7.1 Combustion installations < 1 MW with domestic combustion installation included

7.1.1 Coverage

Domestic combustion can be a significant source of NO_X, SO_2, VOC and dust emissions depending on the type of fuel used. This chapter covers domestic appliances used for home heating and sanitary water heating. It covers installations with a thermal input < 350MW.

7.1.2 Combustion technologies

Domestic combustion appliances can be fed with different fuels, such as: natural gas, fuel oil, wood and coal. A combination of different technologies of burners and different technologies of boilers can be used in these appliances. For wood and coal use, stoves, inserts and open fire place can be used as domestic appliances, as well as manually and automatically fuelled boilers.

7.1.2.1 Burner technologies

Gaseous fuels

Gaseous fuel burners are atomizing burners. Atomization increases the surface contact between air combustion and fuel; it thus improves the combustion process. Atmospheric burners are used as well as forced air burners.
Gaseous fuel burners can have different operating modes: on-off, 2 loads, modulating load.
On-off burners operate at nominal load.
2 load burners operate at nominal load or 40 – 60 % load depending on the demand.
Graduated load burners operate gradually depending on the demand, with a minimum of 30% load. This last operating mode permits a better management of the fuel consumption. Hence, emissions are reduced, especially start-up and shut-down-emissions.[1]

Different technologies of gaseous fuel burners can be used in domestic appliances.

Low NO_x burners limit the formation of NO_x emissions. One of the techniques used consists in recycling combustion flue gases into the burner air inlet. This reduces flame temperature, the oxygen concentration and thus enables the reduction of NO_x emissions.

Premixing type burners consist in mixing of gaseous fuel and air inside a premixing chamber. The mix is then distributed on a specific surface where the flame is developing. Different design of surface can be used. This technique enables control and optimisation of the mixing. It is based on a modular air/fuel ratio. It avoids air excess during the combustion and thus NO_x emissions. This technique can be used with catalytic combustion.

Radiating burners are only used with gaseous fuel. This technique permits flame temperature reduction and thus limit NO_x emissions during the combustion.

Liquid fuels

Liquid fuel burners are mostly atomizing burners and have the same operating modes as gaseous fuel burners: on-off; 2 loads; modulating load.
Different technologies of liquid fuel burners can be used in domestic appliances.

Vaporizing burners are burners where liquid fuel is atomized under gaseous form. It enables a more complete combustion and thus limits pollutant emissions but it is rarely used in boilers.

Low NO_x burners are also used for liquid fuel, based on similar techniques as for gaseous fuel.

Biomass fuels

For wood combustion, burners are essentially used for pellets combustion in boilers or stoves. Pellets are automatically supplied to the burner with a screw conveyor.

7.1.2.2 Boiler technologies used with gaseous and liquid fuel

A **liquid or gas boiler** generally consists of a burner, a combustion chamber and a heat exchanger. It is equipped with a stack.
Burner burns fuel in the combustion chamber where combustion gases heat water in the heat exchanger before exiting through the stack. The heated water can be used for home heating and/or sanitary water.
Different types of boilers technologies can be used.

In **low temperature boilers**, burners are not operating at nominal load and water is heated at lower temperatures (25-75°C instead of 70-80°C). Fuel consumption reductions of 12 to 15 % can be expected in using this technology compared to the use of traditional technologies.[1]

Condensing technology is used with gaseous fuel and, increasingly, with liquid fuels. It consists in recovering the latent heat from water contained in the flue gas.
In using the heat exchanger with water at low temperature, the latent heat of the combustion gases can be recovered. Combustion gases are condensed during the heat exchange. Thus, in using condensing technology, more heat is recovered with less energy spent than using traditional technology.
Boiler yield can be increased by 15 to 20 % using this technology compared to the use of recent standard boilers.[1]
The firm Ökofen uses condensing technology in one of its models to diffuse the emitted dust in the condensed water contained in combustion gases. The advantage of this technique is both improvement of energy efficiency and reduction of dust emissions (-10%). However, atmospheric dust emissions avoided are contained in condensates. [8]

Flue gases from liquid fuel combustion contain less water to be condensed. Hence, condensing boiler is less used for liquid fuels.
Condensing boilers are generally associated with low NO_x burners.

Micro combustion technology is composed of an immersed combustion chamber, and a multitubular heat exchanger. The combustion happens under the form of micro combustions (115 per second). This technology enables to recover the latent heat from water contained in the flue gas like condensing technology.
While condensing technology can be used with different type of fuel, micro combustion technology can only be used with gaseous fuel.[5]

7.1.2.3 Technologies used with biomass fuel

Boilers

There are different types of wood boilers; mainly **logs boilers and pellets boilers.**
Wood chips boilers can be used but are mainly used in larger installations (thermal output >30 kW).
The same technology is employed for pellets and wood chips boilers: fuel is automatically burnt by a burner and the flue gases heat a calorific fluid (generally water) in a heat exchanger.
For log wood boilers, logs are loaded on a grate and are burnt using different technologies: vertical, horizontal or inverted combustion and natural or forced draft.

For natural draft, three combustion techniques are used:

- Vertical combustion: all the wood logs loaded on the grate catch fire at the same time. This type of combustion is very difficult to control; hence emissions are high and energy efficiency is low (10-20%).
- Horizontal combustion: wood logs don't catch fire at the same time. Wood logs are first dried and then burnt. Flames are horizontal. This type of combustion is easier to control than horizontal combustion and thus performances are higher.
- Inverted combustion: as in horizontal combustion, wood logs don't catch fire at the same time and are dried before being burnt. It is called inverted combustion because instead of going up as in vertical combustion, flames are going down, through the grate. It is the best controlled combustion type for natural draft; hence performances are the highest.

Forced draft boilers (also called “turbo” boilers) are more recent and have higher performances than natural draft. Technique employed is the same as inverted combustion, but in “turbo” boilers, introduction of combustion air is made by a fan and flue gases are sucked out. The control of combustion is better; hence these boilers have higher performances.
With log, a heat accumulator can be used so as to load all energy produced during combustion and discharge it whenever it is needed. The boiler can be operated at full load, which reduces emissions of combustion residues. In an automatically charged boiler a heat accumulator is advisable as it helps to reduce part load emissions.
Low NO_x technology as recycling of the combustion flue gases can also be applied to wood boiler. Self cleaning option is available with some boilers. It contributes to maintain appliances energy efficiency.

Other domestic appliances
Stoves, inserts and open fire places can be used for wood combustion:

- Open fire places are the worst technique: combustion is made in the ambient air. There is no control of the combustion, energy efficiency is bad and emissions are high.
- Different technologies can be used in inserts: air regulation (air combustion can be heated before to be injected in the combustion chamber), catalysis (a catalyst is added to drop combustion temperature).
- Stoves: different technologies can be used.
  - Air regulation: air combustion can be heated before being injected in the combustion chambe and it can be controlled automatically using an electronic device. This option reduces real-life emissions.
  - Combustibles used (pellets or wood logs) varies from a technology to another. Masonry stove can accumulate energy during the combustion and then diffuse heat several hours after combustion.
  - Airtight stove: outside air is used as air combustion. There is thus no air exchange between combustion air and inside air. Performances of this technique are higher than a classic stove and it avoids indoor air quality problems.

Energy efficiency of appliances depends a lot on heat exchange. Therefore, improvements in heat exchange are always in development. Longer smoke pipe and the use of fan for convection air can be used. It transfers more energy from flue gases to indoor air and thus improves energy efficiency and reduces emissions.
Appliances performances depend also on combustion rate. When the rate of combustion is lower than the nominal rate (reduced combustion), combustion is bad; emissions are high and energy efficiency is low. This is due to the low temperature in the combustion chamber.
Automatic appliances, which burn pellets or wood chips, enable to operate at a nominal combustion rate; therefore performances are better than with manual appliances.

7.1.2.4 Technologies used with solid fossil fuel

No information is available at the moment concerning technologies using coal.

7.1.3 Available Techniques, Emission Levels

Reducing emissions in domestic combustion mainly means increasing appliances energy efficiency by using advanced technologies. Nevertheless, so as to achieve the best energy efficiency, measures taken on appliances have to be followed through by measures on buildings thermal insulation and on the whole heating network.

Pollutant emissions depend on the type of fuel used:

- Gaseous fuels use is mainly a source of NO_X emissions.
- Liquid fuels use is mainly a source of SO_2 and NO_X emissions.
- Solid fuels: emissions arising from wood combustion are mainly dust and VOC while emissions from coal combustion are mainly SO_2 and dust.

Combustion technologies depend also on the type of fuels used. Therefore, available techniques to reduce emissions from domestic appliances mainly depend on it too.

7.1.3.1 Type of fuel used

Gaseous fuels

Condensing boiler technology combined with the use of a specific burner can be considered as high efficient technique when gaseous fuels are used. Specific burners enable further reduction especially low NO_x burners for NO_x emissions. Micro combustion can also be considered as high efficient technique with the use of gaseous fuels. [1] [2].

Liquid fuels

Low temperature or condensing boilers combined with the use of specific burners are considered as high efficient technique with the use of liquid fuels. Further NO_x emission reductions can also be achieved by the use of specific burners.

Biomass fuels

For wood logs boilers, inverted combustion with forced draft and recycling of the combustion flue gases can be considered as high efficient technique. Energy efficiency can be increased and emissions reduced with the use of a water tank as hydro-accumulator.
The use of pellets as fuel in boilers can also be considered as high efficient technique, so is the use of condensing technology for solid fuels use.

Dust and VOC emission level mainly depend on the combustion efficiency; the more complete the combustion is, the lower are the emission levels.

For insert, the use of catalysts reduces atmospheric emissions of combustion residues by dropping combustion temperature. This technique is currently used in USA and begins to appear in Europe. According to measurements reports [10] and [11], use of catalysts in inserts can divide dust emissions by two.

For stoves, the use of pellets can be considered as a high energy efficiency technique.
Masonry stoves diffuse energy stored during several hours. It allows obtaining a good ambient temperature during several hours without use reduced combustion which produces a lot of pollutants.

However, any technology used to increase energy saving and combustion efficiency, whatever fuel used, contributes to pollutant emissions reduction by reduction of fuel consumption.

Solid fossil fuels

No information is available at the moment concerning technologies using coal.

7.1.3.2 Pollutants

SO2

SO_2 emissions depend on the sulphur content of the fuel used. Therefore, the main measure to reduce SO_2 emissions is to use sulphur-free fuels or fuels with low sulphur content. For brown coal, the addition of calcium hydroxide is possible in order to fix sulphur in the ash.

NOx

NO_x emissions are influenced by different parameters such as: the type of fuel, the flame temperature, the air volume, the residence time in the combustion chamber and the nitrogen content of the fuel.

Available techniques to reduce specifically NO_x emissions are the use low NO_x burners or premixed modular air/fuel ratio burner. The premixed modular air/fuel ratio burner enables the NO_x formation reduction in controlling the air content in the mix.
The following table gives an overview of achievable NO_x emission levels using selected gas firing domestic combustion appliances at full load.

Table 1: achievable NO_x emissions using selected gas firing domestic combustion appliances. [2]

	Heat output (kW)	NO_x (g/GJ)
Forced air condensing boiler + premixing burner with modular gas/air ratio	24	18
Forced air boiler + premixed low-NO_x burner	24	29
Forced air boiler + conventional burner	24.6	62
Conventional boiler and burner	24.2	85

VOC

VOC emissions are mainly influenced by the combustion efficiency. There is no technology used to reduce specifically VOC. Available techniques to reduce VOC emissions are actually the use of technologies enabling the more complete combustion as possible. These technologies are detailed in the previous paragraphs concerning wood fuels technologies.

Dust

In domestic combustion as in combustion in general, dust emissions are influenced by the type of fuel used. With the use of gaseous or liquid fuels, measures to improve energy efficiency are primary measures presented in section 2. They are the only measures considered in this chapter to reduce dust emission from gaseous or liquid fuels use.

Solid fuels are the main source of dust emission. Hence secondary measures to reduce dust emissions would be considered with the use of solid fuel.
Small electrostatic precipitators (ESP) have been developed in some countries, e.g. Norway and Switzerland, and can be considered as available techniques to reduce dust emissions. ESP can reduce 90 % of the dust particle with a diameter superior to 0.1 µm. [7]

Studies have shown that electrostatic precipitators (ESP) or fabric filters (FF) are suited in the range of 100 kW up to 2 MW. For installations < 500 kW, costs are still relatively high, but there is positive experience with some reference installations in this range. Emission reductions to 20 mg/m³ (13% O2) have been demonstrated with optimized ESP, while FF can reduce emissions to < 5 mg/m³. [8]

More generally, dust is deposited in the stoves, boilers, ducts, stacks, etc. Thus, to limit emissions of dust, boilers or stoves need to be clean regularly. Self cleaning option can also be seen as an efficient technique for the dust reduction.

7.1.4 Emerging techniques

The micro-cogeneration is an emerging technique to reduce energy consumption. The energy use for home heating or sanitary water heating is also used to produce electricity.

The use of pellets which is being developed for inserts technology increases energy efficiency.

7.1.5 Cost data for emission reduction technique

The investment cost of a low NO_x boiler is about 500 euros more than for a conventional boiler.[10]

The investment cost for a wood boiler with inverted combustion and forced draft is from 3 000 to 7 650 euros, for installations from 15kW to 150kW. An investment for heat accumulator is from 1 500 to 2 750 euros. [10] [12]

The investment cost for a pellet boiler is 7 000 to 15 000 euros for installations from 15 kW to a few MW. [12]

According to Swiss studies [13], the investment cost for an ESP reducing 80 – 90 % of dust would be 1 000 to 1 500 euros.

Additional cost of catalysts addition in inserts is about 1 000 euros. [14]

Table 2: Investment per kW heat output for wood heating systems and dust abatement equipment [8][1]

Power [kW]	Technology (heater system) [€/kW]	Building (without silo) [€/kW]	ESP [€/kW]	FF [€/kW]
100	965	520	660	450
200	800	430	405	240
500	630	340	195	115
1000	420	225	115	70
2000	315	170	75	50

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[1] Data from 2005/2006, converted to € (1 SFR= 0,64523 €) and rounded ; for calculation details see source report