Category		Title
NFR:	**1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a**	**Small combustion**
SNAP:	**020103a 020103b 020106 020202a 020202b 020205 020302a 020302b 020305**	**Commercial/institutional — Combustion plants 20–50 MW Commercial/institutional — Combustion plants < 20 MW Commercial/institutional — Other stationary equipments Residential — Combustion plants 20–50 MW Residential — Combustion plants < 20 MW Residential — Other stationary equipments Agriculture/forestry/aquaculture — Combustion plants 20–50 MW Agriculture/forestry/aquaculture — Combustion plants < 20 MW Agriculture/forestry/aquaculture — Other stationary equipments**
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Contents

1 Overview

This chapter covers the methods and data needed to estimate stationary combustion emissions under NFR sectors 1.A.4.a.i, 1.A.4.b.1, 1.A.4.c.1 and 1.A.5.a. . The sectors cover combustion installations activities in the following sectors which, for the purpose of this guidance, are considered to have a thermal capacity ≤ 50 MW_{th}.

- 1.A.4.a — Commercial/institutional
- 1.A.4.b — Residential
- 1.A.4.c — Agriculture/forestry
- 1.A.5.a — Other (stationary combustion)

The activities essentially cover combustion in smaller-scale combustion units and installations than those in Chapter 1.A.1, Energy industries. The combustion technologies employed may be relevant to sectors in Chapter 1.A.1. Chapter 1.A.1 provides additional emission information for the activities in this chapter (and vice versa). The information within this chapter is also appropriate for assessing stationary combustion emissions within certain other sectors.

The sectors covered in this chapter can include the following activities:

- commercial and institutional heating
- residential heating, cooking
- agriculture/forestry and
- other stationary combustion (including military).

The open-field burning of agricultural residues is not included in this chapter. The range of activities relevant to sector 1.A.4 are summarised in section 2. The most important pollutants emitted to atmosphere are summarised in Table 1-1

Table 1-1 Pollutants with potential for small combustion activities to be a key category

Source releases													
Activity	PM (TSP)	PM_{10}	$PM_{2.5}$	Oxides of sulphur	Oxides of nitrogen	Oxides of carbon	Hydrogen chloride, fluoride	Volatile organic compounds	Metals (excluding mercury and cadmium) and their compounds	Mercury, Cadmium	PAH	Dioxins, PCB, HCB	Ammonia
Commercial and institutional heating	X	X	X	X	X	X	X	X	X	X	X	X	
Residential heating	X	X	X	X	X	X	X	X	X	X	X	X	X
Agriculture and other	X	X	X	X	X	X	X	X	X	X	X	X	

2 Description of sources

2.1 Process description

The small combustion installations included in this chapter are mainly intended for heating and provision of hot water in residential and commercials/institutional sectors. Some of these installations are also used for cooking (primarily in the residential sector). In the agricultural sector the heat generated by the installations is used also for crops drying and for heating greenhouses.

In some instances, combustion techniques and fuels can be specific to an NFR activity category; however most techniques are not specific to an NFR classification. The applications can be conveniently sub-divided considering the general size and the combustion techniques applied:

- residential heating — fireplaces, stoves, cookers, small boilers (< 50 kW);
- institutional/commercial/agricultural/other heating including:
  - heating — boilers, spaceheaters (> 50 kW),
  - smaller-scale combined heat and power generation (CHP).

Emissions from smaller combustion installations are significant due to their numbers, different type of combustion techniques employed, and range of efficiencies and emissions. Many of them have no abatement measures nor low efficiency measures. In some countries, particularly those with economies in transition, plants and equipment may be outdated, polluting and inefficient. In the residential sector in particular, the installations are very diverse, strongly depending on country and regional factors including local fuel supply.

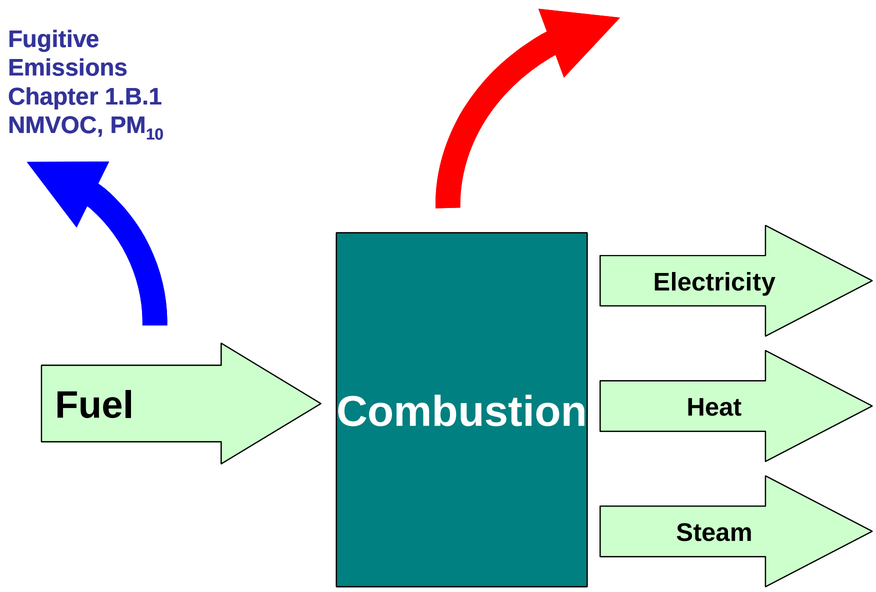

Figure 2-1 Illustration of the main process in small combustion installations; figure adapted from 2006 IPCC Guidelines for National Greenhouse Gas Inventories

2.2 Techniques

2.2.1 Residential heating (1.A.4.b)

2.2.1.1 General

In small combustion installations a wide variety of fuels are used and several combustion technologies are applied. In the residential activity, smaller combustion appliances, especially older single household installations are of very simple design, while some modern installations of all capacities are significantly improved. Emissions strongly depend on the fuel, combustion technologies as well as on operational practices and maintenance.

For the combustion of liquid and gaseous fuels, the technologies used are similar to those for production of thermal energy in larger combustion activities, with the exception of the simple design of smaller appliances like fireplaces and stoves.

The technologies for solid fuels and biomass utilization vary widely due to different fuel properties and technical possibilities. Small combustion installations employ mainly fixed bed combustion technology, i.e. grate-firing combustion (*GF*) of solid fuels. Solid fuels include mineral and biomass solid fuels, with grain size varying from a few mm to 80 mm.

More detailed descriptions of techniques can be found in Kubica, et al., (2004).

2.2.1.2 Fireplaces overview

Fireplaces are the most simple combustion devices, and are often used as supplemental heating appliances primarily for aesthetic reasons in residential dwellings. There are solid- and gas-fuelled fireplaces. The fireplaces can be divided into open, partly-closed and closed fireplaces. Based on the type of construction materials used, they can be divided into cut stone and/or brick (masonry) fireplaces, or, and cast-iron or steel. Masonry fireplaces are usually built on site and integrated into the building structure, while iron or steel are prefabricated for installation with a suitable chimney or flue.

Solid fuel fireplaces

Solid fuel fireplaces are manually-fired fixed bed combustion appliances. The user intermittently adds solid fuels to the fire by hand. They can be distinguished into the following.

Open fireplaces

> This type of fireplace is of very simple design — a 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 the dwelling mainly by radiation. Open fireplaces are usually of masonry type and have very low efficiency while having significant emissions of total suspended particulates (TSP), CO, non-methane volatile organic compounds (NMVOC) and polycyclic aromatic hydrocarbons (PAH) resulting from the incomplete combustion of the fuels.

Partly-closed fireplaces

> 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.

Closed fireplaces

These fireplaces 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 to stoves, i.e. lower than open or partly-closed fireplaces. For this reason they can be rated on a similar basis to stoves.

Fuels used in solid fuel fireplaces are mainly log, lump wood, biomass briquettes, and charcoal, coal and coal briquettes. Multifuel appliances are available which can burn a range of solid fuels including manufactured solid fuels and wood.

Gas-fuelled fireplaces

Gas fireplaces are also of simple design; materials and equipment are similar to those of solid fuels fireplaces, yet equipped with a gas burner. Because of the simple valves employed for adjustment of fuel/air ratio and non-premixing burners, NO_x emissions are lower, but emissions of CO and NMVOC can be higher in comparison to gas-fired boilers.

2.2.1.3 Stoves

Stoves are enclosed appliances in which useful heat is transmitted to the surroundings by radiation and convection. They can vary widely due to fuels type, application, design and construction materials, and also combustion process organisation.

The stoves utilizing solid fuels are usually used for heating of the rooms (room heaters), but also for cooking, and hot water preparation (boilers and water heaters), while liquid and gas stoves tend to be used mainly for space heating.

Solid fuel stoves

The solid fuel stoves can be classified on the basis of the combustion principle, which primarily depends on the airflow path through the charge of fuel in a combustion chamber. Two main types exist: up-draught (under-fire, down-burning combustion) and downdraught (up-burning combustion). The vast majority of older stoves are of the up-draught type, which is of simpler design, but has higher emissions.

Different kinds of solid fuels are used, such as coal and its products (usually anthracite, hard coal, brown coal, patent fuels, and brown coal briquettes) and biomass — wood logs, wood chips and wood pellets and briquettes. Coals of different grain sizes are used usually 20–40 mm, and above 40 mm, or mixtures of both. Peat is also occasionally used.

The stoves can be made as prefabricated iron or steel appliances or masonry stoves, which are usually assembled on site with bricks, stone or ceramic materials. Regarding the main mode of heat transfer, solid fuel stoves can be divided into two main subgroups which are radiating stoves, and heat storing or, heat accumulating stoves. Radiating stoves are usually prefabricated iron or steel appliances; some of them can provide water heating, indirect heating (boilers) and some are used as cooking stoves.

Conventional, traditional stoves

These 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 (i.e. the ability to operate without user intervention) is low, lasting from three to eight 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.

Energy efficient conventional stoves

Essentially, traditional stoves with improved utilization of secondary air in the combustion chamber. Their efficiency is between 55 % and 75 % and emissions of pollutants are lower, their autonomy ranges from 6 to 12 hours.

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.

Modern pellet stoves

This is a type of advanced stove using pelletized fuels such as wood pellets, which are distributed to the combustion chamber by a fuel feeder from small fuel storage. Modern pellets stoves are often equipped with active control system for supply of the combustion air. They reach high combustion efficiencies by providing the proper air/fuel mixture ratio in the combustion chamber at all times (CITEPA, 2003). For this reason they are characterized by high efficiency (between 80 % and 90 %) and low emissions of CO, NMVOC, TSP and PAH.

Masonry (heat accumulating) stoves

These stoves are made of materials able to accumulate heat (e.g. fire brick, ceramic tiles or certain volcanic rocks (Finish stove for example)). Slow heat-release appliances are generally masonry stoves. A rapid heating in large thermal mass of masonry materials is achieved. Heat is slowly released by radiation to the surrounding area. Their combustion efficiency ranges from 70 to 80 % and their autonomy from 8 to 12 hours (CITEPA, 2003).

Catalytic combustor stoves

Stoves, in particular for wood combustion, can be equipped with a catalytic converter in order to reduce emissions caused by incomplete combustion. Due to more complete oxidation of the fuels, energy efficiency also increases. Catalytic combustors are not common for coal stoves.

Liquid/gas-fuelled stoves

The liquid/gas stoves have simple design; gas stoves are equipped with simple valves for fuel/air ratio adjustment and non-pre-mixing burners. For that reason emissions of NO_x from these are lower in comparison to gas-fired boilers. Simple liquid fuel stoves use evaporation systems for preparation of fuel/air mixture.

Regarding construction material and design, liquid and gas stoves are generally less diversified than those for solid fuels. They are made of steel and prefabricated.

2.2.1.4 Small boilers (single household/domestic heating) — indicative capacity ≤ 50 kW output

In general, boilers are devices which heat water for indirect heating. Small boilers of this capacity are used in flats and single houses. Designs are available for gaseous, liquid and solid fuels. They are mainly intended for generation of heat for the central heating system (including hot air systems) or hot water, or a combination of both.

Solid fuel small boilers

Small boilers for central heating for individual households are more widespread in temperate regions and usually have a nominal output between 12 kW to 50 kW. They use different types of solid fossil fuels and biomass usually depending on their regional availability. They could be divided into two broad categories regarding the organisation of combustion process: overfeed boiler (overfeed burning — over-fire and under-fire — down-burning) and underfeed boiler (underfeed burning — over-fire). They can be differentiated between conventional and advanced combustion boilers.

Conventional, coal/biomass boilers

Over-fire boilers

Over-fire boilers are commonly used in residential heating due to their simple operation and low investment cost. An incomplete combustion process takes place due to the non-optimal combustion air supply, which is usually generated by natural draught. The fuel is periodically fed onto the top of the burning fuel bed. The efficiency of the over-fire boiler is similar to the efficiency of conventional stoves, and is usually between 50 % and 65 %, depending on construction design and load. The emission of pollutants resulting from incomplete combustion of fuel may be very high particularly if they are operated at low load.

Under-fire boilers

Under-fire boilers have manual fuel feeding systems, and stationary or sloping grates. They have a two-part combustion chamber. The first part is used for storage of fuel and for partial devolatilization and combustion of the fuel layer. In the second part of the combustion chamber the combustible gases are oxidized. In older designs, natural draught is used. Combustion in under-fire boilers is more stable than in over-fire boilers, due to continuous gravity feed of fuel onto the fire bed. This results in higher energy efficiency (60-70 %) and lower emissions in comparison to overfeed combustion.

Advanced combustion boilers

Advanced, 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 optimised combustion process, emissions due to incomplete combustion are low.

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. The 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 boilers

Automatic log-fired boilers are available. However. most small boilers are wood pellet or chip-fired. These have a fully automatic system for feeding of pellet or woodchip fuels and for supply of combustion air, which is distributed into primary and secondary. The boilers are equipped with a smaller fuel storage bin, which is fuelled manually or by an automatic system from a larger chamber storage. The pellets are introduced by screw into the burner. These boilers are characterised by a high efficiency (usually above 80 %) and their emissions are comparable to those of liquid fuel boilers.

Liquid/gas-fuelled small boilers

These are usually two-function appliances used for hot water preparation and for heat generation for the central heating system. In the capacity range below 50 kW output they are used mainly in single households. Water-tube low temperature boilers (temperature of water below 100 ^oC) with open combustion chamber are usually used. These devices can be made of cast iron or steel. The boilers with capacity below 50 kW, can be divided into two main groups, i.e. standard boiler and condensing boilers.

Standard boilers

Standard boilers have an open combustion chamber, having maximum energy efficiency above 80 %, because of the comparatively high flue gas losses. Due to very simple design of combustion process automation system they can have higher emissions of CO and VOC in comparison to larger boilers and industrial installations.

Condensing boilers (room-sealed boilers)

These devices recover more heat from the exhaust gases by condensing moisture released in the combustion process and can operate with efficiency more than 90 %. Condensing boilers are also available for oil-firing boilers.

2.2.1.5 Cooking

Domestic cooking using solid fuel

These appliances are usually made of iron or steel and the combustion chamber is often covered with fire bricks; modern devices may incorporate a hot-water boiler for indirect heating of a dwelling. Their combustion efficiency ranges from 50 to 70 % depending on the type and quality of the installation and also the operation mode. Their autonomy is a few hours. Pollutant emissions are quite high in old installations, while in the most recent ones, the use of secondary or tertiary air allows a better combustion control. Solid fuel barbecues (outdoor cooking including 'disposable' single use barbecue packs) are used seasonally.

Cooking using gas

Gas-fired units are widely used in the residential sector. These comprise hobs (including heating rings for pots) and ovens. Outdoor cooking uses bottled gas (LPG).

2.2.1.6 Outdoor heating and other combustion

Residential and commercial use of outdoor heating has increased in some countries in recent years through the use of gas-fired patio heaters and similar devices. Traditional solid fuel fire pits and chimney devices are also relevant.

Combustion appliances are used to heat stones used in saunas in Scandinavia.

2.2.2 Non-residential heating (1.A.4.a, 1.A.4.c, 1.A.5.a)

2.2.2.1 Boilers with indicative capacity between 50 kW and 50 MW_{th}

Boilers of such a capacity are used for heating in multi-residential houses, office, school, hospital and apartment blocks and are most commonly found small sources in commercial and institutional sector as well as in agriculture. The largest units are more likely to be associated with other NFR sectors but are included for convenience.

Solid fuel boilers

Fixed and moving bed combustion technology is commonly used for combustion of solid fuels in this capacity range. This is a well-established technology, and a great variety of fixed-bed layer and moving layer boilers (travelling grate combustion, stokers) are in use. In addition to fixed bed combustion, fluidised bed combustion boilers are in use in this capacity range, frequently for biomass combustion.

Installations are differentiated into two main subgroups:

- manually fuelled
- automatically fuelled.

Manual feed boilers

Due to economical and technical reasons manual-fired boilers usually have a capacity lower than 1 $MW_{th.}$

Coal/wood boilers

Manually fed boilers in this capacity range apply two combustion techniques, under-fire and upper-fire, similar as in boilers of lower capacity range (see subsection 2.2.1.4 of the present chapter).

- Overfeed boilers, under-fire boilers: coal fuels of different grain size (usually between 5 mm and 40 mm) or lump wood are used in this type of installations. Their thermal efficiency ranges from 60 % to 80 % and depends on the air distribution into

primary/secondary system and secondary sub-chamber design. The emissions of pollutants, i.e. CO, NMVOC, TSP and PAH resulting from incomplete combustion are generally high.
- Overfeed boilers, upper-fire boilers: fine coal, or mixture of fine coal with biomass chips, which are periodically moved into combustion chamber are used in this type of boilers. The ignition is started from the top of the fuel charge. Their efficiency ranges from 75 % to 80 %. The emissions of pollutants of TSP, CO, NMVOC, PAH are lower in comparison to overfeed boilers due to different combustion process organization, which is similar to stoker combustion.

Both the under-fire and upper-fire boilers in this capacity range have better organisation of the combustion air compared with the ones used in single households.

Biomass/straw boilers

Overfeed boilers, biomass/straw fixed grate boilers are developed and applied for straw and cereal bale combustion. The straw bales are fed to the combustion chamber by hand. Due to the very fast combustion of this type of biomass, such installations contain a hot-water accumulation system. For this reason they are used only in small-scale applications up to a nominal boiler capacity of 1,5 MW_{th}. They are popular in the agricultural regions due to their relatively low costs and simple maintenance.

Automatic feed boilers

The automatic feed boilers usually have a capacity above 1 MW_{th}, but nowadays also lower capacity boilers are equipped with automatic feeding (including residential units). In addition, these installations have, in general, better control of the combustion process compared with manually fed ones. They typically require fuels of standardised and stable quality. These installations might also have particulate abatement equipment.

Moving bed (GF) combustion is commonly classified according to the way in which fuel is fed to the grate, as spreader stokers, overfeed stokers, and underfeed stokers.

Coal of smaller granulation or fine wood (e.g. wood pellet, chips or sawdust) is charged on a mechanical moving grate. The combustion temperatures are between 1 000 °C and 1 300 °C. The grate-fired installations are also suitable for co-combustion of coal with biomass. General applications are aimed at production of heat and/or hot water, and/or low-pressure steam for commercial and institutional users, in particular for district heating. Due to the highly controlled combustion process of solid fuels in moving-bed techniques and usually fully automatic process control systems, the emissions of pollutants, resulting from incomplete combustion, is significantly lower in comparison to manual feed boilers.

Advanced techniques

Underfeed coal/wood boilers; upper-fire burning, stoker boilers, underfeed rotating grate

These are used for both coal and wood combustion. The process principle is combustion in underfeeding stoker. The fuel with low ash contents (wood chips, sawdust, pellets; particle sizes up to 50 mm, or coal up to 30 mm) is fed into the combustion chamber through a screw conveyor and is transported to a retort when is oxidised.

Cigar straw boiler technology

This is applied for combustion of straw and cereal bales. The fuel bales are automatically transported to the combustion chamber by a hydraulic piston through an inlet tunnel into the combustion chamber.

Indirect combustor, gasification of wood biomass

This uses a separate gasification system for the chipped wood fuels, and the subsequent combustion of the product fuel gases in the gas boiler. An advantage of this technology is a possibility to use wet wood fuels of varying quality. This technique has low emissions of pollutants resulting from incomplete combustion of fuels.

Pre-ovens combustion system:

Wood chip combustion installations are used in some countries, especially in the countryside, heating larger houses and farms. This system contains automatic chips fuel feeding by a screw and pre-ovens (well-insulated chamber) and could be connected to an existing boiler. Pre-ovens systems apply a fully automatic combustion process and consequently emissions are low.

Advance automatically stoked wood chip and wood pellet boilers

They generally have a high level of autonomy. Inverted combustion is generally used with forced draught providing the best performances. The combustion efficiency ranges from 85 to 90 % and the degree of autonomy depends on the degree of automation applied to fuel and ash handling equipment (ranges from 24 hours to all the heating season).

Fluidised bed combustion

Fluidised bed combustion (FBC) can be divided into bubbling fluidised bed (BFB) and circulating fluidised bed combustion (CFB), depending on the fluidisation velocity. FBC is particularly suitable for low-quality, high-ash content coal or other ‘difficult’ solid fuels. The FBC is often used for co-combustion of coal with biomass. There are only few medium size installations of this type in operation.

Liquid/gas fuels

For gas and oil boilers the fuel and air are introduced as a mixture using dedicated burners in the combustion chamber. The burners on these small boilers tend to be self-contained units from specialist manufacturers which are fitted to a boiler.

Boilers fired with gaseous and liquid fuels are produced in a wide range of different designs and are classified according to burner configuration (injection burner or blow burner), construction material, the type of medium transferring heat (hot water, steam) and their power, the water temperature in the water boiler (which can be low temperature $\leq 100\ ^{o}C$, medium-temperature $> 100\ ^{o}C$ to $\leq 115\ ^{o}C$, high-temperature $> 115\ ^{o}C$), the heat transfer method (water-tube, fire-tube) and the arrangement of the heat transfer surfaces (horizontal or vertical, straight or bent over tube).

Cast iron boilers

Produce mainly low-pressure steam or hot water. Typically, they are used in residential and commercial/institutional sectors up to a nominal boiler capacity of about 1,5 MW_{th}.

Steel boilers

Manufactured, up to a nominal capacity of 50 MW_{th}, from steel plates and pipes by means of welding. Their characteristic feature is the multiplicity of their design considering the orientation of heat transfer surface. The most common are water-tube boilers, fire-tube boilers and condensing boilers.

Water-tube boilers

Equipped with external steel water jacket. Water-tubes (water flows inside, exhaust gasses outside) are welded in the walls of the jacket.

Fire-tube boilers

In these boilers combustion gasses flow inside smoke tubes, which are surrounded by water. They are designed as cylinder or rectangular units.

Furnace-fire-tube boilers made of steel

These devices are produced as the horizontal cylinders. The cylinder made of rolled steel plate ends at both sides with bottoms. The front bottom in its lower part (under the cylinder axis) is equipped with a furnace tube, which plays the role of combustion chamber.

Condensing boilers

Partly utilize the latent heat of the water vapour in the flue gases due to its condensation in the heat exchanger. For that reason their efficiency is higher than for other boiler systems. Their efficiency is more than 90 %. They could efficiently operate at lower inlet water temperatures. Besides high efficiency their advantage is also a lower emission of NO_X.

2.2.2.2 Cooking

Commercial cooking using solid fuel

The extent of solid fuel use in commercial cooking is not known, but is likely to be in specialised areas such as bakeries and traditional wood-fired pizza ovens.

Cooking using gas

Gas-fired units are widely used in the commercial sectors. These comprise hobs (including heating rings for pots) and ovens. Outdoor cooking uses bottled gas (LPG).

2.2.2.3 Space heating (direct heating)

Fireplaces and stoves are residential spaceheaters which may also find use in commercial and institutional premises. However, larger gas and oil-fired combustion units are used for heating in the commercial and industrial sectors. Units can be fixed (to ceilings and walls) or semi-portable.

2.2.2.4 Outdoor heating and other combustion

Commercial use of outdoor heating has increased in some countries in recent years through the use of gas-fired patio heaters and similar devices. Larger hot air furnaces are often used to heat temporary buildings and marquees.

Combustion appliances are used to heat stones used in saunas in Scandinavia.

Steam cleaning equipment often incorporates an oil burner to provide hot water.

2.2.2.5 Combined heat and power (CHP)

Requirements to increase the efficiency of the energy transformation and the use of renewable energy sources have led to the development of small CHP units. Use of steam boiler plus back-pressure turbine for electricity generation is the traditional approach and can allow use of biomass fuels. However, use of small-scale internal combustion cogeneration technology (gas turbine or stationary engine with heat recovery) is increasingly common. The cogeneration technology can be applied in comparatively small applications using small gas-fired reciprocating engines, but large reciprocating engines and gas turbines are also applied. Tri-generation (CHP and cooling) is also applied using this technology.

There are examples of small-scale wood gasification technology, primarily for waste wood streams, but also capable of operation on non-waste wood.

2.3 Emissions

Relevant pollutants are SO_2, NO_x, CO, NMVOC, particulate matter (PM), heavy metals, PAH, polychlorinated dibenzo-dioxins and furans (PCDD/F) and hexachlorobenzene (HCB). For solid fuels, generally the emissions due to incomplete combustion are many times greater in small appliances than in bigger plants. This is particularly valid for manually-fed appliances and poorly controlled automatic installations.

For both gaseous and liquid fuels, the emissions of pollutants are not significantly higher in comparison to industrial scale boilers due to the quality of fuels and design of burners and boilers, except for gaseous- and liquid-fuelled fireplaces and stoves because of their simple organization of combustion process. However, 'ultra-low' NOx burner technology is available for gas combustion in larger appliances. In general, gas- and oil-fired installations generate the same type of pollutants as for solid fuels, but their quantities are significantly lower.

Emissions caused by incomplete combustion are mainly a result of insufficient mixing of combustion air and fuel in the combustion chamber (local fuel-rich combustion zone), an overall lack of available oxygen, too low temperature, short residence times and too high radical concentrations (Kubica, 1997/1 and 2003/1). The following components are emitted to the atmosphere as a result of incomplete combustion in small combustion installations: CO, PM and NMVOCs, NH_3 , PAHs as well as PCDD/F.

NH_3 — small amounts of ammonia may be emitted as a result of incomplete combustion process of all solid fuels containing nitrogen. This occurs in cases where the combustion temperatures are very low (fireplaces, stoves, old design boilers). NH_3 emissions can generally be reduced by primary measures aiming to reduce products of incomplete combustion and increase efficiency.

TSP, PM_{10}, $PM_{2.5}$ — particulate matter in flue gases from combustion of fuels (in particular of solid mineral fuels and biomass) may be defined as carbon, smoke, soot, stack solid or fly ash. Emitted particulate matter can be classified into three groups of fuel combustion products.

The first group is formed via gaseous phase combustion or pyrolysis as a result of incomplete combustion of fuels (the products of incomplete combustion (PIC)): soot and organic carbon particles (OC) are formed during combustion as well as from gaseous precursors through nucleation and condensation processes (secondary organic carbon) as a product of aliphatic, aromatic radical reactions in a flame-reaction zone in the presence of hydrogen and oxygenated species; CO and some mineral compounds as catalytic species; and VOC, tar/heavy aromatic compounds species as a result of incomplete combustion of coal/biomass devolatilization/pyrolysis products (from the first combustion step), and secondary sulphuric and nitric compounds. Condensed heavy hydrocarbons (tar substances) are an important, and in some cases, the main contributor, to the total level of particles emission in small-scale solid fuels combustion appliances such as fireplaces, stoves and old design boilers.

The next groups (second and third) may contain ash particles or cenospheres that are largely produced from mineral matter in the fuel; they contain oxides and salts (S, Cl) of Ca, Mg, Si, Fe, K, Na, P, heavy metals, and unburned carbon formed from incomplete combustion of carbonaceous material; black carbon or elemental carbon — BC (Kupiainen, et al., 2004).

Particulate matter emission and size distribution from small installations largely depends on combustion conditions. Optimization of solid fuel combustion process by introduction of continuously controlled conditions (automatic fuel feeding, distribution of combustion air) leads to a decrease of TSP emission and to a change of PM distribution (Kubica, 2002/1 and Kubica et al., 2004/4). Several studies have shown that the use of modern and 'low-emitting' residential biomass combustion technologies leads to particle emissions dominated by submicron particles (< 1 μm) and the mass concentration of particles larger than 10 μm is normally < 10 % for small combustion installations (Boman et al., 2004 and 2005, Hays et al., 2003, Ehrlich et al, 2007).

Note that there are different conventions and standards for measuring particulate emissions. Particulate emissions can be defined by the measurement technique used including factors such as the type and temperature of filtration media and whether condensable fractions are measured. Other potential variations can include the use of manual gravimetric sampling techniques or aerosol instrumentation. Similarly, particulate emission data determined using methodology based on a dilution tunnel may differ from emission data determined by a direct extractive measurement on a stack. These issues in measurement methodology, and hence definition, mean that it can be difficult to compare reported emission data.

Heavy metals (HM) — the emission of heavy metals strongly depends on their contents in the fuels. Coal and its derivatives normally contain levels of heavy metals which are several orders of magnitude higher than in oil (except for Ni and V in heavy oils) and natural gas. All 'virgin' biomass also contains heavy metals. Their content depends on the type of biomass.

Most heavy metals considered (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn) are usually released as compounds associated and/or adsorbed with particles (e.g. sulphides, chlorides or organic compounds). Hg, Se, As and Pb are at least partially present in the vapour phase. Less volatile metal compounds tend to condensate onto the surface of smaller particles in the exhaust gases.

During the combustion of coal and biomass, particles undergo complex changes, which lead to vaporization of volatile elements. The rate of volatilization of heavy metal compounds depends on technology characteristics (type of boilers; combustion temperature) and on fuel characteristics (their contents of metals, fraction of inorganic species, such as chlorine, calcium, etc.). The chemical form of the mercury emitted may depend in particular on the presence of chlorine compounds. The nature of the combustion appliance used and any associated abatement equipment will also have an effect (Pye et al., 2005/1).

Mercury emitted from small combustion installations (SCIs), similarly to emission from large scale combustion, occurs in elementary form (elemental mercury vapour Hg^0), reactive gaseous form (reactive gaseous mercury (RGM)) and total particulate form (TPM) (Pacyna et al, 2004).

Meanwhile, it has been shown (Pye et al., 2005) that in the case of SCIs, distribution of particular species of emitted mercury is different to the one observed under large scale combustion. Contamination of biomass fuels, such as impregnated or painted wood, may cause significantly higher amounts of heavy metals emitted (e.g. Cr, As). With the exception of Hg, As, Cd and Pb (which have a significant volatile component), heavy metals emissions can be reduced by secondary (particulate) emission reduction measures.

PCDD/F — the emissions of dioxins and furans are highly dependent on the conditions under which cooling of the combustion and exhaust gases is carried out. Carbon, chlorine, a catalyst and oxygen excess are necessary for the formation of PCDD/F. They are found to be consequence of the de-novo synthesis in the temperature interval between 180 ^{o}C and 500 ^{o}C (Karasek et al., 1987). Coal-fired stoves in particular were reported to release very high levels of PCDD/F when using certain kinds of coal (Quass U., et al., 2000). The emission of PCDD/F is significantly increased when plastic waste is co-combusted in residential appliances or when contaminated/treated wood is used. The emissions of PCDD/F can be reduced by introduction of advanced combustion techniques of solid fuels (Kubica, 2003/3).

HCB — emissions of HCB from combustion processes are highly uncertain but, on the whole, processes resulting in PCDD/F formation lead also to HCB emissions (Kakeraka, 2004).

PAH — emissions of polycyclic aromatic hydrocarbons results from incomplete (intermediate) conversion of fuels. Emissions of PAH depend on the combustion process, particularly on the temperature (too low temperature favourably increases their emission), the residence time in the reaction zone and the availability of oxygen (Kubica K., 1997/1, 2003/1). It was reported that coal stoves and old type boilers (hand-fuelled) emit several times higher amounts of PAH in comparison to new design boilers (capacity below 50 kW_{th}), such as boilers with semi-automatic feeding (Kubica K., 2003/1, 2002/1,3). Technology of co-combustion of coal and biomass that can be applied in commercial/institutional and in industrial SCIs leads to reduction of PAH emissions, as well as TSP, NMVOCs and CO (Kubica et al., 1997/2 and 2004/5).

CO — carbon monoxide is found in gas combustion products of all carbonaceous fuels, as an intermediate product of the combustion process and in particular for under-stoichiometric conditions. CO is the most important intermediate product of fuel conversion to CO_2; it is oxidized to CO_2 under appropriate temperature and oxygen availability. Thus CO can be considered as a good indicator of the combustion quality. The mechanisms of CO formation, thermal-NO, NMVOC and PAH are, in general, similarly influenced by the combustion conditions. The emissions level is also a function of the excess air ratio as well as of the combustion temperature and residence time of the combustion products in the reaction zone. Hence, small combustion installations with automatic feeding (and perhaps oxygen 'lambda' sensors) offer favourable conditions to achieve lower CO emission. For example, the emissions of CO from solid fuelled small appliances can be several thousand ppm in comparison to 50–100 ppm for industrial combustion chambers, used in power plants.

NMVOC — for small combustion installations (e.g. residential combustion) emissions of NMVOC can occur in considerable amounts; these emissions are mostly released from inefficiently working stoves (e.g. wood-burning stoves). VOC emissions released from wood-fired boilers (0.510 MW) can be significant. Emissions can be up to ten times higher at 20 % load than those at maximum load (Gustavsson et al, 1993). NMVOC are all intermediates in the oxidation of fuels. They can adsorb on, condense, and form particles. Similarly as for CO, emission of NMVOC is a result of low combustion temperature, short residence time in oxidation zone, and/or insufficient oxygen availability. The emissions of NMVOC tend to decrease as the capacity of the combustion installation increases, due to the use of advanced techniques, which are typically characterized by improved combustion efficiency.

Sulphur oxides — in the absence of emission abatement, the emission of SO_2 is dependent on the sulphur content of the fuel. The combustion technology can influence the release of SO_2 with (for solid mineral fuels) higher sulphur retention in ash than is commonly associated with larger combustion plant.

Nitrogen oxides — emission of NOx is generally in the form of nitric oxide (NO) with a small proportion present as nitrogen dioxide (NO_2). Although emissions of NOx are comparatively low in residential appliances compared to larger furnaces (due in part to lower furnace temperatures), the proportion of primary NO_2 is believed to be higher.

Carbon dioxide — refer to Intergovernmental Panel on Climate Change (IPCC) guidance.

Nitrous oxide — refer to IPCC guidance.

Methane — refer to IPCC guidance.

2.4 Controls

Reduction of emissions from combustion process can be achieved by either avoiding formation of such substances (primary measures) or by removal of pollutants from exhaust gases (secondary measures).

The key measure for residential appliances is combustion control; emission of PM, CO, NMVOC and PAH are very dependent on combustion control, and measures to improve this include better control of temperature, air distribution and fuel quality. A modern enclosed fireplace burning fuel of the correct quality is less polluting than an open fire.

Primary measures which change appliance population or fuel quality are not directly relevant to current emissions except for trying to assess how far national or regional policies may have been implemented. The timing or progress of implementation of national measures for primary measures is also relevant for projections.

Primary measures: there are several common possibilities (Kubica, 2002/3, Pye et al., 2004):

- modification of fuels composition and improvement of their quality; preparation and improvement of quality of solid fuels, in particular of coal (in reference to S, Cl, ash contents, and fuel size range); modification of the fuels granulation by means of compacting — briquetting, pelletizing; pre-cleaning — washing; selection of grain size in relation to the requirements of the heating appliances (stove, boilers) and supervision of its distribution; partial replacement of coal with biomass (implementation of co-combustion technologies enabling reduction of SO_2, and NOx), application of combustion modifier; catalytic and S-sorbent additives (limestone, dolomite), reduction and modification of the moisture contents in the fuel, especially in the case of solid biomass fuels;
- replacing of coal by upgraded solid derived fuel, biomass, oil, gas;
- control optimization of combustion process;

- management of the combustion appliance population: replacement of low efficiency heating appliances with newly designed appliances, and supervision of their distribution by obligatory certification system; supervision over residential and communal system heating;
- improved construction of the combustion appliances; implementation of advanced technologies in fire places, stoves and boilers construction (implementation of Best Available Techniques (BAT) for combustion techniques and good combustion practice).

Co-combustion of coal and biomass that can be applied in commercial/institutional and in industrial SCIs leads to reduction of TSP and PIC emission, mainly PAHs, NMVOCs and CO, (Kubica et al., 1997/2 and 2004/5).

Secondary emission reduction measures: for small combustion installations a secondary measure can be applied to remove emissions, in particular PM. In this way emissions of pollutants linked with the PM, such as heavy metals, PAHs and PCDD/F can also be significantly reduced due to their removal together with particulate matter. These measures/controls are characterized by various dedusting efficiency (Perry at al., 1997 and Bryczkowski at al., 2002) and tend to be applied in accordance with national emission control requirements which vary considerably. For particulate matter the following options can be considered:

- settling chambers: gravity separation characterised by a low collection efficiency and ineffective for the fine particulate fraction;
- cyclone separators: commonly applied but have a comparatively low collection efficiency for fine particles (< 85 %);
- for higher effectiveness (94–99 %), units with multiple cyclones (cyclone batteries) are applied, and multi-cyclones allow for increased gas flow rates;
- electrostatic precipitators (their efficiency is between 99.5 % to 99.9 %) or fabric filters (with efficiency about 99.9 %) can be applied to the larger facilities.

The range of emission control encompasses manually-fired residential appliances with no control measures through to large boilers with fabric filters. Although emission control may be limited for small appliances, automatic biomass heating boilers as small as 100 kW output are commonly fitted with a cyclone.

Small (residential) wood combustion appliances, stoves in particular, can be equipped with a catalytic converter in order to reduce emissions caused by incomplete combustion. The catalytic converter is usually placed inside the flue gas channel beyond the main combustion chamber. When the flue gas passes through catalytic combustor, some pollutants are oxidized. The catalyst efficiency of emission reduction depends on the catalyst material, its construction (active surface), the conditions of flue gases flow inside converter (temperature, flow pattern, residence time, homogeneity, type of pollutants). For wood stoves with forced draught, equipped with catalytic converter (Hustad, et al., 1995) the efficiency of emission reduction of pollutants is as follows: CO 70–93 %, CH_4 29–77 %, other hydrocarbons more than 80 %, PAH 43–80 % and tar 56–60 %. Reduction of CO emissions from stoves equipped with catalytic converter is significant in comparison to an advanced downdraught staged-air wood stove under similar operating conditions (Skreiberg, 1994). However, the catalysts needs frequent inspection and cleaning. The lifetime of a catalyst in a wood stove with proper maintenance is usually about 10 000 hours. Modern wood appliances are generally not fitted with catalytic control systems.

FBC furnaces can incorporate lime injection into the combustion bed to capture SO_2.

3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating process emissions from the relevant activities. The main ideas behind the decision tree are:

- if detailed information is available, use it.

If the source category is a key source, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is easier to obtain the necessary input data for this approach than to collect facility level or appliance data needed for a Tier 3 estimate.

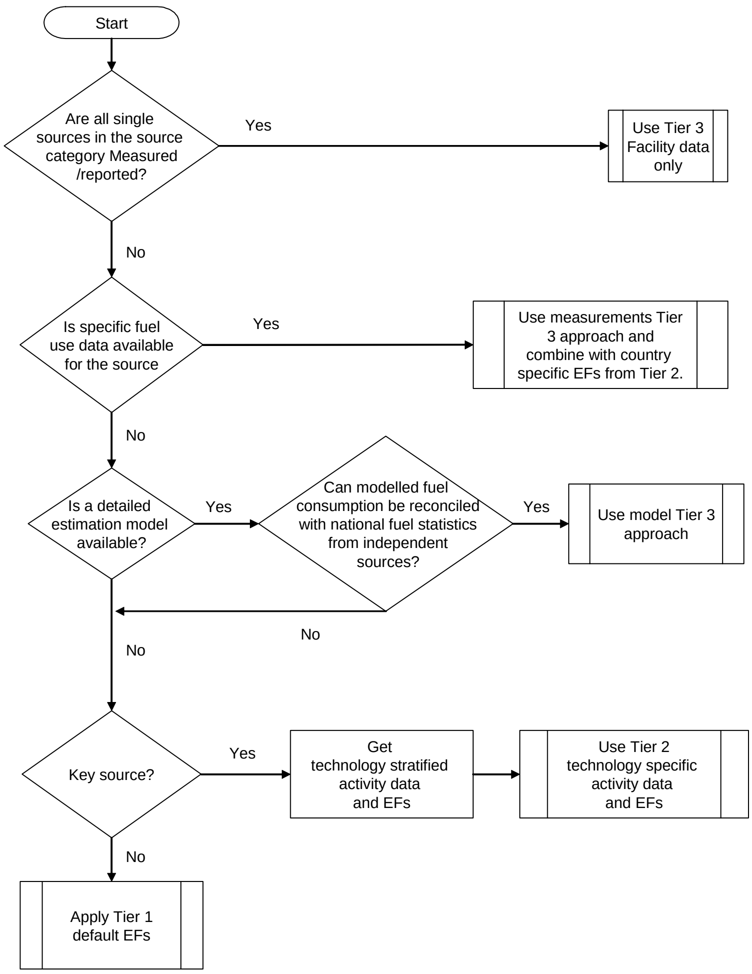

Figure 3-1 Decision tree for source category 1.A.4 Small combustion

Note that for the combustion activities in this chapter it is unlikely that a facility-specific approach could be adopted because detailed information on individual installations is unlikely to be available. However, modelling of the NFR sector and appliance population is consistent with a Tier 3 approach.

3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for process emissions from small combustion installations uses the general equation:

$$E_{pollutant} = AR_{fuelconsumption} \times EF_{pollutant} \qquad (1)$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{fuelconsumption}$ = the activity rate for fuel consumption,

$EF_{pollutant}$ = the emission factor for this pollutant.

This equation is applied at the national level, using annual national fuel consumption for small combustion installations in various activities.

In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or, if practical, Tier 3 approach must be used.

3.2.2 Default emission factors

Factors are provided for major fuel classifications and applying a distinction between residential and non-residential (institutional, commercial, agricultural and other) activities which can have significantly different emission characteristics.

Table 3-1 Summary of Tier 1 emission factor categories

Activity	Application
1.A.4.b Residential combustion	Hard coal, brown coal, natural gas, other liquid fuels, biomass
1.A.4.a/c, 1.A.5.a Non-residential (institutional, commercial, agricultural and other)	Hard coal, brown coal, natural gas, heavy fuel oils, other liquid fuels, biomass

The general Tier 1 fuel types are provided in Table 3-2. The hard and brown coal types are treated as one fuel type. Liquid fuels (heavy fuel oil and other liquid fuel) are treated as one fuel type. Similarly, natural gas and derived gases are treated as one fuel type at Tier 1.

Where ‘Guidebook 2006’ is referenced in the tables, the emissions factor is taken from chapter B216 of the 2006 Guidebook. The original reference could not be determined and the factor represents an expert judgement based on the available data.

Table 3-2 Summary of Tier 1 fuels

Tier 1 Fuel type	Associated fuel types
Hard coal	Coking coal, other bituminous coal, sub-bituminous coal, coke, manufactured 'patent' fuel
Brown coal	Lignite, oil shale, manufactured 'patent' fuel, peat
Natural gas	Natural gas
Derived gases	Gas works gas, coke oven gas, blast furnace gas
Heavy fuel oil	Residual fuel oil, refinery feedstock, petroleum coke
Other liquid fuels	Gas oil, kerosene, naphtha, natural gas liquids, liquefied petroleum gas, orimulsion, bitumen, shale oil, refinery gas
Biomass	Wood, charcoal, vegetable (agricultural) waste

Default Tier 1 emission factors are provided in Table 3-3 to Table 3-10.

3.2.2.1 Residential combustion (1.A.4.b)

Table 3-3 Tier 1 emission factors for NFR source category 1.A.4.b, using hard coal and brown coal

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Hard Coal and Brown Coal				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	110	g/GJ	36	200	Guidebook (2006) chapter B216
CO	4600	g/GJ	3000	7000	Guidebook (2006) chapter B216
NMVOC	484	g/GJ	250	840	Guidebook (2006) chapter B216
SOx	900	g/GJ	300	1000	Guidebook (2006) chapter B216
NH3	0.3	g/GJ	0.1	7	Guidebook (2006) chapter B216
TSP	444	g/GJ	80	600	Guidebook (2006) chapter B216
PM10	404	g/GJ	76	480	Guidebook (2006) chapter B216
PM2.5	398	g/GJ	72	480	Guidebook (2006) chapter B216
Pb	130	mg/GJ	100	200	Guidebook (2006) chapter B216
Cd	1.5	mg/GJ	0.5	3	Guidebook (2006) chapter B216
Hg	5.1	mg/GJ	3	6	Guidebook (2006) chapter B216
As	2.5	mg/GJ	1.5	5	Guidebook (2006) chapter B216
Cr	11.2	mg/GJ	10	15	Guidebook (2006) chapter B216
Cu	22.3	mg/GJ	20	30	Guidebook (2006) chapter B216
Ni	12.7	mg/GJ	10	20	Guidebook (2006) chapter B216
Se	1	mg/GJ	1	2.4	Expert judgement based on Guidebook (2006) chapter B216
Zn	220	mg/GJ	120	300	Guidebook (2006) chapter B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	800	ng I-TEQ/GJ	300	1200	Guidebook (2006) chapter B216
Benzo(a)pyrene	230	mg/GJ	60	300	Guidebook (2006) chapter B216
Benzo(b)fluoranthene	330	mg/GJ	102	480	Guidebook (2006) chapter B216
Benzo(k)fluoranthene	130	mg/GJ	60	180	Guidebook (2006) chapter B216
Indeno(1,2,3-cd)pyrene	110	mg/GJ	48	144	Guidebook (2006) chapter B216
HCB	0.62	µg/GJ	0.31	1.2	Guidebook (2006) chapter B216

Note:
900 g/GJ of sulphur dioxide corresponds to 1.2 % S of coal fuel of lower heating value on a dry basis 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-4 Tier 1 emission factors for NFR source category 1.A.4.b, using natural gas (and derived gases)

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Natural Gas				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	57	g/GJ	25	200	Guidebook (2006) chapter B216
CO	31	g/GJ	18	70	Guidebook (2006) chapter B216
NMVOC	10.5	g/GJ	6	28	Guidebook (2006) chapter B216
SOx	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
TSP	0.5	g/GJ	0.1	0.75	Guidebook (2006) chapter B216
PM10	0.5	g/GJ	0.1	0.75	Guidebook (2006) chapter B216
PM2.5	0.5	g/GJ	0.1	0.75	Guidebook (2006) chapter B216
Pb	0.984	mg/GJ	0.492	1.97	US EPA (1998), chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA (1998), chapter 1.4
Hg	0.234	mg/GJ	0.0781	0.703	US EPA (1998), chapter 1.4
As	0.0937	mg/GJ	0.0312	0.281	US EPA (1998), chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA (1998), chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA (1998), chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA (1998), chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA (1998), chapter 1.4
Zn	13.6	mg/GJ	4.53	40.7	US EPA (1998), chapter 1.4
PCDD/F	0.5	ng I-TEQ/GJ	0.3	1	Guidebook (2006) chapter B216
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)

Note:

Concerning the respective heating value used to convert US Environmental Protection Agency (USEPA) factors, the USEPA quotes higher heating value (HHV) = 1 020 MMBtu/MM scf; derived lower heating value (LHV) = 920 MMBTU/MM scf (90 % of HHV). The derivation calculations are based on 1 lb/MMscf being equivalent to 0.468 g/GJ (LHV) (note 1 MM= 1x 10^6).

Table 3-5 Tier 1 emission factors for NFR source category 1.A.4.b, using other liquid fuels

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	'Other' Liquid Fuels				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Se, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	68	g/GJ	30	80	EMEP/CORINAIR B216
CO	46	g/GJ	30	120	EMEP/CORINAIR B216
NMVOC	15.5	g/GJ	10	30	EMEP/CORINAIR B216
SOx	140	g/GJ	70	210	EMEP/CORINAIR B216
TSP	6	g/GJ	3	18	EMEP/CORINAIR B216
PM10	3.7	g/GJ	2	12	EMEP/CORINAIR B216
PM2.5	3.7	g/GJ	2	12	EMEP/CORINAIR B216
Pb	15.5	mg/GJ	3	24	EMEP/CORINAIR B216
Cd	1.5	mg/GJ	0.2	2.4	EMEP/CORINAIR B216
Hg	0.03	mg/GJ	0.015	0.045	EMEP/CORINAIR B216
As	0.9	mg/GJ	0.3	1.2	EMEP/CORINAIR B216
Cr	15.5	mg/GJ	3	24	EMEP/CORINAIR B216
Cu	7.9	mg/GJ	1.5	12	EMEP/CORINAIR B216
Ni	240	mg/GJ	80	350	EMEP/CORINAIR B216
Zn	8.5	mg/GJ	3	12	EMEP/CORINAIR B216
PCDD/F	10	ng I-TEQ/GJ	5	15	EMEP/CORINAIR B216
Benzo(a)pyrene	22	mg/GJ	5	60	EMEP/CORINAIR B216
Benzo(b)fluoranthene	25.7	mg/GJ	5	75	EMEP/CORINAIR B216
Benzo(k)fluoranthene	12.5	mg/GJ	3	40	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	14.8	mg/GJ	2	50	EMEP/CORINAIR B216

Note:
140 g/GJ of sulphur dioxide corresponds to 0.3 % S of liquid fuel of lower heating value 42 GJ/t. Because the sulphur content of liquid fuels is defined also by national regulations, compilers of the emission inventory should consider the national standards for sulphur content as well as information on average sulphur content on the market, if available.

Table 3-6 Tier 1 emission factors for NFR source category 1.A.4.b, using biomass

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Biomass				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	74.5	g/GJ	30	150	EMEP/CORINAIR B216
CO	5300	g/GJ	4000	6500	EMEP/CORINAIR B216
NMVOC	925	g/GJ	400	1500	EMEP/CORINAIR B216
SOx	20	g/GJ	10	30	EMEP/CORINAIR B216
NH3	3.8	g/GJ	3.04	14	EMEP/CORINAIR B216
TSP	730	g/GJ	500	1260	EMEP/CORINAIR B216
PM10	695	g/GJ	475	1200	EMEP/CORINAIR B216
PM2.5	695	g/GJ	475	1190	EMEP/CORINAIR B216
Pb	40	mg/GJ	10	60	EMEP/CORINAIR B216
Cd	1.4	mg/GJ	0.1	2.5	EMEP/CORINAIR B216
Hg	0.5	mg/GJ	0.2	0.6	EMEP/CORINAIR B216
As	1	mg/GJ	0.3	2.5	EMEP/CORINAIR B216
Cr	2.9	mg/GJ	1	10	EMEP/CORINAIR B216
Cu	8.6	mg/GJ	0.5	11.2	EMEP/CORINAIR B216
Ni	4.4	mg/GJ	1	250	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.25	0.75	EMEP/CORINAIR B216
Zn	130	mg/GJ	60	250	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	700	ng I-TEQ/GJ	500	1000	EMEP/CORINAIR B216
Benzo(a)pyrene	210	mg/GJ	130	300	EMEP/CORINAIR B216
Benzo(b)fluoranthene	220	mg/GJ	150	260	EMEP/CORINAIR B216
Benzo(k)fluoranthene	130	mg/GJ	60	180	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	140	mg/GJ	80	200	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

3.2.2.2 Non-residential combustion (1.A.4.a, 1.A.4.c, 1.A.5)

Table 3-7 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using hard and brown coal

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i	Commercial / institutional: stationary			
Fuel	Hard Coal and Brown Coal				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	173	g/GJ	150	200	EMEP/CORINAIR B216
CO	931	g/GJ	150	2000	EMEP/CORINAIR B216
NMVOC	88.8	g/GJ	10	300	EMEP/CORINAIR B216
SOx	900	g/GJ	450	1000	EMEP/CORINAIR B216
TSP	124	g/GJ	70	250	EMEP/CORINAIR B216
PM10	117	g/GJ	60	240	EMEP/CORINAIR B216
PM2.5	108	g/GJ	60	220	EMEP/CORINAIR B216
Pb	134	mg/GJ	50	300	EMEP/CORINAIR B216
Cd	1.8	mg/GJ	0.2	5	EMEP/CORINAIR B216
Hg	7.9	mg/GJ	5	10	EMEP/CORINAIR B216
As	4	mg/GJ	0.2	8	EMEP/CORINAIR B216
Cr	13.5	mg/GJ	0.5	20	EMEP/CORINAIR B216
Cu	17.5	mg/GJ	5	50	EMEP/CORINAIR B216
Ni	13	mg/GJ	0.5	30	EMEP/CORINAIR B216
Se	1.8	mg/GJ	0.2	3	EMEP/CORINAIR B216
Zn	200	mg/GJ	50	500	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	203	ng I-TEQ/GJ	40	500	EMEP/CORINAIR B216
Benzo(a)pyrene	45.5	mg/GJ	10	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	58.9	mg/GJ	10	180	EMEP/CORINAIR B216
Benzo(k)fluoranthene	23.7	mg/GJ	8	100	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	18.5	mg/GJ	5	80	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:
900 g/GJ of sulphur dioxide corresponds to 1.2 % S of coal fuel of lower heating value on a dry basis 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-8 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using gaseous fuels

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i	Commercial / institutional: stationary			
Fuel	Gaseous Fuels				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	70	g/GJ	35	200	EMEP/CORINAIR B216
CO	25	g/GJ	20	30	EMEP/CORINAIR B216
NMVOC	2.5	g/GJ	2	3	EMEP/CORINAIR B216
SOx	0.5	g/GJ	0.05	1	EMEP/CORINAIR B216
TSP	0.5	g/GJ	0.1	2	EMEP/CORINAIR B216
PM10	0.5	g/GJ	0.1	2	EMEP/CORINAIR B216
PM2.5	0.5	g/GJ	0.1	2	EMEP/CORINAIR B216
Pb	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	100	240	US EPA 1998, chapter 1.4
PCDD/F	2	ng I-TEQ/GJ	1	3	EMEP/CORINAIR B216
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Table 3-9 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using liquid fuels

Tier 1 default emission factors						
	Code	Name				
NFR Source Category	1.A.4.a.i	Commercial / institutional: stationary				
Fuel	Liquid Fuels					
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP					
Not estimated	NH3, Se, Total 4 PAHs					
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**	
			Lower	**Upper**		
NOx	100	g/GJ	50	150	EMEP/CORINAIR B216	
CO	40	g/GJ	20	60	EMEP/CORINAIR B216	
NMVOC	10	g/GJ	5	15	EMEP/CORINAIR B216	
SOx	140	g/GJ	20	500	See note	
TSP	27.5	g/GJ	5	50	EMEP/CORINAIR B216	
PM10	21.5	g/GJ	3	40	EMEP/CORINAIR B216	
PM2.5	16.5	g/GJ	3	30	EMEP/CORINAIR B216	
Pb	16	mg/GJ	10	20	EMEP/CORINAIR B216	
Cd	0.3	mg/GJ	0.15	0.45	EMEP/CORINAIR B216	
Hg	0.1	mg/GJ	0.05	0.15	EMEP/CORINAIR B216	
As	1	mg/GJ	0.5	1.5	EMEP/CORINAIR B216	
Cr	12.8	mg/GJ	2	20	EMEP/CORINAIR B216	
Cu	7.2	mg/GJ	3	10	EMEP/CORINAIR B216	
Ni	260	mg/GJ	200	300	EMEP/CORINAIR B216	
Zn	8	mg/GJ	5	10	EMEP/CORINAIR B216	
PCDD/F	10	ng I-TEQ/GJ	5	15	EMEP/CORINAIR B216	
Benzo(a)pyrene	5.2	mg/GJ	1	8	EMEP/CORINAIR B216	
Benzo(b)fluoranthene	6.2	mg/GJ	2	9	EMEP/CORINAIR B216	
Benzo(k)fluoranthene	4	mg/GJ	1	6	EMEP/CORINAIR B216	
Indeno(1,2,3-cd)pyrene	2.2	mg/GJ	1	3	EMEP/CORINAIR B216	

Note:
140 g/GJ of sulphur dioxide corresponds to 0.3 % S of liquid fuel of lower heating value 42 GJ/t. Because the sulphur content of liquid fuels is defined also by national regulations, compilers of the emission inventory should consider the national standards for sulphur content as well as information on average sulphur content on the market, if available.
Sulphur emission factor can be calculated from fuel sulphur content. Emission factor range provided corresponds to approximately 0.05 to 1 % sulphur content.

Table 3-10 Tier 1 emission factors for NFR source category 1.A.4.a/c, 1.A.5.a, using biomass

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i	Commercial / institutional: stationary			
Fuel	Biomass				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	150	g/GJ	90	300	EMEP/CORINAIR B216
CO	1600	g/GJ	200	4500	EMEP/CORINAIR B216
NMVOC	146	g/GJ	10	450	EMEP/CORINAIR B216
SOx	38.4	g/GJ	20	50	EMEP/CORINAIR B216
TSP	156	g/GJ	60	250	EMEP/CORINAIR B216
PM10	150	g/GJ	50	240	EMEP/CORINAIR B216
PM2.5	149	g/GJ	50	240	EMEP/CORINAIR B216
Pb	24.8	mg/GJ	5	30	EMEP/CORINAIR B216
Cd	1.8	mg/GJ	0.1	3	EMEP/CORINAIR B216
Hg	0.7	mg/GJ	0.4	1.5	EMEP/CORINAIR B216
As	1.4	mg/GJ	0.25	2	EMEP/CORINAIR B216
Cr	6.5	mg/GJ	1	10	EMEP/CORINAIR B216
Cu	4.6	mg/GJ	1	5	EMEP/CORINAIR B216
Ni	2	mg/GJ	0.1	300	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.1	2	EMEP/CORINAIR B216
Zn	114	mg/GJ	1	150	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	326	ng I-TEQ/GJ	30	500	EMEP/CORINAIR B216
Benzo(a)pyrene	44.6	mg/GJ	10	100	EMEP/CORINAIR B216
Benzo(b)fluoranthene	64.9	mg/GJ	10	120	EMEP/CORINAIR B216
Benzo(k)fluoranthene	23.4	mg/GJ	5	40	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	22.3	mg/GJ	2	60	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

3.2.3 Activity data

Information on the use of energy suitable for estimating emissions using the Tier 1 simpler estimation methodology, is available from national statistics agencies or the International Energy Agency (IEA).

Further guidance is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 on Stationary combustion www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

The activity rate and the emission factor have to be determined on the same level of aggregation depending on the availability of data. The activity statistic should be determined within the considered country or region by using adequate statistics. The activity should refer to the energy input of the emission sources considered (net or inferior fuel consumption in [GJ]).

3.3 Tier 2 technology-specific approach

3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach, using activity data and emission factors to estimate the emissions. The main difference is that the detailed methodology requires more fuel, technology and country-specific information. Development of the detailed methodology has to be focused to the combinations of the main installation types/fuels used in the country.

The annual emission is determined by an activity data and an emission factor:

$$E_i = \sum_{j,k} EF_{i,j,k} \cdot A_{j,k} \ , \qquad (1)$$

where

E_i = annual emission of pollutant *i*,

$EF_{i,j,k}$ = default emission factor of pollutant *i* for source type *j* and fuel *k*,

$A_{j,k}$ = annual consumption of fuel *k* in source type *j*.

For example, the sources may be characterised as:

- residential heating : fire places, water heaters, stoves, boilers, cookers;
- non-residential heating : space heating, boilers;
- CHP.

The non-residential activities need to be apportioned to the appropriate NFR activity sectors.

3.3.2 Technology-specific emission factors

The detailed methodology envisages the use of default emission factors for different types of fuel and combustion appliance technology and these are summarised in Table 3-11. These factors can be used with knowledge of equipment populations and sectors to develop aggregate factors or emissions for the NFR subsectors.

The development of national emission factors should consider the combination of installation types and fuels in the country and, where relevant, emission controls. When deriving specific emission factors, the emphasis has to be given to taking into account start-up emissions. These could, especially in the case of stoves and solid fuel small boilers, significantly influence the emissions of the total combustion cycle.

Table 3-11 Tier 2 emission factor summary

Activities	Fuels
Residential (1.A.4.b < 50 kW):	
Fireplace/sauna/outdoor	Hard and brown coal, biomass
Stoves	Hard and brown coal, biomass, gas, oil
Water heaters/boilers	Hard and brown coal, biomass, gas, oil
Non-residential (1.A.4.a/c, 1.A.5.a > 50 kW to 50 MW):	
Boilers	Hard and brown coal, biomass, heavy fuel oil, gas
CHP (< 50 MW): Gas turbines Reciprocating engines	Gas, gas oil

3.3.2.1 Residential heating technologies (1.A.4.b)

Table 3-12 Tier 2 emission factors for source category 1.A.4.b.i, fireplaces burning solid fuel (except biomass)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Solid Fuel (not biomass)				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Fireplaces, Saunas and Outdoor Heaters				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	60	g/GJ	36	84	EMEP/CORINAIR B216
CO	5000	g/GJ	3000	7000	EMEP/CORINAIR B216
NMVOC	600	g/GJ	360	840	EMEP/CORINAIR B216
SOx	500	g/GJ	300	700	EMEP/CORINAIR B216
NH3	5	g/GJ	3	7	EMEP/CORINAIR B216
TSP	350	g/GJ	210	490	EMEP/CORINAIR B216
PM10	330	g/GJ	198	462	EMEP/CORINAIR B216
PM2.5	330	g/GJ	198	462	EMEP/CORINAIR B216
Pb	100	mg/GJ	60	140	EMEP/CORINAIR B216
Cd	0.5	mg/GJ	0.3	0.7	EMEP/CORINAIR B216
Hg	3	mg/GJ	1.8	4.2	EMEP/CORINAIR B216
As	1.5	mg/GJ	0.9	2.1	EMEP/CORINAIR B216
Cr	10	mg/GJ	6	14	EMEP/CORINAIR B216
Cu	20	mg/GJ	12	28	EMEP/CORINAIR B216
Ni	10	mg/GJ	6	14	EMEP/CORINAIR B216
Se	1	mg/GJ	0.6	1.4	EMEP/CORINAIR B216
Zn	200	mg/GJ	120	280	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	500	ng I-TEQ/GJ	300	700	EMEP/CORINAIR B216
Benzo(a)pyrene	100	mg/GJ	60	140	EMEP/CORINAIR B216
Benzo(b)fluoranthene	170	mg/GJ	102	238	EMEP/CORINAIR B216
Benzo(k)fluoranthene	100	mg/GJ	60	140	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	80	mg/GJ	48	112	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:
500 g/GJ of sulphur dioxide is equivalent to 0.8 % S of coal fuels of lower heating value of fuel on a dry basis 29 GJ/t and an average sulphur retention in ash value of 0.1.

Table 3-13 Tier 2 emission factors for source category 1.A.4.b.i, fireplaces burning gaseous fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Gaseous Fuels				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Fireplaces, Saunas and Outdoor Heaters				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	50	g/GJ	30	70	EMEP/CORINAIR B216
CO	50	g/GJ	30	70	EMEP/CORINAIR B216
NMVOC	20	g/GJ	12	28	EMEP/CORINAIR B216
SOx	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
TSP	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM10	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM2.5	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
Pb	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	4.53	40.7	US EPA 1998, chapter 1.4
PCDD/F	1.5	ng I-TEQ/GJ	0.9	2.1	UNEP (2005)
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Table 3-14 Tier 2 emission factors for source category 1.A.4.b.i, fireplaces burning biomass

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Biomass				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Fireplaces, Saunas and Outdoor Heaters				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	50	g/GJ	30	70	EMEP/CORINAIR B216
CO	6000	g/GJ	4000	6500	EMEP/CORINAIR B216
NMVOC	1300	g/GJ	780	1500	EMEP/CORINAIR B216
SOx	10	g/GJ	6	14	EMEP/CORINAIR B216
NH3	10	g/GJ	6	14	EMEP/CORINAIR B216
TSP	900	g/GJ	540	1260	EMEP/CORINAIR B216
PM10	860	g/GJ	516	1200	EMEP/CORINAIR B216
PM2.5	850	g/GJ	510	1190	EMEP/CORINAIR B216
Pb	40	mg/GJ	24	56	EMEP/CORINAIR B216
Cd	2	mg/GJ	1.2	2.8	EMEP/CORINAIR B216
Hg	0.4	mg/GJ	0.24	0.56	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.3	0.7	EMEP/CORINAIR B216
Cr	1	mg/GJ	0.6	1.4	EMEP/CORINAIR B216
Cu	8	mg/GJ	4.8	11.2	EMEP/CORINAIR B216
Ni	2	mg/GJ	1.2	2.8	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.3	0.7	EMEP/CORINAIR B216
Zn	100	mg/GJ	60	140	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	800	ng I-TEQ/GJ	500	1000	EMEP/CORINAIR B216
Benzo(a)pyrene	180	mg/GJ	130	300	EMEP/CORINAIR B216
Benzo(b)fluoranthene	180	mg/GJ	150	260	EMEP/CORINAIR B216
Benzo(k)fluoranthene	100	mg/GJ	60	140	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	140	mg/GJ	84	180	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-15 Tier 2 emission factors for source category 1.A.4.b.i, stoves burning solid fuel (except biomass)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Solid Fuel (not biomass)				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Stoves				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	100	g/GJ	60	150	EMEP/CORINAIR B216
CO	5000	g/GJ	3000	7000	EMEP/CORINAIR B216
NMVOC	600	g/GJ	360	840	EMEP/CORINAIR B216
SOx	900	g/GJ	540	1000	EMEP/CORINAIR B216
TSP	500	g/GJ	240	600	EMEP/CORINAIR B216
PM10	450	g/GJ	228	480	EMEP/CORINAIR B216
PM2.5	450	g/GJ	216	480	EMEP/CORINAIR B216
Pb	100	mg/GJ	60	240	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.6	3.6	EMEP/CORINAIR B216
Hg	5	mg/GJ	3	7.2	EMEP/CORINAIR B216
As	1.5	mg/GJ	0.9	6	EMEP/CORINAIR B216
Cr	10	mg/GJ	6	18	EMEP/CORINAIR B216
Cu	20	mg/GJ	12	36	EMEP/CORINAIR B216
Ni	10	mg/GJ	6	24	EMEP/CORINAIR B216
Se	2	mg/GJ	1.2	2.4	EMEP/CORINAIR B216
Zn	200	mg/GJ	120	360	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	1000	ng I-TEQ/GJ	300	1200	EMEP/CORINAIR B216
Benzo(a)pyrene	250	mg/GJ	150	324	EMEP/CORINAIR B216
Benzo(b)fluoranthene	400	mg/GJ	150	480	EMEP/CORINAIR B216
Benzo(k)fluoranthene	150	mg/GJ	60	180	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	120	mg/GJ	54	144	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Table 3-16 Tier 2 emission factors for source category 1.A.4.b.i, boilers burning solid fuel (except biomass)

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Solid Fuel (not biomass)				
SNAP (if applicable)					
Technologies/Practices	Small (single household scale, capacity <=50 kWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	130	g/GJ	60	150	EMEP/CORINAIR B216
CO	4000	g/GJ	3000	7000	EMEP/CORINAIR B216
NMVOC	300	g/GJ	250	840	EMEP/CORINAIR B216
SOx	900	g/GJ	540	1000	EMEP/CORINAIR B216
TSP	400	g/GJ	240	600	EMEP/CORINAIR B216
PM10	380	g/GJ	228	462	EMEP/CORINAIR B216
PM2.5	360	g/GJ	216	462	EMEP/CORINAIR B216
Pb	200	mg/GJ	60	240	EMEP/CORINAIR B216
Cd	3	mg/GJ	0.6	3.6	EMEP/CORINAIR B216
Hg	6	mg/GJ	3	7.2	EMEP/CORINAIR B216
As	5	mg/GJ	0.9	6	EMEP/CORINAIR B216
Cr	15	mg/GJ	6	18	EMEP/CORINAIR B216
Cu	30	mg/GJ	12	36	EMEP/CORINAIR B216
Ni	20	mg/GJ	6	24	EMEP/CORINAIR B216
Se	2	mg/GJ	1.2	2.4	EMEP/CORINAIR B216
Zn	300	mg/GJ	120	360	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	500	ng I-TEQ/GJ	300	1200	EMEP/CORINAIR B216
Benzo(a)pyrene	270	mg/GJ	150	324	EMEP/CORINAIR B216
Benzo(b)fluoranthene	250	mg/GJ	150	480	EMEP/CORINAIR B216
Benzo(k)fluoranthene	100	mg/GJ	60	180	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	90	mg/GJ	54	144	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Table 3-17 Tier 2 emission factors for source category 1.A.4.b.i, stoves burning wood and similar wood waste

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Wood and similar wood waste				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Stoves				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	50	g/GJ	30	150	EMEP/CORINAIR B216
CO	6000	g/GJ	4000	6500	EMEP/CORINAIR B216
NMVOC	1200	g/GJ	720	1500	EMEP/CORINAIR B216
SOx	10	g/GJ	6	40	EMEP/CORINAIR B216
NH3	5	g/GJ	3.8	7	EMEP/CORINAIR B216
TSP	850	g/GJ	510	1190	EMEP/CORINAIR B216
PM10	810	g/GJ	486	1130	EMEP/CORINAIR B216
PM2.5	810	g/GJ	486	1130	EMEP/CORINAIR B216
Pb	40	mg/GJ	24	56	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.6	2.5	EMEP/CORINAIR B216
Hg	0.4	mg/GJ	0.24	0.56	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.3	2.5	EMEP/CORINAIR B216
Cr	2	mg/GJ	1.2	2.8	EMEP/CORINAIR B216
Cu	8	mg/GJ	4.8	11.2	EMEP/CORINAIR B216
Ni	2	mg/GJ	1.2	2.8	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.3	0.7	EMEP/CORINAIR B216
Zn	100	mg/GJ	60	250	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	800	ng I-TEQ/GJ	500	1000	EMEP/CORINAIR B216
Benzo(a)pyrene	250	mg/GJ	150	300	EMEP/CORINAIR B216
Benzo(b)fluoranthene	240	mg/GJ	180	260	EMEP/CORINAIR B216
Benzo(k)fluoranthene	150	mg/GJ	90	180	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	180	mg/GJ	108	200	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-18 Tier 2 emission factors for source category 1.A.4.b.i, boilers burning wood and similar wood waste

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Wood and similar wood waste				
SNAP (if applicable)					
Technologies/Practices	Small (single household scale, capacity <=50 kWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	120	g/GJ	30	150	EMEP/CORINAIR B216
CO	4000	g/GJ	3000	6500	EMEP/CORINAIR B216
NMVOC	400	g/GJ	300	1500	EMEP/CORINAIR B216
SOx	30	g/GJ	6	40	EMEP/CORINAIR B216
NH3	3.8	g/GJ	3.04	14	EMEP/CORINAIR B216
TSP	500	g/GJ	400	1190	EMEP/CORINAIR B216
PM10	475	g/GJ	450	1130	EMEP/CORINAIR B216
PM2.5	475	g/GJ	450	1130	EMEP/CORINAIR B216
Pb	40	mg/GJ	24	56	EMEP/CORINAIR B216
Cd	2	mg/GJ	0.6	2.5	EMEP/CORINAIR B216
Hg	0.6	mg/GJ	0.24	1	EMEP/CORINAIR B216
As	2	mg/GJ	0.3	2.5	EMEP/CORINAIR B216
Cr	5	mg/GJ	1.2	6	EMEP/CORINAIR B216
Cu	10	mg/GJ	4.8	11.2	EMEP/CORINAIR B216
Ni	10	mg/GJ	1.2	15	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.3	0.7	EMEP/CORINAIR B216
Zn	200	mg/GJ	60	250	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	500	I-Teq ng/GJ	400	1000	EMEP/CORINAIR B216
Benzo(a)pyrene	130	mg/GJ	100	300	EMEP/CORINAIR B216
Benzo(b)fluoranthene	200	mg/GJ	150	260	EMEP/CORINAIR B216
Benzo(k)fluoranthene	100	mg/GJ	80	180	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	80	mg/GJ	50	180	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-19 Tier 2 emission factors for source category 1.A.4.b.i, stoves burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Natural Gas				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Stoves				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	50	g/GJ	25	200	EMEP/CORINAIR B216
CO	30	g/GJ	18	42	EMEP/CORINAIR B216
NMVOC	10	g/GJ	6	14	EMEP/CORINAIR B216
SOx	0.5	g/GJ	0.05	1	EMEP/CORINAIR B216
TSP	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM10	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM2.5	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
Pb	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	4.53	40.7	US EPA 1998, chapter 1.4
PCDD/F	1.5	ng I-TEQ/GJ	0.8	2.3	UNEP (2005)
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Table 3-20 Tier 2 emission factors for source category 1.A.4.b.i, boilers burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Natural Gas				
SNAP (if applicable)					
Technologies/Practices	Small (single household scale, capacity <=50 kWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	70	g/GJ	35	200	EMEP/CORINAIR B216
CO	30	g/GJ	18	42	EMEP/CORINAIR B216
NMVOC	10	g/GJ	6	14	EMEP/CORINAIR B216
SOx	0.5	g/GJ	0.05	1	EMEP/CORINAIR B216
TSP	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM10	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
PM2.5	0.5	g/GJ	0.3	0.7	EMEP/CORINAIR B216
Pb	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	4.53	40.7	US EPA 1998, chapter 1.4
PCDD/F	1.5	ng I-TEQ/GJ	0.8	2.3	UNEP (2005)
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Table 3-21 Tier 2 emission factors for source category 1.A.4.b.i, stoves burning liquid fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Liquid Fuels				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Stoves				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Se, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	50	g/GJ	30	80	EMEP/CORINAIR B216
CO	100	g/GJ	40	120	EMEP/CORINAIR B216
NMVOC	20	g/GJ	15	30	EMEP/CORINAIR B216
SOx	140	g/GJ	25	168	EMEP/CORINAIR B216 + see
TSP	15	g/GJ	5	18	EMEP/CORINAIR B216
PM10	10	g/GJ	3	12	EMEP/CORINAIR B216
PM2.5	10	g/GJ	3	12	EMEP/CORINAIR B216
Pb	5	mg/GJ	3	24	EMEP/CORINAIR B216
Cd	0.3	mg/GJ	0.2	2.4	EMEP/CORINAIR B216
Hg	0.03	mg/GJ	0.024	0.036	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.3	1.2	EMEP/CORINAIR B216
Cr	5	mg/GJ	3	24	EMEP/CORINAIR B216
Cu	3	mg/GJ	1.5	12	EMEP/CORINAIR B216
Ni	100	mg/GJ	80	350	EMEP/CORINAIR B216
Zn	5	mg/GJ	3	12	EMEP/CORINAIR B216
PCDD/F	10	ng I-TEQ/GJ	8	12	EMEP/CORINAIR B216
Benzo(a)pyrene	50	mg/GJ	10	60	EMEP/CORINAIR B216
Benzo(b)fluoranthene	60	mg/GJ	11	75	EMEP/CORINAIR B216
Benzo(k)fluoranthene	30	mg/GJ	5	40	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	40	mg/GJ	4	50	EMEP/CORINAIR B216

Note:
140 g/GJ of sulphur dioxide corresponds to 0.3 % S of liquid fuel of lower heating value 42 GJ/t. Emission factor range provided corresponds to about 0.05 to about 1 % sulphur content.
Because the sulphur content of liquid fuels is defined also by national regulations, compilers of the emission inventory should consider the national standards for sulphur content as well as information on average sulphur content on the market, if available.

Table 3-22 Tier 2 emission factors for source category 1.A.4.b.i, boilers burning liquid fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Liquid Fuels				
SNAP (if applicable)					
Technologies/Practices	Small (single household scale, capacity <=50 kWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Se, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	70	g/GJ	50	80	EMEP/CORINAIR B216
CO	40	g/GJ	30	120	EMEP/CORINAIR B216
NMVOC	15	g/GJ	10	30	EMEP/CORINAIR B216
SOx	140	g/GJ	25	168	EMEP/CORINAIR B216 + see
TSP	5	g/GJ	3	18	EMEP/CORINAIR B216
PM10	3	g/GJ	2	12	EMEP/CORINAIR B216
PM2.5	3	g/GJ	2	12	EMEP/CORINAIR B216
Pb	20	mg/GJ	5	24	EMEP/CORINAIR B216
Cd	2	mg/GJ	0.3	2.4	EMEP/CORINAIR B216
Hg	0.03	mg/GJ	0.024	0.036	EMEP/CORINAIR B216
As	1	mg/GJ	0.5	1.2	EMEP/CORINAIR B216
Cr	20	mg/GJ	5	24	EMEP/CORINAIR B216
Cu	10	mg/GJ	3	12	EMEP/CORINAIR B216
Ni	300	mg/GJ	100	350	EMEP/CORINAIR B216
Zn	10	mg/GJ	5	12	EMEP/CORINAIR B216
PCDD/F	10	ng I-TEQ/GJ	8	12	EMEP/CORINAIR B216
Benzo(a)pyrene	10	mg/GJ	5	60	EMEP/CORINAIR B216
Benzo(b)fluoranthene	11	mg/GJ	5	75	EMEP/CORINAIR B216
Benzo(k)fluoranthene	5	mg/GJ	3	40	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	4	mg/GJ	2	50	EMEP/CORINAIR B216

Note:
140 g/GJ of sulphur dioxide corresponds to 0.3 % S of liquid fuel of lower heating value 42 GJ/t. Emission factor range provided corresponds to about 0.05 to about 1 % sulphur content.
Because the sulphur content of liquid fuels is defined also by national regulations, compilers of the emission inventory should consider the national standards for sulphur content as well as information on average sulphur content on the market, if available.

Table 3-23 Tier 2 emission factors for source category 1.A.4.b.i, advanced stoves burning coal fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Coal Fuels				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Advanced coal combustion techniques <1MWth - Advanced stove				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	150	g/GJ	50	200	EMEP/CORINAIR B216
CO	2000	g/GJ	200	3000	EMEP/CORINAIR B216
NMVOC	300	g/GJ	20	400	EMEP/CORINAIR B216
SOx	450	g/GJ	300	900	EMEP/CORINAIR B216
TSP	250	g/GJ	80	260	EMEP/CORINAIR B216
PM10	240	g/GJ	76	250	EMEP/CORINAIR B216
PM2.5	220	g/GJ	72	230	EMEP/CORINAIR B216
Pb	100	mg/GJ	80	200	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.5	3	EMEP/CORINAIR B216
Hg	5	mg/GJ	3	9	EMEP/CORINAIR B216
As	1.5	mg/GJ	1	5	EMEP/CORINAIR B216
Cr	10	mg/GJ	5	15	EMEP/CORINAIR B216
Cu	15	mg/GJ	10	30	EMEP/CORINAIR B216
Ni	10	mg/GJ	5	20	EMEP/CORINAIR B216
Se	2	mg/GJ	1	2.4	EMEP/CORINAIR B216
Zn	200	mg/GJ	120	300	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	500	ng I-TEQ/GJ	40	600	EMEP/CORINAIR B216
Benzo(a)pyrene	150	mg/GJ	13	180	EMEP/CORINAIR B216
Benzo(b)fluoranthene	180	mg/GJ	17	200	EMEP/CORINAIR B216
Benzo(k)fluoranthene	100	mg/GJ	8	150	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	80	mg/GJ	6	100	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:

450 g/GJ of sulphur dioxide is equivalent to 0.6 % S of coal fuel of lower heating value on a dry basis, 24 GJ/t and average sulphur retention in ash value of 0.1.

Table 3-24 Tier 2 emission factors for source category 1.A.4.b.i, advanced fireplaces burning wood

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Wood				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Advanced wood combustion techniques <1MW - Advanced fireplaces				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	90	g/GJ	50	150	EMEP/CORINAIR B216
CO	4500	g/GJ	300	5000	EMEP/CORINAIR B216
NMVOC	450	g/GJ	20	500	EMEP/CORINAIR B216
SOx	20	g/GJ	15	50	EMEP/CORINAIR B216
TSP	250	g/GJ	70	260	EMEP/CORINAIR B216
PM10	240	g/GJ	66	250	EMEP/CORINAIR B216
PM2.5	240	g/GJ	65	250	EMEP/CORINAIR B216
Pb	30	mg/GJ	20	60	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.5	2.5	EMEP/CORINAIR B216
Hg	0.4	mg/GJ	0.2	0.6	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.3	2.5	EMEP/CORINAIR B216
Cr	8	mg/GJ	1	10	EMEP/CORINAIR B216
Cu	2	mg/GJ	1	11.2	EMEP/CORINAIR B216
Ni	2	mg/GJ	0.1	200	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.25	0.75	EMEP/CORINAIR B216
Zn	80	mg/GJ	60	250	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	300	ng I-TEQ/GJ	30	500	EMEP/CORINAIR B216
Benzo(a)pyrene	100	mg/GJ	12	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	90	mg/GJ	14	120	EMEP/CORINAIR B216
Benzo(k)fluoranthene	40	mg/GJ	8	50	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	60	mg/GJ	6	80	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-25 Tier 2 emission factors for source category 1.A.4.b.i, advanced stoves burning wood

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.b.i	Residential plants			
Fuel	Wood				
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)			
Technologies/Practices	Advanced wood combustion techniques <1MW - Advanced stoves				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	90	g/GJ	50	150	EMEP/CORINAIR B216
CO	3000	g/GJ	300	5000	EMEP/CORINAIR B216
NMVOC	250	g/GJ	20	500	EMEP/CORINAIR B216
SOx	20	g/GJ	15	50	EMEP/CORINAIR B216
TSP	250	g/GJ	70	260	EMEP/CORINAIR B216
PM10	240	g/GJ	66	250	EMEP/CORINAIR B216
PM2.5	240	g/GJ	65	250	EMEP/CORINAIR B216
Pb	30	mg/GJ	20	60	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.5	2.5	EMEP/CORINAIR B216
Hg	0.4	mg/GJ	0.2	0.6	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.3	2.5	EMEP/CORINAIR B216
Cr	8	mg/GJ	1	10	EMEP/CORINAIR B216
Cu	2	mg/GJ	1	11.2	EMEP/CORINAIR B216
Ni	2	mg/GJ	1	200	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.25	0.75	EMEP/CORINAIR B216
Zn	80	mg/GJ	60	250	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	300	ng I-TEQ/GJ	30	500	EMEP/CORINAIR B216
Benzo(a)pyrene	100	mg/GJ	12	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	90	mg/GJ	14	120	EMEP/CORINAIR B216
Benzo(k)fluoranthene	40	mg/GJ	8	50	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	60	mg/GJ	6	80	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-26 Tier 2 emission factors for source category 1.A.4.b.i, pellet stoves burning wood

Tier 2 emission factors						
	Code	Name				
NFR Source Category	1.A.4.b.i	Residential plants				
Fuel	Wood					
SNAP (if applicable)	020205	Residential - Other equipments (stoves, fireplaces, cooking,...)				
Technologies/Practices	Advanced wood combustion techniques <1MW - Pellet stoves					
Region or regional conditions	NA					
Abatement technologies	NA					
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP					
Not estimated	NH3, Total 4 PAHs					
Pollutant	Value	Unit	95% confidence interval		Reference	
			Lower	Upper		
NOx	90	g/GJ	50	150	EMEP/CORINAIR B216	
CO	500	g/GJ	300	5000	EMEP/CORINAIR B216	
NMVOC	20	g/GJ	10	500	EMEP/CORINAIR B216	
SOx	20	g/GJ	15	50	EMEP/CORINAIR B216	
TSP	80	g/GJ	70	250	EMEP/CORINAIR B216	
PM10	76	g/GJ	66	240	EMEP/CORINAIR B216	
PM2.5	76	g/GJ	65	240	EMEP/CORINAIR B216	
Pb	20	mg/GJ	10	60	EMEP/CORINAIR B216	
Cd	0.5	mg/GJ	0.1	2.5	EMEP/CORINAIR B216	
Hg	0.4	mg/GJ	0.2	0.6	EMEP/CORINAIR B216	
As	0.5	mg/GJ	0.3	2.5	EMEP/CORINAIR B216	
Cr	3	mg/GJ	1	10	EMEP/CORINAIR B216	
Cu	1	mg/GJ	0.5	11.2	EMEP/CORINAIR B216	
Ni	2	mg/GJ	1	200	EMEP/CORINAIR B216	
Se	0.5	mg/GJ	0.25	0.75	EMEP/CORINAIR B216	
Zn	80	mg/GJ	60	250	EMEP/CORINAIR B216	
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)	
PCDD/F	50	ng I-TEQ/GJ	30	500	EMEP/CORINAIR B216	
Benzo(a)pyrene	50	mg/GJ	12	100	EMEP/CORINAIR B216	
Benzo(b)fluoranthene	15	mg/GJ	14	120	EMEP/CORINAIR B216	
Benzo(k)fluoranthene	16	mg/GJ	8	40	EMEP/CORINAIR B216	
Indeno(1,2,3-cd)pyrene	10	mg/GJ	6	60	EMEP/CORINAIR B216	
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216	

3.3.2.2 Non-residential heating (1.A.4.a, 1.A.4.c, 1.A.5.a)

Table 3-27 Tier 2 emission factors for non-residential sources, medium-size (> 50 kWth to ≤ 1 MWth) boilers burning coal fuels

Tier 2 emission factors						
	Code	Name				
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary				
Fuel	Coal Fuels					
SNAP (if applicable)						
Technologies/Practices	Medium size (>50 kWth to <=1 MWth) boilers					
Region or regional conditions	NA					
Abatement technologies	NA					
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP					
Not estimated	NH3, Total 4 PAHs					
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**	
			Lower	**Upper**		
NOx	160	g/GJ	150	200	EMEP/CORINAIR B216	
CO	2000	g/GJ	200	3000	EMEP/CORINAIR B216	
NMVOC	200	g/GJ	20	300	EMEP/CORINAIR B216	
SOx	900	g/GJ	450	1000	EMEP/CORINAIR B216	
TSP	200	g/GJ	80	250	EMEP/CORINAIR B216	
PM10	190	g/GJ	76	240	EMEP/CORINAIR B216	
PM2.5	170	g/GJ	72	220	EMEP/CORINAIR B216	
Pb	200	mg/GJ	80	300	EMEP/CORINAIR B216	
Cd	3	mg/GJ	1	5	EMEP/CORINAIR B216	
Hg	7	mg/GJ	5	9	EMEP/CORINAIR B216	
As	5	mg/GJ	0.5	8	EMEP/CORINAIR B216	
Cr	15	mg/GJ	1	20	EMEP/CORINAIR B216	
Cu	30	mg/GJ	8	50	EMEP/CORINAIR B216	
Ni	20	mg/GJ	2	30	EMEP/CORINAIR B216	
Se	2	mg/GJ	0.5	3	EMEP/CORINAIR B216	
Zn	300	mg/GJ	100	500	EMEP/CORINAIR B216	
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)	
PCDD/F	400	ng I-TEQ/GJ	40	500	EMEP/CORINAIR B216	
Benzo(a)pyrene	100	mg/GJ	13	150	EMEP/CORINAIR B216	
Benzo(b)fluoranthene	130	mg/GJ	17	180	EMEP/CORINAIR B216	
Benzo(k)fluoranthene	50	mg/GJ	8	100	EMEP/CORINAIR B216	
Indeno(1,2,3-cd)pyrene	40	mg/GJ	6	80	EMEP/CORINAIR B216	
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216	

Note:
900 g/GJ of sulphur dioxide corresponds to 1.2 % S of coal fuel of lower heating value on a dry basis, 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-28 Tier 2 emission factors for non-residential sources, medium-size (> 1 MWth to ≤ 50 MWth) boilers burning coal fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Coal Fuels				
SNAP (if applicable)					
Technologies/Practices	Medium size (>1 MWth to <=50 MWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	180	g/GJ	150	200	EMEP/CORINAIR B216
CO	200	g/GJ	150	3000	EMEP/CORINAIR B216
NMVOC	20	g/GJ	10	300	EMEP/CORINAIR B216
SOx	900	g/GJ	450	1000	EMEP/CORINAIR B216
TSP	80	g/GJ	70	250	EMEP/CORINAIR B216
PM10	76	g/GJ	60	240	EMEP/CORINAIR B216
PM2.5	72	g/GJ	60	220	EMEP/CORINAIR B216
Pb	100	mg/GJ	80	200	EMEP/CORINAIR B216
Cd	1	mg/GJ	0.5	3	EMEP/CORINAIR B216
Hg	9	mg/GJ	5	10	EMEP/CORINAIR B216
As	4	mg/GJ	0.5	5	EMEP/CORINAIR B216
Cr	15	mg/GJ	1	20	EMEP/CORINAIR B216
Cu	10	mg/GJ	8	30	EMEP/CORINAIR B216
Ni	10	mg/GJ	2	20	EMEP/CORINAIR B216
Se	2	mg/GJ	0.5	3	EMEP/CORINAIR B216
Zn	150	mg/GJ	100	300	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	100	ng I-TEQ/GJ	40	500	EMEP/CORINAIR B216
Benzo(a)pyrene	13	mg/GJ	10	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	17	mg/GJ	10	180	EMEP/CORINAIR B216
Benzo(k)fluoranthene	9	mg/GJ	8	100	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	6	mg/GJ	5	80	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:
900 g/GJ of sulphur dioxide corresponds to 1.2 % S of coal fuel of lower heating value on a dry basis, 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-29 Tier 2 emission factors for non-residential sources, manual boilers burning coal fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Coal Fuels				
SNAP (if applicable)					
Technologies/Practices	Advanced coal combustion techniques <1MWth - Manual Boiler				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	200	g/GJ	150	300	EMEP/CORINAIR B216
CO	1500	g/GJ	200	3000	EMEP/CORINAIR B216
NMVOC	100	g/GJ	20	300	EMEP/CORINAIR B216
SOx	450	g/GJ	300	900	EMEP/CORINAIR B216
TSP	150	g/GJ	80	250	EMEP/CORINAIR B216
PM10	140	g/GJ	76	240	EMEP/CORINAIR B216
PM2.5	130	g/GJ	72	220	EMEP/CORINAIR B216
Pb	150	mg/GJ	80	200	EMEP/CORINAIR B216
Cd	2	mg/GJ	1	3	EMEP/CORINAIR B216
Hg	6	mg/GJ	5	9	EMEP/CORINAIR B216
As	4	mg/GJ	0.5	5	EMEP/CORINAIR B216
Cr	10	mg/GJ	1	15	EMEP/CORINAIR B216
Cu	15	mg/GJ	8	30	EMEP/CORINAIR B216
Ni	15	mg/GJ	2	20	EMEP/CORINAIR B216
Se	2	mg/GJ	0.5	3	EMEP/CORINAIR B216
Zn	200	mg/GJ	100	300	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	200	ng I-TEQ/GJ	40	500	EMEP/CORINAIR B216
Benzo(a)pyrene	90	mg/GJ	13	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	110	mg/GJ	17	180	EMEP/CORINAIR B216
Benzo(k)fluoranthene	50	mg/GJ	8	100	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	40	mg/GJ	6	80	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:
450 g/GJ of sulphur dioxide corresponds to 0.6 % S of coal fuel of lower heating value on a dry basis, 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-30 Tier 2 emission factors for non-residential sources, automatic boilers burning coal fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Coal Fuels				
SNAP (if applicable)					
Technologies/Practices	Advanced coal combustion techniques <1MWth - Automatic Boiler				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	200	g/GJ	150	300	EMEP/CORINAIR B216
CO	400	g/GJ	200	3000	EMEP/CORINAIR B216
NMVOC	20	g/GJ	10	300	EMEP/CORINAIR B216
SOx	450	g/GJ	400	1000	EMEP/CORINAIR B216
TSP	80	g/GJ	70	250	EMEP/CORINAIR B216
PM10	76	g/GJ	60	240	EMEP/CORINAIR B216
PM2.5	72	g/GJ	60	220	EMEP/CORINAIR B216
Pb	80	mg/GJ	50	300	EMEP/CORINAIR B216
Cd	2	mg/GJ	0.2	5	EMEP/CORINAIR B216
Hg	8	mg/GJ	5	10	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.2	8	EMEP/CORINAIR B216
Cr	1	mg/GJ	0.5	20	EMEP/CORINAIR B216
Cu	8	mg/GJ	5	50	EMEP/CORINAIR B216
Ni	2	mg/GJ	0.5	30	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.2	3	EMEP/CORINAIR B216
Zn	100	mg/GJ	50	500	EMEP/CORINAIR B216
PCB	170	µg/GJ	85	260	Kakareka et. al (2004)
PCDD/F	40	ng I-TEQ/GJ	20	500	EMEP/CORINAIR B216
Benzo(a)pyrene	17	mg/GJ	13	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	18	mg/GJ	17	180	EMEP/CORINAIR B216
Benzo(k)fluoranthene	8	mg/GJ	5	100	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	7	mg/GJ	6	80	EMEP/CORINAIR B216
HCB	0.62	µg/GJ	0.31	1.2	EMEP/CORINAIR B216

Note:
450 g/GJ of sulphur dioxide corresponds to 0.6 % S of coal fuel of lower heating value on a dry basis, 24 GJ/t and average sulphur retention in ash as value of 0.1.

Table 3-31 Tier 2 emission factors for non-residential sources, manual boilers burning wood

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Wood				
SNAP (if applicable)					
Technologies/Practices	Advanced wood combustion techniques <1MW - Manual Boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	150	g/GJ	90	200	EMEP/CORINAIR B216
CO	3000	g/GJ	300	5000	EMEP/CORINAIR B216
NMVOC	250	g/GJ	20	500	EMEP/CORINAIR B216
SOx	20	g/GJ	15	50	EMEP/CORINAIR B216
TSP	80	g/GJ	70	250	EMEP/CORINAIR B216
PM10	76	g/GJ	66	240	EMEP/CORINAIR B216
PM2.5	76	g/GJ	65	240	EMEP/CORINAIR B216
Pb	10	mg/GJ	5	30	EMEP/CORINAIR B216
Cd	0.3	mg/GJ	0.1	2	EMEP/CORINAIR B216
Hg	0.5	mg/GJ	0.4	0.8	EMEP/CORINAIR B216
As	1	mg/GJ	0.25	2	EMEP/CORINAIR B216
Cr	2	mg/GJ	1	10	EMEP/CORINAIR B216
Cu	3	mg/GJ	1	5	EMEP/CORINAIR B216
Ni	200	mg/GJ	0.1	250	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.1	2	EMEP/CORINAIR B216
Zn	5	mg/GJ	1	150	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	300	ng I-TEQ/GJ	30	500	EMEP/CORINAIR B216
Benzo(a)pyrene	50	mg/GJ	12	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	60	mg/GJ	14	120	EMEP/CORINAIR B216
Benzo(k)fluoranthene	20	mg/GJ	8	50	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	20	mg/GJ	6	80	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-32 Tier 2 emission factors for non-residential sources, automatic boilers burning wood

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Wood				
SNAP (if applicable)					
Technologies/Practices	Advanced wood combustion techniques <1MW - Automatic Boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	150	g/GJ	90	200	EMEP/CORINAIR B216
CO	300	g/GJ	200	5000	EMEP/CORINAIR B216
NMVOC	20	g/GJ	10	500	EMEP/CORINAIR B216
SOx	20	g/GJ	15	50	EMEP/CORINAIR B216
TSP	70	g/GJ	60	250	EMEP/CORINAIR B216
PM10	66	g/GJ	50	240	EMEP/CORINAIR B216
PM2.5	66	g/GJ	50	240	EMEP/CORINAIR B216
Pb	20	mg/GJ	10	30	EMEP/CORINAIR B216
Cd	0.5	mg/GJ	0.3	2	EMEP/CORINAIR B216
Hg	0.6	mg/GJ	0.4	0.8	EMEP/CORINAIR B216
As	0.5	mg/GJ	0.25	2	EMEP/CORINAIR B216
Cr	4	mg/GJ	2	10	EMEP/CORINAIR B216
Cu	2	mg/GJ	1	5	EMEP/CORINAIR B216
Ni	2	mg/GJ	0.1	200	EMEP/CORINAIR B216
Se	0.5	mg/GJ	0.1	2	EMEP/CORINAIR B216
Zn	80	mg/GJ	5	150	EMEP/CORINAIR B216
PCB	0.06	mg/GJ	0.012	0.3	Kakareka et. al (2004)
PCDD/F	30	ng I-TEQ/GJ	20	500	EMEP/CORINAIR B216
Benzo(a)pyrene	12	mg/GJ	10	150	EMEP/CORINAIR B216
Benzo(b)fluoranthene	14	mg/GJ	10	120	EMEP/CORINAIR B216
Benzo(k)fluoranthene	8	mg/GJ	5	50	EMEP/CORINAIR B216
Indeno(1,2,3-cd)pyrene	6	mg/GJ	2	80	EMEP/CORINAIR B216
HCB	6	µg/GJ	3	9	EMEP/CORINAIR B216

Table 3-33 Tier 2 emission factors for non-residential sources, medium-sized (> 50 kWth to ≤ 1 MWth) boilers burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Natural Gas				
SNAP (if applicable)					
Technologies/Practices	Medium size (>50 kWth to <=1 MWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	70	g/GJ	35	200	Guidebook (2006) chapter B216
CO	30	g/GJ	18	42	Guidebook (2006) chapter B216
NMVOC	3	g/GJ	1.8	4.2	Guidebook (2006) chapter B216
SOx	0.5	g/GJ	0.05	1	Guidebook (2006) chapter B216
TSP	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
PM10	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
PM2.5	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
Pb	0.98	mg/GJ	0.49	2	US EPA (1998), chapter 1.4
Cd	0.52	mg/GJ	0.17	1.5	US EPA (1998), chapter 1.4
Hg	0.23	mg/GJ	0.078	0.7	US EPA (1998), chapter 1.4
As	0.094	mg/GJ	0.031	0.28	US EPA (1998), chapter 1.4
Cr	0.66	mg/GJ	0.22	2	US EPA (1998), chapter 1.4
Cu	0.4	mg/GJ	0.2	0.8	US EPA (1998), chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA (1998), chapter 1.4
Se	0.011	mg/GJ	0.0037	0.034	US EPA (1998), chapter 1.4
Zn	13.6	mg/GJ	4.5	41	US EPA (1998), chapter 1.4
PCDD/F	2	ng I-TEQ/GJ	1	3	Guidebook (2006) chapter B216
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.561	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)

Table 3-34 Tier 2 emission factors for non-residential sources, medium sized (> 1 MWth to ≤ 50 MWth) boilers burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.c.i	Commercial / institutional: stationary Stationary			
Fuel	Natural Gas				
SNAP (if applicable)					
Technologies/Practices	Medium size (>1 MWth to <=50 MWth) boilers				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	70	g/GJ	35	200	Guidebook (2006) chapter B216
CO	20	g/GJ	12	28	Guidebook (2006) chapter B216
NMVOC	2	g/GJ	1.2	2.8	Guidebook (2006) chapter B216
SOx	0.5	g/GJ	0.05	1	Guidebook (2006) chapter B216
TSP	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
PM10	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
PM2.5	0.5	g/GJ	0.3	0.7	Guidebook (2006) chapter B216
Pb	0.98	mg/GJ	0.49	2	US EPA (1998), chapter 1.4
Cd	0.52	mg/GJ	0.17	1.5	US EPA (1998), chapter 1.4
Hg	0.23	mg/GJ	0.078	0.7	US EPA (1998), chapter 1.4
As	0.094	mg/GJ	0.031	0.28	US EPA (1998), chapter 1.4
Cr	0.66	mg/GJ	0.22	2	US EPA (1998), chapter 1.4
Cu	0.4	mg/GJ	0.2	0.8	US EPA (1998), chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA (1998), chapter 1.4
Se	0.011	mg/GJ	0.0037	0.034	US EPA (1998), chapter 1.4
Zn	13.6	mg/GJ	4.5	41	US EPA (1998), chapter 1.4
PCDD/F	2	ng I-TEQ/GJ	1	3	Guidebook (2006) chapter B216
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA (1998), chapter 1.4 ("Less than" value based on method detection limits)

Table 3-35 Tier 2 emission factors for non-residential sources, gas turbines burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.b.i	Commercial / institutional: stationary Residential plants			
Fuel	Natural Gas				
SNAP (if applicable)	020104	Comm./instit. - Stationary gas turbines			
Technologies/Practices	Gas Turbines				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, PCDD/F, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	153	g/GJ	92	245	US EPA 2000, chapter 3.1
CO	39.2	g/GJ	24	63	US EPA 2000, chapter 3.1
NMVOC	1	g/GJ	0.3	3	US EPA 2000, chapter 3.1
SOx	0.281	g/GJ	0.169	0.393	US EPA 1998, chapter 1.4
TSP	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
PM10	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
PM2.5	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
Pb	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.1	mg/GJ	0.05	0.15	van der Most & Veldt 1992
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	4.53	40	US EPA 1998, chapter 1.4
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Notes:

1. Concerning the respective heating value used to convert USEPA factors, the USEPA quotes higher heating value (HHV) = 1020 MMBtu/MM scf; derived lower heating value (LHV) = 920 MMBTU/MM scf (90 % of HHV). The derivation calculations are based on 1 lb/MMscf being equivalent to 0.468 g/GJ (LHV) (note 1 MM= 1x 10^6).
2. The SO2 emission factor refers to USEPA 1998 and not USEPA 2000, as this former factor was considered to more consistent with the other USEPA factors for natural gas.

Table 3-36 Tier 2 emission factors for non-residential sources, gas turbines burning gas oil

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.b.i	Commercial / institutional: stationary Residential plants			
Fuel	Gas Oil				
SNAP (if applicable)	020104	Comm./instit. - Stationary gas turbines			
Technologies/Practices	Gas Turbines				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, As, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	398	g/GJ	239	557	US EPA 2000, chapter 3.1
CO	1.49	g/GJ	0.89	2.09	US EPA 2000, chapter 3.1
NMVOC	0.19	g/GJ	0.11	0.26	US EPA 2000, chapter 3.1
SOx	46.1	g/GJ	4.61	460	See Note
TSP	3	g/GJ	1.5	6	Rubenstein (2003)
PM10	3	g/GJ	1.5	6	Rubenstein (2003)
PM2.5	3	g/GJ	1.5	6	Rubenstein (2003)
Pb	6.34	mg/GJ	2.11	19	US EPA 2000, chapter 3.1
Cd	2.17	mg/GJ	0.723	6.51	US EPA 2000, chapter 3.1
Hg	0.543	mg/GJ	0.181	1.63	US EPA 2000, chapter 3.1
Cr	4.98	mg/GJ	1.66	14.9	US EPA 2000, chapter 3.1

Note:
Factor for SO_2 assumes no SO_2 abatement and is based on 0.1 % mass sulphur content.

Table 3-37 Tier 2 emission factors for non-residential sources, reciprocating engines burning gas fuels

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.b.i	Commercial / institutional: stationary Residential plants			
Fuel	Gas fuel (includes dual fuel 95% gas + 5% gas oil)				
SNAP (if applicable)	020105	Comm./instit. - Stationary engines			
Technologies/Practices	Stationary reciprocating Engines - gas-fired, includes dual fuel				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, PCDD/F, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	1420	g/GJ	708	2120	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
CO	407	g/GJ	204	611	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
NMVOC	46	g/GJ	23	69	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
SOx	0.281	g/GJ	0.169	0.393	US EPA (1998), chapter 1.4
TSP	1.5	g/GJ	0.01	20	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
PM10	1.5	g/GJ	0.01	20	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
PM2.5	1.5	g/GJ	0.01	20	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
Pb	0.234	mg/GJ	0.0781	0.703	US EPA (1998), chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA (1998), chapter 1.4
Hg	0.1	mg/GJ	0.05	0.15	van der Most & Veldt (1992)
As	0.0937	mg/GJ	0.0312	0.281	US EPA (1998), chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA (1998), chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA (1998), chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA (1998), chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA (1998), chapter 1.4
Zn	13.6	mg/GJ	4.53	40.7	US EPA (1998), chapter 1.4
Benzo(a)pyrene	0.0027	mg/GJ	0.00135	0.00405	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
Benzo(b)fluoranthene	0.018	mg/GJ	0.009	0.027	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
Benzo(k)fluoranthene	0.002	mg/GJ	0.001	0.003	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4
Indeno(1,2,3-cd)pyrene	0.0047	mg/GJ	0.00235	0.00705	Expert judgement based on US EPA 2000, chapt 3.2 and US EPA 1996, chapt 3.4

Note:
Concerning the emission factor reference in the table above 'Expert judgement based on US EPA 2000, chap 3.2 and US EPA 1996, chap 3.4' — the factors are an average of different engine type subgroups in the AP42 chapters 3.2 and 3.4 calculated using a simple geometric mean (with no application of any population/use weighting procedure).

Table 3-38 Tier 2 emission factors for non-residential sources, reciprocating engines burning gas oil

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.b.i	Commercial / institutional: stationary Residential plants			
Fuel	Gas Oil				
SNAP (if applicable)	020105	Comm./instit. - Stationary engines			
Technologies/Practices	Reciprocating Engines				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, PCDD/F, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	1450	g/GJ	680	2050	US EPA (1996), chapter 3.4
CO	385	g/GJ	193	578	US EPA (1996), chapter 3.4
NMVOC	37.1	g/GJ	18.5	55.6	US EPA (1996), chapter 3.4
SOx	46.1	g/GJ	4.61	461	See note in Guidebook text
TSP	28.1	g/GJ	14.1	56.2	US EPA (1996), chapter 3.4
PM10	22.4	g/GJ	11.2	44.8	US EPA (1996), chapter 3.4
PM2.5	21.7	g/GJ	10.8	43.4	US EPA (1996), chapter 3.4
Pb	4.07	mg/GJ	0.41	40.7	US EPA (1998), chapter 1.3
Cd	1.36	mg/GJ	0.14	13.6	US EPA (1998), chapter 1.3
Hg	1.36	mg/GJ	0.14	13.6	US EPA (1998), chapter 1.3
As	1.81	mg/GJ	0.18	18.1	US EPA (1998), chapter 1.3
Cr	1.36	mg/GJ	0.14	13.6	US EPA (1998), chapter 1.3
Cu	2.72	mg/GJ	0.27	27.1	US EPA (1998), chapter 1.3
Ni	1.36	mg/GJ	0.14	13.6	US EPA (1998), chapter 1.3
Se	6.79	mg/GJ	0.68	67.9	US EPA (1998), chapter 1.3
Zn	1.81	mg/GJ	0.18	18.1	US EPA (1998), chapter 1.3
Benzo(a)pyrene	0.116	mg/GJ	0.0582	0.116	US EPA (1998), chapter 1.3 ("Less than" value based on method detection limits)
Benzo(b)fluoranthene	0.502	mg/GJ	0.251	0.754	US EPA (1996)
Benzo(k)fluoranthene	0.0987	mg/GJ	0.0493	0.0987	US EPA (1998), chapter 1.3 ("Less than" value based on method detection limits)
Indeno(1,2,3-cd)pyrene	0.187	mg/GJ	0.0937	0.187	US EPA (1998), chapter 1.3 ("Less than" value based on method detection limits)

Notes:
1. Factor for SO_2 assumes no SO_2 abatement and is based on 0.1 % mass sulphur content.
2. TSP is based on AP 42 factor for PM_{10}.

3.3.3 Abatement

A limited number of add-on technologies exist that are aimed at reducing the emissions of primarily PM in these sectors. The resulting emission can be calculated by extending the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1 - \eta_{abatement}) \times EF_{technology,unabated} \quad (5)$$

However, as abatement technology is rarely specified in terms of efficiency, it may be more relevant to develop abated emission factors from the final emission concentrations achieved using abatement.

Guidance on estimating emission factors from concentrations is provided at subsection 4.3 of the present chapter.

3.3.4 Activity data

In most cases the statistical information includes data on annual fuel consumption in the relevant activities. However, data on use of fuels in different technologies may be limited. To fill these data gaps the following sources could be used:

- information from emission trading schemes
- information from the fuel suppliers and individual companies
- energy conservation/climate change mitigation studies for relevant sectors
- residential, commercial/institutional and agriculture sector surveys
- energy demand modelling.

The data from sources should be compared, taking into account their inherent uncertainties in order to obtain the best assessment of appliance population and fuel use. To improve reliability of the activity data, appropriate efforts should be made in order to encourage the institution responsible for national energy statistics to report the fuel consumption at the adequate level of sectoral disaggregation in their regular activity.

Also, when data on fuel consumption are provided at an appropriate level of sectoral split, they should be checked for possible anomalies. Wood and other types of biomass consumption (in some cases also gas oil consumption) in the residential sector requires particular consideration.

For example, the self-supply and direct purchase of the wood from farmers might not be taken into account when energy statistics are based mainly on the data obtained from the fuel suppliers. This could lead to a significant underestimation of the wood consumption, especially in the countries with abundant wood supplies and greater share of heating with stoves and small solid fuel boilers. In that case, the data on wood consumption should be adjusted. Consultation with the forestry experts and/or energy demand modelling is recommended.

The Tier 2 methodology requires further allocation of the fuel consumed according to the installation types. This is particularly relevant to the residential sector where, for example, the proportion of solid fuel burned in traditional low technology appliances is important to understanding the significance of the emissions. The data needed are generally not available in statistics reports. In most cases the inventorying agency would have to use surrogate data to assess the activity data at the required level of desegregation. National approaches have to be developed depending on the availability and quality of surrogate data. Some examples of surrogate data sources are:

- residential, commercial/institutional and agriculture sector surveys
- energy conservation/climate change mitigation studies for relevant sectors
- energy demand modelling
- information from the fuel suppliers
- information from producers and sellers of heating appliances
- chimney sweeping organisations.

Particularly in the case of the residential sector it should be emphasised that the surveys have to be based on a representative sample. In some countries the means of heating of the households are regionally very inhomogeneous with a significantly greater share of solid-fuel stoves and boilers in traditionally coal mining regions and in some rural areas. Additional data could be obtained from the chimney-sweeper organisations and from environmental inspectorates, particularly for the commercial-institutional sector.

Another important source of data could be housing statistics. Within the scope of national census, the data on dwellings occupied by households are usually collected. Data on individual dwellings might include:

- number of residents,
- area of the dwelling,
- type of building (individual house, attached house, block of flats),
- construction year,
- existence or not of central heating,
- central heating boiler in the flat or common for block of flats,
- fuels used for heating.

Dwelling statistics could be used to extrapolate results of the household survey or to perform detailed energy demand/emission modelling. Especially in the case where household emissions represent a key source or are of a great relevance due to local air quality, it is recommended to perform such an exercise. Detailed energy demand/emission modelling may be usually performed at local or regional level; however the extension to the national level does not pose significant additional requirements. To justify the additional effort required for energy demand/emission modelling of the households, the emission inventorying agency might find it appropriate to initiate a common project with other stakeholders, such as, for instance, agencies involved in energy conservation, climate change mitigation or energy supply.

3.4 Tier 3 emission modelling and use of facility data

Installation-specific emission estimation is not considered to be applicable for the activities detailed. However the Tier 3 methodology allows a modelling-based approach using more detailed appliance population data and applies more technology-specific emission factors — guidance on determining plant-specific emission factors is given in the Measurement Protocol. Relevant emission factors are also provided at Appendix A.

4 Data quality

4.1 Completeness

The potential for self-supply or other unrecorded fuel supply needs to be considered.

4.2 Avoiding double counting with other sectors

In cases where it is possible to split the emissions, it is good practice to do so. However, care must be taken that the emissions are not double counted.

4.3 Verification

4.3.1 Best Available Technique emission factors

The size of combustion appliance will generally fall below the threshold where guidance on BAT emission levels applies.

However, many countries apply emission controls on appliances in the size range considered and selected emission limit values are provided in the following sections. Details of the methodology applied to calculate emission factors from emission limits are provided in Appendix B.

4.3.2 Fuel sulphur content

For processes without SO_2 abatement, the sulphur content of the fuel provides a means to calculate the SO_2 emission factor.

$$EF_{SO2} = \frac{[S] \times 2 \times 1000}{100 \times CV}$$

where:

- EF_{SO2} is the SO_2 emission factor $g.GJ^{-1}$,
- [S] is the percent sulphur (w/w),
- CV is the net/inferior calorific value $GJ.kg^{-1}$,
- 2 is the ratio of the RMM of SO_2 to Sulphur.

This equation can be extended to include a factor for retention of SO_2 in ash.

Liquid fuels in the EC are subject to sulphur limits (EC SCOLF, 1999/2005) as summarised in Table 4-1. The SO_2 emission factors in Table 4-1 have been calculated assuming 100 % conversion of fuel sulphur and applying UK net calorific values for fuel oils (DUKES, 2007).

Table 4-1 Sulphur emission factors from oil sulphur limits

Fuel oil	Implementation date	Maximum sulphur content	SO_2 emission factor, $g.GJ^{-1}$	Comment
Heavy fuel oil	1.1.2003	1 %	485	Assumes net CV of 41.2 $GJ.tonne^{-1}$
Gas oil	Pre 1.1.2008	0.2 %	92	Assumes net CV of 43.4 $GJ.tonne^{-1}$
	Post 1.1.2008	0.1 %	46	

4.3.3 Residential and small (< 300 kW output) non residential solid fuel boilers

EN303 pt5 is a non-harmonised tandard which incorporates emission 'classes' for CO, OGC (volatile organic compounds) and TSP. The emission factors associated with the emission concentrations are provided in Table 4-2.

Many countries operate type-approval schemes for residential coal and biomass appliances which apply TSP emission limits on solid fuel appliances and these can be developed into emission factors. Ecolabelling schemes for gas appliances may include labelling for NOx emissions.

The following emission factors are calculated using procedure described in Appendix B.

Table 4-2 EN303 Pt 5 emission classes as emission factors

Fuel	Fuel	Appliance	Emission concentration, mg m^{-3} at STP (0 °C, 101.3 kPa), dry and 10 % O_2								
feed	type	output	CO			'OGC' (VOC)			PM		
type		kW	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Manual	biogenic	< 50	25 000	8 000	5 000	2 000	300	150	200	180	150
		50–150	12 500	5 000	2 500	1 500	200	100	200	180	150
		150–300	12 500	2 000	1 200	1 500	200	100	200	180	150
	fossil	< 50	25 000	8 000	5 000	2 000	300	150	180	150	125
		50–150	12 500	5 000	2 500	1 500	200	100	180	150	125
		150–300	12 500	2 000	1 200	1 500	200	100	180	150	125
Automatic	biogenic	< 50	15 000	5 000	3 000	1 750	200	100	200	180	150
		50–150	12 500	4 500	2 500	1 250	150	80	200	180	150
		150–300	12 500	2 000	1 200	1 250	150	80	200	180	150
	fossil	< 50	15 000	5 000	3 000	1 750	200	100	180	150	125
		50–150	12 500	4 500	2 500	1 250	150	80	180	150	125
		150–300	12 500	2 000	1 200	1 250	150	80	180	150	125
			Emission factors, g.GJ^{-1} (net thermal input)								
Manual	biogenic	< 50	13 181	4 218	2 636	1 054	158	79	105	95	79
		50–150	6 591	2 636	1 318	791	105	53	105	95	79
		150–300	6 591	1 054	633	791	105	53	105	95	79
	fossil	< 50	13 181	4 218	2 636	1 054	158	79	95	79	66
		50–150	6 591	2 636	1 318	791	105	53	95	79	66
		150–300	6 591	1 054	633	791	105	53	95	79	66
Automatic	biogenic	< 50	7 909	2 636	1 582	923	105	53	105	95	79
		50–150	6 591	2 373	1 318	659	79	42	105	95	79
		150–300	6 591	1 054	633	659	79	42	105	95	79
	fossil	< 50	7 909	2 636	1 582	923	105	53	95	79	66
		50–150	6 591	2 373	1 318	659	79	42	95	79	66
		150–300	6 591	1 054	633	659	79	42	95	79	66

4.3.4 Selected national emission limits for small combustion installations

Many countries apply emission controls to combustion appliances smaller than 50 MW_{th} and a summary of selected countries' pollutant limit values is provided as emission factors below; further details (and countries) are provided at Appendix C.

Table 4-3 Selected national emission limits as emission factors for coal-fired boilers

Country	Size	Ref.	Emission concentrations, mg.m^{-3} at STP (0ºC, 101.3 kPa) dry at reference O_2 content							
		O2	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High		
France	20–50 MW	6	450	650	850	2 000	50	100	200	110
France	< 4 MW	6	550	825	2 000		150			
France	4–10 MW	6	550	825	2 000		100			
France	> 10 MW	6	550	825	2 000		100			
Finland	1–50 MW	6	275	550	1 100	1 100	55	140		
Germany	< 2.5 MW	7	300	500	350	1 300	50		150	
Germany	< 5 MW	7	300	500	350	1 300	50		150	
Germany	> 5 MW	7	300	500	350	1 300	20		150	
Germany	> 10 MW	7	300	400	350	1 300	20		150	
			Emission factor, g.GJ^{-1} (net basis)							
France	20–50 MW		163	235	308	725	18	36	72	40
France	< 4 MW		199	299	725		54			
France	4–10 MW		199	299	725		36			
France	> 10 MW		199	299	725		36			
Finland	1–50 MW		100	199	398	398	20	51		
Germany	< 2.5 MW		116	194	136	505	19		58	
Germany	< 5 MW		116	194	136	505	19		58	
Germany	> 5 MW		116	194	136	505	8		58	
Germany	> 10 MW		116	155	136	505	8		58	

Table 4-4 Selected national emission limits as emission factors for wood-fired boilers

Country	Size	Ref.	Emission concentrations, $mg.m^{-3}$ at STP (0ºC, 101.3 kPa) dry at reference O_2 content							
		O2	NO_x		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High		
France	20–50 MWth	11	400	650	200	2000	50	100	200	110
France	< 4 MW	11	500	750	200		150			
France	4–10 MW	11	500	750	200		100			
France	> 10 MW	11	500	750	200		100			
Finland	1–5 MW	6	250	500			250	375		
Finland	5–10 MW	6	250	500			125	250		
Finland	10–50 MW	6	250	500			50	125		
Germany	< 2.5 MW	11	250		350		100			10
Germany	< 5 MW	11	250		350		50			10
Germany	> 5 MW	11	250		350		20			10
			Emission factor, $g.GJ^{-1}$ (net basis)							
France	20–50 MWth		232	377	116	1161	29	58	116	64
France	< 4 MW		290	435	116		87			
France	4–10 MW		290	435	116		58			
France	> 10 MW		290	435	116		58			
Finland	1–5 MW		96	193			96	145		
Finland	5–10 MW		96	193			48	96		
Finland	10–50 MW		96	193			19	48		
Germany	< 2.5 MW		145		203		58			6
Germany	< 5 MW		145		203		29			6
Germany	> 5 MW		145		203		12			6

Table 4-5 Selected national emission limits as emission factors for oil-fired boilers

Country	Size	Ref.	Emission concentrations, $mg.m^{-3}$ at STP (0ºC, 101.3 kPa) dry at reference O_2 content							
		O2	NO_x		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High		
France	20–50 MWth	3	450	650	850	1 700	50	100	100	110
France	< 4 MW	3	550	825	1 700		150			
France	4–10 MW	3	550	825	1 700		100			
France	> 10 MW	3	500	750	1 700		100			
Finland	1–15 MW	3	800	900	1 700		50	200		
Finland	15–50 MW	3	500	670	1 700		50	140		
Germany	HWB	3	180	350			50		80	
Germany	LPS	3	200	350			50		80	
Germany	HPS	3	250	350			50		80	
			Emission factor, $g.GJ^{-1}$ (net basis)							
France	20–50 MWth	3	127	184	241	481	14	28	28	31
France	< 4 MW		156	233	481		42			
France	4–10 MW		156	233	481		28			
France	> 10 MW	3	141	212	481		28			
Finland	1–15 MW	3	226	255	481		14	57		
Finland	15–50 MW	3	141	190	481		14	40		
Germany	HWB	3	51	99			14		23	
Germany	LPS	3	57	99			14		23	
Germany	HPS	3	71	99			14		23	

Table 4-6 Selected national emission limits as emission factors for gas-fired boilers

Country	Size	Ref.	Emission concentrations, mg.m^{-3} at STP (0°C, 101.3 kPa) dry at reference O_2 content							
		O2	NO_x		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High		
France	20–50 MWth	3	120	350	35		5		100	110
France	< 10 MW	3	150	225	35		5			
France	> 10 MW	3	100	150	35		5			
Finland	1–15 MW	3	340	400						
Finland	15–50 MW	3	170	300						
Germany	HWB	3	100		10		5		50	
Germany	LPS	3	110		10		5		50	
Germany	HPS	3	150		10		5		50	
			Emission factor, g.GJ^{-1} (net basis)							
France	20–50 MWth		34	99	10		1		28	31
France	< 10 MW		42	64	10		1			
France	> 10 MW		28	42	10		1			
Finland	1–15 MW		96	113						
Finland	15–50 MW		48	85						
Germany	HWB		28		3		1		14	
Germany	LPS		31		3		1		14	
Germany	HPS		42		3		1		14	

4.4 Developing a consistent time series and recalculation

The emissions of non-CO_2 emissions from fuel combustion change with time as equipment and facilities are upgraded or replaced by less-polluting energy technology. The mix of technology used with each fuel will change with time and this has implications for the choice of emission factor at Tier 1 and Tier 2.

4.5 Uncertainty assessment

4.5.1 Emission factor uncertainties

There is uncertainty in the aggregated emission factors used to estimate emissions. The number of sources, range of use, sizes, fuel quality (particularly solid fuels including biomass) and technologies in the residential sector will impact on the uncertainty to be expected from the application of an 'average' emission factor.

4.5.2 Activity data uncertainties

The activity data for residential fuel use may be subject to uncertainty from issues of self-supply, waste disposal or ‘unofficial’ fuel sources.

4.6 Inventory quality assurance/quality control QA/QC

No specific issues

4.7 Mapping

No specific issues

4.8 Reporting and documentation

No specific issues

5 Glossary

Automatic feed boiler:	boiler with fully automated fuel supply
Boiler:	any technical apparatus in which fuels are oxidised in order to generate thermal energy, which is transferred to water or steam
Briquettes:	refers to patent fuels from hard/sub-bituminous coal (NAPFUE 104) and brown coal briquettes (NAPFUE 106)
Brown coal:	refers to brown coal/lignite (NAPFUE 105) of gross caloric value (GHV) less than 17 435 kJ/kg and containing more than 31 % volatile matter on a dry mineral matter free basis
Charcoal:	refers to temperature treated wood (NAPFUE 112)
Chimney:	brick, metal or concrete stack used to carry the exhaust gases into the free atmosphere and to generate draught
CHP:	combined heat and power production
Coke:	refers to the solid residue obtained from hard coal (NAPFUE 107) or from brown coal (NAPFUE 108) by processing at high temperature in the absence of air
Efficiency:	is the ratio of produced output heat energy to energy introduced with the fuel, with reference to net (low) calorific value of fuel
Fireplace:	usually very simple combustion chamber, with or without front door, in which fuels are oxidized to obtain thermal energy, which is transferred to the dwelling mainly by radiation
Gaseous fuels:	refers to natural gas (NAPFUE 301), natural gas liquids (NAPFUE 302) and liquefied petroleum gases (LPG; NAPFUE 303), biogas (NAPFUE 309)
Hard coal:	refers to coal of a gross caloric value greater than 17 435 kJ/kg on

	ash-free but moisture basis, i.e. steam coal (NAPFUE 102, GHV> 23 865 kJ/kg), sub-bituminous coal (NAPFUE 103, 17 435 kJ/kg < GHV<23 865 kJ/kg) and anthracite
Liquid fuels:	refers to kerosene (NAPFUE 206), gas oil (gas/diesel oil (NAPFUE 204), residual oil, residual fuel oil (NAPFUE 203) and other liquid fuels (NAPFUE 225)
Manual feed boiler:	boiler with periodical manual fuel supply
Patent fuels:	refers to manufactured smokeless fuels from hard/sub-bituminous coal (NAPPFUE 104)
Peat:	refers to peat-like fuels (NAPFUE 113)
Solid biomass fuel:	refers to wood fuels which are wood and similar wood wastes (NAPFUE 111) and wood wastes (NAPFUE 116) and agricultural wastes used as fuels (straw, corncobs, etc; NAPFUE 117)
Stove:	simple appliance in which fuels are combusted to obtain thermal energy, which is transferred to the interior of the building by radiation and convection

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.

Appendix A Technology-specific emission factors

In this annex a compilation of various emission data is given to enable users' comparison with their own data.

Table A 1 Emission factors for small coal combustion installations

Installation	Pollutants						
	g/GJ					mg/GJ	
	SO_2	NO_x	CO	NMVOC 1)	VOC 1)	PAH	BaP
Domestic open fire	n.d	n.d	n.d.	14 1)	n.d.	n.d.	n.d.
Domestic closed stoves	2) 420	75	1500	n.d.	60	n.d.	n.d.
	3) 104 1)	8 1)	709 1)	n.d.	n.d.	n.d.	n.d.
Domestic boiler	4) 17.2 1)	6.2 1)	1.8 1)	n.d.	0.02 1)	n.d.	n.d.
Small commercial or institutional boiler	n.d.	n.d.	416 2)	n.d.	n.d.	n.d.	0.1 2)

Source: Hobson M., et al., 2003.
Notes:
1. No information about NMVOC and VOC standard reference — usual CH4 or C3H8 are used.
2. Original data in g/kg;.
3. Original data in g/kg; for recalculation Hu of 24 GJ/t (d.b.) was assumed.
4. Coal stove;.
5. Roomheater 12.5 kW, anthracite.
6. Boiler, bituminous coal; n.d. — no data.

Table A 2 Emission factors for combustion of manufactured solid fuels

Installation	Pollutants						
	g/GJ					Mg/GJ	
	SO_2	NO_x	CO	NMVOC 1)	VOC 1)	PAH	BaP
Domestic open fire	2) n.d	n.d	n.d.	n.d.	5.0–20	n.d.	n.d.
Domestic closed stoves	3) n.d.	n.d.	121–275 2)	10.5 2); 16.1 2)	n.d.	n.d.	n.d.
	4) 75 2) and 127 2)	4 2) and 7 2)	1 125 2); 1 193 2)	n.d.	n.d.	n.d.	n.d.
Domestic boiler	5) 371	382	12 400	n.d.	91	n.d.	n.d.
	6) n.d.	64–73	140–7 400	n.d.	0–500 7)	n.d.	n.d.
Small commercial or institutional boiler	8) n.d.	35	270	n.d.	2 7)	n.d.	n.d.

Source: Hobson M., et al., (2003). Notes:
1. No information about NMVOC and VOC standard reference — usually CH_4 or C_3H_8 are used.
2. Original data in g/kg.
3. 10 kW open fire, smokeless coal brands.
4. Stoves, charcoal and char briquettes, 12.5 kW roomheater, coke and manuf. briq.
5. UNECE TFEIP: Dutch fig. for coke use.

6. UNECE TFEIP: Sweden, pellet boilers, 1.8–2 MW.
7. As THC.
8. 8) UNECE TFEIP: Sweden, briquette boilers 1.8–2 MW; n.d.- no data.

Table A 3 Range of emission value from small coal appliances which employ fixed bed combustion with counter-current techniques (manually fuelled)

Types of appliances	Efficiency %	Assortment of fuel	Emissions factor of pollutants						
			CO G/GJ	SO_2 [a] g/GJ	NO_x G/GJ	TSP g/GJ	16 PAH g/GJ	B[a]P mg/GJ	VOC (C3) g/GJ
Standard stove	45–75	Un-assortment coal	3 500–12 500	200–800	100–150	700–900	20–40	200–600	500–700
Masonry stove	60–75		2 500–11 000	200–800	100–200	600–1 200	15–25	150–350	400–800
Kitchen stove	40–60		3 600–11 000	200–800	50–150	300–1 000	50–90	400–650	500–1 100
Standard boiler	50–67		1 800–7 000	200–800	50–150	150–500	30–90	600–900	400–1 200
Advanced boiler	76–82	Assortment coal,	200–1 500	200–800	150–200	50–100	0.2–0.6	2–30	60–120

Source: Kubica, 2003/1.
Note:
[a] Emission factor of sulphur dioxide strongly depends on sulphur content of fuel; these emission factors are for sulphur content between 0.5 % and 1.0 % with oxidation efficiency of sulphur about 90 %.

Table A 4 Range of emissions from small coal appliances which employ fixed bed combustion with co-current techniques (in principle automatic fuelled)

Types of appliances	Efficiency %	Assortment of fuel	Emissions factor of pollutants						
			CO g/GJ	SO2[a] g/GJ	NOx G/GJ	TSP g/GJ	16 PAH g/GJ	B [a]P mg/GJ	VOC (C3) g/GJ
Advanced boiler [b]	76–80	Fine coal	2 800–1 100	250–750	150–200	50–200	0.2–0.8	3–50	100–250
Burners boiler	77–84	Fine coal	1 500–400	250–750	150–250	30–120	0.2–2.0	5–50	2–50
Stoker, retort boiler	77–89	5–25 mm [c]	120–800	130–350	150–300	30–60	0.1–0.7	1–20	1–50

Source: Kubica, 2003/1.
Notes:
1. [a] Emission factor of sulphur dioxide strongly depends on sulphur content of fuel; these emission factors are for sulphur content between 0.5 % and 1.0 % with oxidation efficiency of sulphur about 90 %.
2. [b] Manually fuelled.
3. [c] For capacity above 50 kW, grain size 5–30 mm.

Table A 5 Emission value of coal combustion in stoves and small boilers derived from measurement campaign in Poland

Parameter	Unit	Advance under-fire boiler 30 kW		Advance upper-fire, retort boiler		Stove 5.7 kW	
		Coal J	Coal W	50 kW	150 kW	Coal J	Coal W
Thermal efficiency	%	**67.8**	**70.9**	**82.9**	**82.0**	**54.7**	**51.2**
CO	g/GJ	3 939	2 994	48	793	3 271	2 360
SO_2	g/GJ	361.6	282.8	347.8	131.5	253.0	211.0
NOx as NO_2	g/GJ	190.3	162.3	172.9	160.0	81.2	104.0
VOCs (C3)	g/GJ	514.2	483.1	6.1	4.8	486.0	700.0
Dust; TSP	g/GJ	227.0	294.0	267	30.0	523.0	720.0
16 PAHs	Mg/GJ	26 688	29 676	87.2	0.2	39 500	3 2800
PCDD/F	Ng I-Teq/GJ	285.0	804.1	n.d.	n.d.	n.d.	n.d.

Source: Kubica, UN-ECE TFEIP, 2002/1.
Note:
n.d. — no data.

Table A 6 Emission factors for advanced coal-fire small boilers (< 1 MW) in Poland. Voluntary standard requirements

Pollutants	Advanced under-fire boilers, manual fuelled	Advanced upper-fire boilers, automatic fuelled
	Emission factors (g/GJ)	
Carbon monoxide, CO	≤ 2 000	≤ 1 000
Nitrogen dioxide; NO_x as NO_2	≤ 150	≤ 200
Sulphur dioxide; SO_2 [1)]	≤ 400	≤ 400
Dust; TSP	≤ 120	≤ 100
TOC [2)]	≤ 80	≤ 50
16 PAHs acc. EPA	≤ 1.2	≤ 0.8
Benzo(a)pyrene; B(a)P	≤ 0.08	≤ 0.05

Source: Kubica, 2003/1, Kubica, UN-ECE TFEIP, (2002/1).
Notes:
1. [1)] Emission factor of sulphur dioxide strongly depends on sulphur content of fuel; these emission factors were established for sulphur content of < 0.6 %.
2. [2)] TOC is the sum of organic pollutants both in the gaseous phase and as organic solvent soluble particles except C_1–C_5 (Kubica 2003/1).

Table A 7 Emission values of co-combustion of coal and wood in small and medium boilers in Poland

Parameter	Unit	Automatic fuelled burner boiler 25 kW		Fluidized bed boiler 63 MW		Travelling grate combustion; 10 MW		Travelling grate combustion, 25 MW	
		Coal	80 %m/m coal 20 % wood	Coal	91 % w/w coal 9 % wood	Coal	92 % w/w coal, 8 % wood	Coal	97 % w/w coal, 3 % dry sewage sludge
Thermal efficiency	%	79.1	81.6	87.4	86.2	81.1	81.4	84.4	85.7
CO	g/GJ	254	333	35.2	41.5	120	63	23.8	24.7
SO_2	g/GJ	464	353	379	311	290	251	490	557
NO_x as NO_2	g/GJ	269	232	109	96	150	155	137	141
VOCs (C3)	g/GJ	14.0	9.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dust; TSP	g/GJ	50.3	37.6	6.6	7.7	735	948	133	111
16 PAHs	Mg/GJ	401	207	346	121	126	117	269	63

Source: Kubica, et al., 2003/2.
Note:
n.d. — no data.

Table A 8 Emission factors for combustion of biomass; comparison between poor and high standard furnace design

Emissions	Poor standard	High standard
Excess air ratio, λ	2–4	1.5–2
CO; g/GJ	625–3125	13–156
CxHy [2)]; g/GJ	63–312	< 6
PAH; mg/GJ	62–6 250	< 6.2
Particles, after cyclone; g/GJ	94–312	31–94

Source: van Loo, 2002.
Notes
1. [1)] Original data in mg/m^3_o at 11 % O_2, for recalculation H_u of 16 GJ/t and $10m^3/kg$ of flue gases were assumed.
2. [2)] No information about CxHy standard reference — usually CH_4 or C_3H_8 are used.

Table A 9 Emission factors for pellet burners in Sweden

Type of the burners	**TSP (g/GJ)**	**CO_2 (%)**	**O_2 (%)**	**THC [1] (g/GJ)**	**NO_x (g/GJ)**	**Effect (kW)**
Pellet burner (continuous operation)						
Nominal effect	22	9.5	11.1	3	73	10.7
6 kW capacity	4	6.0	14.6	78	70	6.2
6 kW generated power*	28	4.8	15.8	31	68	6.2
3 kW generated power	65	3.7	16.9	252	66	3.2
Pellet burner (electric ignition)						
Nominal effect	16	13.0	7.4	1	70	22.2
6 kW generated power	64	9.1	11.3	60	64	6.1
6 kW generated power+	-	10.6	9.7	41	174	6.3
3 kW generated power	15	8.6	11.9	10	67	3.1

Source: Bostrom, 2002.
Notes:
1. No information about THC standard reference — usual CH_4 or C_3H_8 are used.
2. *High ventilation, $^+$ wood with high ash content.

Table A 10 Emission factors for wood boilers in Sweden

Type of the burners	**TSP (g/GJ)**	**CO_2 (%)**	**O_2 (%)**	**THC [1] (g/GJ)**	**CO (g/GJ)**	**NO_x (g/GJ)**
Water cooled boiler						
Intermittent log burning	89	6.8	13.4	1 111	4 774	71
Water cooled boiler						
Operation using accumulator	103	8.3	11.8	1 500	5 879	67
Intermittent log burning	n.d.	5.6	13.4	4 729	16 267	28
Cold-start	2 243	6.9	14.6	2 958	8 193	64

Source: Bostrom; (2002).
Note:
1) No information about THC standard reference — usual CH_4 or C_3H_8 are used.
2) n.d. — no data.

Table A 11 Arithmetic average emission values for wood combustion. The data were collected from investigations in various IEA countries (Norway, Switzerland, Finland, UK and Denmark)

Techniques	NO_x (g/GJ)	CO (g/GJ)	VOC [a)] (g/GJ)	THC as CH_4 (g/GJ)	Particles, TSP (g/GJ)	PAH (mg/GJ)
Cyclone furnaces	333	38	2.1	n.d.	59	n.d.
Fluidized bed boilers	170	0	n.d.	1	2	4
Pulverised fuel burners	69	164	n.d.	8	86	22
Grate plants	111	1 846	n.d.	67	122	4 040
Stoker burners	98	457	n.d.	4	59	9
Wood boilers	101	4 975	n.d.	1 330	n.d.	30
Modern wood-stoves	58	1 730	n.d.	200	98	26
Traditional wood-stoves	29	6 956	671	1 750	1 921	3 445
Fireplaces	n.d.	6 716	520	n.d.	6 053	105

Source: van Loo, (2002).

Notes

1. No information about VOC standard reference — usual CH_4 or C_3H_8 are used.
2. n.d. — no data.

Table A 12 Arithmetic averages of emission values from biomass combustion in small-scale applications

Techniques	Load (kW)	Excess air ratio	CO (g/GJ)	CxHy[a)] (g/GJ)	Part. TSP (g/GJ)	NO_x (g/GJ)	Temp. (^oC)	Efficiency (%)
Wood — stoves	9.33	2.43	3 116	363	81	74	307	70
Fire place inserts	14.07	2.87	2 702	303	41	96	283	74
Heat storing stoves	13.31	2.53	1 723	165	34	92	224	78
Pellet stoves	8.97	3.00	275	7	28	92	132	83
Catalytic wood-stoves	6.00	n.d.	586	n.d.	n.d.	n.d.	n.d.	n.d.

Source: van Loo, 2002.

Notes:

1. Original date in mg/m^3_o at 13 % O_2, for recalculation H_u of 16 GJ/t and $10m^3/kg$ of flue gases were assumed.
2. [a)] No information about CxHy standard reference — usual CH_4 or C_3H_8 are used.
3. n.d. — no data.

Table A 13 Emissions from small industrial wood-chip combustion applications in the Netherlands (g/GJ)

Type of operation	Combustion principle	Draught control	Capacity kW	CO	CxHy [a)]	NO_x	TSP	Efficiency (%)
Manual	Horizontal grate	Natural uncontrolled	36	1 494	78	97	13	85
		Forced uncontrolled	34.6	2 156	81	108	18	83.5
			30	410	13	114	21	90
Automatic	Stoker boiler	Forced controlled	~40	41	2	74	50	85.4
			320	19	2	116	32	89.1

Source: van Loo, 2002.

Notes:

1. Original date in mg/m^3_o at 11 % O_2, for recalculation H_u of 16 GJ/t and 10 m^3/kg of flue gases were assumed.
2. [a)] No information about CxHy standard reference — usual CH_4 or C_3H_8 are used.
3. n.d. — no data.

Table A 14 Emission value from biomass combustion in small-scale applications derived from measurement campaign in Poland

Techniques	Capacity (kW)	SO_2 (g/GJ)	CO (g/GJ)	VOC as C3 (g/GJ)	TSP (g/GJ)	NO_x (g/GJ)	16 PAH g/GJ	Efficiency (%)
Wood — log, stoves	5.7	9.8	6 290	1 660	1 610	69	33 550	64.4
Upper fire stocker, pellet combustion	25	29	200	21	9.9	179	71	80.4
Pellet burners	20.5	6.0	58.5	7.2	29.7	295	122	85.7
Gas fire, pre-oven	20.0	21.0	1 226	6.8	15.6	78.9	480	83.9

Source: Kubica, et al., 2002/2.

Table A 15 Emission value of biomass combustion in small and medium boilers derived from measurement campaign in Poland

Parameter	Unit	Straw fixed grate boiler 65 kW		Advance under-fire boiler 30 kW		Automatic boilers	
						3,5 MW	1,5 MW
		Rape straw	Wheat straw	Briquettes of sawdust	Lump pine wood	Mixture of cereal straws	
Thermal efficiency	%	81.	84.2	81.3	76	90.1	84.3
CO	g/GJ	2 230	4 172	1 757	2 403	427	1 484
SO_2	g/GJ	127.1	66.5	15.9	4.8	74.6	151.0
NO_x (as NO_2)	g/GJ	105.3	76.1	41.6	31.7	110.1	405.0
VOC (as C3)	g/GJ	n.a.	n.a.	176.1	336.4	n.a.	n.a.
TSP	g/GJ	654.0	901.0	39.0	116.0	31.5	109.0
TOC [1)]	g/GJ	59.4	39.4	98.6	176.0	18.1	39.0
16 PAHs acc EPA	Mg/GJ	9 489	3 381	9 100	9 716	197	0.4
PCDD/F	ng I-TEQ/GJ	840.9	746.2	107.5	1 603	n.a.	n.a.

Source: Kubica, 2003/1; Kubica, UN-ECE TFEIP, (2002/1)

Table A 16 Emission factors for 1.75 MW and 2 MW boilers in Sweden

Fuel	Effect (%)	O_2 (%)	CO (g/GJ)	THC (g/GJ) [a)]	CH_4 (g/GJ)	TSP (g/GJ)	NO_x (g/GJ)	NH_3 (g/GJ)
Pellets	20	4	7 400	500	400	43	17	6
Pellets	50	7	1 600	17	< 1	43	27	1
Pellets	100	4	140	< 1	< 1	32	37	< 1
Briquettes	100	6.3	270	2	< 1	36	35	< 1
Logging residue	100	6.5	42	< 1	< 1	71	74	< 1
Wood chips	100	7.2	3 900	48	31	51	25	2

Source: Bostrom C-A, UN-ECE TFEIP (2002).

Note:

[a)] No information about CxHy standard reference — usual CH_4 or C_3H_8 are used.

Table A 17 Emission factors for biomass small combustion installations

Installation	Pollutants						
	g/GJ					mg/GJ	
	SO_2	NO_x	CO	NMVOC [1]	VOC [1]	PAH	BaP
Domestic open fire	n.d	n.d	4 000	n.d	90–800	13 937; 10 062; 7 9371 [2]	n.d
Domestic closed stoves	[3] n.d.	29	7 000	1 750 [5]	670	3 500	n.d
	[4] n.d.	58	1 700	200 [5]	n.d	26	n.d
Domestic boiler	[6] n.d.	101	5 000	1 330 [5]	n.d	n.d	n.d
Small commercial or institutional boiler	[7] n.d.	25	3 900	n.d	n.d.	n.d.	n.d.
	[8] n.d	n.d.	n.d.	480	n.d	n.d.	n.d.
	[9] n.d.	n.d.	n.d.	96	n.d.	n.d.	n.d.

Source: Hobson M., et al., 2003.

Notes:

1. [1] No information about NMVOC and VOC standard reference — usual CH_4 or C_3H_8 are used.
2. [2] Original data in g/kg for recalculation H_u of 16 GJ/t was assumed and PAH that is ∑16 PAH.
3. [3] Traditional wood stove.
4. [4] Modern wood stove.
5. [5] THC as CH_4.
6. [6] Wood boilers.
7. [7] Wood chips boilers 1.8–2 MW.
8. [8] Wood, charcoal, 120 kW boiler, benchmark.
9. [9] Wood, charcoal, 120 kW, improved boiler.
10. n.d. — no data.

Table A 18 Emission factors for domestic combustion processes (g/GJ) in the Netherlands

Pollutant	Fuel				
	Natural gas	Oil	LPG	Petroleum	Coal
VOC[1]	6.3	15	2	10	60
SO_2	0.22	87	0.22	4.6	420
N_2O	0.1	0.6	0.1	0.6	1.5
NO_x (as NO_2)	57.5	50	40	50	75
CO	15.8	60	10	10	1 500
CO_2	55 920	73 000	66 000	73 000	103 000
TSP	0.3	5	10	2	200
PM_{10}	0.3	4.5	2	1.8	120
Particles >PM_{10}	-	0.5	-	0.2	80

Source: Heslinga D., 2002.

Note:

[1] No information about VOC standard reference — usual CH_4 or C_3H_8 are used.

Table A 19 Emission factors for small combustion installations of gas and oil fuels (g/GJ) derived from measurement campaign in Poland

Pollutant	Fuel							
	Natural gas				Oil			
	35 kW	218 kW	210 kW	650 kW	35 kW	195 kW	400 kW	650 kW
NMVOC (as C3) [1)]	8.9	7.8	6.2	0.6	5	4.2	10	2.1
SO_2 [1)]	-	-	-	-	110	112	140	120.3
NO_x (as NO_2) [1)]	142	59.1	24.6	38.4	43	56.4	60	56.7
CO [1)]	10.3	30.9	21.2	15.3	46	44	45	33.6
TOC [1)]	5.5	6.4	4.2	4.5	25	20.8	15	7.5
SO_2 [2)]	n.d.	-	-	-	115–145 average 130	-	-	-
NO_x (as NO_2) [2)]	17–22 average 20	-	-	-	35–55 average 40	-	-	-
CO [2)]	7–12 average 9	-	-	-	10–12 average 11	-	-	-

Source: [1)] Kubica et al., 1999; [2)] Kubica et al., 2005/2 The measurements were done in the field.
Note:
n.d. — no data.

Table A 20 Emission factors for small combustion installations of gas and oil fuels (g/GJ) derived from measurement campaign in Poland

Pollutant	Fuel						
	Natural gas					Oil	
	2.1 MW	11.0 MW	5.8 MW	4.6 MW	2.3 MW	1.7 MW	2.2 MW
NO_x (as NO_2)	64	30	29	38	23	66	63
CO	3.1	0.0	0.0	3.6	0.4	0.0	1.4
SO_2	n.m.	n.m.	n.m.	n.m.	n.m.	105	69
TSP	n.m.	0.2	0.2	n.m.	0.1	n.m.	0.2

Source: Czekalski B et al., 2003.

Table A 21 Emission factors for gas-fired small combustion installations

Installation	Pollutants						
	g/GJ					mg/GJ	
	SO_2	NO_x	CO	NMVOC [1)]	VOC [1)]	PAH	BaP
Open fire	0.5	50	20	6	n.d.	n.d	n.d.
Closed stoves	0.5	50	10	3	n.d.	n.d.	n.d.
Domestic boiler	0.2; 0.5	40.2; 57.5	8.5; 15.8	3.0; 15.0	5–30	n.d	1.5 [2)]
Small commercial or institutional boiler	n.d.	n.d.	n.d.	1.0; 5.0	5.0	n.d.	0.1 [1)] 38 [3)]
Agricultural heater	0.22	65	10	n.d.	30	n.d.	n.d.
CHP Steam, gas turbine;	n.d.	179	43	2.1	n.d.	n.d.	n.d.

Source: Hobson M., et al., 2003.
Notes:.
1) No information about VOC standard reference — usual CH_4 or C_3H_8 are used. Original data in mg/t for recalculation H_u of 35 GJ/t was assumed.
2) mg/1000xm^3.
3) n.d. — no data.

Table A 22 Emission factors for LPG small combustion installations

Installation	Pollutants						
	g/GJ					mg/GJ	
	SO_2	**NO_x**	**CO**	**NMVOC [1)]**	**VOC [1)]**	**PAH**	**BaP**
Open fire	None						
Closed stoves	n.d.	n.d.	454 [1)]	447 [1)]	n.d	n.d	n.d
Domestic boiler	0.22	40	10	n.d.	2	n.d.	n.d.
Small commercial or institutional boiler	n.d.	n.d.	n.d.	n.d.	2	n.d.	n.d.
Agricultural heater	0.22	40	10	n.d.	2	n.d.	n.d.
CHP Steam, gas turbine	None						

Source: Hobson M., et al., 2003.
Notes
1) [1)] No information about VOC standard reference — usual CH_4 or C_3H_8 are used. Original data in g/kg for recalculation H_u of 42 GJ/t was assumed.
2) n.d. — no data.

Table A 23 Emission factors for burning oil (kerosene) small combustion installations

Installation	Pollutants						
	g/GJ					mg/GJ	
	SO_2	NO_x	CO	NMVOC [1)]	VOC [1)]	PAH	BaP
Domestic open fire	None						
Domestic closed stoves	n.d.	n.d.	421 [2)]; 1 478 [2)]	354 [2)]; 1 457 [2)]	n.d	n.d	n.d
Domestic boiler	87	50	60	1.5; 7.5	15	n.d.	0.1
Small commercial or institutional boiler	n.d.	n.d.	n.d.	1.0; 5.0	n.d.	n.d.	n.d.
Agricultural heater	0.22	50	10	n.d.	10	n.d.	n.d.
CHP Steam, gas turbine	None						

Source: Hobson M., et al., 2003.

Notes:

1) No information about VOC standard reference — usual CH_4 or C_3H_8 are used.
2) Original data in g/kg t for recalculation Hu of 42 GJ/t was assumed.
3) n.d. — no data.

Table A 24 Emission factors for fuel oil small combustion installations

Installation	Pollutants						
	g/GJ					Mg/GJ	
	SO_2	NO_x	CO	PM_{10}	NMVOC [1)]	VOC [1)]	PAH	BaP
Domestic open fire	None							
Domestic closed stoves	None							
Domestic boiler	n.d.	n.d.	n.d.	8.0–50	n.d.	10	n.d.	0.08 [2)]
Small commercial or institutional boiler	[3)] 449	62.4	15.6	3.1	n.d.	0.6	n.d.	n.d.
	[4)] 467	61.4	15.4	18.5	n.d.	0.6	n.d..	n.d.
	[5)] 488	169	15.4	26.4	n.d.	0.9	n.d.	n.d.
	n.d	n.d	n.d.	3–23	n.d.	8	n.d.	0.1 [2)]; 0.5 [2)]; 0.5 [2)]
Agricultural heater	n.d.	n.d.	n.d.		n.d.	n.d.	n.d.	0.08 [2)]
CHP [6)]	n.d	186	14		2.1	6.8	n.d.	0.1 [2)]

Source: Hobson M., et al., 2003).

Notes:

1) [1)] No information about VOC standard reference — usual CH_4 or C_3H_8 are used.
2) [2)] Original data in g/Mt for recalculation H_u of 42 GJ/t was assumed.
3) [3)] 1.5 % of S.
4) [4)] 4.5 % of S.
5) [5)] 5.5 % of S.
6) [6)] Power station.
7) n.d. — no data.

Table A 25 Emission of pollutants for gaseous, liquid and coal fuels for small combustion installations in Italy

Installation		**Pollutants**						
		g/GJ						
		SO_2	**NO_x**	**CO**	**VOC[1)]**	**TSP**	**PM_{10}**	**$PM_{2.5}$**
Natural gas	Range	0.22–0.5	7.8–350	20–50	0.5–10	0.03–3	0.03–3	0.03–0.5
	Average	0.5	50	25	5	0.2	0.2	0.2
LPG	Range	9.7–150	30–269	20–40	0.1–15	0.2–50	0.2–50	0.2–50
	Average	100	50	20	3	5	5	5
Burning oil	Range	69–150	24–370	5–40	1.1–48	1.5–60	1.5–60	1.5–50
	Average	150	150	16	10	40	40	30
Coal	Range	60–2 252	45–545	100–5 000	3–600	70–350	10–400	30–200
	Average	650	150	2 000	200	150	140	70

Source: Caserini S. 2004.
Note:
1) No information about VOC standard reference — usual CH_4 or C_3H_8 are used.

Table A 26 Sectoral emission factors for firing appliances in Germany in the household and small consumer sectors, in 1995 (Pfeiffer et al. 2000)

Sector	Fuel	Pollutants g/GJ				
		SO_2	NO_x as NO_2	CO	CO_2	TSP
Households	High rank coal and products	456	51	4 846	95 732	254
	High rank coals	380	49	5 279	95 930	278
	Briquettes	561	54	4 246	95 457	221
	Coke from high rank coals	511	60	6 463	106 167	15
	Brown coal briquettes	261	71	3 732	96 021	86
	Natural wood	7	50	3 823	103 093	42
	Distillate oil	77	46	25	73 344	1.6
	Natural gas	0.5	38	14	55 796	0.03
Small consumers	High rank coal and products	419	108	564	95 930	278
	High rank coals	419	108	564	95 930	278
	Coke from high rank coals	370	61	1 498	106 167	12
	Brown coal briquettes	234	87	4 900	95 663	59
	Natural wood and wood wastes	9.1	78	2 752	101 099	45
	Distillate oil	77	47	14	73 344	1.7
	Residual oil	384	162	9.9	75 740	38
	Natural gas	0.5	31	11	55 796	0.03

Table A 27 Emission factors of CO, NOx and SO_2 for advanced combustion techniques of coal and biomass

Source	Installation/fuel	Pollutants (g/GJ)		
		SO_2	NO_x (as NO_2)	CO
BLT, 2000/1	Wood boilers with two combustion chambers and sonar Lambda	n.d.	100	141
BLT, 2005/1	Wood pellets and chip boiler 25 kW 100 % and 33 % of capacity	n.d.	127; n.d.	186; 589
	Pellets and wood chips boiler 43 kW 100 % and 33 % of capacity	n.d.	110; 71	60; 37
	Wood boiler 60 kW, air dry oak 100 % and 33 % of capacity	n.d.	79; n.d.	127; 720
	Boiler, wood chips 25 kW 100 % and 33 % of capacity	n.d.	115; n.d.	23; 358
	Pellets boiler 46.7 kW 100 % and 33 % of capacity	n.d.	110; 118	118; 172

Source	Installation/fuel	Pollutants (g/GJ)		
		SO_2	NO_x (as NO_2)	CO
BLT, 2003	Pellets and briq., boiler 7.7, 26 kW 100 % and 33 % of capacity	n.d.	67; n.d.	7; 44
BLT, 1999	Wood chips, boiler 500 kW 100 % and 33 % of capacity	n.d.	123; n.d.	16; 126
BLT, 2004/1	Wood chips, boiler 20 kW 100 % and 33 % of capacity	n.d.	44; n.d.	17; 108
BLT, 2004/2	Wood log and briq., boiler 50 kW 100 % and 33 % of capacity	n.d.	109; n.d.	44; n.d.
BLT, 2000/2	Wood briq., chamber boiler 60 kW 100 % and 33 % of capacity	n.d.	88; n.d.	30; 120
BLT, 2005/2	Wood log, chamber boiler 27 kW	n.d.	78	131
Houck et al., 2001 [1)]	Fireplaces; dry wood	n.d.	n.d.	4 010
Hübner et al.,20051 [2)]	Boiler < 50 kW; pelleted wood	n.d.	n.d.	120
	Boiler; chopped wood log	n.d.	n.d.	790–1 400
	Boiler; coke	n.d.	n.d.	2 400
	Boiler; wood and coke	n.d.	n.d.	3 500
	Boiler; wood, brown coal briquettes	n.d.	n.d.	4 200
	Boiler; wood logs (beech, spruce)	n.d.	n.d.	3 800
	Boiler; wood (beech, spruce), coke	n.d.	n.d.	2 100
	Stove; wood, brown coal briquettes wood	n.d.	n.d.	2 100
	Stove; beach wood logs	n.d.	n.d.	2 100–4 700
	Stove; wood	n.d.	n.d.	1 500
	Stove; spruce wood (small logs)	n.d.	n.d.	2 400
	Stove; wood (small logs)	n.d.	n.d.	1 600
	Stove; wood briquettes	n.d.	n.d.	4 600
Johansson at al., 2001 [1)]	Pellet boilers with fixed grates with moving scrapes 1.75–2.5 MW	n.d.	30–50	20–100
Houck et al., 2000 [1)]	Conventional stove, cordwood	n.d.	n.d.	7 200
	Pellet stoves, softwood	n.d.	n.d.	1 400–1 630
	Pellets stove, hardwood	n.d.	n.d.	125; 188; 219
	Pellets boiler, top-feed, softwood	n.d.	n.d.	146; 449; 510
	Pellets boiler, bottom-feed softwood	n.d.	n.d.	112; 169
Boman et al., 2005	Pellet stove 4.8 kW (high load)	n.d.	31–36; average 33	52–100; average 88

Source	Installation/fuel	Pollutants (g/GJ)		
		SO_2	NO_x (as NO_2)	CO
	Pellet stove 4.8 kW (low load 2.3 kW)	n.d.	29–33; average 31	243–383; average 299
	Natural-draft wood stove, 9 kW; birch pine spruce	n.d.	37–71; average 50	1 200–7 700; average 3 800
	Pellet stove, 4–9.5 kW; pine and spruce (high load)	n.d.	57–65; average 61	110–170; average 140
	Pellet stove, 4- 9,5 kW; pine and spruce (low load 30 %)	n.d.	52–57; average 54	320–810; average 580
Kubica, 2004/2	Pellet boilers			
Kubica at al., 2005/4	Automatic-fuelled coal boilers - stocker; pea coal (qualified size)	120–450; average 260	96–260; average 190	90–850 average 280
	Automatic-fuelled coal boilers; fine coal (qualified coal size)	355–600 average 420	70–200 average 145	60–800 average 450
Kubica K.; 2004/1	Conventional stove 5 kW	253	81	2 272
Kubica, 2004/2	Boiler, stocker; wood pellets	n.d.	n.d.	300–500
	Chamber boiler, top feed; fine coal	250–700	100–150	1 100–2 800
	Automatic boiler, stocker; pea coal	130–350	100–250	120–800
	Automatic coal boiler; fine coal	250–700	100–250	400–1500
	Chamber boiler, advanced technique; qualified size coal	150–550	150–250	50–100
Kubica et al., 2005/1	Boilers with moving grate 5–32 MW	n.d.	116–137	10–24
	Boilers with moving grate 0.3–0.6 MW	n.d.	146–248	36–363 [4)]
	Automatic-fuelled coal boiler, fine coal	n.d.	140	130
	Automatic-fuelled coal boiler — stocker	n.d.	70–220	120–800
	Boiler, bottom feed, nut coals	n.d.	150–200	200–1500
	Boiler, top feed, nut coals	n.d.	50–150	1 800–3 500
	Boiler, bottom feed, log wood	n.d.	32	2 403
	Boiler, bottom feed, wood briquettes	n.d.	42	1 757
	Automatic-fuelled boiler — stocker 30 kW, pellets	n.d.	200	200
	Automatic-fuelled boiler, wood chips	n.d.	150	880
Kubica at al., 2005/23)	Automatic-fuelled coal boiler — stocker, ≤ 25 kW (120 pieces); pea coal	n.d.	67–207; average 161	104–320; average 150

Source	Installation/fuel	Pollutants (g/GJ)		
		SO_2	NO_x (as NO_2)	CO
	Automatic-fuelled coal boiler, ≤ 35 kW (68 pieces); fine coal,	155–496 average 252	64–208; average 122	119–435; average 232

Notes:
1) [1] Original factors in g/kg of fuels, for recalculation H_u of 24 GJ/t (d.b.) for hard coal was of 17 GJ/t (d.b.) for lignite and brown coal, of 30 GJ/t (d.b.) for anthracite, of 30 GJ/t (d.b.) for coke; of 16 GJ/t for wood, of 42 GJ/t for oil and of 35 GJ/t for natural gas were assumed.
2) [2] Capacity of all boilers < 50 kW and all stove < 10 kW.
3) [3] A measurement was done in the field.
4) n.d. — no data.

Table A 28 Wood burning appliance emission factors in British Columbia (Gulland, 2003)

Installation	Pollutants [1]						
	g/GJ						
	SO_2	NO_x	CO	VOC [1]	TSP	PM_{10}	$PM_{2.5}$
Fireplace							
Conventional with glass doors	12.5	87.5	6 162.5	1 312.5	843.75	812.5	806.25
Conventional without glass doors	12.5	87.5	4 856.3	406.3	1 206.3	1 156.3	1 156.3
Advanced technology	12.5	87.5	4 400	437.5	318.75	300	300
Insert; conventional	12.5	87.5	7 212.5	1 331.3	900	850	850
Insert; catalytic	12.5	87.5	4 400	437.5	318.8	300	300
Insert; advanced technology	12.5	87.5	4 400	437.5	318.8	300	300
Woodstove							
Conventional	12.5	87.5	6 250	2 218.8	1 537.5	1 450	1 450
Conventional, not air-tight	12.5	87.5	6 250	2 218.8	1 537.5	1 450	1 450
Conventional, air-tight	12.5	87.5	7 212.5	1 331.3	900	850	850
Advanced technology	12.5	87.5	4 400	437.5	318.8	300	300
Catalytic	12.5	87.5	4 400	437.5	318.8	300	300
Pellet stove	12.5	87.5	550	94	75	69.7	64
Boilers							
Central furnace/ boiler (inside)	12.5	87.5	4 281.3	1 331.3	881.3	831.3	831.3
Central furnace/ boiler (outside)	12.5	87.5	4 281.3	1 331.3	881.3	831.3	831.3
Other equipment	12.5	87.5	7 212.5	1 331.3	900	850	850

Note:
[1] Original factors in kg/tonne of fuels, for recalculation H_u of 16 GJ/t for wood was assumed.

Table A 29 Emission factors for particulate matter reported in the literature for coal and manufactured solid fuels combustion (g/GJ)

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
BUWAL, 2001 [1)]	Small furnaces	n.d.	110	270
	Domestic boiler	n.d.	90	150
CEPMEIP, 2002 [1)]	Residential, brown coal	70	140	350
	Residential, hard coal ('high')	60	120	300
	Residential, hard coal ('low')	25	50	100
	Residential, low grade hard coal	100	200	800
Pfeiffer et al., 2000 [1)]	Residential, hard coal	n.d.	n.d.	260–280
	Residential, brown coal briquettes	n.d.	n.d.	120–130
	Residential, coke	n.d.	n.d.	14
Spitzer et al., 1998 [1)]	Residential heating	n.d.	n.d.	153±50 %
	Single family house boiler, stoves	n.d.	n.d.	94±54 %
Winiwarter et al, 2001 [1)]	Residential plants	75	85	94
	Domestic stoves, fireplaces	122	138	153
UBA, 1999a [1)]	Domestic furnaces, hard coal	n.d.	n.d.	250
	Domestic furnaces, brown coal	n.d.	n.d.	350
EPA, 1998a [1)]	Small boilers, top loading	n.d.	n.d.	291
	Small boilers, bottom loading	n.d.	n.d.	273
	Hard coal, stoker firing	n.d.	n.d.	1 200
	Pulverized lignite boilers	n.d.	n.d.	1 105
Meier & Bischoff, 1996 [1)]	Grate firing, lignite	n.d.	n.d.	2 237
Hobson M. et al, 2003	Domestic open fire; < 10 kW, coal	n.d.	375 [2)] – 459 [2)]	n.d.
	Domestic open fire; < 10 kW, smokeless coal brands	n.d.	38–67 [2)]	n.d.
	Domestic open fire; < 10 kW, pet coke blends	n.d.	96–117 [2)]	n.d.
	Domestic open fire; < 5 kW coal	n.d.	1 683 [2)]	n.d.
	Domestic closed stove; US EPA, developing stoves charcoal	n.d.	n.d.	100 [2)]
	Domestic closed stove; US EPA, developing stoves char briquette	n.d.	n.d.	121 [2)]
	Domestic closed stove; CRE; < 10 kW, smokeless coal brands	n.d.	42-50 [2)]	n.d.
	Domestic closed stove; CRE; < 10 kW, pet coke blends	n.d.	108-133 [2)]	n.d.

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
	Domestic boilers; ERA research, boiler Efis, bituminous coal	n.d	250 [2)]	n.d.
	Domestic boilers; UNECE TFEIP, Dutch figures for coke use	n.d.	6	n.d.
	UNECE TFEIP; Sweden, briquette boilers 1.8–2 MW	n.d.	n.d.	36
Kubica, 2004/1	Conventional stove 5 kW	n.d.	n.d.	523
Kubica, 2004/2	Chamber boiler, top feed; fine coal	n.d.	n.d.	50–200
	Automatic-fuelled coal boiler, stocker	n.d.	n.d.	30–60
	Automatic-fuelled boiler, fine coal	n.d.	n.d.	30–120
	Chamber boiler, qualified size coal; distribution of combustion air	n.d.	n.d.	50–150
Kubica et al., 2005/1	Boilers with moving grate 5–32 MW	n.d.	n.d.	58–133
	Boilers with moving grate 0.3–0.6 MW	n.d.	n.d.	51–64
	Automatic-fuelled coal boiler, fine coal	n.d.	n.d.	50
	Automatic-fuelled coal boiler — stocker	n.d.	n.d.	30–60
	Boiler, bottom feed, nut coals	n.d.	n.d.	50–100
	Boiler, top feed, nut coals	n.d.	n.d.	300–1100
Kubica at al., 2005/2 [3)]	Automatic-fuelled coal boiler — stocker, 25 kW (120 pieces)	n.d.	n.d.	54–133 average 78
	Automatic-fuelled coal boiler, fine coal, 25 and 35 kW (68 pieces)	n.d.	n.d.	70–380 average 187
Kubica et al., 2005/3	Hard coal; stoves and boilers < 1 MW	25-100 average 65	25-1050 aver.270	30-1,200 average 360
	Hard coal; boilers > 1 MW < 50 MW	70-122 average 70	90-250 average 110	25-735 average 140
	Brown coal Residential/commercial/institutional/	140	260	350
	Coke Residential/commercial/institutional/	30 -80 average 80	96-108 average 90	14-133 average 110
Krucki A. et al., 2006 [2)]	Automatic-fuelled coal boiler — stocker, 100 kW	n.d.	n.d.	98
	Automatic-fuelled coal boiler, fine coal, 25 kW	n.d.	n.d.	13
	Automatic-fuelled coal boiler, fine coal, 90 kW	n.d.	n.d.	16

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
Lee et al., 2005 [2)]	Open fire place	n.d.	1 200	n.d.

Notes:
1) [1)] As quoted in Klimont et al., 2002.
2) [2)] Original data in g/kg for recalculation Hu of 24 GJ/t (d.b.) was assumed.
3) [3)] The measurements were done in the field.
4) n.d. — no data.

Table A 30 Particulate matter size fractions reported in the literature for coal combustion (per cent of TSP emissions)

Source	Installation type	PM2.5	PM10	TSP
UBA, 1999a [1)]	Domestic furnaces, hard coal	n.d.	90 %	100 %
EPA, 1998a [1)]	Small boilers, top loading	14 %	37 %	100 %
	Small boilers, bottom loading	25 %	41 %	100 %
Hlawiczka et al., 2002	Domestic furnaces, hard coal	n.m.	76 % [2)]	100 %

Notes:
1. [1)] As quoted in Klimont et al., 2002.
2. [2)] Original data 76 % of PM was emitted as the size fractions up to 12 µm.

Table A 31 Particulate matter emission factors reported in the literature for wood burning (g/GJ)

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
BUWAL, 2001 [1)]	Domestic open fire places	n.d.	150	150
	Domestic furnaces	n.d.	150	150
	Domestic small boilers, manual	n.d.	50	50
	Small boilers, automatic loading	n.d.	80	80
Karvosenoja, 2000 [1)]	Domestic furnaces	n.d.	n.d.	200–500
Dreiseidler, 1999 [1)]	Domestic furnaces	n.d.	n.d.	200
Baumbach, 1999 [1)]	Domestic furnaces	n.d.	n.d.	50–100
Pfeiffer et al., 2000 [1)]	Residential and domestic	n.d.	n.d.	41–65
CEPMEIP, 2002 [1)]	'High emissions'	270	285	300
	'Low emissions'	135	143	150
Winiwarter et al, 2001 [1)]	Residential plants	72	81	90
	Domestic stoves, fireplaces	118	133	148
NUTEK, 1997 [1)]	Single family house boiler, conventional	n.d.	n.d.	1 500
	Single family house boiler, modern with accumulator tank	n.d.	n.d.	17
Smith, 1987 [1)]	Residential heating stoves < 5 kW	n.d.	n.d.	1 350
	Residential cooking stoves < 5 kW	n.d.	n.d.	570
BUWAL, 1995 (1992 Swiss limit value) [1)]	up to 1 MW	n.d.	n.d.	106

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
Spitzer et al., 1998 [1)]	Residential heating	n.d.	n.d.	148±46 %
	Single family house boiler, stoves	n.d.	n.d.	90±26%
Zhang et al., 2000 [1)]	Firewood in China	n.d.	n.d.	760–1 080
Houck and Tiegs, 1998/1 [3)]	Conventional stove	n.d.	n.d.	1 680
	Conventional stove with densified fuel	n.d.	n.d.	1 200
	Non-catalytic stove	n.d.	n.d.	490
	Catalytic stove	n.d.	n.d.	440
	Masonry heater	n.d.	n.d.	250
	Pellet stove	n.d.	n.d.	130
	Fireplace, conventional	n.d.	n.d.	8 600
	Double-shell convection, national draft	n.d.	n.d.	4 600
	Convectiontubes, 'C' shaped, glass door	n.d.	n.d.	4 000
	Double-shell convection, blower, glass doors	n.d.	n.d.	1 900
	Masonry fireplace with shaped fire chambers and gladd doors	n.d.	n.d.	1 200
	Fireplace, non-catalytic insert	n.d.	n.d.	500
	Fireplace, catalytic insert	n.d.	n.d.	450
	Fireplace, pellet insert	n.d.	n.d.	130
EPA, 1998b [(1,2)]?	Open fireplaces	n.d.	805	875
	Wood stove	n.d.	724	787
Hobson M. et al, 2003	UNECE TFEIP, Sweden, wood chips boilers 1.8–2 MW	n.d.	n.d.	51
	Open fire < 5 kW, hardwood [2)]	n.d.	494	n.d.
	Domestic open fire: hundreds of source studies [2)]	n.d	n.d.	738
CITEPA, Paris, 2003	Open fire places	698	713	750
	Conventional closed fireplaces and inserts	288	295	310
	Conventional closed stoves and cooking	288	295	310
	Hand-stoked log wood boiler	233	238	250
	Automatically-stoked wood boiler	9	10	10
EPA, 1998a [4)]	Boilers, bark	n.d.	n.d.	2 266
Lammi et al., 1993 [4)]	Fluidized bed in large boilers	n.d.	n.d.	1 000 –3 000
	Grate firing in large boilers	n.d.	n.d.	250–1 500
Tullin et al.; 2000	Wood/pellet boilers and stoves	n.d.	n.d.	50

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
	Old wood boiler	n.d.	n.d.	1 000
Hays et al. (2003) [2)]	Wood stove	143.8–637.5	n.d.	n.d.
	Fireplaces	537.5	n.d.	n.d.
BLT, 2000/1	Wood boilers with two combustion chambers and sonar Lambda	n.d.	n.d.	20
BLT, 2005/1	Wood pellets and chip boiler 25 kW	n.d.	n.d.	14
	Pellets and wood chips boiler 43 kW–100 % and 33 % of capacity	n.d.	n.d.	23; 9
	Wood boiler 60 kW	n.d.	n.d.	28
	Boiler, wood chips 25 kW	n.d.	n.d.	18
	Pellets boiler 46.7 kW–100 % and 33 % of capacity	n.d.	n.d.	5; 12
BLT, 2003	Pellets and briquettes, boiler 7.7–26 kW	n.d.	n.d.	4
BLT, 1999	Wood chips, boiler 500 kW	n.d.	n.d.	28
BLT, 2004/1	Wood chips, boiler 20 kW	n.d.	n.d.	8
BLT, 2004/2	Wood log and briquettes, boiler 50 kW	n.d.	n.d.	16
BLT, 2000/2	Wood briquettes, chamber boiler 60 kW	n.d.	n.d.	10
BLT, 2005/2	Wood log, chamber boiler 27 kW	n.d.	n.d.	12
McDonald et. al., 2000 [2)]	Fireplaces	As $PM_{2.5.}$	n.d.	180–560; average 380
	Woodstove	n.d.	n.d.	140–450; average 270
Lee et al., 2005 [2)]	Open fire place	n.d.	425	n.d.
Gullet et al., 2003	Fireplace, pine	n.d.	n.d.	147
	Fireplace, artificial logs (wax and sawdust)	n.d.	n.d.	483
	Stove, oak	n.d.	n.d.	504
Fine et al., 2002 [2)]	Fireplaces; hardwood — yellow poplar	n.d.	n.d.	425 ± 50
	Fireplaces; hardwood — white ash	n.d.	n.d.	206 ± 19
	Fireplaces; hardwood — sweetgum	n.d.	n.d.	218 ± 25
	Fireplaces; hardwood — mockernut hickory	n.d.	n.d.	425 ± 56
	Fireplaces; softwood — loblolly Pine	n.d.	n.d.	231 ± 25
	Fireplaces; softwood — slash Pine	n.d.	n.d.	100 ± 19
Fine et al.; 2001 [2)]	Conventional masonry fireplaces; hardwood — red maple northern	n.d.	n.d.	206 ± 19

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
	Conventional masonry fireplaces; hardwood — red oak	n.d.	n.d.	356 ± 19
	Conventional masonry fireplaces; hardwood — paper birch	n.d.	n.d.	169 ± 19
	Conventional masonry fireplaces softwoods — eastern white pine	n.d.	n.d.	713 ± 125
	Conventional masonry fireplaces softwoods — eastern hemlock	n.d.	n.d.	231 ± 25
	Conventional masonry fireplaces softwoods — balsam fir	n.d.	n.d.	300 ± 31
	Fireplaces; wood	170–710	n.d.	n.d.
Boman et al., 2004	Pellet burner boilers 10–15 kW, overfeeding of the fuel; sawdust, logging residues and bark	n.d.	n.d.	114–377 average 240
	Pellet burner boilers 10–15 kW, horizontal feeding of the fuel; sawdust, logging residues and bark	n.d.	n.d.	57-157 average 95
	Pellet burner boilers 10–15 kW, underfeeding of the fuel; sawdust, logging residues and bark	n.d.	n.d.	64-192 average 140
Broderick et al. 2005 [2)]	All masonry and factory-built (zero clearance)	n.d.	n.d.	590
	Fireplaces, all cordwood	n.d.	n.d.	810
	Fireplaces, all dimensional lumber	n.d.	n.d.	410
	Fireplaces, all with closed doors	n.d.	n.d.	350
	Fireplaces, all with open doors	n.d.	n.d.	690
	Fireplaces, all masonry fireplaces	n.d.	n.d.	660
	Fireplaces, all factory-built fireplaces	n.d.	n.d.	580
	Fireplaces, cordwood, factory-built, open doors	n.d.	n.d.	870
	Fireplaces, dimensional lumber, factory built, open doors	n.d.	n.d.	510
	All fireplaces, all wood types	n.d.	n.d.	Average 590
	All factory-built fireplaces with open door, cordwood	n.d.	n.d.	Average 840
Gaegauf et al., 2001	Wood room heaters	n.d.	n.d.	70 ± 25
	Wood accumulating stoves	n.d.	n.d.	167 ±44
	Wood log boilers	n.d.	n.d.	28 ±11
	Pellet boilers	n.d.	n.d.	20 ±0.4

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
	Pellet room heaters	n.d.	n.d.	54 ± 3
	Wood chip boilers — dry fuel	n.d.	n.d.	94 ± 13
	Wood chip boilers — wet fuel	n.d.	n.d.	48 ± 6
	Wood chip boilers — residuals	n.d.	n.d.	64 ± 7
Johansson at al., 2001 [7)]	Pellet boilers with fixed grates with moving scrapes 1.75–2.5 MW	n.d.	n.d.	35–40
Nussbaumer, 2001 [2)]	All automatic wood furnaces	n.d.	n.d.	< 110
	Understoker furnaces	n.d.	n.d.	< 55
	Log wood boilers	n.d.	n.d.	34
	Wood chips boiler [5)]	n.d.	n.d.	68
	Wood residues, boiler [5)]	n.d.	n.d.	70
	Urban waste wood, boiler [6)]	n.d.	n.d.	1.5
Houck et al., 2000 [2)]	Conventional stove, cordwood	n.d.	n.d.	750
	Pellet stoves, softwood	n.d.	n.d.	80–170
	Pellets stove, hardwood	n.d.	n.d.	125; 190;220
	Pellets boiler, top-feed, softwood	n.d.	n.d.	27.5; 37.5; 62.5
	Pellets boiler, bottom-feed softwood	n.d.	n.d.	16.3; 25.0
Houck et al., 2005 [2)]	Conventional stove woodstove	890	n.d.	n.d.
	Catalytic certified woodstove	430	n.d.	n.d.
	Non-catalytic certified woodstove	330	n.d.	n.d.
	Pellet stove exempt	160	n.d.	n.d.
	Certified pellet stove	160	n.d.	n.d.
Boman et al., 2005	Pellet stove 4.8 kW (high load)	n.d.	n.d.	11–20 average 15
	Pellet stove 4.8 kW (low load 2.3 kW)	n.d.	n.d.	32–81 average 51
	Natural-draft wood stove, 9 kW; birch pine spruce	n.d.	n.d.	37–350 average 160
	Pellet stove, 4–9,5 kW; pine and spruce (high load)	n.d.	n.d.	15–17; average 16
	Pellet stove, 4–9,5 kW; pine and spruce (low load 30 %)	n.d.	n.d.	21–43 average 34
Krucki et al., 2006 [(2)]	Biomass boiler, two stage combustor 95 kW, log wood	n.d.	n.d.	34
	Biomass boiler, two-stage combustor 22 kW, log wood	n.d.	n.d.	13
Kubica, 2004/1	Conventional stove 5 kW	n.d.	n.d.	1 610

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
Kubica, 2004/2	Pellet burner/boilers	n.d.	n.d.	20–60
	Chamber boiler (hand-fuelled), log wood	n.d.	n.d.	70–175
Kubica et al., 2005/1	Boiler, bottom feed, log wood	n.d.	n.d.	116
	Boiler, bottom feed, wood briquettes	n.d.	n.d.	39
	Automatic-fuelled boiler — stocker 30 kW, pellets	n.d.	n.d.	6
	Automatic-fuelled coal boiler, wood chips	n.d.	n.d.	60
Kubica et al., 2005/3	Residential/commercial/institutional/	9–698 average 450	10–713 average 490	17–4 000 average 520
	Boilers > 1MW < 50 MW	9–170 average 80	60–214 average 80	20–500 average 100
Hedberg et al., 2002 [2)]	Commercial soapstone stove, birch logs	6–163 average 81	n.d.	n.d.
Johansson et al, 2006	Single family house boiler, modern with accumulator tank	n.d.	n.d.	26–450
Johansson et al, 2006	Single family house boiler, conventional	n.d.	n.d.	73–260
Johansson et al, 2004 a	Single family house boiler, modern with accumulator tank	n.d.	n.d.	23–89
Johansson et al, 2004 a	Single family house boiler, conventional	n.d.	n.d.	87–2 200
Johansson et al, 2006	Single family house boiler, conventional	n.d.	n.d.	73–260
Johansson et al, 2004 a	Pellets burners/boiler	n.d.	n.d.	12–65
Ohlström, 2005	Wood log stove	90 [8)]	n.d.	100
	Sauna	190 [8)]	n.d.	200
	Pellets burner	70 [8)]	n.d.	n.d.
	Pellets burner	25 [8)]	n.d.	35
	Wood chips/pellets boiler 30–50 kW	15 [8)]	n.d.	20
	Wood chips boiler 30–50 kW	10 [8)]	n.d.	20
	Pellets boiler 30–50 kW	10 [8)]	n.d.	15
	Wood chips/pellets stoker [6)] 50–500 kW	20 [8)]	n.d.	40
	Wood chips stoker 30–500 kW [6)]	30 [8)]	n.d.	50
	Pellets stoker 50–500 kW [6)]	10 [8)]	n.d.	20
	Wood chips grate boiler 5–20 MW	20–55 [6)]		
	Wood chips Fluidized bed 20–100 MW	2–20 [7)]		

Source	Installation type	$PM_{2.5}$	PM_{10}	TSP
	Wood chips grate boiler 20–100 MW 7)	3–10		
	Wood chips grate boiler 10 MW 6)	3 8)	n.d.	10
Paulrud et al. 2006.	Wood log stove	n.d	n.d	22–181
Johansson et al, 2004b	Pellets stove	30–55	30–58	n.d.
	Pellets burner/boiler	10–60	10–75	n.d.
Glasius et al, 2005	Wood stove	n.d.	n.d.	200–5 500
Schauer et. al., 2001	Open fire place	330–630	n.d.	n.d.
Purvis et. al., 2000	Open fire place	n.d.	n.d.	170–780
Wierzbicka, 2005	Moving grate 1.5 MW saw dust, low load	36 6,8)	n.d.	
	Moving grate 1.5 MW saw dust, Medium load	28 6,8)	n.d.	
	Moving grate 1.5 MW saw dust, high load	25 6,8)	n.d.	n.d.
	Moving grate 1.5 MW pellets, low load	20 6,8)	n.d.	n.d.
	Moving grate 1.5 MW pellets, medium load	19 6,8)	n.d.	n.d.
	Moving grate 1 MW forest residue, medium load	676 6,8)	n.d.	n.d.
	Moving grate 1 MW forest residue, high load	57 6,8)	n.d.	n.d.
Strand. et al, 2004	Moving grate 6 MW forest residue, high load	43 6,8)	n.d.	n.d.
	Moving grate 12 MW forest residue, high load	77 6,8)	n.d.	n.d.
	Moving grate 0.9 MW pellets, low load	10 6,8)	n.d.	n.d.

Notes:
1. As quoted in Klimont et al., 2002.
2. Original factors in lb/ton or in g/kg for recalculation H_u of 16 GJ/t were assumed.
3. Original factors are estimated per unit of heat delivered, no conversion was made.
4. The data for large scale combustion for illustration only.
5. Cyclone separator-dust control.
6. Filter separator-dust control.
7. PM mainly 0.1-0.3 µm. Typically more than 80 % of all particles are smaller than 1 µm. The mean particle size is typically around 0.1 µm (between 50 nm to 200 nm).
8. Measured as PM1.
9. n.d. — no data.

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Appendix B Calculation of emission factors from emission concentrations

B.1 Standardisation of emission concentrations from combustion activities

Annual emissions, emission rates and emission limit values are generally expressed in terms of pollutant mass (for example tonnes.year^{-1}, kg.hr^{-1}, mg.m^{-3}). Note that a mass concentration is meaningless unless the volume conditions are defined — typically for a combustion process the conditions will be a dry volume, at STP (0 °C, 101.3 kPa) and normalised to a reference oxygen concentration. Consumption of fuel requires a minimum theoretical (stoichiometric) quantity of air. In practise, more air than the stoichiometric quantity is required to achieve combustion. The oxygen content in exhaust gases from a combustion appliance is indicative of the amount of excess air and air ingress in the combustion system. Normalisation to a reference oxygen content allows comparison between technologies as it removes a diluting (or concentrating) effect of different levels of excess air/air ingress on the pollutant concentration.

Common oxygen concentrations for emission normalisation are:

- oil- or gas-fired boilers — 3 % O_2
- solid-fuel boilers — 6, 7 % O_2
- wood-fired boilers — 6, 7, 10, 11 or 13 % O_2
- incineration — 11 % O_2
- gas turbines — 15 % O_2
- stationary engines — 5, 15 % O_2
- dryers — 17 % O_2.

Other normalisation oxygen concentrations are used including 0 % O_2 which is commonly used in the testing of residential gas appliances. Concentrations can also be normalised using carbon dioxide (although this is much less common).

Usually emission concentration data will be provided as mass concentrations at a specified oxygen content. However, where emission data are provided in other forms, the following equations may help the user manipulate the date into a more useful form.

Some pollutants are measured and reported on a wet basis and may require standardisation to the dry condition.

$$[X]_d = [X]_w \cdot \frac{100}{(100-[H_2O])}$$

where:

- $[X]_w$ is the measured concentration for a wet flue gas (ppm, mg.m^{-3}, %v/v),
- [X]d is the measured concentration for a dry flue gas (same units as the dry concentration),
- [H2O] is the flue gas moisture content as % v/v on a wet basis.

Many pollutants are measured as volume (molar) concentrations. Conversion to a mass concentration assumes ideal gas behaviour and is detailed below:

$$[X]_m = [X]_d \cdot \frac{MW}{22.4}$$

where:

- $[X]_d$ is the measured concentration in ppm (parts per million) by volume for a dry flue gas,
- $[X]_m$ is the measured concentration in mg.m^{-3} by volume for a dry flue gas,
- MW is the relative molecular mass of the pollutant (for example 64 for SO_2),
- 22.4 is the volume occupied by 1 kgmole of an ideal gas at 0°C, 101.3 kPa (m^3).

Note that NO_x emission concentrations and emission factors are defined in terms of NO_2. Hence, the relative molecular mass used for NO_x is 46. VOC emission concentrations are often defined in terms of carbon. Hence, the relative molecular mass used for VOC is 12, but this will often be modified further for the calibration gas applied (for example MW for concentrations measured as propane C_3H_8 'equivalents' would 3 x 12 - 36).

Normalisation to a reference O_2 concentration is given by:

$$[X]_{ref} = [X]_m \cdot \frac{(20.9-[O_2]_{ref})}{(20.9-[O_2]_m)}$$

where :

- $[X]_{ref}$ is the standardised concentration of the pollutant at the reference O_2 content,
- $[x]_m$ is the measured concentration in mg.m^{-3} for a dry flue gas,
- $[O_2]_m$ is the measured O_2 concentration in % on a dry basis,
- $[O_2]_{ref}$ is the reference O_2 concentration in % on a dry basis (for example 3, 6 or 15 %).

This calculation is appropriate where pollutant and O_2 concentrations are measured on a dry basis.

B.2 Calculation of emission factors

An emission factor relates the release of a pollutant to a process activity. For combustion processes, emission factors are commonly described as the mass of pollutant released per unit of fuel burned.

An emission factor can be calculated in several ways; the approach adopted uses the standardised pollutant emission concentrations and the specific theoretical (stoichiometric) volume of flue gas for the relevant fuel. This approach avoids measurement of exhaust gas flow and fuel flows which can have a high uncertainty and may not be practical at many combustion plant.

The approach requires knowledge of the fuel used, the pollutant concentration and the oxygen concentration.

Fuel analysis, where available, allows calculation of the specific flue gas volume from the elemental analysis. However, the US Environmental Protection Agency Method 19 provides flue gas volume for common fuels. For other fuels (for example derived gases, landfill gas, unrefined natural gas or waste-derived fuels) fuel analysis is advised to minimise uncertainty.

Fuel analysis route: the fuel analysis and combustion calculations are used to determine the stoichiometric air requirement and dry flue gas volume per volume or mass of fuel. Note that is important to understand the analysis reporting conditions, particularly for solid fuels. The calculations assume ideal gas behaviour. A dry flue gas volume is calculated for the reference O_2 concentration used to normalise the pollutant emission concentration. A pollutant emission factor (EF) can hence be calculated by multiplying the standardised pollutant concentration by the dry flue gas volume at the same reference oxygen content.

Generally, the flue gas volumes generated from combustion of fuel can be calculated in accordance with the following equations.

$C_XH_Y + (X+(Y/4)O_2 = X\ CO_2 + (Y/2)\ H_2O$

Note that some of the oxygen may be sourced from the fuel. For combustion in air, each cubic metre of oxygen is associated with (79.1/20.9) cubic metres of nitrogen.

The dry flue gas volume at stoichiometric conditions ($DFGV_{SC}$) per unit mass of fuel (or volume for gaseous fuels) can be calculated and hence the dry flue gas volume at the normalised condition ($DFGV_{ref}$) for the required reference oxygen content:

$$DFGV_{ref} = DFGV_{SC} \cdot (20.9/(20.9-[O_{2ref}]))$$

A pollutant emission factor (EF) can hence be calculated by multiplying the standardised pollutant concentration by the dry flue gas volume at the same reference oxygen content. For example, at 15 % oxygen:

$$EF = [X]_{15\%} \cdot DFGV_{15}$$

Emission factors are reported in several ways and these are generally recalculated using physical or other properties of the fuel.

For example, a thermal emission factor (as used in the Guidebook) can be derived by dividing the emission factor calculated above by the calorific value of the fuel. For the Guidebook, this is the net (inferior) CV.

$$EF_{thermal} = \frac{EF}{CV}$$

where:

- $EF_{thermal}$ is the thermal emission factor expressed in units to suit the user (for example g GJ^{-1}),
- CV is the net calorific value of the fuel in appropriate units to suit the units of the emission factor.

USEPA Method 19: the USEPA provides stoichiometric dry flue gas volume for fuel oil. The USEPA data can be found in USEPA Method 19 (US Code of Federal Regulations, Title 40 Part 60, Appendix A). The USEPA 'F-factor' data are presented as the volume of dry flue gas at 20 °C associated with the gross thermal input of the fuel. These USEPA conditions are not consistent with the Guidebook or emission reporting practise in Europe and consequently some manipulation of the data is required. Calculations assume an ideal gas.

The USEPA method can be obtained here www.epa.gov/ttn/emc/methods/method19.html and the F-factors are provided below.

TABLE 19-2. F FACTORS FOR VARIOUS FUELS[1]

Fuel Type	F_d		F_w		F_c	
	dscm/J	dscf/10^6 Btu	wscm/J	wscf/10^6 Btu	scm/J	scf/10^6 Btu
Coal:						
Anthracite[2]	2.71×10^{-7}	10,100	2.83×10^{-7}	10,540	0.530×10^{-7}	1,970
Bituminus[2]	2.63×10^{-7}	9,780	2.86×10^{-7}	10,640	0.484×10^{-7}	1,800
Lignite	2.65×10^{-7}	9,860	3.21×10^{-7}	11,950	0.513×10^{-7}	1,910
Oil[3]	2.47×10^{-7}	9,190	2.77×10^{-7}	10,320	0.383×10^{-7}	1,420
Gas:						
Natural	2.34×10^{-7}	8,710	2.85×10^{-7}	10,610	0.287×10^{-7}	1,040
Propane	2.34×10^{-7}	8,710	2.74×10^{-7}	10,200	0.321×10^{-7}	1,190
Butane	2.34×10^{-7}	8,710	2.79×10^{-7}	10,390	0.337×10^{-7}	1,250
Wood	2.48×10^{-7}	9,240	--	--	0.492×10^{-7}	1,830
Wood Bark	2.58×10^{-7}	9,600	--	--	0.516×10^{-7}	1,920
Municipal	2.57×10^{-7}	9,570	--	--	0.488×10^{-7}	1,820
Solid Waste	--					

[1]Determined at standard conditions: 20 °C (68 °F) and 760 mm Hg (29.92 in. Hg)
[2]As classified according to ASTM D 388.
[3]Crude, residual, or distillate.

The F_d factors are used — these represent the dry stoichiometric flue gas volume per unit of energy input. The F_w and F_c factors represent the wet flue gas volume and CO_2 volumes respectively.

The USEPA dry flue gas volume at stoichiometric conditions are first recalculated to provide the flue gas volume ($DFGV_{ref}$) for the required oxygen content at STP and for the net energy input.

$$F_d' = F_d \cdot (273/293) \cdot ((CV_{gross})/CV_{net}))$$

where :

- F_d' is the stoichiometric dry flue gas volume at STP per unit of net energy input – $m^3.J^{-1}$,
- Fd is the USEPA factor (20 °C and gross energy input),
- 273/293 volume correction — ratio of temperatures in Kelvin.

Note that it is the ratio between the fuels' gross and net calorific values that is needed. Indicative ratios are provided below based on UK data (DUKES 2007).

Table B1 Fuel calorific values

Fuel	CVgross	CVnet	Units	Ratio
Power stn coal	26.2	24.9	$GJ.tonne^{-1}$	1.05
Industrial coal	26.6	25.3	$GJ.tonne^{-1}$	1.05
Wood	11.9	10	$GJ.tonne^{-1}$	1.08
HFO	43.3	41.2	$GJ.tonne^{-1}$	1.05
Gas oil	45.6	43.4	$GJ.tonne^{-1}$	1.05
Natural gas	39.8	35.8	$MJ.m^{-3}$	1.11

The dry flue gas volume at the normalised oxygen content can then be calculated:

$$F_{dref} = F_d' . (20.9/(20.9-[O_{2ref}]))$$

A pollutant emission factor ($EF_{thermal}$) can then be calculated by multiplying the standardised pollutant concentration by the dry flue gas volume at the same reference oxygen content. For example at 15 % oxygen:

$$EF_{thermal} = [X]_{15\%} . F_{d15\%}$$

Emission factors are reported in several ways and these are generally recalculated using physical or other properties of the fuel.

For example, a mass emission factor can be derived by multiplying the thermal emission factor calculated above by the net calorific value of the fuel.

$$EF = EF_{thermal} . CV$$

where:

- $EF_{thermal}$ is the thermal emission factor expressed in units to suit the user (for example g GJ^{-1}),
- CV is the net calorific value of the fuel in appropriate units to suit the units of the emission factor.

Example figures for correlation of emission concentrations to emission factors from USEPA Method 19 F factors are provided in Figures B1 and B2 below.

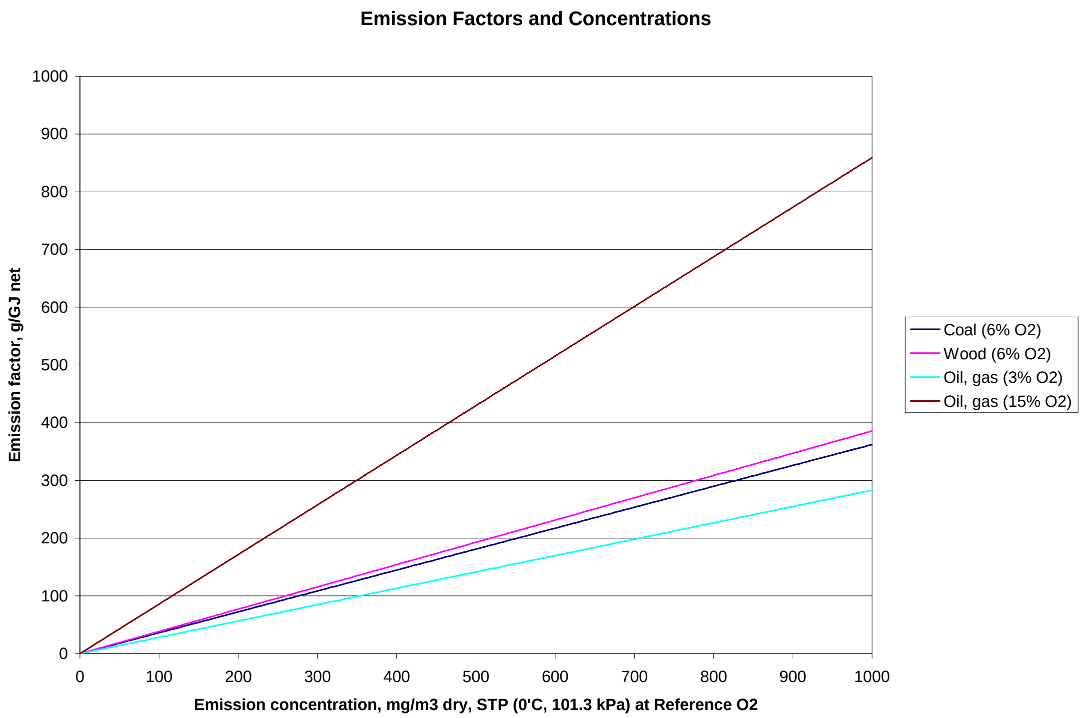

Figure B1 Emission factors — selected fuels and standardised concentrations up to 1 000 mg.m^{-3}

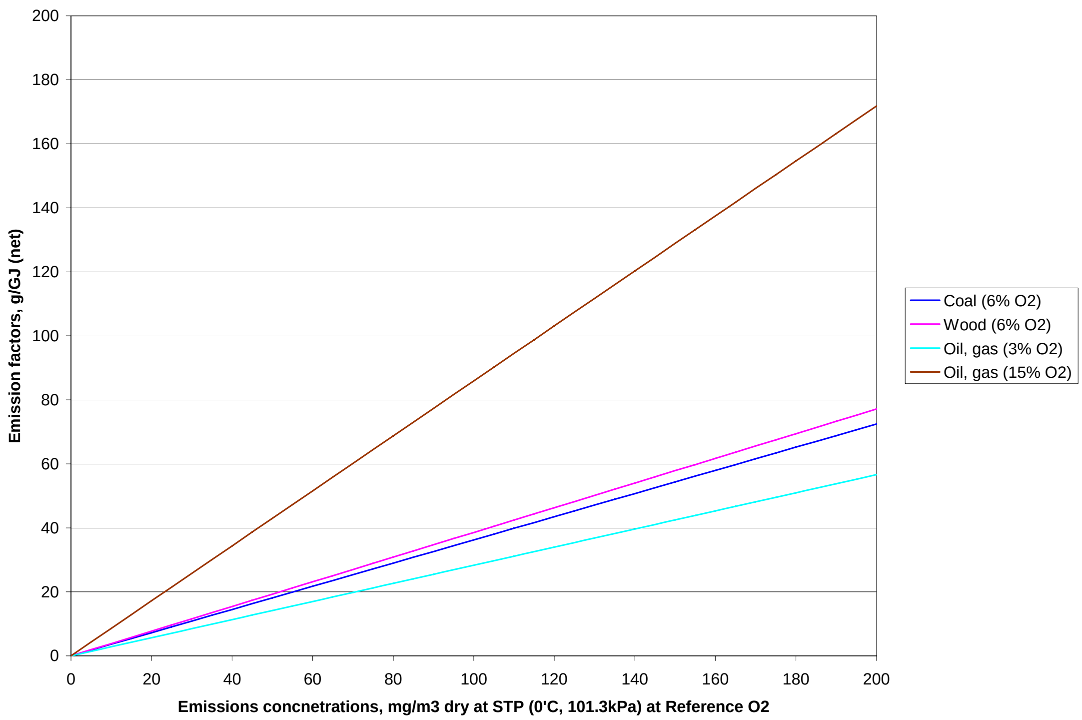

Figure B2 Emission factors — selected fuels and standardised concentrations up to 200 mg.m^{-3}

Appendix C Emission factors associated with emission limit values in selected countries

Table C1 Selected national emission limit values for small coal-fired combustion installations

Country	Size	Ref.	Emission concentrations, $mg.m^{-3}$ at STP (0ºC, 101.3 kPa) d								Emission factor, $g.GJ^{-1}$ (net basis)							
		O2	NOx		SO_2		PM		CO	VOC	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High			Low	High	Low	High	Low	High		
Belgium	0.3-5 MW	6	300	800	1250	1250	100	200	250		109	290	453	453	36	72	91	
Belgium	5-20 MW	6	300	800	1250	1250	50	200	200		109	290	453	453	18	72	72	
Belgium	20-50 MW	6	300	600	1250	1250	50	200	250		109	217	453	453	18	72	91	
Czech republic	0.2-50 MW	6	650				250		650	50	235				91		235	18
Czech republic	<50 MW	6	1500		800	2500			1000	50	543		290	906			362	18
France	20-50 MW	6	450	650	850	2000	50	100	200	110	163	235	308	725	18	36	72	40
France	<4 MW	6	550	825	2000		150				199	299	725		54			
France	4-10 MW	6	550	825	2000		100				199	299	725		36			
France	>10 MW	6	550	825	2000		100				199	299	725		36			
Finland	1-50 MW	6	275	550	1100	1100	55	140			100	199	398	398	20	51		
Germany	<2.5 MW	7	300	500	350	1300	50		150		116	194	136	505	19		58	
Germany	<5 MW	7	300	500	350	1300	50		**150**		116	194	136	505	19		58	
Germany	>5MW	7	300	500	350	1300	20		150		116	194	136	505	8		58	
Germany	>10 MW	7	300	400	350	1300	20		150		116	155	136	505	8		58	
Italy	20-50 MW	6	400		200		30		200	20	145		72		11		72	7
Latvia	<10 MW	6	600		2500		1000		2000		217		906		362		725	
Latvia	10-50 MW	6	600		2500		500		2000		217		906		181		725	
Norway	0.5-1 MW	7	250				100		150		97				39		58	
Norway	1-5 MW	7	250				20		100		97				8		39	
Norway	5-50 MW	7	200				20		100		78				8		39	
Poland	<5	6					630								228			
Poland	5-50 MW	6					400								145			
Portugal		6	1500		2700				1000	50	543		978				362	18
Slovakia	0.2-2 MW	6			2500		250						906		91			
Slovakia	02-50 MW	6					150								54			
Slovenia	1-50 MW	6	100		2000		150		100		36		725		54		36	
Slovenia	5-50 MW	6					50								18			
UK	20-50 MW	6	450	650	2000	3000	300		150		163	235	725	1087	109		54	

Notes:

1. All combustion unit sizes are MW_{th} (thermal input).
2. Range of concentrations (NO_x, SO_2 and PM) generally corresponds to ELVs for new and existing combustion plant. Some countries apply BAT achievable emission levels rather than ELVs.

Table C2 Selected national emission limit values for small coal-fired combustion installations

Country	Size	Ref.	Emission concentrations, mg.m^{-3} at STP (0ºC, 101.3 kPa) d								Emission factor, g.GJ^{-1} (net basis)							
		O2	NOx		SO_2		PM		CO	VOC	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High			Low	High	Low	High	Low	High		
France	20-50 MWth	11	400	650	200	2000	50	100	200	110	232	377	116	1161	29	58	116	64
France	<4 MW	11	500	750	200		150				290	435	116		87			
France	4-10 MW	11	500	750	200		100				290	435	116		58			
France	>10 MW	11	500	750	200		100				290	435	116		58			
Finland	1-5 MW	6	250	500			250	375			96	193			96	145		
Finland	5-10 MW	6	250	500			125	250			96	193			48	96		
Finland	10-50 MW	6	250	500			50	125			96	193			19	48		
Germany	<2.5 MW	11	250		350		100			10	145		203		58			6
Germany	<5 MW	11	250		350		50			10	145		203		29			6
Germany	>5MW	11	250		350		20			10	145		203		12			6
Italy		6	400		200		30		200	20	154		77		12		77	8
Latvia	<10 MW	6	600		200		1000		2000		231		77		386		771	
Latvia	10-50 MW	6	600		200		500		2000		231		77		193		771	
Norway	0.5-1 MW	11	250				100	300	150		145				58	174	87	
Norway	1-5 MW	11	250				20	300	100		145				12	174	58	
Norway	5-20 MW	11	200	300			20	100	100		116	174			12	58	58	
Norway	20-50MW	11	200	300			20	50	100		116	174			12	29	58	
Poland	<5	6					700								270			
Poland	5-50 MW	6					400								154			
Portugal		6	1500		2700				1000	50	579		1041				386	19
UK	20-50 MW	6	450				300		150		174				116		58	

Notes:

1. All combustion unit sizes are MW_{th} (thermal input).
2. Range of concentrations (NO_x, SO_2 and PM) generally corresponds to ELVs for new and existing combustion plant. Some countries apply BAT achievable emission levels rather than ELVs.

Table C3 Selected national emission limit values for small oil-fired combustion installations

Country	Size	Ref.	Emission concentrations, $mg.m^{-3}$ at STP (0ºC, 101.3 kPa) d								Emission factor, $g.GJ^{-1}$ (net basis)							
		O2	NOx		SO_2		PM		CO	VOC	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High			Low	High	Low	High	Low	High		
Czech republic		3			1700		100						481		28			
Czech republic		3			1700		100						481		28			
France	20-50 MWth	3	450	650	850	1700	50	100	100	110	127	184	241	481	14	28	28	31
France	<4 MW	3	550	825	1700		150				156	233	481		42			
France	4-10 MW	3	550	825	1700		100				156	233	481		28			
France	>10 MW	3	500	750	1700		100				141	212	481		28			
Finland	1-15 MW	3	800	900	1700		50	200			226	255	481		14	57		
Finland	15-50MW	3	500	670	1700		50	140			141	190	481		14	40		
Germany	HWB	3	180	350			50		80		51	99			14		23	
Germany	LPS	3	200	350			50		80		57	99			14		23	
Germany	HPS	3	250	350			50		80		71	99			14		23	
Italy	5-50 MW	3	500		1700		100				141		481		28			
Latvia	<10 MW	3	400		1700		50		400		113		481		14		113	
Latvia	10-50 MW	3	400		1700		50		400		113		481		14		113	
Norway	0.5-1 MW	3	250				100	100	10		71				28	28	3	
Norway	1-5 MW	3	250				20	100	10		71				6	28	3	
Norway	5-50 MW	3	200	600			20	150	10		57	170			6	42	3	
Poland	<5	3																
Portugal		3	1500		2700				1000	50	424		764				283	14
Slovakia	0.2-2 MW	3			1700		100						481		28			
Slovenia	1-50 MW	3			1700		50						481		14			
Slovenia	5-50 MW	3					50								14			
UK	20-50 MW	3	200	600	1700		100	150	150		57	170	481		28	42	42	

Notes

1. All combustion unit sizes are MW_{th} (thermal input).
2. Range of concentrations (NO_x, SO_2 and PM) generally corresponds to ELVs for new and existing combustion plant. Some countries apply BAT achievable emission levels rather than ELVs.
3. Note that for $SO_{2,}$ the ELV for unabated combustion units is determined by fuel sulphur content and Directive 1999/32/EC on sulphur content of certain liquid fuels (1 % for heavy fuel oil and 0.2 % for gas oil until 1.1.2008 when the gas oil sulphur limit will be 0.1 %).
4. Germany distinguishes NOx emissions by application; HWB — hot water boiler, LPS — steam boiler supplying steam at temperature up to 210 ºC and up to 1.8 Mpa, HPS — boilers supplying steam at temperature greater than 210 ºC or pressure over 1.8 Mpa.

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Table C4 Selected national emission limit values for small gas-fired combustion installations

Country	Size	Ref.	Emission concentrations, $mg.m^{-3}$ at STP (0ºC, 101.3 kPa) d								Emission factor, $g.GJ^{-1}$ (net basis)							
		O2	NOx		SO_2		PM		CO	VOC	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High			Low	High	Low	High	Low	High		
Czech republic		3			35		10						10		3			
Czech republic		3			35		10						10		3			
France	20-50 MWth	3	120	350	35		5		100	110	34	99	10		1		28	31
France	<10MW	3	150	225	35		5				42	64	10		1			
France	>10 MW	3	100	150	35		5				28	42	10		1			
Finland	1-15 MW	3	340	400							96	113						
Finland	15-50MW	3	170	300							48	85						
Germany	HWB	3	100		10		5		50		28		3		1		14	
Germany	LPS	3	110		10		5		50		31		3		1		14	
Germany	HPS	3	150		10		5		50		42		3		1		14	
Italy		3	350		35		5				99		10		1			
Latvia	<10 MW	3	350		35		5		150		99		10		1		42	
Latvia	10-50 MW	3	350		35		5		150		99		10		1		42	
Norway	0.5-1 MW	3	120						10		34						3	
Norway	1-5 MW	3	120						10		34						3	
Norway	5-50 MW	3	120	200					10		34	57					3	
Poland		3					5								1			
Portugal		3	1500		2700				1000	50	425		765				283	14
Slovakia	0.2-2 MW	3			35		10						10		3			
Slovenia	1-50 MW	3			35		5						10		1			
Slovenia	5-50 MW	3					5								1			
UK	20-50 MW	3	140		35		5		100		40		10		1		28	

Notes:

1. All combustion unit sizes are MW_{th} (thermal input).
2. Range of concentrations (NO_x, SO_2 and PM) generally corresponds to ELVs for new and existing combustion plant. Some countries apply BAT achievable emission levels rather than ELVs.
3. Germany distinguishes NOx emissions by application; HWB — hot water boiler, LPS — steam boiler supplying steam at temperature up to 210 ºC and up to 1.8 Mpa, HPS — boilers supplying steam at temperature greater than 210 ºC or pressure over 1.8 Mpa.

Table C5 Selected national emission limit values for engines and gas turbines

Country	Fuel	Ref.	Emission concentrations, mg.m^{-3} at STP (0ºC, 101.3 kPa)								Emission factor, g.GJ^{-1} (net basis)							
		O2	NOx		SO_2		PM		CO	VOC	NOx		SO_2		PM		CO	VOC
		%	Low	High	Low	High	Low	High			Low	High	Low	High	Low	High		
Engines :																		
France	Gas	5	350								112							
France	Oil	5	1000								319							
Finland	Gas	15	750	1750							644	4561						
Finland	Oil	15	750	2300	600		60	70			644	5990	1563		156	182		
Germany	Gas, <3MW	5	1000				20		300	2000	319				19		290	1934
Germany	Gas	5	500				20		300	650	159				19		290	629
Germany	Oil, <3MW	5	1000				20		300		319				19		290	
Germany	Oil	5	500				20		300		159				19		290	
UK	Gas	15	500	750			50	100	450	200	430	1955			130	261	1173	521
UK	Oil	15	1100	1800			100		150	150	944	4688			260		391	391
Gas turbines :																		
Finland	Gas	15	115	175							99	150						
Finland	Oil	15	115	175							99	150						
Germany	Gas	15	75						100		64						86	
Germany	Oil	15	150						100		129						86	
UK	Gas	15	60	125					60		52	107					52	
UK	Oil	15	125	165					60		107	142					52	

Notes:

1. All combustion unit sizes are MW_{th} (thermal input).
2. Range of concentrations (NO_x, SO_2 and PM) generally corresponds to ELVs for new and existing combustion plant. Some countries apply BAT achievable emission level ranges rather than ELVs.
3. Note that for SO_2, the ELV for unabated combustion units is determined by fuel sulphur content and Directive 1999/32/EC on sulphur content of certain liquid fuels (1 % for heavy fuel oil and 0.2 % for gas oil until 1.1.2008 when the gas oil sulphur limit will be 0.1 %).