to allow a small increase in pollutant concentrations locally in small areas in order that development is not unduly constrained.

The provision of chimneys for biomass burners less than 50 kW thermal is covered by the Building Regulations.

3.2 Dispersion modelling

The dispersion model ADMS was used to predict ground level concentrations for a unit (1 g s⁻¹) emission rate of pollutant from discharge stacks with heights in the range 10.6-40 m and diameters in the range 0.1-1m. ADMS is an up-to-date dispersion model widely used to assess the air quality impact of pollutant emissions. The discharge stack was assumed to be located at the centre of a 10 m cubical building. The discharge temperature was assumed to be 100°C, typical of biomass combustion appliances. Discharge velocities from the stacks were estimated on the basis that the appliances operate with forced draught just sufficient to overcome the pressure drops through the appliance. Table 3.2 lists the model runs and input values. Table 3.3 shows both the actual stack height above ground, C and the effective stack height, U:

$U = 1.66(C - H)$ for $C < 2.5H$; otherwise $U = C$, where: H is the building height.

Table 3.1: Actual and effective stack height modelling

Run	Stack height, m	Effective stack height, m	Stack diameter, m	Discharge velocity, m s ⁻¹
A1_1	10.6	1	0.1	1.3
A2_1	11.2	2	0.1	1.3
A5_1	13	5	0.1	1.3
A10_1	16	10	0.1	1.3
A20_1	22	20	0.1	1.3
A40_1	40	40	0.1	1.3
A1_2	10.6	1	0.2	1.9
A2_2	11.2	2	0.2	1.9
A5_2	13	5	0.2	1.9
A10_2	16	10	0.2	1.9
A20_2	22	20	0.2	1.9
A40_2	40	40	0.2	1.9
A1_5	10.6	1	0.5	3
A2_5	11.2	2	0.5	3
A5_5	13	5	0.5	3
A10_5	16	10	0.5	3
A20_5	22	20	0.5	3
A40_5	40	40	0.5	3
A1_10	10.6	1	1	4.2
A2_10	11.2	2	1	4.2
A5_10	13	5	1	4.2
A10_10	16	10	1	4.2
A20_10	22	20	1	4.2
A40_10	40	40	1	4.2

The model was run with hourly sequential meteorological data for Heathrow Airport, 2005 and 2006 with surface roughness 1 m locally and 0.1 m at the airport. The model was run with receptor locations on a 1 km square grid centred on the stack at 10 m intervals. Maximum annual mean, 90th percentile 24-hour mean and 99.8th percentile hourly mean concentrations were calculated. The emission rate, E_A (g/s) that would lead to an increase in the maximum ground level concentration of 1 µg m⁻³ was then calculated¹ (as the inverse of the maximum ground level concentration for unit emission). Cubic polynomial curves were fitted through the modelled data of the form:

$$y = ax^3 + bx^2 + cx + d$$

where: x is log₁₀(U); and y=log₁₀(E_A).

Table 7.3: Shows the values of the constants a, b, c and d

¹ The nomographs were developed based on a contribution of 1 µg m⁻³ to ground level concentrations. The allowable contribution to ground level concentrations from the plant will depend on the background concentration and on local authority policies. The procedures developed below allow these factors to be taken into account.

Table 3.2: Values of the constants a, b, c and d

Statistic	Stack diameter, m	a	b	c	d	Range of effective stack heights, m
90 th percentile of 24 hour means	0.1	0.373	0.1922	0.2193	-3.2269	1-40
	0.2	0.3418	0.2323	0.2104	-3.158	1-40
	0.5	0.3442	0.1309	0.3063	-2.9656	2-40
	1	0.221	0.3501	0.2056	-2.7288	5-40
Annual mean	0.1	0.4990	-0.1051	0.4351	-2.8062	1-40
	0.2	0.4920	-0.1211	0.4478	-2.7296	1-40
	0.5	0.4790	-0.1904	0.5228	-2.5349	2-40
	1	0.2923	0.1984	0.2894	-2.2548	5-40
99.8 th percentile of hourly means	0.1	-0.2570	1.4398	-0.3227	-3.896	1-40
	0.2	-0.2412	1.2842	-0.1655	-3.7481	1-40
	0.5	-0.9642	3.3411	-1.9382	-3.0675	2-40
	1	-1.6681	5.8307	-4.6034	-2.0738	5-40

Figures 3.1, 3.2 & 3.3 show nomographs based on the polynomial curve fits. Figs 3.1 and 3.2 show the emission rates that correspond to an increase in maximum ground level 90th percentile and annual mean concentrations of 1 $\mu\text{g m}^{-3}$. Fig. 3.3 shows the emission rate that corresponds to an increase in the 99.8th percentile oxides of nitrogen concentration of 40 $\mu\text{g m}^{-3}$

Figure 3.1: Particulate emissions necessary to give a 90th percentile of 24 hour mean ground level concentrations of $1 \mu\text{g m}^{-3}$

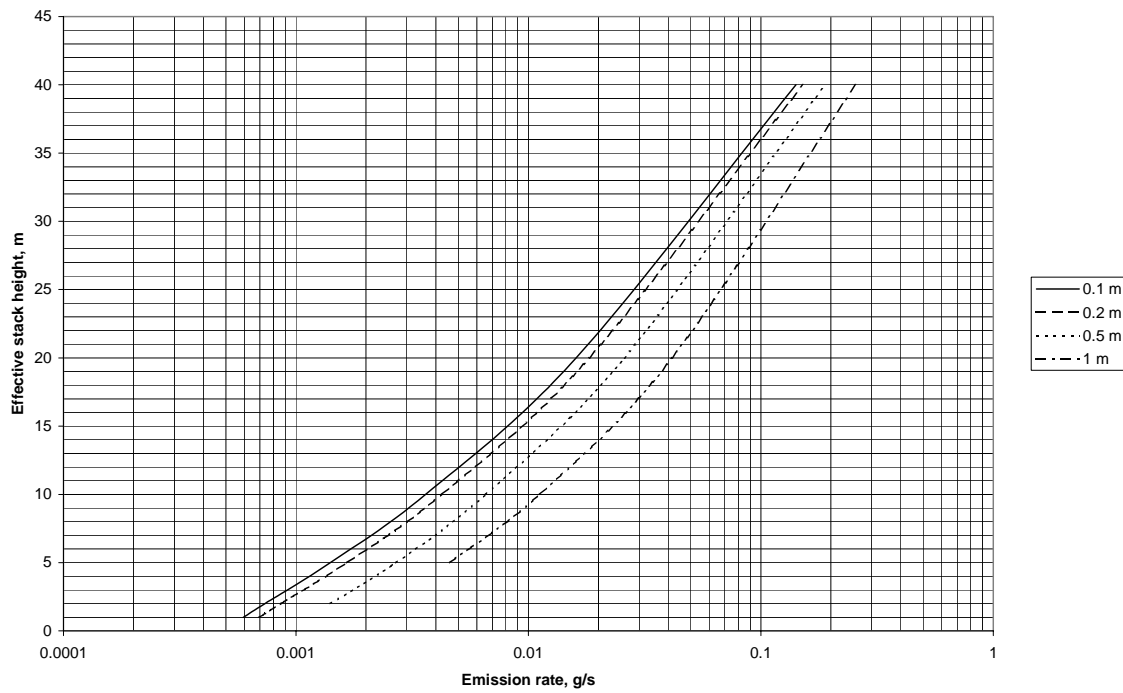


Figure 3.2: Emissions necessary to give an annual mean ground level concentration of $1 \mu\text{g m}^{-3}$ of oxides of nitrogen or particulate matter

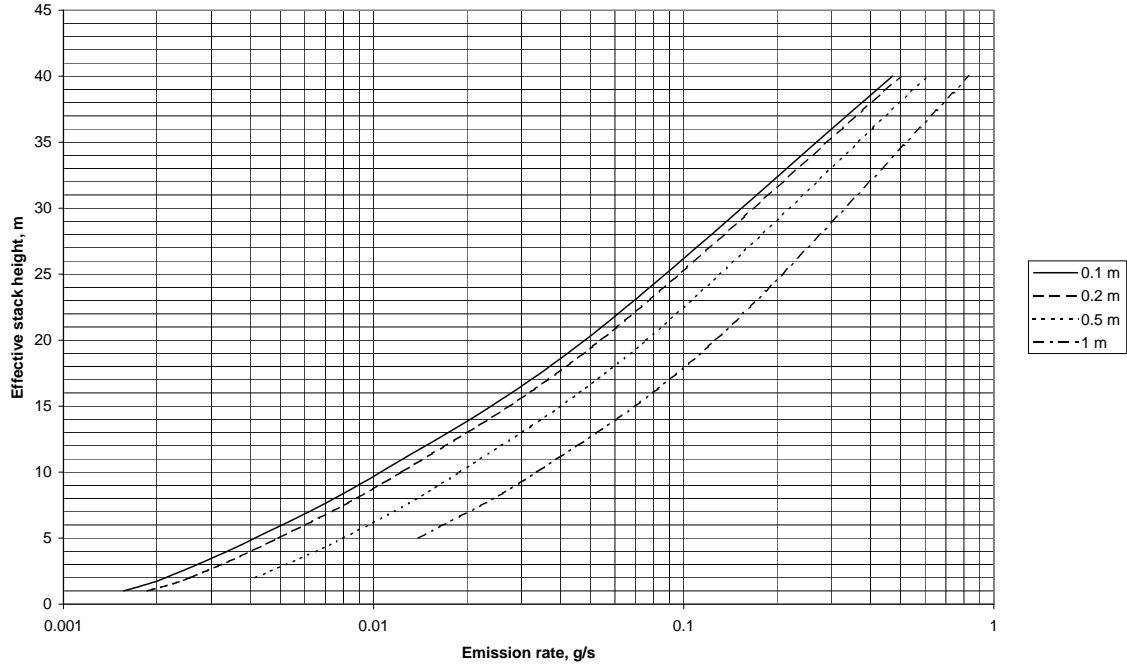
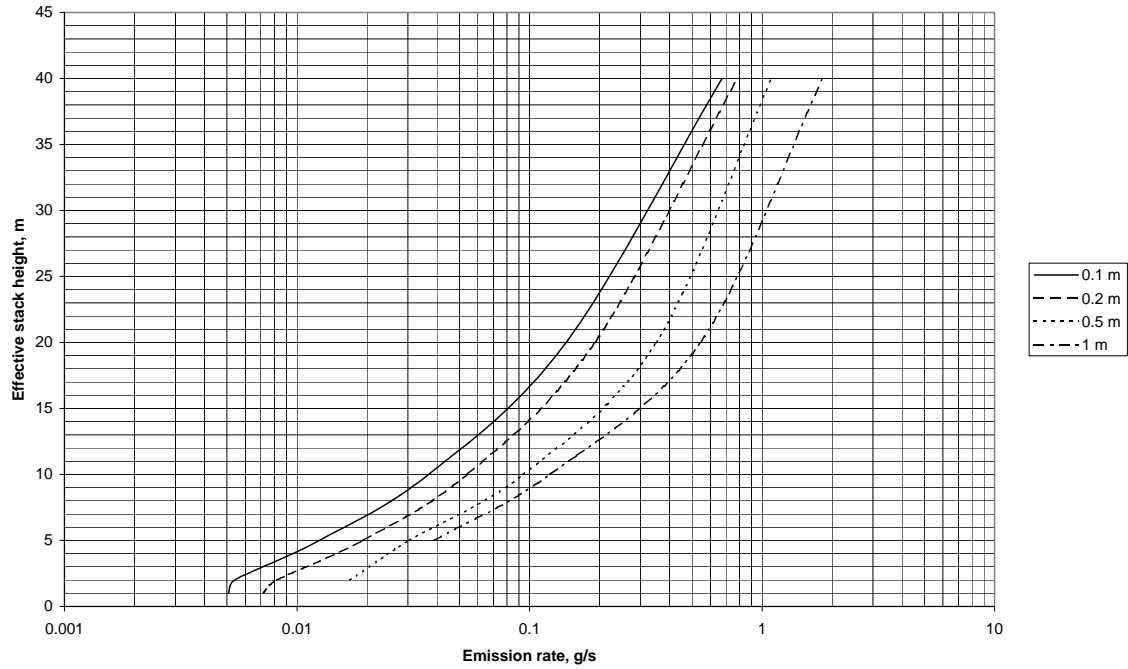


Figure 3.3: Emissions of oxides of nitrogen that will give a 99.8th percentile hourly mean concentration of $40 \mu\text{g m}^{-3}$



3.3 Procedures

The following sections describe how local authorities should use the nomographs to assess the potential impact on local air quality of proposed developments involving biomass combustion appliances.

In order to use the nomographs, the local authority should estimate/derive the following information:

- Height of stack above ground;
- Diameter of stack;
- Dimensions of buildings within a distance from the stack of five times the stack height above ground;
- Description of the combustion appliance; and
- Maximum rates of emission of particulate matter (PM₁₀ and PM_{2.5}) and oxides of nitrogen when operating at capacity.

The local authority may obtain details of the maximum thermal capacity of the appliance instead of the maximum rates of emission. Local authorities may then estimate rates of emission based on the Clean Air Act exemption limits or on the basis of emission factors provided by the EMEP/CORINAIR Emission Inventory Guidebook – 2006. In smoke-controlled areas, biomass burners require exemption under the Clean Air Act. Exempted appliances are required to emit less than 5 g/h particulate matter plus 0.1 g/h per 0.3 kW of heat output. The EMEP/CORINAIR Emission Inventory Guidebook – 2006 gives typical emission factors solid fuel appliances. These are summarised in Appendix 1.

Note that for modern appliances with well –designed combustion the particles emitted are all thought to be less than 2.5 μm , hence the total particles, PM₁₀ and PM_{2.5} emissions are equivalent. For traditional appliance designs this may not be so but is a conservative assumption in the absence of size fractionated measurements.

In addition, local authorities should estimate background pollutant concentrations in their area from 1 km x 1 km maps provided for Local Authority Review and Assessment (<http://www.airquality.co.uk/archive/laqm/tools.php?tool=background04>) or from measurements at similar background locations.

Where there are multiple stacks at the same site, a precautionary approach may be taken by assuming the total emissions (from all stacks) are released from the smallest stack. Where there are complex sites with many stacks, the nomographs are unlikely to be applicable, and authorities are advised to proceed to a more detailed assessment.

3.3.1 PM₁₀

The nomograph at Figure 3.1 may be used to assess whether the proposed biomass combustion installation is likely to lead to an exceedence of the 24 hour objective for PM₁₀. First, calculate a “background- adjusted” emission rate using:

$$E_A = \frac{E}{(32 - G)}$$

where: E is the emission rate in g s⁻¹ for the plant operating at capacity; and G is the annual average background concentration in $\mu\text{g m}^{-3}$. The 32 $\mu\text{g m}^{-3}$ represents the annual average concentration at which given a typical distribution of concentrations with time the 90th percentile of 24 hour means will exceed the objective.

If the actual stack above ground height is less than 2.5 times the height of the building to which it is attached or any other building within 5 times the stack height then it will be necessary to calculate an effective stack height. The effective stack height can be calculated from the following formula:

$$C = 1.6(U - H)$$

where C is the effective stack height,

U is the actual stack height above ground,

H is the height of the tallest building within a distance of 5 times the stack height.

Otherwise, if the stack is more than 2.5 times the building height, then $C=U$.

The nomographs cannot be used if the building height, H, is greater than the actual stack height.

To use the nomograph, identify the line that corresponds to the diameter of the stack under consideration and locate the point on this line whose ordinate corresponds to the effective stack height. Read off the corresponding threshold emission rate on the horizontal axis and compare this with the "background- adjusted" emission rate. If the "background- adjusted" emission rate is greater than or equal to the threshold emission rate, the authority will need to proceed to a more detailed assessment.

3.3.2 **PM_{2.5}**

A similar procedure applies for PM_{2.5}. The procedure uses the annual average nomograph Fig. 3.2. Firstly, determine the emission rate at capacity. The emission rate of PM_{2.5} may be conservatively assessed as equal to the PM₁₀ emission. The background annual average PM_{2.5} concentration, G, may be determined from measurements at similar locations in the local authority area or neighbouring areas.

AEA/ED48673005/R2655 Issue 1

The background adjusted emission rate for PM_{2.5} is calculated using:

$$E_A = \frac{E}{(25 - G)}$$

where: E is the emission rate in g s⁻¹ at capacity; and G is the annual average background concentration in µg m⁻³. The 25 µg m⁻³ represents the annual average cap for PM_{2.5}.

Calculate the effective stack height as above.

To use the nomograph, identify the line that corresponds to the diameter of the stack under consideration and locate the point on this line whose ordinate corresponds to the effective stack height. Read off the corresponding threshold emission rate on the horizontal axis and compare this with the “background- adjusted” emission rate. If the “background- adjusted” emission rate is greater than or equal to the threshold emission rate, the authority will need to proceed to a more detailed assessment.

3.3.3 Nitrogen dioxide, annual mean

A similar procedure applies for the annual mean nitrogen dioxide. The procedure uses the annual average nomograph Fig. 3.2. First determine the emission rate at capacity. The background concentration may be determined from 1 km x 1 km provided for Local Authority Review and Assessment (<http://www.airquality.co.uk/archive/laqm/tools.php?tool=background04>). The background adjusted emission rate for annual average oxides of nitrogen is calculated using:

$$E_A = \frac{E}{(40 - G)}$$

where: E is the emission rate in g s⁻¹ at capacity; and G is the annual average background of nitrogen dioxide concentration in µg m⁻³. The 40 µg m⁻³ represents the annual average objective.

Calculate the effective stack height as above.

To use the nomograph, identify the line that corresponds to the diameter of the stack under consideration and locate the point on this line whose ordinate corresponds to the effective stack height. Read off the corresponding threshold emission rate on the horizontal axis and compare this with the “background- adjusted” emission rate. If the “background- adjusted” emission rate is greater than or equal to the threshold emission rate, the authority will need to proceed to a more detailed assessment.

3.3.4 Nitrogen dioxide, 1 hour average

A similar procedure applies for the 1 hour average objective for nitrogen dioxide. The procedure uses the 99.8th percentile hourly nomograph Fig. 3.3. Firstly, determine the emission rate at capacity. The background concentration may be determined from 1 km x 1 km provided for Local Authority Review and Assessment (<http://www.airquality.co.uk/archive/laqm/tools.php?tool=background04>).

The background adjusted emission rate for the hourly oxides of nitrogen is calculated using:

$$E_A = \frac{40E}{(200 - 2G)}$$

where: E is the emission rate in g s^{-1} at capacity; and G is the annual average background nitrogen dioxide concentration in $\mu\text{g m}^{-3}$. The background concentration is multiplied by two to represent the typical ratio between the annual mean and the 99.8th percentile of 1 hour means taking into account the partial correlation between the variation in background concentration and the dispersion of a given plume which is then subtracted from the objective.

Calculate the effective stack height as above.

To use the nomograph, identify the line that corresponds to the diameter of the stack under consideration and locate the point on this line whose ordinate corresponds to the effective stack height. Read off the corresponding threshold emission rate on the horizontal axis and compare this with the “background- adjusted” emission rate. If the “background- adjusted” emission rate is greater than or equal to the threshold emission rate, the authority will need to proceed to a more detailed assessment.

3.4 An example

A 500 kW net thermal input capacity pellet stove is installed in a building 15 m high. The stack height is 21 m and the stack diameter is 0.5 m.

The pollutant emission rates are estimated from the factors for pellet stoves given in Appendix 1. These are 76 g/GJ for PM_{10} , 76 g/GJ for $\text{PM}_{2.5}$ and 90 g/GJ for oxides of nitrogen. The emission rates are then:

$$76 \times 500 \times 10^{-6} = 0.038 \text{ g s}^{-1} \text{ for } \text{PM}_{10} \text{ and } \text{PM}_{2.5}, \text{ and}$$

$$90 \times 500 \times 10^{-6} = 0.045 \text{ g s}^{-1} \text{ for } \text{NO}_x.$$

The background annual average nitrogen dioxide concentration is $35 \mu\text{g m}^{-3}$. The background annual average PM_{10} concentration is $25 \mu\text{g m}^{-3}$ and the annual average background $\text{PM}_{2.5}$ concentration is $15 \mu\text{g m}^{-3}$. Table 3.5 shows the calculated background adjusted emission rates.

The effective stack height is $1.66 \times (21-15) = 10 \text{ m}$.

Table 3.5 also shows the threshold emission rates determined for each pollutant metric from Figures 3.1 to 3.3. In each case the background adjusted emission rate is less than the threshold emission rate and so more detailed assessment is not required.

Table 3.5: Background adjusted emission rates and threshold emissions rates

	PM₁₀	PM_{2.5}	Annual mean NO₂	Hourly mean, NO₂
Emission rate, g/s	0.038	0.038	0.045	0.045
Background concentration, $\mu\text{g m}^{-3}$	25	18	35	35
Background adjusted emission rate, g/s	0.0054	0.0054	0.009	0.014
Threshold emission rate, for 10 m effective stack height, g/s	0.0063	0.020	0.020	0.10

4 Combined impacts

4.1 Introduction

A number of local authorities have expressed concern that the effects of many small biomass combustion installations that are individually acceptable could combine and lead to unacceptably high particulate matter concentrations. Technical Guidance LAQM.TG(03) provides a nomograph for assessing whether there is a risk of exceeding air quality objectives for PM₁₀ as the result of emissions from domestic solid fuel consumption. The nomograph can be used to assess the potential impact of domestic wood burning. However, the TG(03) nomograph is likely to be excessively conservative when applied to modern solid fuel appliances.

The TG(03) nomograph is applicable to domestic heating. However, there is potentially widespread application of biomass combustion for service sector heating (commercial offices, communication and transport, education, government, health, hotel and catering, retail, sport and leisure, warehouses) and for heating small industrial units.

This section of the report proposes a revised nomograph that takes into account the improved emissions performance of modern solid fuel appliances. The revised nomograph can be applied to both domestic and service sector heating.

4.2 Dispersion modelling

The dispersion model ADMS4 was used to predict the maximum annual average ground level concentration resulting from a uniform emission rate applied over areas of 1 km², 4 km² and 16 km² representing villages, small towns and relatively large towns respectively. Each area was represented as a square volume source, 10 m deep. The model used hourly sequential meteorological data for Heathrow Airport for 2006. The surface roughness of the modelled area was assumed to be 1 m. Urban heat island effects were taken into account by setting a lower limit of 10 m and 20 m for the Monin-Obukhov length for the small and large towns respectively: no restriction was applied for the "village". The maximum predicted annual mean concentrations for a uniform emission rate of 1 g s⁻¹ km⁻² were 12.4 µg m⁻³ for the "village", 16.9 µg m⁻³ for the "small town" and 17.3 µg m⁻³ for the "large town". On this basis it was calculated that annual emissions of 2.543 tonne km⁻², 1.866 tonne km⁻² and 1.823 tonne km⁻² would result in an increase in the annual mean concentrations of 1 µg m⁻³ in the "village", "small town" and "large town" respectively.

4.3 Estimating emissions

Total domestic energy consumption for space and water heating during 2005 was 39.1 million tonnes of oil equivalent. There were 25,650,000 households in the UK in 2005. (BERR energy consumption tables). Thus the average fuel consumption per household for space and water heating was 1.524 tonnes of oil equivalent (63.8 GJ gross).

Total energy consumption by the service sector for space and water heating in 2005 was 10.866 million tonnes of oil equivalent. Service sector floor area was 854 km². (BERR energy consumption tables). Thus the average fuel consumption per hectare of floor space for space and water heating by the service sector was 127 tonnes of oil equivalent (5327 GJ gross).

Emission factors taken from the EMEP/CORINAIR Emission Inventory Guidebook – 2006 for solid fuel appliances are summarised in Appendix 1. In addition, Appendix 1 includes an assessment of achievable emissions from the best available technology for domestic appliances based on measurement data reported to AEA Technology for exemption of appliances under the Clean Air Act.

The emission factors are presented in terms of net energy input, whereas the fuel consumption estimates are expressed in terms of gross energy content. The ratio of net to gross calorific values is

AEA/ED48673005/R2655 Issue 1

typically 0.95 for coal, 0.5 for wood consumed in domestic appliances and 0.84 for wood consumed in industrial appliances (Digest of UK Energy Statistics). Wood pellets used in domestic appliances have been assumed to have a calorific value ratio of 0.84.

Table 4.1 shows the estimated annual emissions per household from domestic appliances and the estimated annual per emissions per hectare of floorspace for service sector applications.

Table 4.1: Estimated annual emissions per household or hectare of service sector floorspace

Appliance type	Fuel	Emissions per household, kg year ⁻¹		Emissions per hectare of service sector floorspace, kg year ⁻¹	
		PM ₁₀	PM _{2.5}	PM ₁₀	PM _{2.5}
Fireplace	Coal	20.00	20.00	1670	1670
	Wood	27.43	27.12	2291	2264
Stove	Coal	27.27	27.27	2277	2277
	Solid smokeless fuel	6.06	6.06	506	506
	Wood	25.84	25.84	2157	2157
Advanced stove	Coal	14.55	13.33	1215	1113
	Wood	7.66	7.66	639	639
Pellet stove	Wood	4.07	4.07	340	340
Boiler<50 kWth	Coal	23.03	21.82	1923	1822
	Solid smokeless fuels	6.06	6.06	506	506
	Wood	15.15	15.15	1265	1265
Boiler > 50 kW th and < 1MW th	Coal			962	860
	Solid smokeless fuels			405	405
	Wood			1074	1074
Boiler>1MW th	Coal			385	364
	Wood			300	291
Advanced manual boiler	Coal	8.49	7.88	708	658
	Wood	2.42	2.42	202	202
Advanced automatic boiler	Coal	4.61	4.36	385	364
	Wood	3.54	3.54	295	295
Boiler, with fabric filter<20 mg/Nm3 TSP	Coal			30	25
	Wood			31	27
Older boiler with fabric filter or electrostatic precipitator <100 mg/Nm3 TSP	Coal			127	61
	Wood			112	54
Boiler with uncontrolled multicyclone	Coal			304	177
	Wood			313	246
Best available domestic	Wood	1.07	1.07		

4.4 Method

Solid fuel burning tends to be concentrated into small areas or estates, which generally cover less than 1 km². The procedure adopted for LAQM.TG(03) required authorities to identify the area with the highest density of solid fuel burning houses and then to estimate the number of houses burning coal, smokeless fuel or wood within a 500 m x 500 m grid square. The proportion of space in the 500 m x 500m square not occupied by solid fuel burning houses was also required, together with the annual mean background concentration. A similar procedure is recommended here:

- 1 Identify the areas with the highest densities of houses and service sector appliances burning solid fuels.
- 2 Identify the types of solid fuel appliance used in each area from the list in Table 4.1. Appendix 1 provides further descriptions of the appliance types.
- 3 Count the numbers of each domestic heating appliance type in the identified 500 x 500 m squares. Estimate the floorspace occupied in the service sector in each of the identified 500 m x 500 m squares for each of the identified types of solid fuel burning plant.
- 4 Multiply the number of houses for each appliance type by the annual household emission shown in Table 4.1. Sum the emissions from each of the domestic appliance types to give the total annual domestic emission from the 500 m x 500 m square.
- 5 Multiply the service sector floorspace (in hectares) for each appliance type by the annual service sector emission per hectare. Sum the emissions from each of the service sector appliance types to give the total annual service sector emission from the 500 m x 500m square. Add the service sector emissions to the domestic emissions to give the total emissions from the square.
- 6 Estimate the fraction of space in the 500 m x 500 m square occupied by solid fuel burning premises or domestic properties. Divide the annual emission by the fraction occupied by solid fuel burning to give the emissions density for the square (kg emissions per 500 m x 500 m area).
- 7 Figure 4.1 describes the annual emissions from a 500 m x 500m square (the threshold emissions density) that may give rise to an exceedence of the 24 hour mean objective for PM₁₀ for a particular estimated background PM₁₀ concentration. If the emissions density from the square exceeds the threshold emissions density shown in Fig. 4.1, then the authority will need to proceed to a detailed assessment.
- 8 Figure 4.2 describes the annual emissions from a 500 m x 500m square (the threshold emissions density) that may give rise to an exceedence of the annual mean cap for PM_{2.5} for a particular estimated background PM_{2.5} concentration. If the emissions density from the square exceeds the threshold emissions density shown in Fig. 4.2, then the authority will need to proceed to a detailed assessment. Where the assessment is being made against a different annual mean objective, the nomograph may still be used by adjusting the background concentration. (For example, for authorities in Scotland where the annual mean cap for PM_{2.5} is 12 µg m⁻³, the background concentration should be increased by 13 µg m⁻³).
- 9 Figure 4.3 describes the annual emissions from a 500 m x 500m square (the threshold emissions density) that may give rise to an exceedence of the annual mean objective for PM₁₀ for Scotland of 20 µg m⁻³ for a particular estimated background PM₁₀ concentration. If the emissions density from the square exceeds the threshold emissions density shown in Fig. 4.1, then the authority will need to proceed to a detailed assessment.

Fig. 4.1: Threshold emissions density of emissions from a 500 m x 500 m area that may produce an exceedence of the daily average objective for PM₁₀

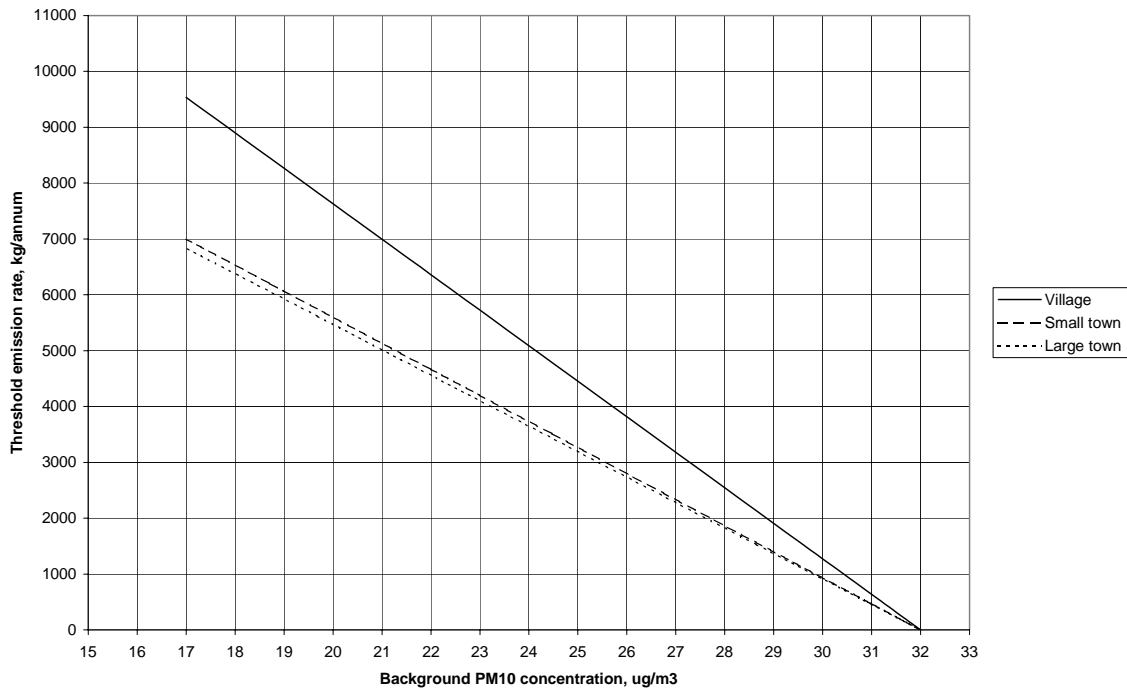


Fig. 4.2: Threshold emissions density of emissions from a 500 m x 500 m area that may produce an exceedence of the annual average cap for PM_{2.5}

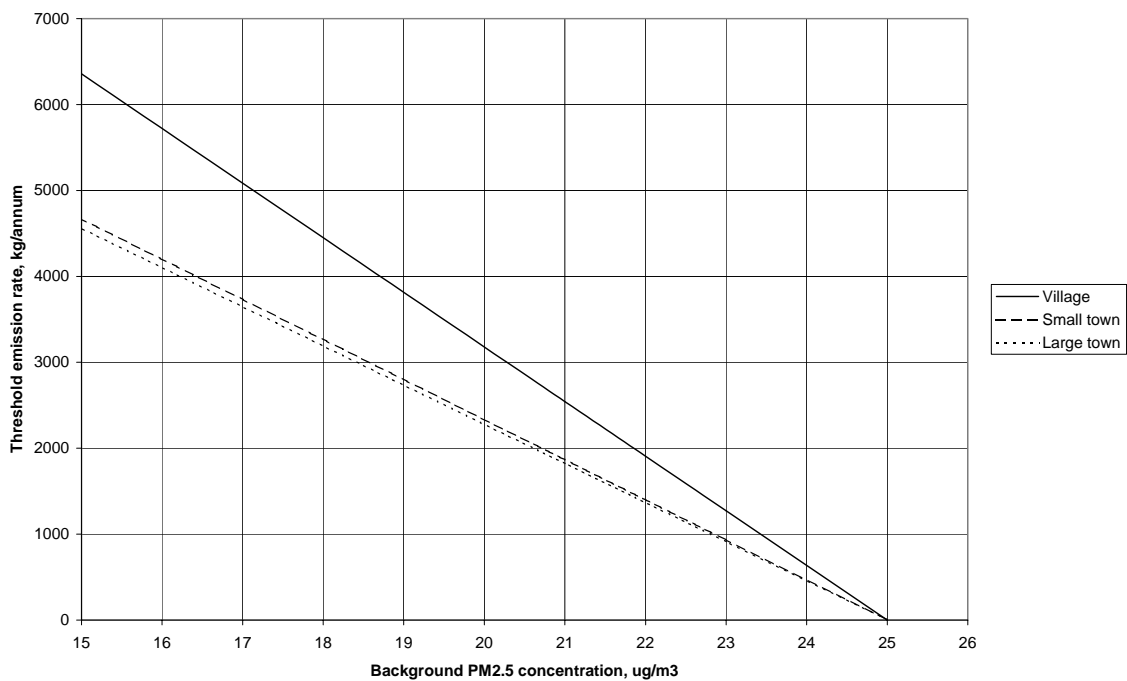
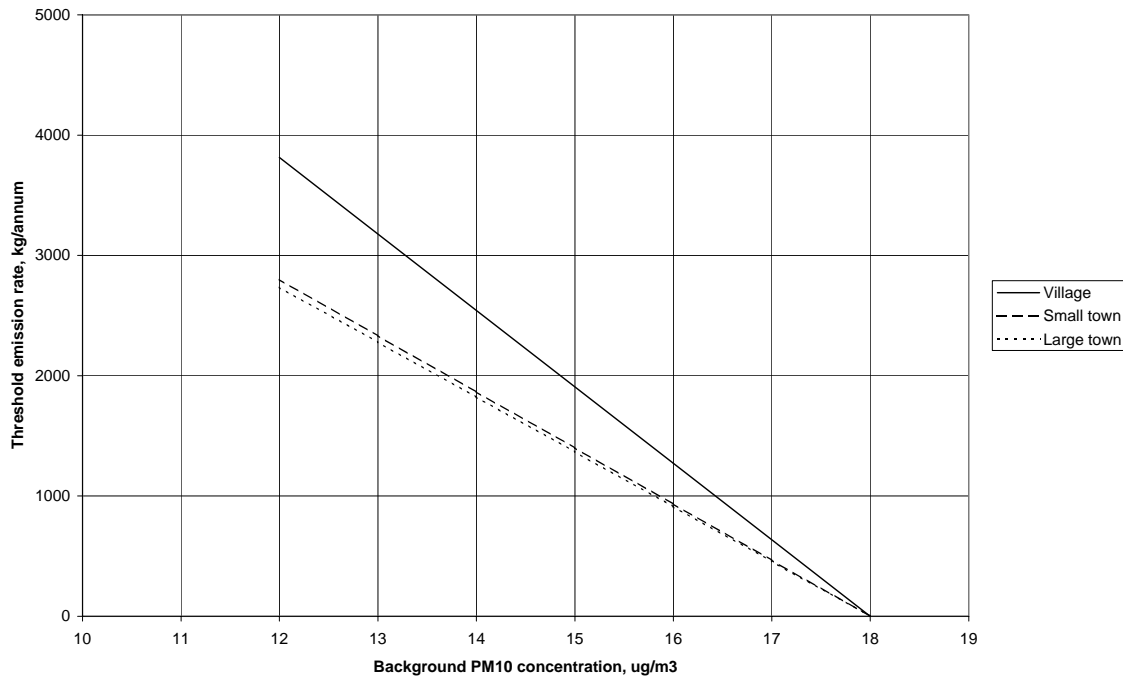


Fig. 4.3: Threshold emissions density of emissions from a 500 m x 500 m area that may produce an exceedence of the annual average objective for PM₁₀ in Scotland



4.5 Example

Consider a 500 m x 500 m square containing a new 6 hectare development of 400 houses on the outskirts of a large town. The houses are fitted with advanced automatic wood pellet boilers. The new development adjoins an 8 hectare older estate. The older estate has largely converted to gas heating but there remain 50 houses that use conventional boilers burning coal. The 500 m x 500 m square also contains a school with floor area of 0.2 hectares in a plot of 1 hectare: the school is heated by means of a wood-burning advanced automatic boiler. There is also a public house with floor area of 0.1 hectare in a plot of 0.5 hectare; the public house is heated by open wood fires. The remaining part of the 500 m x 500 m square does not contain premises burning solid fuels.

The total emissions of PM₁₀ from the residential area is:

$$400 \times 3.54 + 50 \times 23.03 = 1416 + 1152 = 2568 \text{ kg.}$$

The total emissions of PM₁₀ from the school and the public house are:

$$0.2 \times 295 + 0.1 \times 2291 = 59 + 229 = 288 \text{ kg.}$$

The total emissions from all solid fuel sources are then 2568 + 288 = 2856 kg.

The area of the 500 x 500 m square occupied by solid fuel heated premises is:

$$6 + 8 + 1 + 0.5 = 15.5 \text{ hectares.}$$

Thus the fraction occupied is $9.5/25 = 0.62$. The emissions density is then $2856/0.62 = 4606 \text{ kg/year}$.

The background PM₁₀ in the area is estimated from the national maps to be $21 \mu\text{g m}^{-3}$. From Fig. 4.1, the threshold emission density is 5013 kg/year. In this case, the calculated emissions for the 500 m x

Technical Guidance:
Screening assessment for biomass boilers

AEA/ED48673005/R2655 Issue 1

500 m square are less than the threshold and there is no requirement to carry out a detailed assessment.

Appendix 1

Emission factors for solid fuel combustion

Description	Corinair category	Fuel	Emission factor, g/GJ net		
			PM ₁₀	PM _{2.5}	NO _x
<p>Open fireplaces: this type of fireplaces is of very simple design - basic combustion chamber, which is directly connected to the chimney. Fireplaces have large openings to the fire bed. Some of them have dampers above the combustion area to limit the room air intake and resulting heat losses when fireplace is not being used. The heat energy is transferred to dwelling mainly by radiation. Open fireplaces are usually of masonry type and have very low efficiency while having significant emissions of TSP, CO, NMVOC and PAH resulting from the incomplete combustion of the fuels.</p> <p>Partly closed fireplaces are equipped with louvers and glass doors to reduce the intake of combustion air. Some masonry fireplaces are designed or retrofitted in that way in order to improve their overall efficiency.</p>	Fireplace	Coal	330	330	60
		Wood	860	850	50
<p>Closed fireplaces are equipped with front doors and may have distribution of combustion air to primary and secondary as well as a system to discharge the exhaust gases. They are prefabricated and installed as stand-alone units or as a fireplace inserts installed in existing masonry fireplaces. Because of the design and the combustion principle, closed fireplaces resemble stoves and their efficiency usually exceeds 50 %. They have similar emissions like stoves, i.e., lower than open, as well as, partly closed fireplaces. For this reason they can be rated among stoves.</p> <p>Conventional stoves have poorly organised combustion process resulting in low efficiency (40% to 50%) and significant emissions of pollutants mainly originating from incomplete combustion (TSP, CO, NMVOC and PAH). Their autonomy is low, lasting from 3 to 8 hours. Those, which are equipped with hot plate zones, are used also for cooking - kitchen stoves. Some of them could also be used for hot water preparation.</p> <p>Classic energy efficient stoves; due to the utilization of secondary air in the combustion chamber their efficiency is between 55% to 75% and emission of pollutants are lower, their autonomy ranges from 6 to 12 hours.</p>	Stove	Coal	450	450	100
		Solid smokeless fuel	100	100	100
		Wood	810	810	50
<p>Advanced combustion stoves: These stoves are characterized by multiple air inlets and pre-heating of secondary combustion air by heat exchange with hot flue gases. This design results in increased efficiency (near 70% at full load) and reduced CO, NMVOC and TSP emissions in comparison with the conventional stoves.</p>	Advanced stove	Coal	240	220	150
		Wood	240	240	90
<p>Pellet stoves: They can be fed only with pelletised fuels such as wood pellets, which are distributed to the combustion chamber by a fuel feeder from a small fuel storage. Pellets stoves are equipped with a fan and electronic control system for supply of the combustion air. For this reason they are characterized by high efficiency (above 80% up to 90%) and low emissions of CO, NMVOC, TSP and PAH.</p>	Pellet stove	Wood	76	76	90
<p>Conventional natural draught boilers < 50 kWth</p>	Boiler<50 kWth	Coal	380	360	130
		Solid smokeless fuels	100	100	200
		Wood	475	475	120

Description	Corinair category	Fuel	Emission factor, g/GJ net		
			PM ₁₀	PM _{2.5}	NO _x
Conventional natural draught boilers > 50 kWth and <1 MW th					
	Boiler > 50 kW th and < 1MW th	Coal	190	170	160
		Solid smokeless fuels	80	80	150
		Wood	240	240	150
Conventional natural draught boilers >1 MW th					
	Boiler>1MW th	Coal	76	72	180
		Wood	67	65	150
Advance, under-fire coal boilers: In general the design and the combustion technique are similar to the conventional under-fire boiler. The main difference is that a fan controls the flue gases flow. Control system for the primary and secondary air might lead to increase in efficiency above 80% (usually between 70% and 80%).					
Downdraught wood boilers: This type of boiler is considered state of the art in the lump wood combustion. It has two chambers, first one where the fuel is fed for partial devolatilisation and combustion of the fuel layer, and a secondary chamber, where burning of the released combustible gases occurs. The advantage of this boiler is that the flue gases are forced to flow down through holes in a ceramic grate and thus are burned at high temperature within the secondary combustion chamber and ceramic tunnel. Owing to the optimized combustion process, emissions due to incomplete combustion are low.					
	Advanced manual boiler	Coal	140	130	200
		Wood	76	76	150
Stoker coal burners: The fuel with low ash contents and the grain size of between 4 mm up to 25 mm is automatically fed into to a retort by a screw conveyor. Stoker boiler is characterized by higher efficiency, usually above 80%. The advantage of stoker boiler is that it can operate with high efficiency within load range from 30% to nominal capacity. In a properly operated stoker, emissions of pollutants resulting from incomplete combustion are significantly lower, however NO _x increases due to the higher combustion temperature.					
Wood pellet boiler has a fully automatic system for feeding of pellet fuels and for supply of combustion air, which is distributed into primary and secondary. The boilers are equipped with a smaller pellet storage, which is fuelled manually or by an automatic system from larger chamber storage. The pellets are introduced by screw into burner. These boilers are characterised by a high efficiency (usually above 80%) and their emissions are comparable to those of liquid fuel boilers.					
Best Available Technology Domestic Boilers					
ABATED Emissions					
Boiler, with fabric filter<20 mg/Nm³ TSP		Coal	6	5	180
		Wood	7	6	150

*Based on an assessment of achievable performance from measurement data reported to AEA Technology for approval as exempt appliances under the Clean Air Act

Description	Corinair category	Fuel	Emission factor, g/GJ net		
			PM ₁₀	PM _{2.5}	NO _x
Older boiler with fabric filter or electrostatic precipitator <100 mg/Nm ³ TSP		Coal	25	12	180
		Wood	25	12	150
Boiler with uncontrolled multicyclone		Coal	60	35	180
		Wood	70	55	150

