Low emission operation manual for chimney stove users

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Preface

ERA-NET Bioenergy is a network of national research and development programmes focusing on bioenergy which includes 14 funding organisations from 10 European countries: Austria, Denmark, Finland, France, Germany, Ireland, The Netherlands, Poland, Sweden and the United Kingdom. Its mission is to enhance the quality and cost-effectiveness of European bioenergy research programmes, through coordination and cooperation between EU Member States. The project *FutureBioTec* (Future Low Emission Biomass Combustion Systems) has been supported in the period between October 2009 and September 2012 by ERA-NET Bioenergy under the joint call on Clean Biomass Combustion from 2009.

The European Union and its member States aim at an increased use of renewable energy in order to avoid a further increase in atmospheric CO_2 concentrations and therefore, the European Commission actively supports the utilisation of biomass for energy production. However, this aim must be achieved without increasing other harmful emissions such as fine particulate matter ($PM_{2.5}$), nitric oxides (NO_x), carbon monoxide (CO) and organic compounds (OGC, PAH). Therefore, especially regarding the small and medium-scale heating sector, where a great potential for biomass utilisation all over Europe exists, the promotion of energy from biomass must be accompanied by further technology development towards low emission combustion systems.

Against this background, the project *FutureBioTec* aimed to provide a substantial contribution concerning the development of future low emission stoves and automated small and medium-scale biomass combustion systems (<20 MW_{th}). Considering the different states of development of the combustion technologies and capacity ranges addressed, the project focused on the following main objectives.

- The further development of wood stoves towards significantly decreased CO, OGC, PM and NO_x emissions by primary measures (air staging and air distribution, grate design and implementation of automated process control systems).
- The improvement of automated furnaces in the residential and the small to medium-scale (<20 MW_{th}) capacity range towards lower PM and NO_x emissions by primary measures (staged combustion, utilisation of additives as well as fuel blending).
- The evaluation, development and optimisation of secondary measures for PM emission reduction in residential biomass combustion systems.

In order to reach these objectives, a consortium of 8 research organisations and 2 industrial partners from 7 European countries collaborated within FutureBioTec (see next page).

This document summarizes all scientific and practical knowledge which was collected and discussed in the project consortium to provide a sound and general guidance to the end user of a chimney stove which is used with wood logs or wood briquettes. It covers the most important aspects for the choice, functioning and operation of a stove. Results from research which was performed within the project were considered and general knowledge from literature and industry was collected and systematically evaluated in order to reflect the best practise for such heating appliances according to the modern state of the art.

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Industrial partners

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APP	Applied Plasma Physics AS, Norway

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1 Introduction and objectives

All over Europe there is a growing awareness that residential wood fuel appliances are potentially responsible for a great deal of environmental hazards. The complaints are manifold: particle emissions are dangerous to health, bad smell is annoying, wood is used inefficiently, sometimes illegal fuel (waste) is burnt, regional particle emission limits are violated, etc. Consequently, regulations and restrictions for wood combustion are now being revised in many European countries.

At the same time the performance of stoves and knowledge about proper stove technology are progressing and there are various technical and non-technical measures which can be undertaken to avoid the problems described above; the end user can today choose between much better stove products than in the past. He can also optimize the integration of a wood stove into his heating infrastructure. But above all it is the end user's heating behaviour (i. e. fuel selection, stove operation and maintenance) which is most decisive for achieving high efficiency and low emissions.

Figure 1: Avoidable pollutant emissions from residential wood combustion (source: TFZ)

Therefore this guideline is intended to help prevent hazardous combustion performances of chimney stoves which represent todays largest group of appliances. The guideline aims at supporting end users in the operation of their stove. It provides useful information about the influences and mistakes which can occur during wood stove selection, installation, ignition, charging, operation and maintenance.

1.1 Target group

This guideline is intended primarily for end users of chimney stoves. But it is also meant for professional users such as manufacturers, associations or public bodies. They are invited to make the guideline available either as a complete paper or by using fragments in their own brochures or product-specific manuals. Therefore all text, photos and images are cleared for publication by third parties without extra inquiry. We only request that a reference to this guideline is made.

2 Definitions and limitations

2.1 Definition of chimney stove

The following features apply to a chimney stove (Figure 2).

- It is a free standing room heater, not walled, and usually with a front window.
- Only a relatively small amount of heat storage is possible due to the low mass of the stove.
- Fuel is charged in a single layer onto the ember.
- Therefore: frequent recharging is required.
- Heat is released by radiation from the window or from other surfaces and by convection via air ducts and outlets.

Figure 2: Examples of chimney stoves (from left to right: Wodtke, Contura, Rika, Jøtul, Stanley)

2.2 Limitations

Much of the technical information in this Guideline also applies to slow heat releasing stoves (e. g. tiled stove inserts, closed fire place inserts), but such stoves are not the main focus in this document. This is due to the high variation of their designs and features which would make it difficult to give generalized recommendations. Consequently, tiled stoves, open fire places, cooking stoves, all stoves with water jackets, pellet stoves and sauna stoves are not covered in this guideline.

Apart from all practical questions concerning stove proper selection and operation, further technical improvements are also possible, e. g. by a better stove design or by special flue gas treatment. But such primary and secondary measures are separately presented in other guidelines which have also been prepared during this ERA-NET-project (see [1] and [2]).

3 Wood as a fuel

3.1 Energy content

The replacement of 1 litre of mineral heating oil (energy content: 10 kWh) requires about 2.3 kg of air dried wood or 2.1 kg wood briquettes (Figure 3):

- Available fuel energy is determined by the weight rather than by the fuel volume.
- The calorific value of 1 kg dry wood is almost consistent for all wood species (± 3 %).
- The calorific value (by mass) largely depends on the moisture content of the fuel.
- Young (thin) wood has a higher ash content than old (thick) wood (it contains more bark).

				
2.3 kg Softwood	2.4 kg Hardwood	2.1 kg Wood briquette	1.7 kg Brown coal briquette	1 litre Heating oil

Figure 3: Fuel masses of equal energy contents of 10 kWh (36 MJ) (source: TFZ)

During wood drying the calorific value of wood and also the total energy content of a specific volume increases. For example, a stacked cubic metre of beech wood logs of 33 cm length at 15 % moisture content has an energy content which is equivalent to about 190 litres of heating oil (Figure 4).

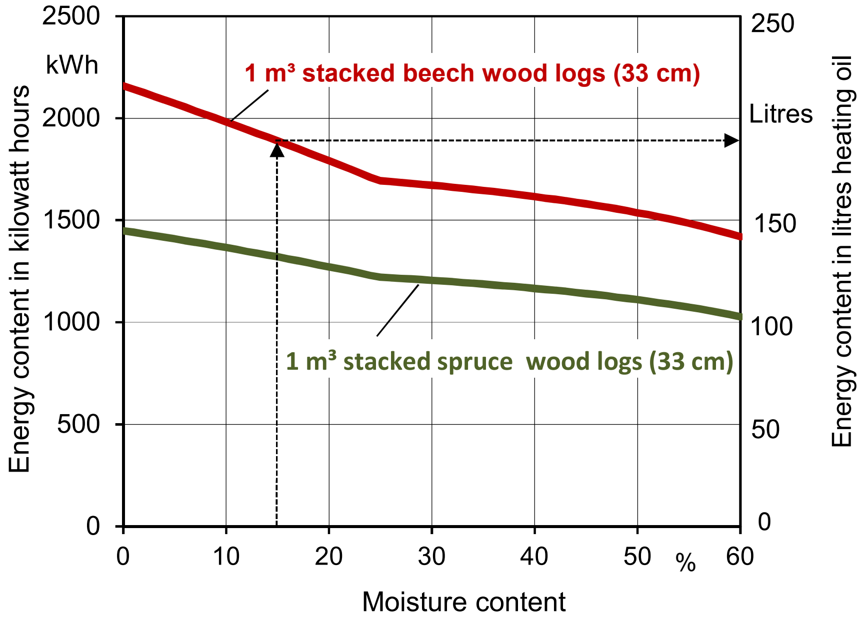


Figure 4: Fuel moisture content affects the energy content of a stock of wood (heating values are based on net calorific value) (source: TFZ)

3.2 Permissible fuels in wood stoves

The technically permissible fuels for a chimney stove are usually listed in the manual of the manufacturer. Newer stoves usually mention the permissible fuels on the identification plate.

<u>Permissible fuels are usually:</u>

- Natural untreated wood, which is either round wood or wood split into logs, with or without adherent bark
- Sawn wood (scantlings, boards), with or without adherent bark
- Wood briquettes made from natural untreated wood
- Ignition fuels (in small quantity): coarse wood chips, brushwood, sticks, kindlings
- Ignition aids (only in small quantity!) made of wood shavings, wood-wool, wood fibre, wax or mineral oil

It is not recommended that fuels of herbaceous crop materials are used in a chimney stove, even if such fuel is legally permitted in the respective country.

<u>Fuel that shall be avoided in chimney stoves are:</u>

- Pure bark briquettes
- Straw, paper, carton and similar products
- Painted, coated, glued wood or wood which is treated with wood protecting chemicals, e. g. used wood from outdoor applications, construction or demolition wood
- One-way pallets or fruit boxes and similar, if any impregnation or impurities cannot reliably be excluded
- Other wastes

These to be avoided fuels are for example in Germany not allowed according to emission regulation [5].

3.3 Suitable log wood quality

For chimney stoves the following log wood fuel recommendations are given:

- Avoid wet wood. Moisture content should be below 20 % (wet basis).
- When mould is visible on the surface the log may be too wet.
- Avoid over-dried wood logs. Moisture content should not be below 8 %. Wood from long storage in a heated room can be over-dried. Wood which comes directly from fuel producers using hot ventilation for drying can also be over-dried. After intermediate storage in ambient air such wood is again suitable for stoves.
- The logs should have a length which allows for several centimetres clearance to the firebox walls when horizontally placed onto the ember. Logs should never be so long as to make it necessary to lean them against the walls of the firebox.
- Logs with a uniform medium thickness (i.e. 20 to 30 cm circumference) should be used (see Figure 5).
- Split logs should be used in preference of round wood (should be split at diameters greater than 8 cm).
- Select thin wood sticks or small logs for the ignition phase. Clean and coarse wood chips can also be selected for ignition.
- Small logs are useful for the ignition batch but not recommended for the recharging of the stove.
- The optimal log size is usually specified by the stove manufacturer (check the manual).
- Use hardwood rather than softwood (if a choice is possible).
- Use logs with low dust or dirt content.

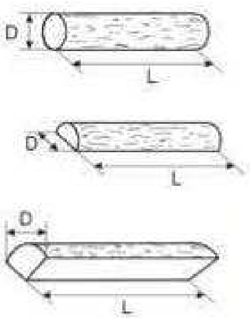
Figure 5: A circumference of 20 cm corresponds to a diameter of about 9 cm (source: TFZ)

Wood fuel standards

With the recent creation of European biomass stove manufacturers and fuel suppliers can now make reference to quality classes as given by the log wood fuel standard EN 14961-5 (see Table 1). Check for compliance with the new standard. But note: the fuel supplier is usually not obliged to make reference to the European log wood standard.

For stoves it is recommended that firewood with a diameter less than 15 cm (D10 and D15) and a moisture content less than 20 % (M20) is used. The diameters D2 and D5 are recommended for cookers and as kindling (ignition wood).

Table 1: Main requirements for traded wood logs defined in European Standard EN 14961-5 [3]. (requirements for most chimney stoves are marked grey).

Property class	Unit	Grades		
		A1	A2	B
Origin and source		1.1.3 Stemwood 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues
Wood species		To be stated		To be stated
Diameter, D[a] 	cm	D2 ≤ 2 D5 2 ≤ D ≤ 5 D10 5 ≤ D ≤10 D15 10 ≤ D ≤15 D15+ > 15 (act. value to be stated)		D15 ≤ 15 D15+ ≥ 15 (actual value to be stated)
Length, L[b]	cm	L20 ≤ 20 L25 ≤ 25 L33 ≤ 33 L50 ≤ 50 L100 ≤ 100		L33 ≤ 33 L50 ≤ 50 L100 ≤ 100
Moisture, M[c]	%, wet basis	M20 ≤ 20 M25 ≤ 25		M25 ≤ 25 M35 ≤ 35
Volume or weight	m^3 stacked or m^3 loose or kg	To be stated which volume or weight is used when retailed		
Proportion of split volume	% of pieces	≥ 90 %	≥ 50 %	No requirements
The cut-off surface		Even and smooth	No requirements	No requirements

[a] 85 % of the firewood should be kept in specified diameter property class.
[b] Length should be in the limits of ± 2 cm. It is allowed to have 15 % firewood shorter than requested length including the limit value.
[c] Moisture content should not be less 12 w-% on wet basis (M)

3.4 Suitable briquette quality

A great variety of briquette types with variable shape and geometry is available (Figure 6).

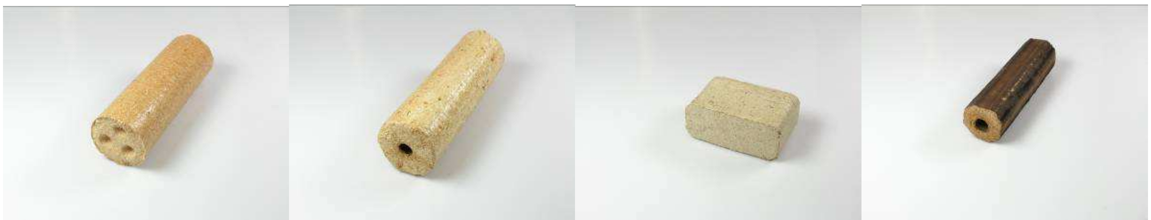


Figure 6: Variety of wood briquettes (source: TFZ)

If briquette fuel is to be used in the stove the following recommendations are made:

- Check if the fuel supplier declares compliance with any of the quality classes in the new European briquette standard EN 14961-3, as presented in Table 2. But note: the supplier is usually not obliged to make reference to the European briquette standard. Standard briquettes usually have a low ash content and the concentration of disturbing or polluting components is usually also low (e. g. chlorine, nitrogen, sulphur or heavy metals). If standard quality is certified (e.g. EN_{plus} or DIN_{plus} certification scheme) the quality is also monitored.
- Avoid the use of briquettes which are made from 100 % bark. Such briquettes can lead to smouldering combustion with high gaseous emissions.
- The briquette length should be significantly shorter than the width of the firebox (due to swelling during combustion of wood briquettes). If volume increase is not allowed for, the briquette may get stuck between the sides of the firebox without any contact to the ember (Figure 7). Long briquettes therefore need to be broken into shorter lengths before use.

Figure 7: Swelling of wood briquettes in the firebox: The briquette is finally stuck between the walls of the firebox and loses contact to the embers. Therefore: break longer briquettes before charging (source: TFZ)

Table 2: Main requirements for traded wood briquettes, defined in EN 14961-3 (for use in most chimney stoves the recommended briquette class is A1) [4]

Property class	Unit	Grades		
		A1	A2	B
Origin and source		1.1.3 Stemwood 1.2.1 Chemically untreated wood residues	1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.1.6 Bark 1.2.1 Chemically untreated wood residues	1.1 Forest plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3 Used wood
Moisture, M	% as received	M12 ≤ 12	M15 ≤ 15	M15 ≤ 15
Ash, A	% dry	A0.7 ≤ 0.7	A1.5 ≤ 1.5	A3.0 ≤ 3.0
Particle density, DE	g/cm^3	DE1.0 ≥ 1:0	DE1.0 ≥ 1.0	DE0.9 ≥ 0.9
Additives[a]	% dry	≤ 2 % Type and amount to be stated	≤ 2 % Type and amount to be stated	≤ 2 % Type and amount to be stated
Net calorific value, Q	MJ/kg or kWh/kg	Q15.5 ≥ 15.5 or Q4.3 ≥ 4.3	Q15.3 ≥ 15.3 or Q4.25 ≥ 4.25	Q14.9 ≥ 14.9 or Q4.15 ≥ 4.15
Nitrogen, N	% dry	N0.3 ≤ 0.3	N0.5 ≤ 0.5	N1.0 ≤ 1.0
Sulphur, S	% dry	S0.03 ≤ 0.03	S0.03 ≤ 0.03	S0.04 ≤ 0.04
Chlorine, Cl	% dry	Cl0.02 ≤ 0.02	Cl0.02 ≤ 0.02	Cl0.03 ≤ 0.03

[a] Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil,…). Also additives which are used after production, before unloading to end-user storages, shall be stated similarly (type and amount).

3.5 Ignition materials

Kindling. For the first fuel batch select a number of normal or rather small wood logs combined with thinly sliced ignition wood sticks or brushwood or coarse wood chips (Figure 8). Such kindling is preferably produced from coniferous wood.

Figure 8: Kindling: wood sticks or coarse wood chips (source: TFZ)

Ignition aids. Use professional ignition aids as available on the market. Such products may be for example:

- Wax-soaked wood wool blocks
- Wood fibre blocks with paraffin

Figure 9: Ignition aids: wax-wood wool blocks, paraffin wood fibre sticks or blocks (source: TFZ)

Do not use the following ignition aids:

- Paper or carton
- Liquid fuels

The use of paper for ignition has several disadvantages. Due to its leafy ash structure the combustion air flow to the bed of ember is disturbed. Also the burning time of paper is too short (and unstable) to guarantee a reliable ignition. In addition, ignition happens too slowly.

4 Log wood drying, storage and quality control

For proper storage and natural drying of the logs:

- Choose windy storage places
- Protect the wood against rain (by coverage of the top)
- Protect against surface water (by stacking on wooden beams)
- Ensure sufficient distance to walls or neighbouring stacks (> 0.1 m)

- Avoid storage of fresh wood in basements or garages
- Be aware that short and split wood logs dry faster than unsplit metre-wood

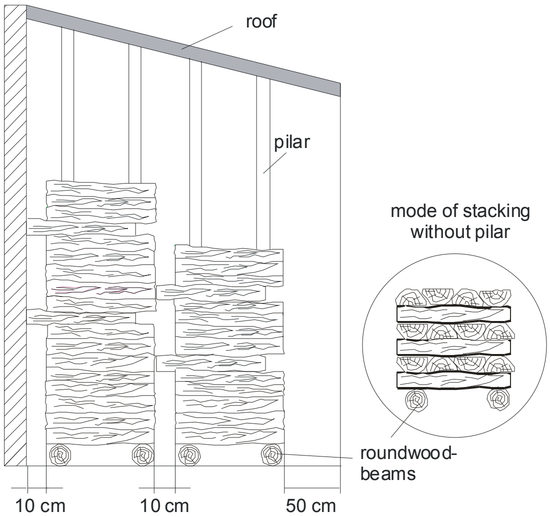



Figure 10: Example of proper outdoor storage of covered wood logs on supporting wood beams (source: TFZ and [6])

Storage and drying time. Fresh wood has a moisture content of around 45 to 60 % when harvested during winter. In Central Europe a storage time of a full summer season can be sufficient to achieve a required moisture content of below 20 % (see Figure 11) - assuming that suitable drying conditions are prevailing. In Nordic countries and on the British Isles or in humid regions further storage time may be required. Wood can also be stored indoors, but the room should not be permanently heated and be well ventilated.

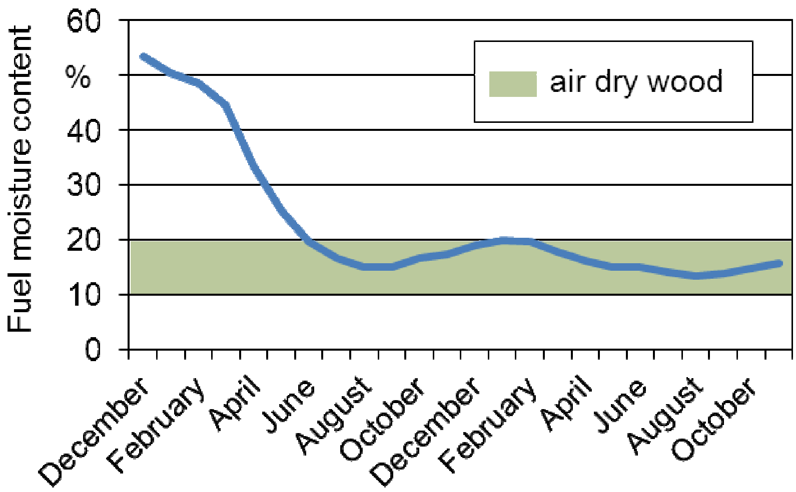


Figure 11: Example of drying progress of wood logs (stacked and split 1 m pieces in covered outdoor storage piles in Germany (source: TFZ)

If fuel is provided from a supplier which applies hot air drying, the fuel can, in some instances be too dry for immediate use in stoves (e. g. at a moisture content below 8 %). In such instances, storage under the conditions described above can ensure sufficient moisture uptake from the atmosphere into the fuel in order to achieve moisture content levels of 10 % or higher.

5 Stove technology

5.1 Design and function

In the following, a typical design and functioning principle of a modern chimney stove is described. For better understanding the following definitions apply:

Primary air. It provides the oxygen needed to gasify the wood fuel and to burn the remaining char in the ember. Primary air is directed to the space where the solid fuel is pyrolysed (ember).

Secondary air. It is needed to provide oxygen to be mixed with released pyrolysis gases which burn as visible flames.

Figure 12 shows the flow of gases in a chimney stove.

For air tight buildings it is required that a combustion air conduit (pipe) can be connected to the chimney stove via a central air inlet socket (1). Such an air inlet socket can also enable the retrofitting of an electronic combustion air control system via a motor driven flap.

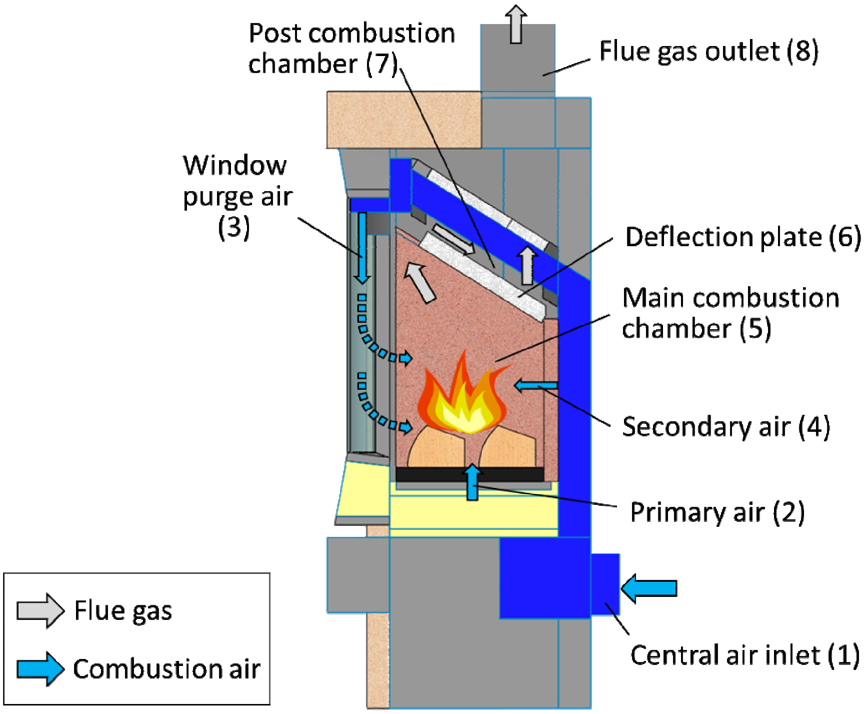


Figure 12: Typical design of a chimney stove (here: stove with central air supply socket and primary air via grate

For buildings which are less air tight or rooms in which the combustion air is usually taken from the heated room itself, a central air insertion socket should not be required although it can be useful.

The combustion air flow into the chimney stove (blue area in Figure 12) is divided into

- a primary air stream (2) which flows through the grate into the firebox and
- a window purge air flow (3) which is conducted to the window top and is then directed through nozzles or slots downward along the window. It flushes the window to prevent

soot or particle depositions. But it also serves as combustion air. One part of it usually reaches the bed of ember and can provide primary air to the wood fuel if either the grate is closed (e. g. by a rotation rosette) or if the grate air damper is locked, or if no grate exists at all. Another part of this air stream is directed above the bed of ember into the combustion chamber (5) to provide oxygen for the flame combustion. Thus, it serves as secondary air.

- Some stoves are equipped with an additional secondary air inlet at the back of the stove wall (4). Such an inlet improves the turbulent mixture of oxygen with the pyrolysis gas released from the solid fuel. The portion of this air stream is usually smaller than the window purge air.

The heat produced in the firebox (i. e. combustion chamber) is conserved by a heat resistant mineral insulation layer made of fire clay or chamotte. This ensures high temperatures for complete combustion reactions.

In the post combustion chamber (7) combustion is completed, therefore high temperatures are here still maintained by refractory lining (fire clay or chamotte insulation). Also high turbulence is here achieved through the deflection plate (6) which leads the hot gases to the narrow entrance of the post combustion chamber. The gases are here finally burnt out and conducted to the flue gas socket from where they exit to the chimney (8) via a connecting pipe.

In the upper area of the stove the hot flue gases heat the cast iron, steel or mineral stove surfaces which reach relatively high temperatures of up to 200°C. Even higher temperatures are achieved on the window surface which contributes largely to the heat release into the room. An additional heating effect is generated by convection which is created by air flow from ground level passing upward along the stove surface or through convection canals in the stove.

5.2 Choosing the right stove

Stove power. Before selecting a stove the useful heat power has to be determined. It depends on the

- size of the heated space (i. e. all rooms connected by a joint airspace) and the
- insulation standard of the building according to the date of erection or renovation.

Table 3 provides some guidance for proper heat power selection.

Table 3: Selection of proper stove heat power output: Minimum required living space of rooms connected by a joint airspace and heated with the designated wood stove (reference climate: Germany)

Specific heat demand of the building	Nominal heat power output of stove		
	5 kW	7 kW	9 kW
70 kWh/(m² a) i. e. modern buildings according to the newest insulation standards	> 100 m²	> 100 m²	> 100 m²
160 kWh/(m² a) i. e. medium insulation standard*	50 m²	70 m²	90 m²
300 kWh/(m² a) i. e. older buildings with low insulation standard	30 m²	40 m²	50 m²

* mean value of building stock in Germany

Example: In an old building with low insulation standard (according to building standards in Central Europe) the heat demand is about 300 kWh/a. For such a building a 7 kW stove would require a minimum of 40 m² directly heated living space (Table 3) if excessive heat production shall be prevented during normal stove operation.

Stove selection. When purchasing a chimney stove with the required heat power output the following criteria should be considered.

- **Air staging:** Staged air supply should be included to the features of the stove. This function is, however, not always easily visible, but it is given for most stoves. Separate handles for air adjustment or extra air inlet nozzles can be an indication. But high performance stoves can also perform air distribution automatically, without any air adjustment handle. Check the user manual or the technical documents of the stove.
- **Refractory lining:** The firebox should have a thick refractory lining to protect the steel or cast iron from high temperatures and to reduce heat losses. The refractory lining also improves the heat storage and serves as a buffer for the otherwise much more variable combustion temperatures.
- **Firebox geometry:** A high and slim combustion chamber geometry is usually preferable compared to a wide and low shape of the firebox (although the smaller base area may then require shorter wood logs). A high and slim shape improves flame dispersion and leads to a more homogeneous residence pattern for the produced pyrolysis gases in the hot zones (i. e. less danger of short circuit flows to the exhaust pipe).
- **Construction:** Look for robust construction with no loose parts, good welding lines and a firm shutting mechanism for the door.
- **Air tightness:** A robust construction will usually lower the risk of false air inlet. Such (uncontrolled) leakage air disturbs the designed and optimized combustion air

distribution and can reduce the air staging effect. In this respect the hinges and the locking system of the front door usually represent a particular weak point.

- **Window:** A small window reduces heat losses from the combustion chamber, thus it is preferable. Double glazed windows with an air gap are beneficial. Windows using special glass with low heat transmission are also favourable. Such windows also have the additional advantage of preventing excessive ash and soot depositions on their surface.
- **Central air socket:** A central air inlet socket is favourable. Such a stove can be applied more universally. In highly air tight and/or ventilated buildings they are even essential to provide an undisturbed combustion air. The socket is connected to a combustion air duct for air supply from outdoors or from the basement (e. g. via a dual wall chimney or via a subsurface air canal). The air inlet socket would also facilitate retrofitting of an electronic combustion air control system via a motor driven flap. Such a flap could also allow a complete closure of the air inlet in order to prevent heat losses from the room through the natural chimney draught which remains effective even when the stove is not operated and cold.
- **Fuel filling mark:** An orientation mark to indicate the maximum fuel filling height in the firebox is useful to prevent overloading. Additional secondary air insertion nozzles (see Figure 12) can also provide such orientation.
- **User manual:** The documents and information provided by the manufacturer should be informative and easy to understand. The manual should also be stove-specific.
- **Quality label:** Look for a quality labelling on the stove. In several European countries there are certification schemes for quality stoves:
  - Austria: Umweltzeichen UZ 37
  - Germany: Din_{Plus}
  - Sweden: Nordic Ecolabel
- **Connection to chimney:** A long flue gas pipe is preferable. This is usually achieved by using the vertical pipe outlet of the stove. The probably also available horizontal flue gas pipe outlet is less suitable. This is because the shorter pipe prevents significant heat portions from being transmitted into the room before reaching the chimney. Using the vertical flue gas outlet will in most cases also have the positive effect that the flue gas passes the final combustion space in the stove (burnout and heat exchanger zone) more consistently which can further increase the efficiency and reduce emissions.
- **Automatic control:** Some modern stoves provide an automatic combustion air control. It can either be electronical (via motor driven flaps) or thermomechanic (flaps are operated via a temperature sensitive expandable liquid). Such functions are usually advantageous as they offer an optimized combustion and they prevent false operations such as an omitted closure of grate air flow after the initial heating phase.

5.3 Positioning the stove in a room

For safe operation of the stove some requirements regarding the distance to walls or other objects must be considered. Some useful recommendations are given in Figure 13. It is strongly suggested to consult the local chimney sweeper before selecting and erecting the stove. In some countries this consultation is even obligatory (e. g. in Germany). The chimney sweeper evaluates the suitability of the chimney and the combustion air provision.

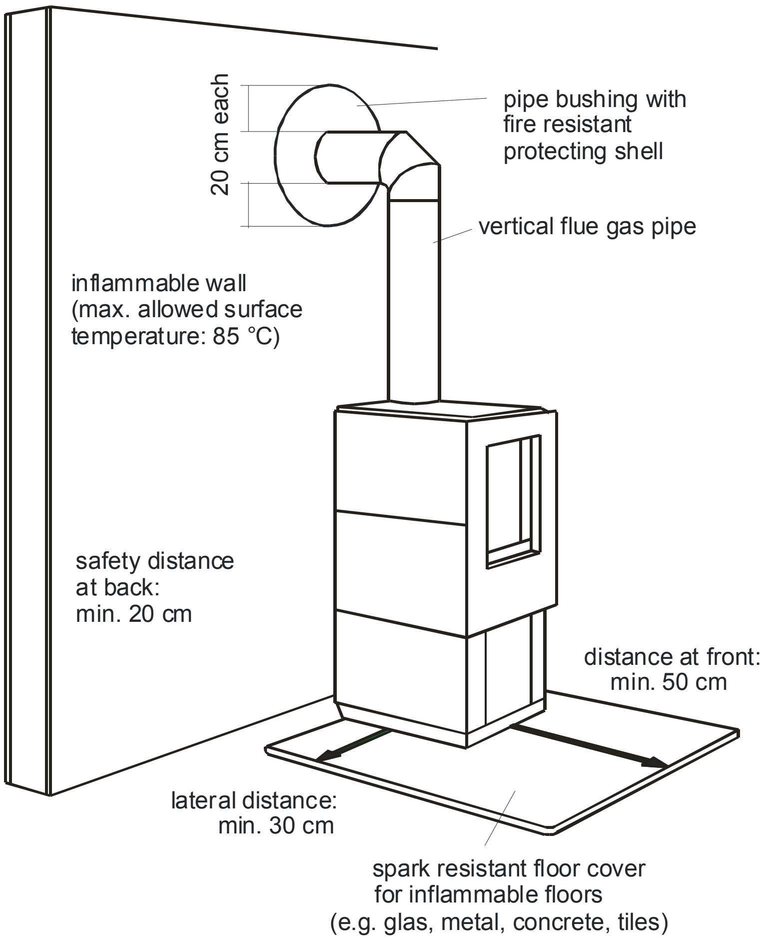


Figure 13: Usual requirements and safety distances for the installation of a chimney stove in rooms with inflammable walls and floor materials [6]

5.4 Retrofit components and useful accessories

A stove can be equipped with the following retrofit components (Figure 14) for improved combustion performance.

Flue gas thermometer. It allows to identify proper charging times. Such thermometers are available from specialized suppliers. Their emplacement requires a small hole in the flue gas pipe, but magnetic thermometer designs are also available.

Bleed air flap. It is fitted at the chimney bottom (e. g. in the basement) to avoid excessive chimney draught. Consult the chimney sweeper for further advice. For stoves with central air inlet socket a special bleed air flap can also be mounted at the stove's flue gas outlet and via a t-fitting be connected to the central air canal to allow combustion air to bypass the stove.

Electronic combustion air supply control. It can be applied if the stove is equipped with a central air inlet socket (see also Chapter 5.2).

Manostat. A manostat (pressure guard) is a sensor which is located in the room where the stove is operated. It is connected to any stationary electric ventilator(s) which can evacuate the room (e. g. fume extractor). When the vacuum exceeds a certain pressure limit (e. g. 4 Pa) the ventilator is shut down to prevent disturbance of the combustion.

Fan on chimney top. Such a fan can improve the chimney draught. Consult your chimney sweeper!

Bleed air flap for chimney

Flue gas thermometer

Electronic air supply control

Figure 14: Examples for retrofit components for chimney stoves (source: TFZ)

6 Stove operation

6.1 Ignition

Ignition should generally be performed in such a way that high temperatures in the firebox are achieved quickly.

Top-down ignition method. This method usually creates best results for stoves (Figure 15):

- Two or three wood logs are placed horizontally next to each other on the bottom of the firebox.
- One ignition block is placed onto the logs.
- The kindling (about 2 to 4 sticks) are placed crosswise on top.
- Ensure that all damper(s) are fully open (all the dampers of the stove and any damper in the flue gas pipe).
- The ignition block is then ignited.

Figure 15: *Ignition module to start the fire from the top (source: TFZ)*

- After ignition when combustion starts (see image Figure 16) the primary air supply to the bed of embers (grate air and/or primary air dampers) shall be closed. In addition, if required by the manufacturer and if technically possible, the secondary air supply has to be reduced slightly.

Figure 16: Ignition phase and start of wood combustion (source: TFZ)

An ignition block burns steadily for about 5 to 7 minutes and provides constant ignition heat while enough combustion air can uninhibitedly passes to the flames and to the already ignited wood (this does not easily happen when using paper or carton for ignition because of residual paper ash flakes!).

The traditional bottom-up ignition method, which is still sometimes used, is today not recommended anymore. In this old method all fuel (including the wood logs) is placed above the ignition zone instead of only the kindling. With the top-down method recommended here a smaller firebox volume is effectively exposed to the small amount of heat radiation that is available and thus the heat losses during this sensitive start-up phase are smaller. As a result this leads to a faster temperature build-up in the zone where it is needed and less fuel is actively used in the ignition process. Consequently, the residence time of the remaining pyrolysis gases is higher and less unburnt gases leave the firebox.

6.2 Heating operation

Low emissions and high efficiencies are achieved with chimney stoves if the recommendations given here are followed.

Recharging procedure

- Contrary to slow heat releasing stoves a chimney stove requires frequent fuel charging.
- The maximum mass which can be loaded per batch is usually mentioned in the user manual for the stove.

- The stove is usually well operated if a wood mass of around 0.15 kg per kilowatt of nominal heating power is charged every half hour. For a 6 kW chimney stove this means that about 0.9 kg fuel is charged every 30 minutes.
- The recharging is typically performed when the flames die down while the bed of ember is still covering the grate (see Figure 17 below). If recharging does not occur the temperature in the firebox would rapidly decrease from this point (see Figure 18) and the emission level would increase.

Figure 17: Recharge shortly before the flames extinguish (source: TFZ)

- To recharge, open the chimney stove door slowly. Reason: In rare cases the fast availability of oxygen can lead to spontaneous ignition of hot pyrolysis gases accumulated in the firebox which can cause injuries from an explosive flame.
- If necessary, level the bed of ember (smoothly) before adding new wood into the oven. Use either a wood log or a poker. The use of heat protecting gloves may be required.
- Avoid the charging of only a single log. Otherwise the stove will cool down too much. An exception from this requirement should only be made if the stove is designed for a single log operation (e. g. if it has an inclined grate).
- The charged wood mass should be achieved by using between 2 logs (small stoves of about 5 kW) and 4 logs (large stoves of about 9 kW).
- Place logs preferably with the bark side downward. This usually prevents the bridge formation of a larger bridge with no contact between wood and ember.
- If possible: keep a small distance between the logs when placing them onto the ember. Also try to keep a distance between the wood and the furnace walls so that air distribution is not disturbed (this requirement cannot easily be met when wooden boards are used, therefore such fuel is less suitable for stoves).
- Do not overload! Never fill up the whole combustion chamber with wood logs. In all cases at least half of the height of the firebox should always be left free for the combustion process. This requirement can be met easier with hard wood than with soft wood, therefore hard wood is preferable.

- Recharge your stove using only one layer of logs so that all the wood has direct contact to the ember.
- It is recommended that the wood is placed in the rear part of the stove. Avoid placing logs too close to the window, where temperatures are lower.
- Do not block any secondary air nozzles when charging (such air nozzles are sometimes placed in the rear refractory lining, e. g. as small holes or slits, about half way up in the firebox, see Figure 12).
- For the determination of the correct charging time the stove thermometer (see Figure 14) can provide some guidance, if installed. The correct temperature for charging can be identified by observing the rapid temperature drop after the flames are extinguished. Charging should take place at the beginning of this rapid temperature drop (Figure 18), or – with some experience – slightly before.

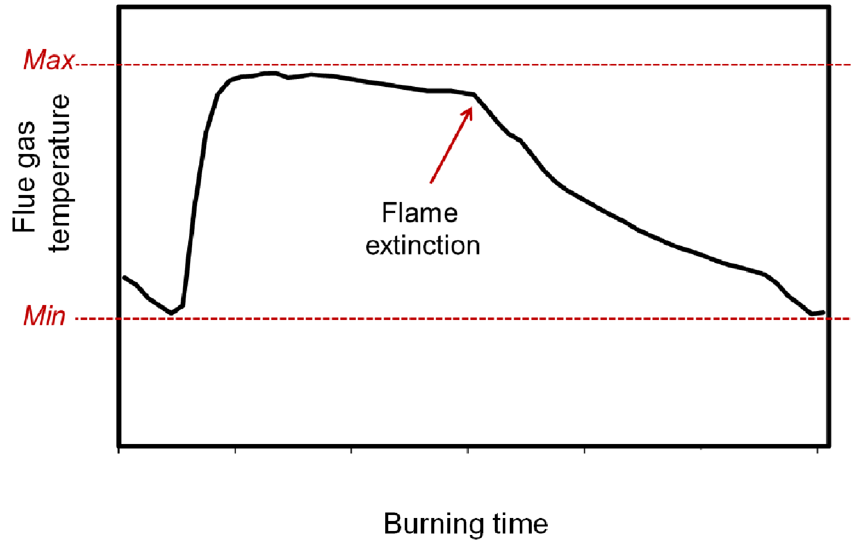


Figure 18: Recommended charging time at flame extinction, when the flue gas temperature declines rapidly (source: TFZ)

- Do not use very small logs for recharging the stove. This will lead to higher pollutant emissions due to too fast pyrolysis and oxygen deficiency. The very small logs should be saved for the next ignition batch. Adequate log sizes are between 7 and 9 cm in diameter (see Figure 5).

Avoid overloading! Avoid too long logs! Avoid charging with only one big log! Avoid large space between logs!

Figure 19: False operation of a chimney stove (source: TFZ)

Air adjustments

- For ignition: Open all dampers during ignition.
- After the logs have started to burn well and for all subsequent batches close the air supply through the grate (if a grate is present) and operate the stove with the window purge air and, if available, secondary air.
- When recharging: Keep the air supply through the grate closed (if a grate is present).
- Stove after shut down: Close all openings when the stove is cold and not operated. This is to prevent heat losses from the room via the chimney.
- Clean the fire box and empty the ash box regularly, otherwise air supply through the grate can be blocked.

6.3 Ash handling and maintenance

Rules for ash handling

- Clean and de-ash the stove frequently and follow the manufacturer's instructions (user manual).
- When de-ashing and cleaning the stove and pipe: Do not inhale any released ash particles and avoid any direct contact of your skin with soot; use protective equipment such as masks or gloves. Carbon and soot containing ashes are known to be poisonous due to high concentrations of polycyclic aromatic hydrocarbons (PAH).
- The ash shall be deposited to the residential waste.
- Hot ash should never be placed in unsuitable containers, e. g. of plastic or flammable material. Use heat resistant containers.

Rules for stove maintenance

- All maintenance and cleaning work is only to be performed when the stove has completely cooled down.
- Check the connecting pipe to the chimney once or twice per year and clean the pipe using a round pipe brush (can also be done by chimney sweep).
- Check if a firm shutting mechanism of the door is still given and if any door sealing is damaged. Adjust the lock or replace the sealing if necessary.
- Check if any refractory lining is broken and if the grate is torn. Replace if necessary (via customer service).
- The chimney must also be regularly cleaned by a chimney sweeper to avoid soot fire, according to the regulations in the respective country.
- For stove-specific maintenance requirements check the user manual of the manufacturer.

6.4 Troubleshooting

Problems which can occur during stove operation are addressed in the following.

Permanent danger of smoke release into the room. Possible reasons are:

- Air dampers or the chimney flap of the stove are closed (if present). Consult the user manual for the stove!
- Too large or too wet wood logs are used. Provide proper fuel!
- Chimney problems (too short chimneys or unsuitable diameters leading to a too low chimney draught). Consult your chimney sweeper!
- Wind is pressed into the chimney due to unsuitable chimney position or length or any deflecting obstacles. Consult your chimney sweeper!

Unexpected smoke release into the room. Possible reasons are:

- Interference with electrical room ventilation systems (e. g. in the bathroom or living room) or fume extractor fan (e. g. in the kitchen). Such ventilators cause a vacuum in the building which can exceed the natural chimney draught and thus redirect the flue gases backward through the stove into the room. Instant remedial measures are: Closure of ventilation, opening of window(s), opening of door(s) to neighbouring rooms. For permanent trouble shooting: install a manostat (pressure guard) as described in Chapter 5.4.
- Blockage of a chimney (e. g. dead birds, loose bricks). Inspect the chimney.

Dirt deposits on stove window. Stoves with a large window area or with ineffective purge air flow tend to ash or soot deposition on the inside of the windows. For avoidance: use dry wood, use smaller recharging mass and smaller logs, charge the logs closer to the back wall of the firebox.

Unusual smell during use after longer shutdown of stove. After longer shutdown periods (e. g. summer season) the stove can release a bad smell into the room during initial use (no smoke!). This is due to house dust deposits which burn off. Heat the stove once to high temperatures and provide fresh air to the room.

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Certifications schemes and labels for stoves:

- Nordic Ecolabel for stoves (Scandinavian countries):
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- DIN_{plus} label for stoves (Germany)
  http://www.dincertco.de/de/kaminoefen_pelletoefen_heizeinsaetze_herde_und_sonstige_haeusliche_heizgeraete.html
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