Biomass heating: a guide to small log and wood pellet systems

- Introducing small and batch fed systems
- Types of biomass boilers
- Wood stoves
- Pellet stoves and boilers
- Log boilers

Forestry Commission

BIOMASS Energy Centre

DEPARTMENT OF ENERGY & CLIMATE CHANGE

REA RENEWABLE ENERGY ASSOCIATION

Introducing small and batch fed systems

This guide describes the use of logs and wood pellets in small and batch fed systems. These are wood stoves, pellet stoves, log boilers and pellet boilers with a maximum output of 50 kilowatts (kW). Installation of appliances up to this size is governed by the Building Regulations.

This guide and the two accompanying publications, *Biomass heating: a guide to medium scale wood chip and wood pellet systems* and *Biomass heating: a guide to feasibility studies*, are collectively concerned with low temperature hot water boilers of up to 3 MW, operating at a maximum flow temperature of 95 ˚C. *A guide to feasibility studies* is recommended for information on system selection, how to carry out a feasibility study, planning and regulations, emissions and chimney heights.

Types of biomass boilers

Low temperature hot water biomass boilers (those operating at up to 95 °C) can be classified by various methods based on fuel type or the physical characteristics of the boilers. The classification used here is based on fuel type. In general, large differences exist between stoves and boilers, stoves usually being much simpler devices than boilers. Some stoves incorporate a boiler; however, while stoves radiate heat into the room in which they stand, true boilers do not.

Pellet boilers and stoves

Pellet boilers and stoves range in size from a few kilowatts (kW), for houses or small commercial buildings, to megawatt (MW) units for district heating systems. Automatic hopper-fed fuel systems are usually used with these boilers and stoves. The hopper can be either built-in, in the case of some smaller systems, or a separate unit.

Of the biomass boilers, pellet systems are generally the most responsive to heat demands, have the simplest controls and are the closest to fossil fuelled boilers in terms of maintenance and operating intervention, although there can be large variations between systems from different manufacturers in terms of sophistication and features.

As mentioned in the introduction, pellet stoves and small pellet boilers (up to around 50 kW) are covered in detail in this guide, while larger pellet boilers (from 50 kW up to several MW) are covered in *Biomass heating: a guide to medium scale wood chip and wood pellet systems.*

Log boilers

Log boilers are fuelled with logs and larger pieces of wood, including joinery offcuts. Wood is manually loaded into the appliance, making them suitable for houses or small commercial applications where labour is available.

Log boilers are batch fed devices and simple to operate, but they require a large water storage cylinder (thermal store, accumulator or buffer tank) to capture the heat produced, and a managed wood store. Log boilers up to 50 kW are covered in detail in this guide. Small log stoves with an integral boiler are usually used in fairly simple systems, and may not always incorporate a thermal store.

Wood chip boilers

Fuelled by wood chips, which can be supplied with moisture contents from 15% to 50%, these boilers use a stoker burner or an underfed stoker for burning fuels between 15% and 30% moisture content, or a moving or stepped grate system for burning fuels up to 50% moisture content.

Sizes range from ≈40 kW to power station sized boilers of 100 MW and more. Boiler responsiveness is determined partly by the fuel moisture content which the boiler is designed to accept; in general the wetter the fuel, the less responsive the boiler. Wood chip boilers are covered in *Biomass heating: a guide to medium scale wood chip and wood pellet systems.*

Wood stoves

In the following description of wood stoves, the safety issues, and their integration into heating systems where an internal boiler is fitted, also apply to the sections on pellet stoves and log boilers covered later in this guide. For the sake of brevity the relevant information is not repeated in those sections.

Wood stoves vs open fires

When looking at wood stoves for the first time, some people use their experience of open fires as a starting point, but there are many differences between them. There is also a significant difference between the burning of solid mineral fuels (e.g. coal) and the burning of wood. As fuels, both coal and smokeless fuel require a considerable air supply from beneath and above the grate to burn the volatile gases given off from the firebed. Wood, however, requires very little air from beneath the grate once combustion is established but needs sufficient air in the gas zone above the fire or in a secondary chamber to ensure efficient combustion. An open fire is at best 20% efficient (37% with smokeless fuel) as large volumes of warm air from the room are lost up the chimney along with the smoke from the fire. Modern 'clean burn'[1] wood stoves, by comparison, may be around 80% efficient. These stoves can be used to heat single rooms or small houses and are available with outputs from 3.5 kW to 20 kW.

Figure 1
Modern clean burning wood stove (Forestry Commission).

Modern wood stoves

Wood stove technology has been developed to a point where clean burning and efficient stoves are now commonly available (Figure 1). Operating in an almost sealed enclosure, and with a well-controlled and distributed air supply, a number of these stoves are now approved for use in smoke control areas. Several types of wood stoves are available: those designed to heat a single room (with or without a back boiler) or, when an internal boiler is incorporated, those that provide all of the heating and hot water requirements of a house.

The use of modern designs results in higher combustion temperatures, and produces better fuel economy and fewer solid deposits than earlier designs. This technology provides the almost complete combustion of the tars and creosotes produced, resulting in a self-cleaning viewing window on the stove door and fewer deposits in the flue ways. For best results wood burning should take place on a bed of embers which trap fragments of charred wood and help to ensure the complete combustion of the fuel. Without an ember bed or a flat fire brick base, partially burned fuel would fall through the grate, resulting in reduced fuel efficiency.

[1] A clean burn wood stove burns wood efficiently by introducing a fresh supply of oxygen above the fire as well as beneath the grate. The gases, which would usually be sucked up the chimney, are burnt in a secondary combustion zone, creating more heat as most of the calorific value of the fuel is contained in these gases. Burning these gases also reduces emissions. Combustion and efficiency are also increased by pre-heating the secondary air supply by drawing it through channels around the hot firebox before it is directed to the top of the fire.

Simple wood stoves

The basic wood stove produces heat in two ways: by radiation from its hot surfaces and by convection from air drawn in around the stove casing which is discharged from slots on top of the casing. Such stoves can generally heat only one room but in a house designed to be open plan, convection currents can move heat to the different parts of the house. Some inset convector stoves have air distribution outlets from the convection chamber, allowing convected heat to be distributed to other rooms. Most of the heat emitted from this type of wood stove is by radiation. However, 'cool to touch' convection stoves, which heat primarily by convection and not by radiation, are becoming increasingly available.

Wood stoves with integral boilers

Wood stoves incorporating a hot water boiler are available. These are not dissimilar to the traditional back boiler in an open fire. Such a stove can potentially provide all the heating and hot water for a house; however, a significant proportion of the heat is still supplied to the room in which the stove is located, typically in the ratio 45% to the room and 55% to the boiler for a free-standing stove. Inset versions of stoves from some manufacturers have greater proportion of heat output to water because the stove jacket is insulated as part of the installation, and radiation only occurs from the front of the appliance.

Multi-fuel stoves

Some manufacturers market stoves suitable for burning both coal and wood, but such stoves are usually a compromise design between the different requirements for burning these two fuels. A multi-fuel stove is unlikely to be optimised for either fuel, while stoves optimised for burning one fuel will usually burn other fuels inefficiently. However, some multi-fuel stoves have an additional insert grate for the fossil fuel option to allow efficient operation with both fuels.

Problems may arise if both coal and wood are burned together. During combustion coal produces volatile gases containing sulphur while the combustion of even well-seasoned wood produces water vapour. Together, the sulphur and water vapour produce sulphurous acid and sulphuric acid which may corrode cold metal surfaces and shorten the life of the stove. This occurs when water in the flue gases condenses to form a liquid.

Flues

Flue liners

While brick chimneys are adequate for an open wood fire they should not be used for a wood stove. Closed wood stoves produce a more concentrated smoke and a higher moisture content in the flue gases. Condensation can occur when flue gases come into contact with a cold chimney surface, resulting in any residual tars and creosotes condensing in the chimney. These can soak into the brickwork, damaging the chimney, and also run back down to the stove causing a fire hazard. For this reason any existing chimney must be lined.

Several methods of lining a chimney are available, for example inserting a flexible stainless steel flue liner manufactured specifically for solid fuel use, using a pumped refractory concrete lining or adding a clay or concrete liner to the brickwork. The chimney must be thoroughly sealed against gas escape along its whole length, and against rain ingress between flue liner and chimney at the top. Flue pipes should have the same diameter or equivalent cross-sectional area as that of the appliance flue outlet. Flue liners must always be installed within a brickwork chimney. Where a chimney isn't available a convenient method of constructing one is to use prefabricated, insulated, twin wall chimney components. Any work on a chimney is notifiable to the local authority Building Control Department unless it is carried out by a registered competent engineer in combination with a stove installation.

Even with a lined and insulated chimney it is important to burn only quality dry timber. The use of damp or unseasoned wood must be avoided and the fire must not be left to slumber for long periods (e.g. overnight). In this situation the stove never reaches its design operating temperature, resulting in incomplete combustion and the production of tars, creosotes and high levels of carbon monoxide (CO) in the flue gases. The tars and creosotes then condense in the liner because there is insufficient heat in the flue gases to maintain a temperature above their condensation point. This is to be avoided because an insufficient draw from the flue can lead to CO spilling back into the dwelling with serious or even fatal health consequences.

Flue height

The height of a flue for an appliance rated at less than 50 kW is regulated by the Building Regulations and, as such, will be determined by the local authority Building Control Department. Building Control Consent or a Building Warrant will be required for all wood stoves in order to ensure compliance with the regulations, and that the flue is correctly matched to the stove. Alternatively, a registered competent engineer who has been approved under a relevant scheme, e.g. HETAS, would be able to self-certify an installation.

A flue which is too short will not produce sufficient negative pressure in the stove to draw the flue gases from the stove, and could allow these gases (including CO) to escape if sufficient combustion air is not available. Building Regulations require and specify minimum flue height which should be sufficient. A flue which is too tall will result in excess air flow through the stove which can cause combustion to occur too quickly; this, in turn, can cause the stove to overheat. Excess air flow in the flue will reduce the efficiency of the stove by carrying more heat than necessary up the flue. If this situation arises expert advice should be sought as draught stabilisation maybe required.

Combustion air supply

An adequate external air supply is essential for the safe operation of the stove. If the air supply in the room in which the stove is installed is insufficient the stove's flue could produce enough suction to place the room under significant negative pressure (European guidelines suggest that negative pressure should not exceed –4 pascals). Once a balance pressure has been reached the stove will be partially deprived of oxygen, resulting in the production of carbon monoxide (CO) and inefficient combustion. The lack of air will allow products of combustion, including CO, back into the room. Not only will the stove burn fuel inefficiently, increasing fuel consumption, but tar deposits may cause chimney fires and partial blockage of the flue. However, by far the greatest hazard is that the CO released creates an extremely dangerous situation for the occupants and must be avoided.

As well as avoiding negative pressure in the room, the stove and flue should ensure that the combustion chamber in the stove is always under negative pressure to prevent the escape of wood gas. Another guideline is that the room volume required for a stove should be a minimum of 4 m^3 per kW of stove rating. For example, in a typical modern living room measuring 5 m by 3 m and with a ceiling height of 2.4 m, a stove rated at no more then 9 kW should be used. In practice, in a well-insulated modern dwelling, a stove of no more than half this size is likely to be required, but in an old solid stone and poorly insulated house a stove of at least this size may be required, and care would be needed to ensure a sufficient air supply to the stove.

A particular issue arises in dwellings with an open-plan ground floor, where the kitchen is fitted with extractor fans. In a close to airtight modern building without adequate fresh air inlet for the stove, a kitchen extractor fan can reduce the room pressure to below the recommended –4 pascals. The installer must take these factors into account and then ensure that a large enough permanent opening to the outside air is provided near the stove for combustion air[2].

In all cases the installation must comply with the relevant advice in approved documents and technical standards.

System design

All batch fed wood boilers and most wood stoves with integral boilers should have an external heat store to take the heat from the boiler when a load is not present[3]. If this store is large enough it can provide for the daily peak loads experienced when a heating system is started each day, and also provide hot water for sinks and showers.

Various rules of thumb exist for sizing thermal stores associated with stoves and other batch fed boilers. European Standard EN 303-5 contains the following formula to calculate the size of storage tank required for a batch fed boiler within a stove:

$$V_{st} = 15\, T_C Q_N \left(1 - 0.3\, \frac{Q_H}{Q_{min}}\right)$$

where V_{st} is the volume of the tank, T_C is the combustion time at rated heat output, Q_N is the nominal heat output, Q_H is the building heat load and Q_{min} is the minimum output of the boiler.

In practice, however, the use of this equation may be unnecessary or too onerous. A commonly encountered rule of thumb suggests that the storage volume should be no less than 50 litres per kW (l/kW) of boiler rating. A range of between 50 l/kW and 75 l/kW is also often quoted although the upper end of this range may be too large for many applications and would, in turn, limit the size of boiler which could be fitted in a batch fed system.

As with the design of all wood burning systems it is important not to oversize the boiler for reasons of capital cost and system efficiency.

[2] The relevant guidance documents revert to HETAS which advises that wood stoves should not be installed where extractor fans are present. However, a passive stack vent is permitted in lieu of an extractor fan and the wood stove chimney can be considered as that passive stack vent for the purposes of complying with regulations.

[3] It is possible to install a log stove on an open vented heating system without a buffer tank but this wastes heat and is inefficient. A wood stove used in a central heating system must have thermostatic control of the burning rate based on the water temperature in the boiler and, as such, a slumber circuit on the thermosyphon is allowed if this is more practicable. This does not normally require a thermal store.

Stove with boiler: heating system design

Figures 2, 3 and 4 show the essential elements of a heating system based on a wood boiler[4]. The boiler should be allowed to heat up once the fire has been laid and before water is circulated around the system. This prevents condensation forming on the outside of the boiler. The simplest way to achieve the necessary level of control is to position a thermostat on the flow pipe from the boiler to control the boiler pump (pump 1). As the stove heats up, the water in the boiler heats up and convective circulation starts from the boiler to the thermal store. When the temperature of the water leaving the boiler is sufficient the thermostat switches on pump 1, dumping the heat produced into the thermal store which then charges up. If no load is present the heat will be stored.

Once a demand for heat occurs the heating pump (pump 2) switches on (shown here in Figure 3 under the control of a room thermostat and time switch) and draws heat from the thermal store. If the stove is producing heat at this time, the thermal store is effectively bypassed as shown. However, if the stove is not operating the thermal store meets the heat load for as long as hot water is available in the store, as shown in Figure 4.

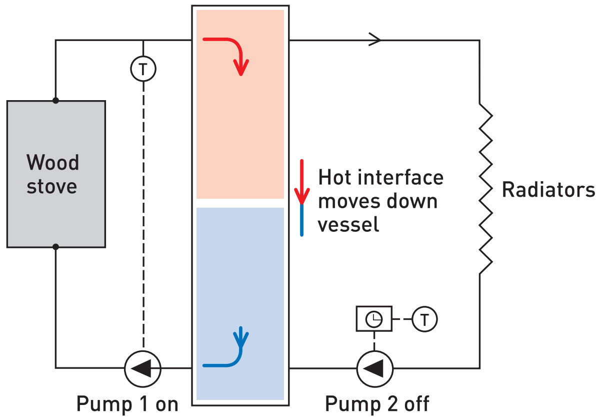

Figure 2
Wood stove burning: no load store charges (after D. Palmer).
Time switch and thermostat

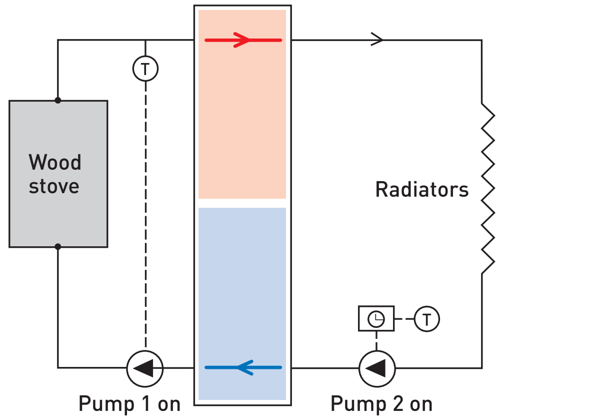

Figure 3
Wood stove on: load supplied from stove (after D. Palmer).
Time switch and thermostat

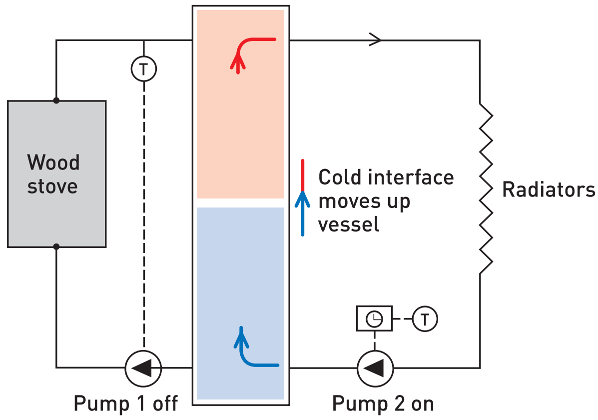

Figure 4
Wood stove off: load supplied from store discharges (after D. Palmer).
Time switch and thermostat

[4] While the schematic figures in this section show pumped solutions these can be installed as both open vented and unvented systems. If a sealed (unvented) system is installed it is essential that provision is made for water expansion and that necessary safety devices are installed including a pressure relief valve on the boiler which must discharge safely to drain via a tundish.

An example system

As an example, the wood stove shown in Figure 5, rated at 16 kW (of which 9 kW is available from the integral boiler), provides all of the heating and hot water for a family of three. The system is installed in a 120 m^2 house which is open plan on the ground floor and has a 500 litre thermal store (accumulator tank, Figure 6), equivalent to 55 l/kW. The thermal store is more than just a water tank as it incorporates a low velocity injection pipe (sparge pipe) for heating system return water to minimise mixing in the store and maximise the temperature difference across the store (stratification). An immersion heater is available to provide additional hot water.

The hydraulic schematic is as shown in Figures 2–4.

Figure 5
A 16 kW wood stove providing heating and hot water for a family home (Forestry Commission).

Figure 6
Thermal store: 500 litre accumulator tank (Forestry Commission).

Domestic hot water and solar panel options

Many manufacturers of thermal storage tanks provide coils within the tanks for hot water supply, for heating from solar panels and for heating from auxiliary heat sources (Figure 7). Figure 8 shows the layout of such a tank where mains cold water is introduced to the bottom of the upper coil and domestic hot water is produced on demand whenever a tap is opened. Solar coils are positioned lower down the tank so that the maximum benefit can be obtained from a solar panel. The solar panel manufacturer's entire installation kit would be used, including the solar pump and solar controller (not shown), to connect to a thermal storage tank. When installing these storage tanks, it is essential to check that the solar panel kit, in particular the pump, is a match for the solar coil in the tank.

Figure 7
Twin coil thermal store (Akvaterm Oy).

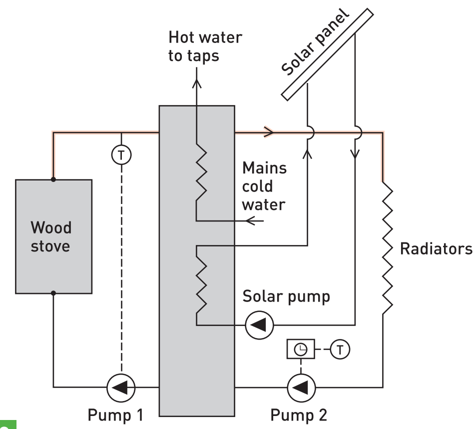

Figure 8
Layout of a thermal store with hot water and solar coils (after D. Palmer).

Time switch and thermostat

Maintenance

Stoves require regular de-ashing but a bed of embers on which to set a fire should be left. Providing the stove has been installed and is operated within the manufacturer's guidelines, and the wood burned is within the specification provided by the manufacturer, the only regular maintenance required will be thorough cleaning of the flueways, appliance flue connector pipe and the chimney. Most problems that may be experienced are likely to be associated with the setting-up and operation of the stove.

Combustion chamber flash back

Great care must always be taken when opening the stove door as burning gases can flare out into the room.

Pellet stoves and boilers

Pellet stoves

As an alternative to burning firewood or logs in a stove, fully automatic stoves designed to burn pellets are also available (Figure 9). These are much more sophisticated devices than wood stoves as, typically, they have automatic ignition, automatic metering and feeding of pellets from an internal hopper, segregation of primary and secondary air supplies (important for good combustion control) and combustion air fans. A fuel hopper can hold two days' fuel supply, and can be loaded manually from bags of pellets (Figure 10) or pneumatically from a larger fuel store.

Figure 9
Pellet stove and pellets (Forestry Commission).

Figure 10
Pellet boiler hopper (Forestry Commission).

As with wood stoves, pellet stoves can be supplied to provide a mixture of radiant and convective heating for a single room, or can incorporate an internal boiler to provide heating for a house. Automatic pellet stoves without internal boilers are particularly suitable for existing buildings where the cost of retrofitting a wet heating system could be prohibitive, or for low energy homes where the pellet stove could provide all of the heat required by air circulation.

Batch fed pellet boilers

Fully automatic, batch fed, pellet boilers are suitable where there is no space available for a fuel silo (store). They can be installed in a boiler room, basement or other suitable area and are loaded with pellets (supplied in bags) through the top of the boiler into an internal hopper as shown in Figure 11. The limited burn time offered by a small internal hopper means that batch fed pellet boilers are available in sizes only up to about 25 kW.

Figure 11
Automatic pellet boiler (Hoval Ltd).

System design

All the considerations relating to flues, air supplies and hydraulic system design (for stoves fitted with internal boilers) described for wood stoves also apply to pellet stoves and boilers: see relevant sections on pages 6-8. All wood burning appliances require some form of control to prevent condensation forming in the heat exchanger, caused by too low a return water temperature, and this often takes the form of a return water flow mixing device.

Maintenance

The burner should be checked daily, and any residue removed; it is important to prevent ash from being pushed into the burner as this could lead to blockages. Pellet stoves require regular cleaning and it is advisable to allow the stove to cool down after every 50 kg of fuel has been burned to permit a more thorough check and cleaning. Pellet stoves also require an annual manufacturer's service to ensure good continuing function of their mechanical components.

When carrying out internal inspections or in-depth cleaning it is important to isolate the stove from the electricity supply and to release the tension in any sprung components. As with wood stoves, it is also important that the fuel is of the highest quality and meets the manufacturer's specification; damp or badly broken pellets should be discarded.

Log boilers

Logs only boilers

Log boilers (Figure 12) are designed to burn much larger pieces of wood than wood stoves or any other type of automatic or semi-automatic boiler. Loaded from they top, they can usually accept logs of up to 1 m in length, and are manufactured with outputs up to about 70 kW.

In operation the controls on log boilers can be as sophisticated as those on fully automatic boilers. Separate control of primary and secondary air is usually provided together with a comprehensive control package to allow control of heating and hot water circuits. As with most batch type biomass boilers, a thermal storage tank is required (and is also highly beneficial for non-batch type boilers). This is particularly important with log boilers because of the high wood loading, and hence energy release, of the boiler. The thermal storage tank should be sized in accordance with the guidance given in the section on wood stoves (pages 7-8).

Log boilers are usually installed in a separate boiler room and are well insulated. Manufacturers can usually provide a complete set of components including a controls package, thermal store and control valves with the boiler, together with recommended connection schematics. The basic hydraulic configuration for a log boiler is essentially the same as that for wood stoves described on pages 8-9, and also requires a return flow mixing device to prevent condensation forming in the heat exchanger. A system able to prevent the boiler overheating following power failure or other major problem is required. Multi-coil storage cylinders can also be used to integrate solar panels into the heating system. The same considerations on flue design and air supply apply as for wood stoves.

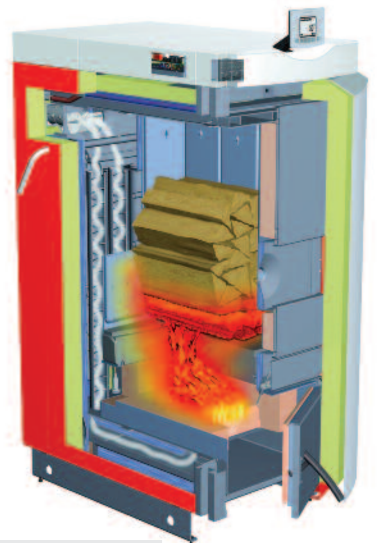

Figure 12
Log boiler (Windhager UK).

Combination log boilers

Some manufacturers produce log boilers that incorporate automatic feed pellet burners. These boilers combine the best features of a batch fed log burner and an automatic pellet burner, giving the user considerable flexibility over the way in which the boiler is operated, depending on the fuels available. A pellet fuel store or silo is required for use with this type of boiler.

Such boilers may have an automatic feed auger entering a pellet burning chamber from the far side, with a separate, adjacent, combustion chamber for logs. They may also feature automatic de-ashing, control of combustion air supply fans by a lambda sensor in the flue, and automatic ignition. For a more complete description of these features see *Biomass heating: a guide to medium scale wood chip and wood pellet systems.*

Maintenance

Following each use for burning logs excess ash needs to be removed from the boiler's loading chamber if automatic de-ashing is not provided. As with wood stoves it is usually necessary to leave some ash in the combustion chamber to provide a burning bed for the logs. Air openings in the combustion chamber should also be checked.

When the boiler is cold, and on a monthly basis, a more detailed clean is usually required, necessitating the removal of accessible combustion chamber parts. The fan should be cleaned every three months. Log boilers must be serviced annually by the manufacturer or installer.

A note on emissions

The complete combustion of wood produces emissions of fine particulates, nitrogen dioxide (NO_2) and carbon dioxide (CO_2), whereas the incomplete combustion of wood results in the release of CO, volatile organic gases, benzene and other undesirable substances some of which can be carcinogenic. For a more detailed understanding of emissions from wood burning appliances see the relevant section of ***Biomass heating: a guide to feasibility studies.***

If an appliance is to be used in a smoke control area it must be included in the Exempt Appliances list. Information is given in the relevant section of *Biomass heating: a guide to feasibility studies.*

Sources of further information

- *Biomass heating: a practical guide for potential users.* CTG012. The Carbon Trust, London, 2009. Download from www.carbontrust.co.uk
- *Home heating with wood* by Chris Laughton. CAT Publications, Machynlleth, Powys. Available from the Centre for Alternative Technology.
- The Biomass Energy Centre publishes a range of information on its website www.biomassenergycentre.org.uk
  These include: ***Wood as fuel: a short guide to buying and using logs in stoves and other appliances.***
  A number of other information notes, factsheets and online calculators are available from the Reference library section.
- HETAS is the official body recognised by government to approve solid fuel domestic heating appliances, fuels and services. Their website www.hetas.co.uk has information on approved installers, appliances and fuels.
- There is further information on smoke control areas and exempt appliances online at http://smokecontrol.defra.gov.uk

Biomass heating guides series

This publication should be cited as: Palmer, D., Tubby, I., Hogan, G. and Rolls, W. (2011). ***Biomass heating: a guide to small log and wood pellet systems.*** Biomass Energy Centre, Forest Research, Farnham.

Other guides in this series:
Biomass heating: a guide to medium scale wood chip and wood pellet systems
Biomass heating: a guide to feasibility studies

This publication was commissioned by the Department of Energy and Climate Change and Forestry Commission Scotland for the Regional Biomass Advice Network (RBAN).

Written, co-ordinated and produced by David Palmer, Ian Tubby, Geoff Hogan and Will Rolls, and peer reviewed by members of the Renewable Energy Association.

Information on flue design and specification kindly supplied by HETAS.

For further information please contact: www.biomassenergycentre.org.uk
email: biomass.centre@forestry.gsi.gov.uk

Editing: Jenny Claridge

Designed and printed by Colourgraphic Arts, Bordon, Hampshire.

Published by the Biomass Energy Centre, Farnham, Surrey.