SEAI SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Biomass Boilers - Technology Guide

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About SEAI
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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1. Introduction

Ireland has a long-term vision for a low-carbon energy system aimed at reducing greenhouse gas emissions from the energy sector by 80–95% (compared to 1990 levels) by 2050[1]. Achieving this target means a radical transformation of Ireland's energy system: reducing energy demand and moving away from fossil fuels to zero or low carbon-fuels and power sources.

Sustainably produced biomass is a low-carbon fuel, but resources are limited. Therefore, it is important to ensure that it is used as efficiently and effectively as possible. Other potential impacts from biomass use, such as emissions of pollutants that affect air quality, need to be minimised and biomass installations must be operated safely. Biomass boiler systems differ significantly from those fuelled by gas or oil. It is important to address these differences in planning, design and operation to ensure a well-functioning, safe and efficient biomass boiler system.

This guide is provided as part of a suite of three biomass guides: an Implementation Guide, Technology Guide, and Operation and Maintenance Guide, which collectively aims to provide an understanding of biomass technology, its implementation and operational management.

1.1 Purpose of this guide

This Technology Guide is principally intended for engineers, consultants and installers, particularly those with limited experience of non-domestic biomass boiler systems. It will also be of interest to others such as facilities/engineering managers, environmental managers and technical maintenance staff, who wish to seek more knowledge on such systems to engage with the supply side. The two main aims are:

1. To provide a guide to understand the technology of biomass boiler systems, good practice and technical issues.
2. To direct the reader to sources of more detailed information on aspects of the technology. This guide and its two companion guides do not duplicate existing publications on biomass boilers; rather, they are intended as a comprehensive starting point for those wishing to better understand the technology, and its implementation and management.

1.2 Scope

- The guides concentrate on solid biomass boilers for non-domestic premises in the heat output range of 50kW to 5MW. Much of the guidance will also apply to smaller and larger scale boilers.
- These guides focus on the distribution of heat from boilers in hot water systems for non-domestic space, water and process heating.
- Power generation, combined heat and power (CHP) and direct air heating systems fuelled by biomass are not covered in these guides.
- These guides focus on wood (both virgin and waste) fuels, mainly in the form of logs, pellets and chips. Other fuels covered are straw and chicken litter (agricultural residues) and energy crops such as short rotation coppiced willow and miscanthus (elephant grass). Liquid and gaseous biofuels are not considered.
- Outside the scope of these guides, are the Support Scheme for Renewable Heat [2] terms and conditions. The Support Scheme for Renewable Heat is a government-funded scheme, to encourage the installation of renewable sources of heat in non-domestic applications in the Republic of Ireland. These guidelines will help applicants identify the appropriate standards and best practice for solid biomass uses. For the avoidance of doubt, these guidelines provide an applicant with guidance on good practice only. The Ministerial Terms and Conditions, the Grant Scheme Operating Rules and Guidelines and the Tariff Scheme Operating Rules and Guidelines, where relevant, set out the basis on which the Support Scheme for Renewable Heat will operate.

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[1] https://www.dccae.gov.ie/en-ie/climate-action/publications/Documents/5/National%20Climate%20Policy%20Position.pdf

[2] https://www.seai.ie/sustainable-solutions/support-scheme-renewable-/

2. Biomass fuels

A range of biomass fuels can be used in boilers, but each fuel has particular characteristics that influence: (i) the choice of boiler type, and (ii) the design and requirements for other parts of the system, such as fuel handling and storage.

The use of unsuitable fuels in a boiler can result in one or more of the following:

- Damage to the boiler.
- Health and safety issues.
- Inefficient operation of the boiler.
- Excessive emissions.
- Blockages in the fuel-feed system.
- Condensation of tar in the flue.
- Disruption to the generation/supply of heat.

As discussed in the accompanying Implementation Guide, the choice of fuel is determined by the availability, reliability of supply and price, as well as site characteristics such as the scale of heat loads to be supplied; space available for fuel deliveries, storage and handling; the level of automation required; and any local air-quality restrictions.

2.1 Types of biomass fuel

2.1.1 Wood fuels

Wood is one of the most commonly used biomass fuels. It is supplied either as logs, chips (or shredded wood) or pellets. The characteristics of each form of wood fuel influences the choice of the boiler type.

Wood logs are more easily available in rural areas and most commonly used in smaller scale systems, as they are usually manual loaded into the boiler.

Figure 2.1: Wood logs stacked for drying

Wood pellets are available from various suppliers. Generally manufactured based on specific standards to ensure consistent combustion and handling qualities (see section 2.2). Wood pellets have a higher energy density than wood chips and take up less storage space. Although pellets tend to be used in smaller boiler installations (up to around 200kW), there are no set rules in this regard, and larger boilers suitable for pellets are available.

Figure 2.2: Wood pellets

Figure 2.3: 'Clean' wood chips

Wood chips are typically cheaper than wood pellets on a euro per kWh basis. More storage space is needed for wood chips, and they are typically used for larger systems. However, boiler systems with lower outputs (~15 kW) suitable for wood chips are also available.

Wood chips may originate from:

- 'Clean' wood (i.e. virgin wood, or untreated wood that is a by-product of processes in sawmills and furniture production).
- Waste wood

The use of some waste wood chips can contribute to environmental pollution[3] due to the presence of:

- Treatments/coatings such as paints, laminates, varnishes and preservatives.
- Resins and glues.
- Extraneous materials such as metals, grit, plastics, glass, paper and textiles.

Contaminants of particular concern include heavy metals and halogenated organic compounds. The waste should be treated as hazardous if copper, chromium or arsenic is present.

[3] EPA Position Paper 'The Regulation and Management of Waste Wood'.
www.epa.ie/pubs/advice/waste/waste/regulationandmanagementofwastewood.html

Figure 2.4: Contaminated waste wood stock for wood chip production

Waste wood is subject to regulatory control unless the holder demonstrates, to the satisfaction of the relevant competent authority (Environmental Protection Agency (EPA) or local authority), that the material meets applicable by-product or end-of-waste status criteria. Burning waste wood must comply with the requirements listed in the Industrial Emissions Directive, unless the EPA has granted an exemption on the basis that the wood is free of halogenated organic compounds or heavy metals.

Determining if wood is waste wood or a by-product
(Extract from 'The Regulation and Management of Waste Wood', EPA, Sept 2013[4])

Regulation 27 of the Waste Directive Regulations[5] (S.I. 126 of 2011) indicates that a substance or object is regarded as a by-product rather than waste if the following conditions are met:

- further use of the substance or object is certain;
- direct use of the wood without any further processing, other than normal industrial practice;
- the wood is produced as an integral part of a production process; and
- further use of the wood is lawful, i.e. the wood fulfils all relevant product, environmental and health protection requirements.

Operators must notify the EPA when they make a decision that a material is to be regarded as a by-product. The material is presumed to be waste wood by the EPA, until proven otherwise.

The EPA considers that the following typically meet Regulation 27 requirements, provided that they are not discarded; not mixed with non-virgin woods; are untreated; and are free of extraneous materials such as metals:

- residual branches, bark, chip and dust arising from tree felling and tree surgery; and
- virgin wood from sawmilling and the manufacture of timber products.

[4] http://www.epa.ie/pubs/advice/waste/waste/regulationandmanagementofwastewood.html
[5] www.irishstatutebook.ie/eli/2011/si/126/made/en/pdf

2.1.2 Other fuels

Other biomass that can be used as a fuel includes straw; poultry litter or other animal bedding; and energy crops.

Straw. This is typically burnt as bales in specially designed boilers. It has a relatively high silica content and often contains high concentrations of chlorides which, by reducing the ash fusion temperature, promote slag formation. Slag can bind to the grate and may block and damage ash-handling equipment. Straw boilers are specifically designed to manage these problems.

Poultry litter or other animal bedding. Poultry litter consists of chicken manure and bedding (typically wood chip/shavings). Under EU regulations, on-farm combustion of poultry litter can be undertaken up to a total rated thermal input of 5MW. The combustion of poultry litter or other animal by-products must conform to the regulations listed in the box on page 6. These regulations are transposed into Irish Law as S.I. No. 187/2014 – European Union (Animal By-Products) Regulations 2014[6]. Enterprise Ireland has produced an explanatory guide to this legislation[7] and further information is available from the Department of Agriculture, Food and the Marine[8].

Figure 2.5: Typical large poultry shed

The combustion of poultry litter is usually, though not exclusively, carried out in fluidised bed combustion (FBC) boilers. These boilers provide more effective combustion, particularly for lower quality and variable moisture content (MC) fuels (see section 3.2.2).

[6] http://www.irishstatutebook.ie/eli/2014/si/187/made/en/print
[7] Enterprise Ireland (2015) Animal By-products legislation: an explanatory guide, see: https://www.leanbusinessireland.ie/wp-content/uploads/2017/05/2015-Animal-By-Products-OCTOBER.pdf
[8] For contact details and relevant forms see: https://www.agriculture.gov.ie/agri-foodindustry/animalbyproducts/applicationformsconditionsforabpprocessingoperations/applicationformsforabpprocessingoperations/

Legislation regarding the on-farm combustion of poultry litter

The requirements for on-farm combustion of poultry litter are set out in Regulation EC 1069 of 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption[9]. This has been transposed into Irish law through S.I. No 187.2014.

There are two relevant amendments:

- EU 142 of 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council: provides for health rules for animal by-products and derived products not intended for human consumption and implements the Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive[10].
- EU Regulation 592/2014 amending Regulation (EU) No 142/2011: focuses on the use of animal by-products and derived products as a fuel in combustion plants[11].

Energy crops. These are crops grown specifically for use as a biomass fuel. They include woody energy crops (e.g. short rotation coppice, such as willow and poplar) that are typically harvested on a 3-year cycle and grassy energy crops such as miscanthus, which is harvested annually. The woody energy crops are normally chipped or pelletised prior to use.

Figure 2.6: Miscanthus crop

Miscanthus can be baled and burnt in boilers, but can also be chipped or pelletised. It is generally used in large scale installations (such as in power stations) although there are wood-chip boilers that can use miscanthus chip and some straw boilers can use baled miscanthus. Miscanthus has a low ash-fusion temperature and is therefore prone to slag formation when combusted. Therefore, the temperature of combustion needs to be carefully controlled and the addition of slaked lime to the fuel to raise the ash-fusion point is sometimes recommended by boiler suppliers.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1448630763314&uri=CELEX:02009R1069-20140101
[10] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32011R0142
[11] https://publications.europa.eu/en/publication-detail/-/publication/aad92ddc-ebbe-11e3-8cd4-01aa75ed71a1/language-en

2.2 Fuel characterisation and quality standards

The characteristics of biomass fuels vary. These fuel characteristics determine how the fuel should be burnt, and what they are best used for. The important characteristics are summarised in Table 1, and should be specified in any fuel supply contract.

Table 1: Summary of key physical characteristics of biomass fuels

Parameter	
Calorific value	The calorific value (CV) of a fuel indicates the energy content that is released when the fuel is completely combusted. CV can be expressed on either a 'gross' or 'net' basis [12] (sometimes referred to as the higher and lower heating values – HHV and LHV respectively). Biomass fuel CVs are normally expressed in net terms as MJ/kg or kWh/tonne. The moisture content (MC) of a biomass material has a significant impact on its CV. The higher the MC, the lower the CV of the fuel. CV may be expressed on an as-received basis, (i.e. reflecting the MC of the fuel when it is delivered to the end user) or expressed on a dry-weight basis, allowing comparisons to be made between fuels. It is important to understand the basis on which any CV value is quoted: net vs. gross and at what MC.
Moisture content	The Moisture Content of a biomass fuel is expressed as a percentage of the fuel's weight; the higher the MC, the lower the CV. In general, wood pellets should have a MC of less than 10%. Wood chip and logs can be purchased at a wide range of MC depending on various factors, but principally on how seasoned the wood is or how dry it is. Specifications for biomass fuels should always include an acceptable range for MC.
Bulk density	Bulk density is a measure of the mass of the fuel divided by its volume. Bulk density is important for transporting and storing the fuel. The volume will include space between the particles (e.g. logs, chips or pellets). The higher the bulk density, the more of the fuel (and therefore energy content) exists in a specific volume. MC impacts bulk density as fuel particles will have a greater mass but will occupy the same space. Consequently, fuel with a high MC will have a higher bulk density and lower energy density than the same volume of fuel with a lower MC.
Energy density	Energy density is a measure of the energy contained within a unit of fuel and is derived from the bulk density and CV. Energy density is expressed in energy available in a specific volume of fuel (e.g. MJ/m^3) and is derived from multiplying the CV of a fuel by the bulk density. Understanding the energy density of a fuel is important, as it matters for fuel consumption rates, size of fuel storage, frequency of deliveries and total annual fuel quantities.
Particle size	Boiler manufacturers specify acceptable fuel particle sizes for their equipment (usually by referencing a particular specification and class) to ensure optimum combustion. Feed systems will be designed accordingly and using fuel with particles oversized or undersized (fines) can lead to blockages. For automatic systems, it is particularly important that the fuel flows well, without bridging (in the case of chips) or disintegration, which can result in the accumulation of fine particles, especially in the case of pellets.
Ash content	The ash content is specified as a percentage of the fuel's mass on a dry basis. The quantity of ash produced depends on: • the fuel's ash content, • low combustion efficiency, • when the fuel contains extraneous matter, • the inclusion of bark.

National and international standards organisations have developed standards for biomass fuels. These cover specifications for the physical and chemical characteristics that are important in combustion, handling and storage; and for procedures analysing fuel characteristics and combustion emissions.

[12] The gross calorific value of a fuel is the total energy released during combustion including that needed to evaporate any water arising as a combustion product and the moisture content of the fuel.
The net calorific value of a fuel is the total energy released during combustion excluding that needed to evaporate any water arising as a combustion product and the moisture content of the fuel.

These standards help ensure that problems with fuels (for example, inefficient combustion, excessive emissions, blockages in the fuel-feed system or condensation in the flue) can be avoided or addressed. Fuel suppliers can process fuels to a common specification, analysts can follow standard procedures and boiler/combustion equipment suppliers can design their equipment to meet these standards. Boiler manufacturers invariably provide specifications that stipulate the fuel standards applicable to their products.

In Europe, the European Committee for Standardization (CEN), under Technical Committee CEN/TC 335[13], has developed a suite of standards on different aspects of biomass fuels. These have been adopted internationally by the International Organization for Standardization (ISO).

The overarching standards for biomass fuels are: 'Solid biofuels - Fuel specifications and classes – Part 1: General requirements' (ISO 17225-1:2014). This provides the most useful parameters and is most widely used for classification and standardisation. The scope of ISO 17225-1:2014 'determines the fuel quality classes and specifications for solid biofuels of raw and processed materials originating from a) forestry and arboriculture; b) agriculture and horticulture; and c) aquaculture.'[14]

The following is a list of further parts of ISO 17225 deal with specific fuels:

- EN ISO 17225-2:2014 Solid biofuels - Fuel specifications and classes - Part 2: Graded wood pellets (ISO 17225-2:2014).
- EN ISO 17225-3:2014 Solid biofuels - Fuel specifications and classes - Part 3: Graded wood briquettes (ISO 17225-3:2014).
- EN ISO 17225-4:2014 - Solid biofuels - Fuel specifications and classes - Part 4: Graded wood chips (ISO 17225-4:2014).

The standards are available to purchase from www.nsai.ie. They provide definitions for key fuel parameters, including:

- Moisture content.
- Dimensions: to ensure it meets the requirements of the boiler and its fuel-handling system.
- Ash content.
- Chlorine content.
- Bulk density.
- The origin of the material: the source and content of the fuel.

There are also various standards setting out methods for testing to demonstrate that a specification is being met. A useful source of information on existing standards is www.Woodenergy.ie[15].

As well as formal standards, there are certification schemes for wood fuels such as the Wood Fuel Quality Assurance (WFQA) scheme for Ireland[16] and Enplus®[17], a European certification scheme for wood pellets that verifies that pellets meet ISO or CEN standards and other requirements such as sustainability.

Wood chip is not always sold under a specific standard. Therefore, it is important that the site operator ensures that the fuel characteristics are clearly specified at the design stage and that fuel purchased meets those requirements. Purchasing fuel certified under schemes such as WFQA or ENplus® will help achieve this.

[13] https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:19930&cs=17158638AB0C35D5E52A369017E54A1D6
[14] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:39131&cs=1D71D6D8661FDD010555C381013211288
[15] http://www.woodenergy.ie/
[16] http://wfqa.org/
[17] https://enplus-pellets.eu/en-in/

2.3 Fuel delivery, storage and handling

2.3.1 Fuel delivery

Practical aspects of fuel delivery include:

- The proposed fuel type (wood chip, pellet, logs, bales, etc.).
- Vehicle access and other site constraints.
- Vehicle types and delivery methods of potential suppliers.

Examples of fuel delivery methods are summarised in Table 2 along with their typical applications, advantages and disadvantages.

Table 2: Summary of fuel delivery methods

Delivery method	Typical applications	Advantages/disadvantages
Tanker with pneumatic flexible hose	Usually pellet, but can be used for chip	Can deliver high volumes but requires specialist vehicles and hose connection points at the fuel store. Hoses can extend; this can be useful for sites with restricted access. Discharge rates should not exceed 12 tonnes/hour per 100mm delivery pipe to avoid pellet damage during delivery. Depending on the store, slower discharge maybe necessary. Pneumatic systems can be noisy and tend to give rise to dust.
Bulk bags	Pellet, chip or logs	Suitable for smaller consumption volumes and flexibility in fuel types. Can be more expensive due to smaller loads. Further handling usually needed post-delivery.
Tipper trailer	Pellet, chip or logs	Widely available, quick to unload. Requires good vehicular access and clearance to tip the trailer. Normally requires a large storage area. Storage is best located underground or with a ramp to allow trailer discharge. Tipper trailer can be noisy and tend to give rise to dust.
Walking floor trailer	Chip	Suitable for large volumes, but good access and clearance required for delivery and turning of vehicles. Walking floor trailer systems can be noisy and tend to give rise to dust.

Fuel discharge to store

As indicated in Table 2, pellets are most commonly blown from lorry to store via a pneumatic hose that is connected to a fill-pipe with a standard industry connector. Deliveries can take a significant amount of time, as the rate of discharge should be limited (to 12 tonnes/hour per 100mm diameter pipe) so as not to damage the pellets.

Wood chips are most often delivered by lorry with a tipper or walking floor trailer, either directly into an underground store via a metal grill or into a surface-level bunker, either directly or via the use of telehandlers or similar machinery.

Fuel storage
Biomass fuel storage design will be site-specific. It depends on the choice of fuel and delivery method, available space at the site and any other physical constraints; and the location of the boiler. Fuel stores can be above or below ground, part of existing or purpose-built buildings, or a containerised system. Some fuels (for example logs and bales) can be stored may outside, but there should be some form of shelter to keep them dry. Wood chip can be stored in open-fronted bays provided there is a roof. The best storage solution for wood chip is a store that is enclosed and has adequate ventilation. Always keep wood pellets in enclosed containers or hoppers as damp conditions can cause the pellets to bond together.

Types of fuel store include:

- Bunkers (purpose-built or converted from existing buildings or stores).
- Bag silos, supported by frames.
- Hoppers and silos.

Fuel monitoring
In many biomass boiler installations, the monitoring of fuel consumption is carried out by visually checking how much fuel remains in the store. For enclosed stores, one or more sight glasses or windows are usually fitted. Ultrasonic or laser fuel-level sensing systems are available that provide a remote-monitoring function and can be connected to a Building Management System (BMS). This can notify the operator or fuel supplier when the fuel level has reached the re-order point.

Fuel handling
The way in which fuel is transferred to the boiler depends on the fuel and storage type. Bales and logs are typically batch-fed, which can be manually intensive and is only suitable for smaller systems or where there is sufficient labour on hand. Wood chip is commonly fed to the boiler via an auger system. This uses an agitator arm within the fuel store and a screw feed to move the fuel from the store to the boiler grate. Walking floor systems and scraper chain conveyors are used for larger systems. Wood pellets are usually pneumatically conveyed from the pellet store, with larger systems being gravity fed from an overhead hopper or silo.

Health and safety
There are various health and safety risks associated with the handling and storage of biomass fuels and a health and safety statement should be produced. Carbon monoxide (CO) from the fuel can build up in sealed pellet storage rooms, bunkers and hoppers. Similar issues can occur with wood chips. The UK Health and Safety Executive suggest taking mitigating actions[18]. It is recommended to install CO alarm/s in the fuel store and plant room.

As well as CO, pellet stores can produce significant amounts of dry dust which , can cause dust explosions when it is highly concentrated. Precautions that should be incorporated at the design stage and during operation can be found in the Operation & Maintenance guide and the Combustion Engineering Association's guidance 'Health and Safety in Biomass Systems'[19].

[18] www.hse.gov.uk/safetybulletins/co-wood-pellets.htm and http://www.hse.gov.uk/research/rrpdf/rr1077.pdf
[19] www.cea.org.uk/files/4313/7502/0795/Biomass_HS_final_071211.pdf

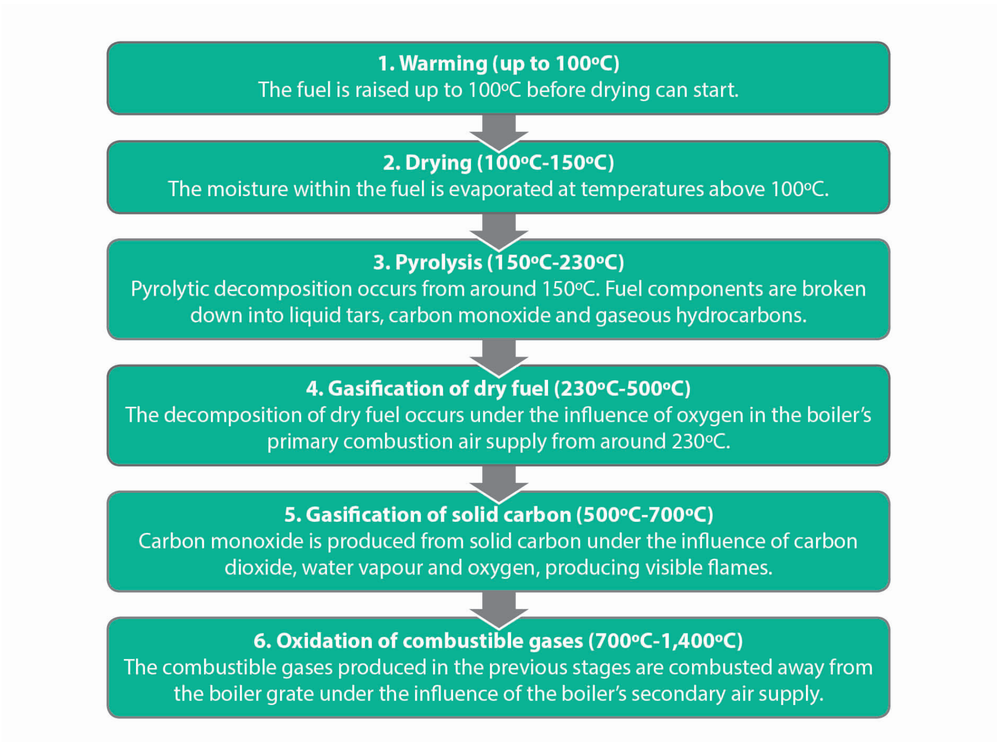
3. Biomass boilers

3.1 Introduction

Biomass boilers differ from oil or gas-fired boiler counterparts in a number of ways. In particular:

- **Boiler size.** Biomass boilers are physically larger than oil and gas-fired equivalents. More space surrounding the biomass boiler is needed (access for cleaning, fuel-feed and ash-removal systems etc.).
- **Boiler responsiveness.** Biomass boilers are slower to respond to changes in heat demand. This can be managed by intelligent control, thermal storage and/or the use of top-up conventional boiler capacity. The turndown ratio[20] of biomass boilers is lower than that of gas or oil-fired boilers.
- **Fuel storage**. More space is needed on site for fuel storage. Boilers that are fired on oil or liquefied petroleum gas (LPG) need space for fuel storage, but biomass systems require far more space due to the lower energy density of the fuel.
- **Fuel delivery**. Due to the lower energy density of biomass fuels, access suitable for large vehicles and/or deliveries that are more frequent is needed.
- **Emissions**. It is more difficult to control emissions from biomass boilers than from oil and gas-fired boilers. Biomass boilers produce fly ash and particulate matter that may require the installation of additional abatement equipment. In addition, nitrogen oxide (NOx) emissions per unit of heat generated are usually higher than those from fossil fuel-fired boilers. If NOx emissions are not sufficiently managed by the control of combustion conditions, then additional flue-gas abatement equipment may be required.

Figure 3.1: The six stages of biomass combustion



A more detailed description of the combustion process can be found in the Chartered Institution of Building Services Engineers (CIBSE) publication 'Biomass Heating, AM15: 2014'.

[20] The turndown ratio of a boiler is a measure of its ability to operate at heat outputs less than the full rated output. It is the ratio of the maximum heat output to the minimum level of heat output at which the boiler will operate efficiently or controllably. For example, a boiler with 2:1 turndown ratio will be able to operate down to 50% of its full rated output.

3.2 Boiler types and characteristics

There are various factors that determine biomass boiler selection, including:
- Heat generating capacity required.
- Fuel type and characteristics.
- Required boiler responsiveness and turndown ratio.
- Requirements for limiting emissions.

There is a wide range of biomass boiler types available that can meet end users' specific preferences and requirements. This guide describes the most common types of boiler available. Additional advice can be sought from biomass boiler suppliers or manufacturers.

Biomass boilers can be classified by a combination of the following parameters:
- Boiler Capacity/rating kW.
- Automatic versus manual feed of fuel.
- Stoker type (fuel supply).
- Ignition: automatic ignition versus slumber mode.
- Fire tube orientation.
- Fuel type (s).

3.2.1 Boiler capacity

The majority of non-domestic biomass boilers have a heat output range of around 50kW to 5MW and are designed to produce heat in the form of hot water. Boilers of capacity greater than 1.5MW can generate steam for heat transfer. Boilers that use thermal oil as the heat transfer medium are usually available above 3MW.

Apart from those using logs, most non-domestic boilers are automatically fed with fuel. Smaller boilers may only have a small integral fuel hopper that requires regular manual reloading with wood pellets. Some larger boilers, for certain fuel types such as straw may also be manually fed, particularly at sites where there is low-cost manual labour available. Automated systems are more complicated and less mechanically robust than manual systems.

3.2.2 Automatic stoker types

Automatic stokers introduce the fuel into the boiler for combustion and are an integral part of the boiler design. The stoker design will be determined by factors including the boiler capacity, the type of fuel and its moisture content (MC), and the degree of control needed for combustion efficiency and boiler emissions.

Stokers are either overfed or underfed, introducing the fuel from above in overfed stokers and below for underfed stokers.

Stoker burner boilers
The stoker burner is an overfed stoker type. They are more common for use with smaller capacity boilers (typically 30kW to 50kW), but can be used for boilers up to 1MW. Using an auger, fuel is transported onto the grate, which can be in the form of a cast iron tube.

Stoker burners are suitable for wood chip and wood pellets, provided the MC is less than about 30%. The small combustion chamber size means that there is limited refractory material present to reflect heat onto and drive moisture from the fuel. This makes this boiler type more sensitive to MC, but more responsive to changes in heat demand than other boiler systems. Ash is pushed off the grate into the ash pan by the auger when introducing new fuel.

Primary and secondary combustion air is normally provided by a single fan, which restricts the ability to limit the temperature at the grate while maintaining a higher temperature in the secondary combustion zone.

Advantages:

- Simplest type of automatically fed boiler.
- Relatively low cost. Good turndown ratios with low fuel consumption in slumber mode (if used).
- Relatively rapid response to changes in heat demand.

Disadvantages: Boiler performance is very sensitive to changes in MC and chip/pellet size. If the MC is too high, black smoke is likely to be produced due to incomplete combustion. Smaller systems may not have separate primary and secondary combustion air fans. This makes it difficult to control the temperature of combustion and may result in ash melting (fusing) on the grate, and can also make it difficult to control the formation of NOx. The first problem can be prevented by incorporating a water-cooling circuit in the grate and the second by recirculation of flue gases into the combustion chamber.

Figure 3.2: Schematic of a stoker burner

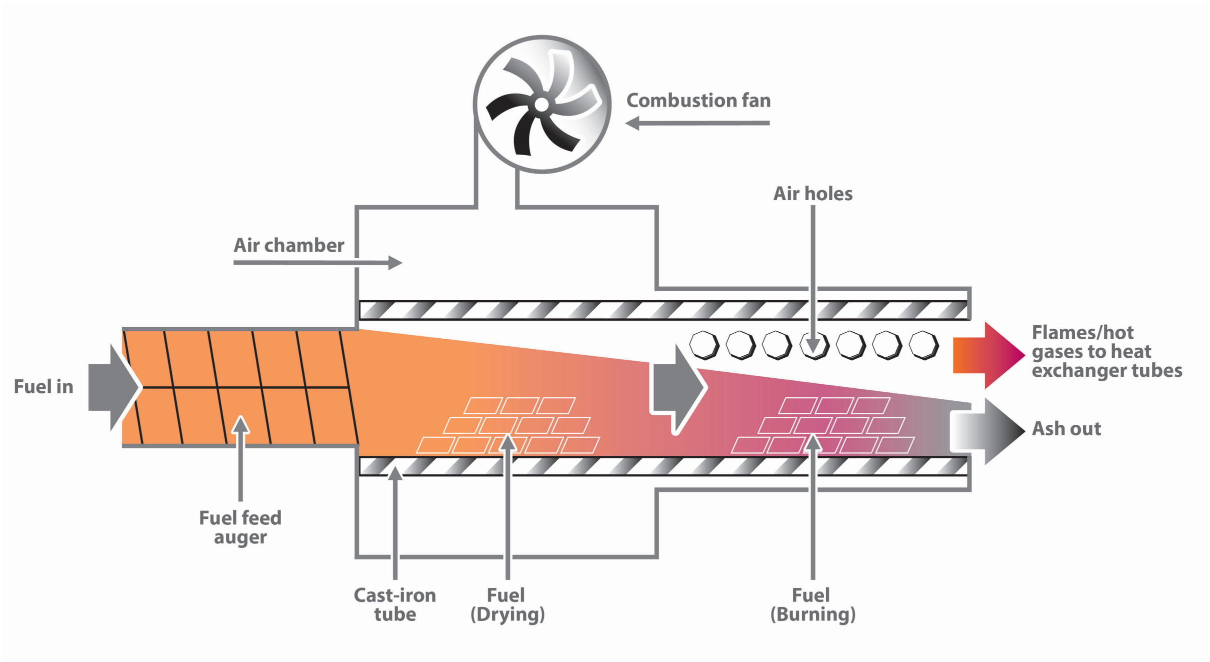


Figure 3.3: Small stoker burner boiler

Moving-grate boilers (also known as stepped or inclined grate boilers)
Moving-grate boilers are overfed and are available in a wide capacity range (10kW to 10MW), and offer great flexibility for boiler design and fuel choice. Fuel is introduced onto a series of inclined flat panels (also called fire bars) which move in sequence, causing the fuel to shuffle down the incline towards the ash pan. This sequence of fuel movement means that the combustion stages occur at different places on the grate, affording greater control of the overall combustion process. By changing the speed of the grate, the duration spent in the drying zone can be changed, ensuring that fuels with a wide range of MC can be accepted by the boiler. This helps complete combustion, preventing black smoke (soot).

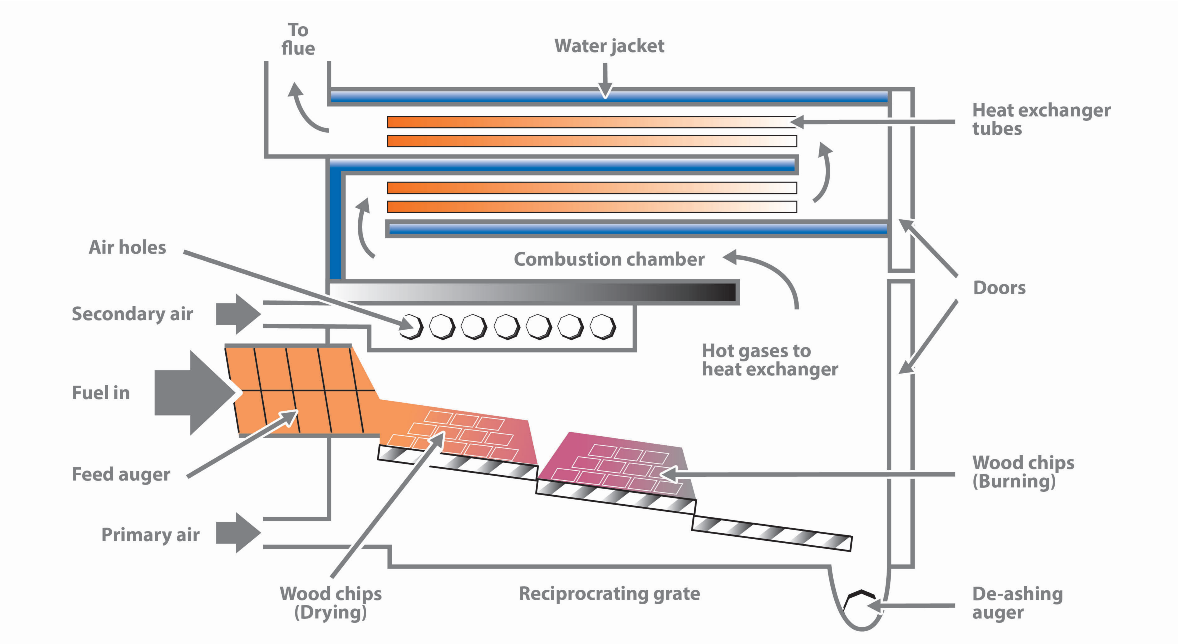
As well as being able to accept fuels with a range of MC, these boilers can accept fuel with high absolute MC. The space inside the combustion chamber allows for high levels of refractory lining, which means that the capacity to reflect heat onto incoming fuel is significant, allowing fuels of high MC to be accepted. On the downside, the high levels of refractory lining mean that the response of the boiler to changes in heat demand is slow.

Moving-grate boilers can burn wood chips and pellets. However, using chips is more common because they are cheaper and the MC tends to be higher than that of wood pellets. Fuel is introduced using either an auger or a ram stoker (see section 3.2.4). Separate fans for primary and secondary combustion air provide additional control.

Advantages: Designs can accept fuels with a range of MC (up to 55%). The moving grate means that problems with clinker (slag) forming on the grate are less likely to occur, which means that these boilers can be fuelled with a wider range of biomass compositions. Separate primary and secondary combustion air fans enable a high level of control.

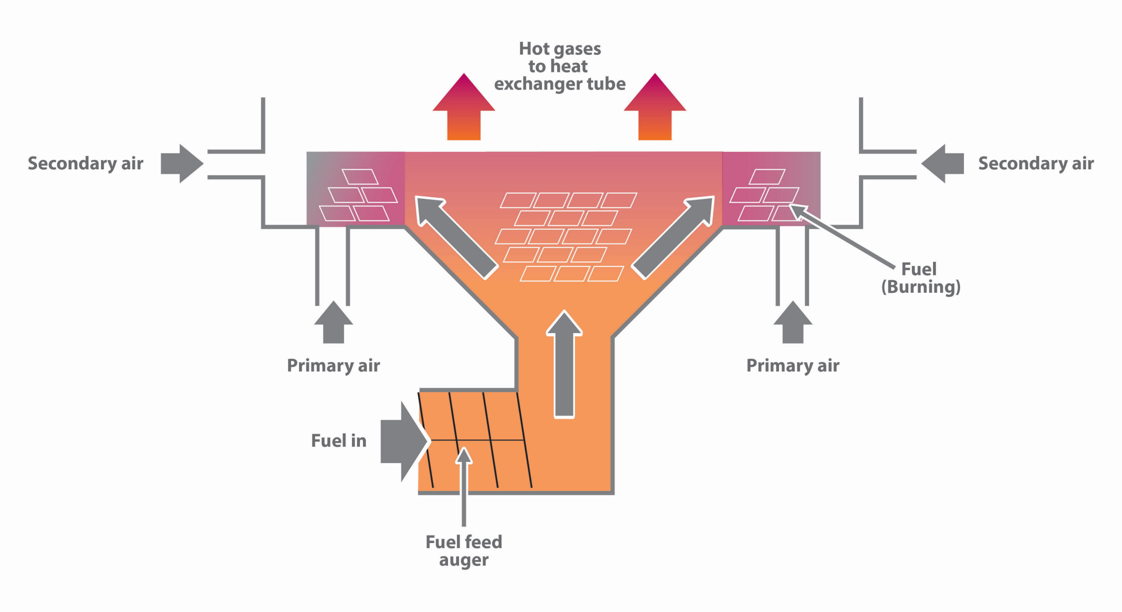
Disadvantages: When designed for high MC fuels, the additional refractory material means that response to changes in heat demand can be slow and the fuel consumption in slumber mode (usually used with this boiler type) is high.

Figure 3.4: Schematic of a boiler using a moving grate



Underfed stoker boilers
In the underfed stoker, fuel is fed by an auger to the combustion chamber from under the grate. The fuel is forced up through an inverted cone to form a dome of fuel on the grate where combustion takes place. As more fuel is introduced, the ash falls from the periphery of the dome into an ash bin below. Wood chip and pellet fuel can be used, usually with a MC less than 30%. Underfed stoker boilers are available up to around 5MW.

Figure 3.5: Schematic of an underfed stoker



Like the stoker burner design, the low refractory mass (low thermal mass) and low fuel inventory mean that these boilers can respond rapidly to changes in heat demand. Most underfed stoker designs have separate primary and secondary combustion air fans, aiding complete combustion.

Figure 3.6: Underfed boiler combustion chamber

Advantages: Simple mechanism with a wide range of boiler sizes available. Good turndown ratios with low fuel consumption in slumber mode (if used). Relatively rapid response to changes in heat demand.

Disadvantages: Boilers can only accept chips/pellets within a narrow range of MC and particle size.

3.2.3 Other boiler types

Log boilers
Log boilers are manually batch-fed and can burn wood logs or briquettes made from forestry waste or brash. Log boilers are relatively cheap, but operation requires more manual labour. Consequently, they tend to be used at sites where there is already labour available, such as workshops and farms. Log boilers are most commonly used in smaller scale systems. An accumulator tank, holding at least 50 litres of water per kW of boiler rating, should normally be connected to a log boiler. Logs need to have a MC of typically less than around 20% throughout to avoid soot due to incomplete combustion.

Advantages: Relatively low cost. Simple and robust, easy to maintain. Fuel is generally low cost.

Disadvantages: The fuel must be relatively dry, typically less than 20% MC. Requires labour and frequent intervention.

Figure 3.7: Schematic of a batch boiler

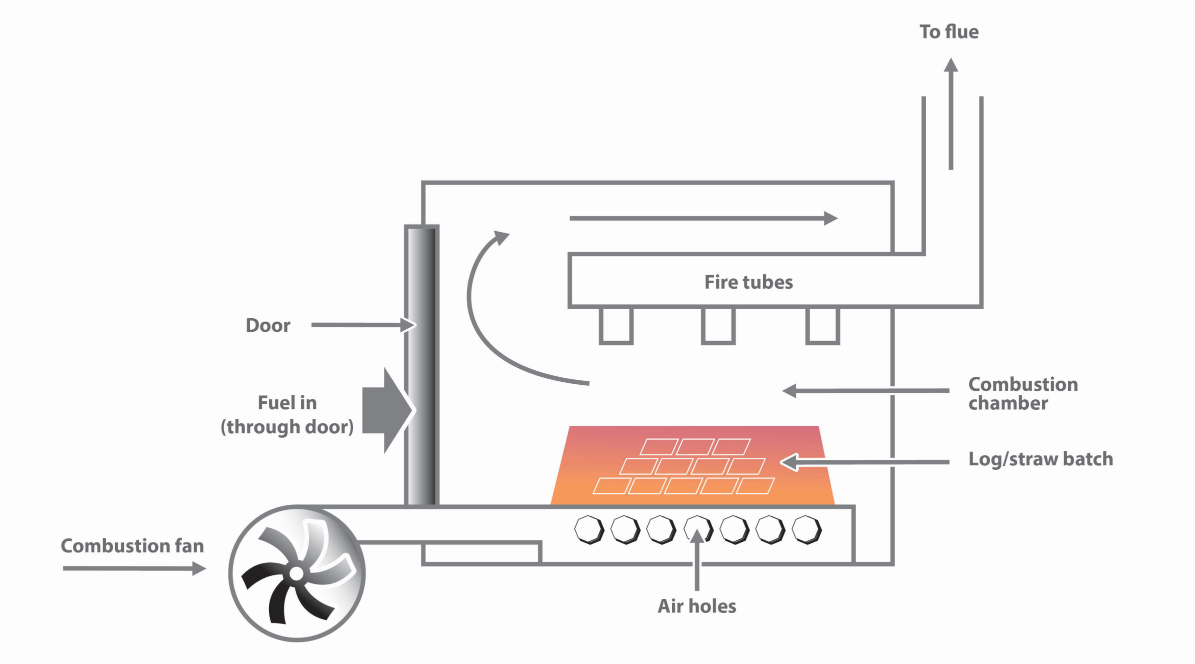
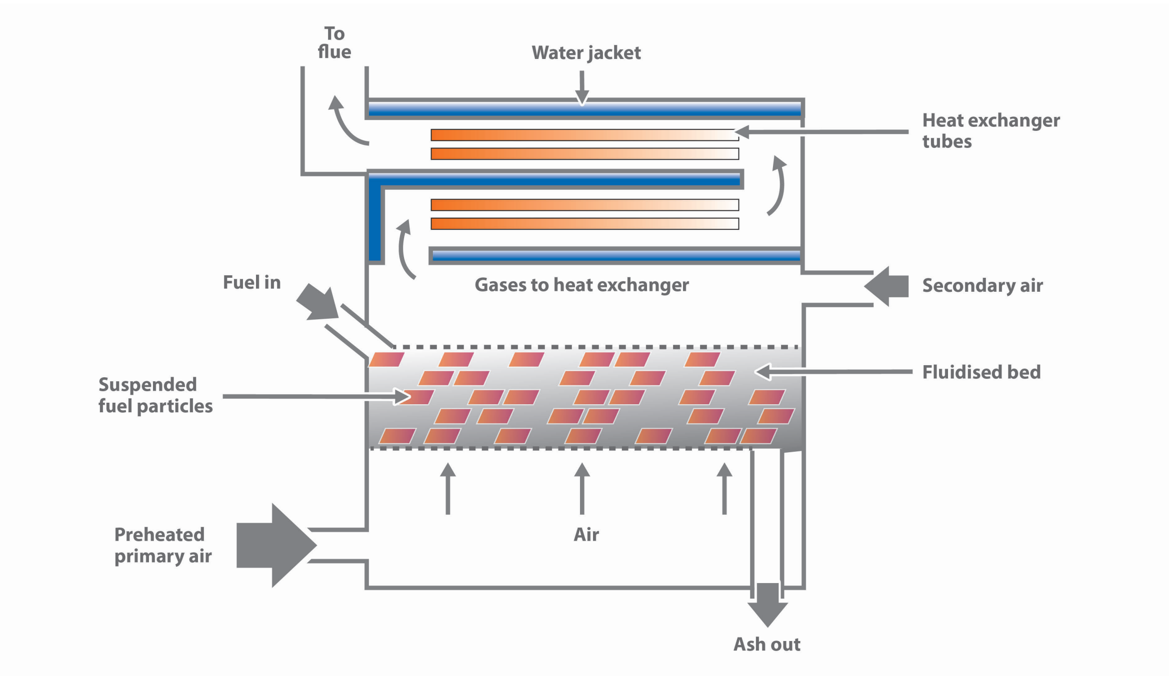


Figure 3.8: 500 kW straw boiler

Straw boilers
Normally, the combustion chamber of straw boilers is manually batch-fed with one or more bales at a time. Straw boilers are generally designed for standard bale sizes. The pros and cons of straw boilers are similar to log boilers. However, because straw is very light, it can be difficult to control emissions, necessitating measures such as additional cyclones and electrostatic precipitators. Straw often contains high concentrations of chlorides, which promotes slag formation by reducing the ash-fusion temperature. Straw boilers are specifically designed to manage this.

Fluidised-bed combustion of poultry litter
The combustion of poultry litter is usually, though not exclusively, carried out in fluidised bed combustion (FBC) boilers. The technology was originally limited to power station-scale plant, but now boilers down to around 500kW are available for use on farms. The principle of FBC is that the fuel particles are suspended and combusted in a bed of hot sand (or similar mineral), which is first heated by an oil or gas burner and fluidised by jets of air from beneath. This provides continuous mixing of the fuel with the primary air and thus more effective combustion, particularly for lower quality and variable MC fuels. Secondary combustion air is introduced above the fluidised bed to ensure complete combustion.

Figure 3.9: Schematic of fluidised bed combustion



3.2.4 Types of fuel feed

For boilers where the fuel is fed automatically, there are two main types of feed system.

Auger feed
An auger is a screw mechanism which, when rotating, transfers fuel material along its length. A big advantage is that fuel can be transported around corners and between different vertical levels if more than one auger is used. This gives more flexibility when positioning the boiler and the fuel store. Auger-fed systems are also cheaper than systems based on hydraulic rams (see below). However, auger-fed systems only work well for fuels within a relatively ridged specification of particle size, shape and MC. Significant deviations from the norm on these properties can lead to blockages.

Hydraulic ram
Compared with auger-fed systems, hydraulic ram systems are more reliable for larger boilers, as they can handle fuels with a range of particle sizes and MC. However, they are more expensive than auger-based systems and cannot operate across more than one level. There is also a small fire risk from the hydraulic oil.

3.2.5 Types of ignition

Manual ignition
When the MC of the fuel is relatively high (greater than 45%), the boiler will normally be ignited manually using a gas lance (or firelighters or paper), which is pushed into the firebed until combustion is self-sustaining. Boilers burning fuel with a MC greater than 45% usually have a moving grate to aid ignition.

Most moving-grate boilers operate in what is known as 'slumber mode'. This means that when the boiler has produced sufficient heat to meet demand, the firebed is maintained at a very low level by reducing the fuel feed to the minimum required to keep the firebed alight. In slumber mode, the primary and secondary air supply is turned right down or may even be switched off.

Advantages: Because the firebed is already established, these boilers can be more responsive when heat demand increases.

Disadvantages: If the boiler is oversized (and other aspects of the system are not well designed), it will be more often in slumber mode, reducing the overall efficiency. Using thermal storage and back-up fossil-fuel-fired boilers (see section 4.2.2) can help to reduce peaks and troughs in heat demands.

Automatic ignition
Automatic ignition systems are used in boilers burning relatively dry fuels (≤45% MC). The ignition system fires as required to meet the load demand (normally the demand for heat from thermal storage) and the firebed is not maintained at times of zero load on the boiler. Firing takes place until the firebox reaches the minimum temperature required for combustion to be self-sustaining.

The type of system used depends on the size of the boiler. Larger boilers will use gas, LPG or oil burners fitted at the side of the firebox. Smaller boilers will use electric hot air blowers.

Automatic ignition must be compatible with the MC of the fuel. If a higher than normal (≥45%) MC fuel is used, then the ignition system may not achieve self-sustaining combustion, but rather a smouldering (pyrolysing) fuel on the grate producing carbon monoxide (CO) and hydrogen. These gases must be purged from the combustion chamber before ignition is attempted again, otherwise an explosion is likely. It is strongly advised that boilers with automatic ignition are not used with fuel of a higher MC than specified by the manufacturer.

3.2.6 Boiler fire-tube orientation
The heat of the biomass combustion pass through fire tubes, heating the water surrounding them. There are two possible orientations of fire tube – vertical and horizontal.

Vertical fire tube
These are found in all three main boiler types (stoker burner, underfed stoker and moving grate). They tend to be found on boilers with capacity up to 1MW, and mostly in the capacity range up to 200kW. The main issue with vertical fire tube boilers is that sufficient clearance must be left above the boiler to allow access for cleaning and maintenance.

Horizontal fire tube
Also found in all three main boiler types but are more common on larger capacity boilers. While less vertical headroom is required than that for the vertical fire-tube boiler, greater horizontal clearance is required for access to clean the fire tubes. Also, horizontal fire-tube boilers need to be cleaned more regularly than vertical fire-tube boilers because of greater accumulation of soot and fly ash.

3.3 Special considerations

When considering the installation of a biomass boiler as opposed to a fossil-fuelled boiler, there are various specific issues that must be taken into account. Further information is provided in the accompanying SEAI Implementation, and Operation and Maintenance Guides.

3.3.1 Delivery of fuel

Natural gas is delivered via the gas transmission and distribution network, LPG and oil is delivered in tankers and is stored in on-site tanks. Biomass will nearly always have to be delivered by road as wood chip or pellets. This means: (i) infrequent delivery by very large vehicles or (ii) more frequent delivery by smaller vehicles. Access and the volume of road traffic in the vicinity of the boiler installation have to be considered.

3.3.2 Physical size of boiler

A biomass boiler will be physically much larger than the equivalent fossil fuel-fired boiler. This is due mainly to the inherent combustion characteristics of solid, organic materials, which require a large volume combustion chamber. Biomass boilers also require more space in the boiler house for access for fire-tube cleaning, and feed and ash-extraction systems.

3.3.3 Boiler responsiveness and ability to modulate

Biomass boilers are less responsive to changes in heat demand and have a smaller turndown ratio. In conventional gas or oil boilers, ignition is instantaneous, and the boiler can also be shut down instantaneously with little residual heat remaining.

However, in the case of biomass boilers, when there is little or no heat demand, the fuel that has already been deposited onto the grate will continue to burn. Depending on the type of boiler, it may also be necessary to empty the contents of the fuel delivery system onto the grate and combust the fuel.

Some biomass boilers will have very significant thermal mass embodied in the boiler refractory linings. These are incorporated into the boiler structure to radiate heat to dry moist fuels prior to pyrolysis and gasification. This slows the response time (compared with oil and gas-fired boilers). This must be accounted for in the design and is generally achieved by judicious boiler sizing and the use of thermal stores (see section 4.2.2).

3.3.4 Waste and cleaning

Biomass boilers produce ash and more cleaning is required than for gas or oil-fired boilers. Ash is not present in the combustion products of oil or gas as these fuels have no (or very little) mineral content. The mineral content of biomass depends on its source, with fuels containing bark and herbaceous (grassy) biomass producing more ash.

There are two types of ash to consider as by-products from biomass combustion: bottom ash and fly ash. Bottom ash is formed on the grate and is pushed off the grate into the ash pan when new fuel is introduced. Fly ash is very fine. It is carried on the thermal currents inside the boiler, deposited in the fire tubes, and captured by abatement systems in the flue or released to the environment. This means that biomass boilers require boiler tube cleaning (unnecessary for oil and gas boilers). It is also necessary to collect and dispose of bottom ash. The amount of ash depends on the composition of the biomass.

Melted ash can form an unwanted clinker on the grate. The melting point of silica (the main component of ash) is 1,700°C. If chlorides are also present in the fuel, the ash can melt at temperatures as low as 773°C, which is well within the combustion temperatures of the boiler.

3.4 Boiler monitoring and control

3.4.1 Control to maximise biomass boiler running hours

The best results (in terms of net carbon dioxide (CO_2) reductions and operational cost savings) come from the boiler running efficiently and for the greatest number of hours possible. In practice, this means running as close as possible to the boiler's rated output for extended periods. This is achieved by specifying a system comprising biomass boiler(s), buffer vessel or thermal store, and potentially top-up/standby fossil-fuel boiler(s) of appropriate capacities (sizing of these plant components is considered further in section 4). The boiler and heating control systems must be designed and configured to achieve the desired system operation. This involves setting various parameters, such as temperature set-points and switching times.

3.4.2 Control to maximise combustion efficiency

Combustion efficiency is maximised (and problematic emissions avoided) when the fuel is completely combusted. This depends on the correct supply of **primary** combustion air (needed to support complete gasification of wood and char) and **secondary** combustion air (needed to ensure complete combustion of hydrogen and CO, which are released when wood and char are gasified).

In practice, this means providing a sub-stoichiometric quantity of air as primary combustion air (λ[21] = 0.7 to 0.8; i.e. only 70% to 80% of the theoretical quantity of air for complete combustion being supplied) and providing secondary combustion air at a super-stoichiometric ratio (λ = 1.42 to 1.63, which corresponds to between 8% and 12% excess oxygen).

The secondary air supply is controlled by monitoring the quantity of oxygen in the flue gas using a 'lambda sensor'. Very high oxygen readings in the flue gas indicate complete combustion, but they also indicate that more heat than is necessary is being carried away unrecovered in the flue gases.

Therefore, a sensible trade-off has to be made between ensuring complete combustion and efficient heat recovery. Such settings can be adjusted on the boiler's control panel, and should be established as part of plant commissioning by the installer or supplier and checked as part of the plant's maintenance regime.

3.4.3 Control to minimise NOx

NOx is a generic term for the nitrogen oxides which is minimised by controlling the combustion temperature. For a given stoichiometric ratio, flame temperatures increase with the dryness of the fuel. NOx formation begins to increase rapidly at combustion temperatures of over 1,300°C.

For this reason, combustion temperatures should be kept at no more than 1,200°C. In addition, boilers designed to burn wet biomass should not be used to burn drier biomass, unless flue (exhaust) gas recirculation (FGR) to primary air is used, as this leads to a higher combustion temperature and more NOx formation.

[21] λ (lambda) is used to denote the ratio between the actual amount of combustion air (oxygen) and the minimum theoretical amount of combustion air (oxygen) required for complete combustion of the fuel.

Along with appropriate settings of lambda and FGR, only use the fuel specified for the boiler. If sufficient NOx control cannot be achieved via boiler set-up, then selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) equipment may be needed, adding to capital and operational costs.

3.4.4 Control to minimise soot

Soot is caused by the incomplete combustion of biomass. Complete combustion is achieved by:

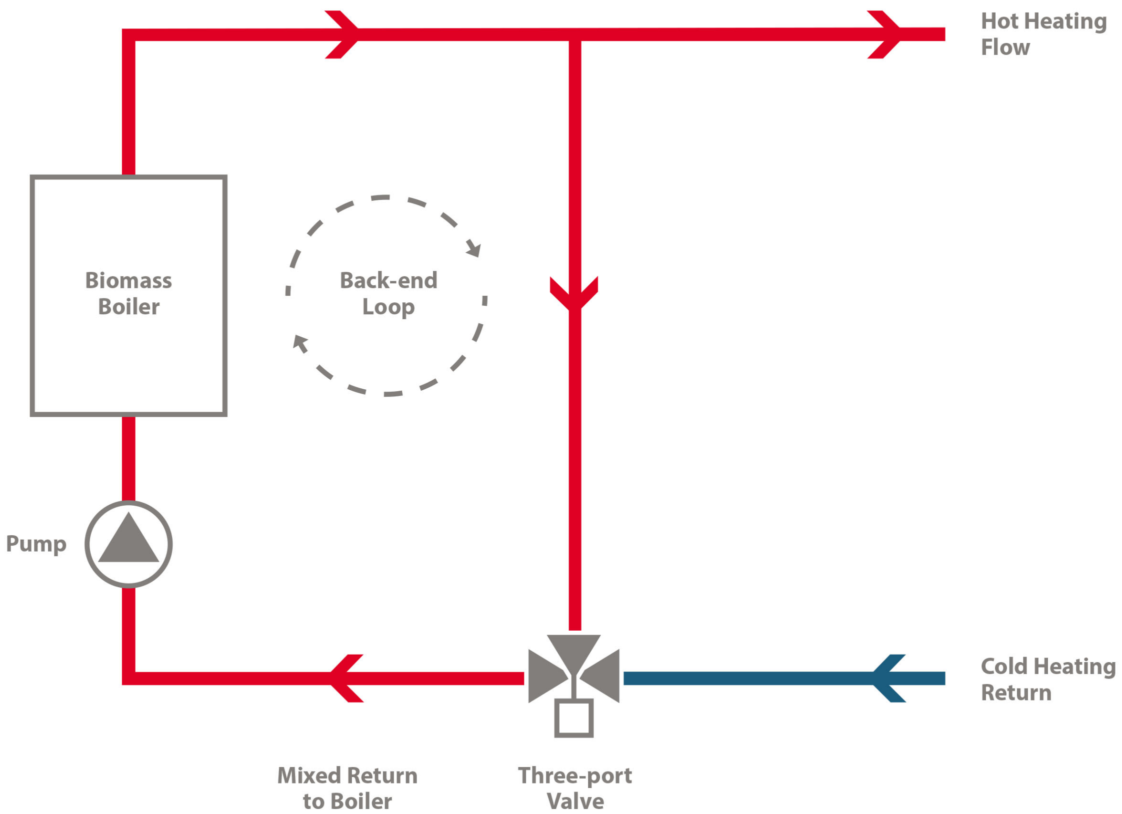
- Ensuring that the biomass is completely dry before the fuel enters the pyrolysis stage of combustion. This means using fuel with the correct MC for the boiler or, in the case of a moving-grate boiler, optimising the grate speed so that the fuel is completely dried.
- Providing the correct quantities of primary and secondary combustion air to ensure that the biomass is completely gasified and the off-gases are completely combusted.

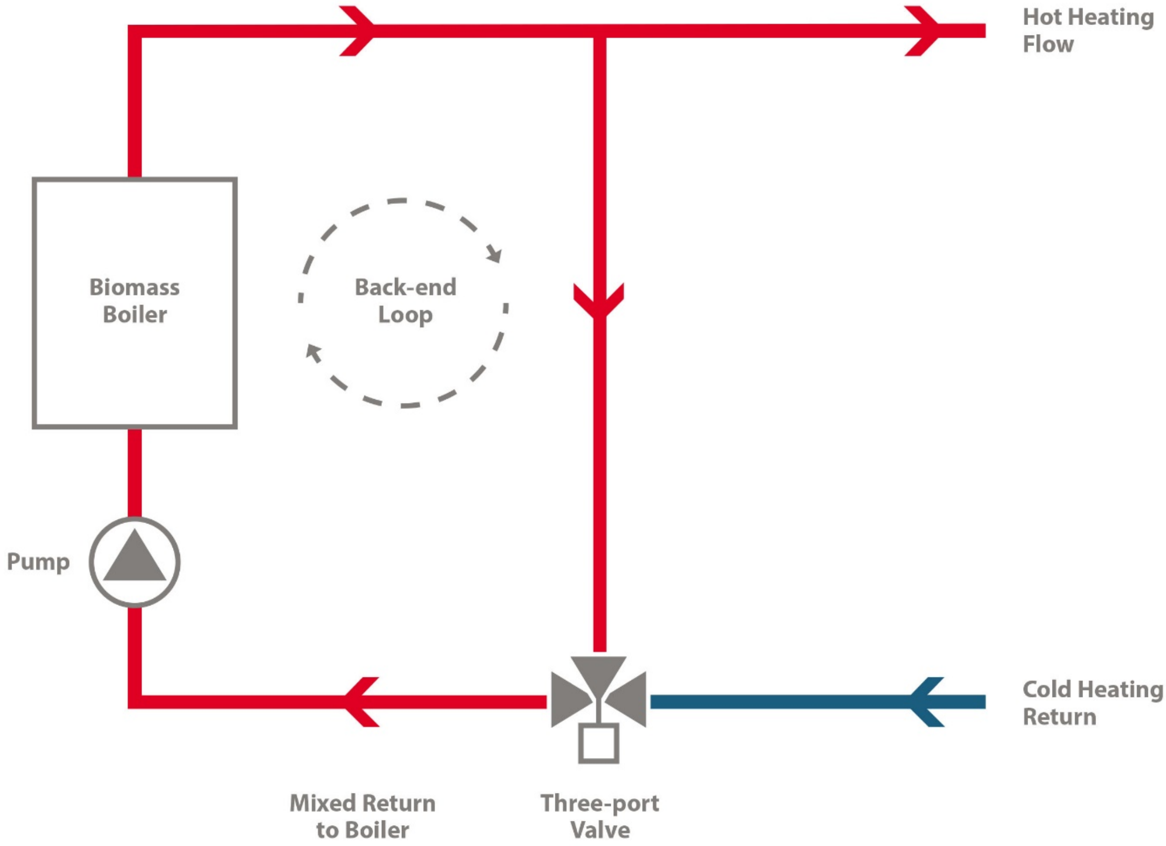
3.4.5 Control to minimise condensation of acidic gases

Burning biomass generates acidic gases in the combustion products, which, if allowed to condense, will produce corrosion. The lower the temperature of the water returning to the boiler and the higher the quantity of water vapour in the fuel, the more likely it is that these acidic gases will condense in the flue gas system and cause corrosion.

Therefore, for high MC fuels, control of the water return temperature can be very important and the boiler manufacturer's recommendation of minimum return temperatures should always be adhered to. In some applications (such as district heating), it is desirable to have low return temperatures from the load. To avoid the problems of acidic gas condensation, the actual return water temperature to the boiler can be controlled using the 'back-end loop' by bleeding some of the hot flow water into the water return line – see Figure 3.10.

Figure 3.10: Biomass boiler back-end loop




Hot Heating
Flow
Biomass
Boiler
Back-end
Loop
Pump
Cold Heating
Return
Mixed Return
to Boiler
Three-port
Valve

3.4.6 Control of grate temperature

If the combustion temperature on the grate becomes too high, then the ash will melt and produce clinker. This is more likely if the fuel used contains high levels of chlorides, which lower the melting temperature of silica (the main constituent of wood ash). It can be avoided by having a water-cooling circuit running through the grate (from which heat is normally recovered). Another method of controlling the formation of clinker on the grate is to use FGR, which suppresses the temperature at the grate and controls NOx generation.

3.4.7 Control of particulate matter emissions

This depends largely on the design of the combustion gas pathways within the boiler. The use of cyclone grit arrestors, bag filters, ceramic filters or electrostatic precipitators (ESPs) to control particulate matter may also be required. These filtration techniques tend to be used for boiler capacities in the range 300kW to 5MW and are usually not needed for boilers below 300kW. Using selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) is another means of controlling particulate matter emissions, but these are relatively expensive.

3.4.8 Control of firebox pressure

As explained previously, CO and hydrogen are generated in the firebox as wood is gasified. The penetration of the firebox by augers and stokers means that these unburned and dangerous gases can escape into the boiler room. To prevent this, the pressure of the combustion chamber should be lower than its surroundings. Achieving this lower pressure mainly by the boiler's induced draught fan. However, flue-system design is also critical, particularly to ensure that negative pressure, is maintained, under fan failure conditions, including loss of power. Otherwise, there is a risk of toxic gases entering the boiler room or of explosion.

4. System design

Section 3 highlighted key differences between biomass and oil and gas-fired boilers that need to be factored into the design and operation of a biomass boiler system. As well as the profile of heat demand, the biomass boiler's response time for modulating its heat output and its turndown ratio are key factors in sizing the boiler, its thermal storage and any top-up fossil-fuel boiler capacity.

Considering response times first, compared with oil and gas-fired boilers, the time lag between the start-up of a biomass boiler and its flow water being up to temperature is greater. This means that heat demand will either have to be anticipated (i.e. scheduled) or initially provided from a separate source. The biomass boiler will need to be switched on earlier: either manually or through controls such as the site's building management system (BMS). Alternatively, heat stored within thermal storage (e.g. from the previous day) can be used to meet the gap between initial demand and the time when the biomass boiler is able to provide the heat required.

Lower turndown ratios for biomass boilers (compared to that for fossil-fuel boilers) mean that careful sizing of the system is needed to maintain efficiency. Biomass boilers can be used with fossil-fuel boilers and thermal stores to provide flexibility and maximise efficiency, but this depends on the heat demand profile.

4.1 System types and heat transfer media

The most common systems consist of:

- Single or multiple biomass boilers - normally with buffer vessel(s).
- Biomass boiler(s) with thermal store.
- Biomass boiler(s) - normally with buffer vessel(s), with top-up or back-up fossil-fuel boiler(s).
- Biomass boiler(s) with top-up or back-up fossil-fuel boiler(s) plus thermal store. Biomass and fossil-fuel boilers can be connected in parallel or in series with the biomass boiler connected to the return from the heat-distribution system.

Readers should note that buffer vessels and thermal storage are different: see section 4.2.

The heat transfer medium can be water, steam or thermal oil. The most common is hot water (at around 85°C). The choice of medium will depend on the grade (temperature) of heat required. Steam and thermal oil are used where higher temperatures are required. Steam and thermal oil systems are more expensive than water systems. They use specifically designed boilers with additional safety considerations. This guide deals with water systems; though many of the general principles will also apply to steam or thermal oil systems.

Figure 4.1 and Figure 4.2 show typical parallel and series configurations for a biomass boiler, thermal store, and fossil-fuel boiler system connected to heat loads via a low loss header. The series connection may be more effective in ensuring that the biomass boiler and thermal store combination act as the lead boiler, maximising the use of the biomass boiler[22].

[22] CIBSE Journal Article, Boilerhouse blues and how to avoid them, David Palmer, February 2018 https://www.cibsejournal.com/technical/boilerhouse-blues-and-how-to-avoid-them/

Figure 4.1: Biomass boiler and its thermal stored connected in parallel with fossil fuel boiler

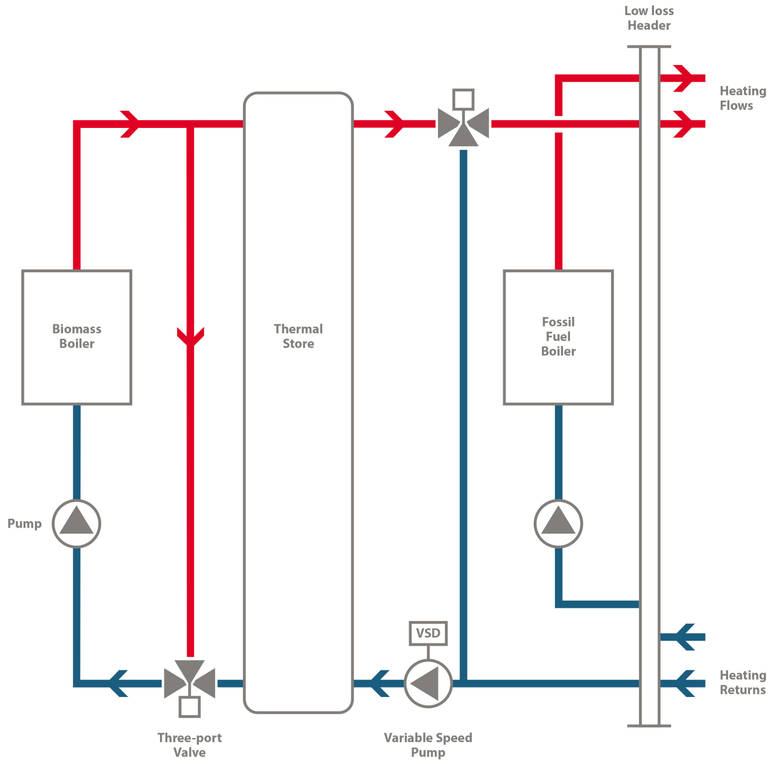
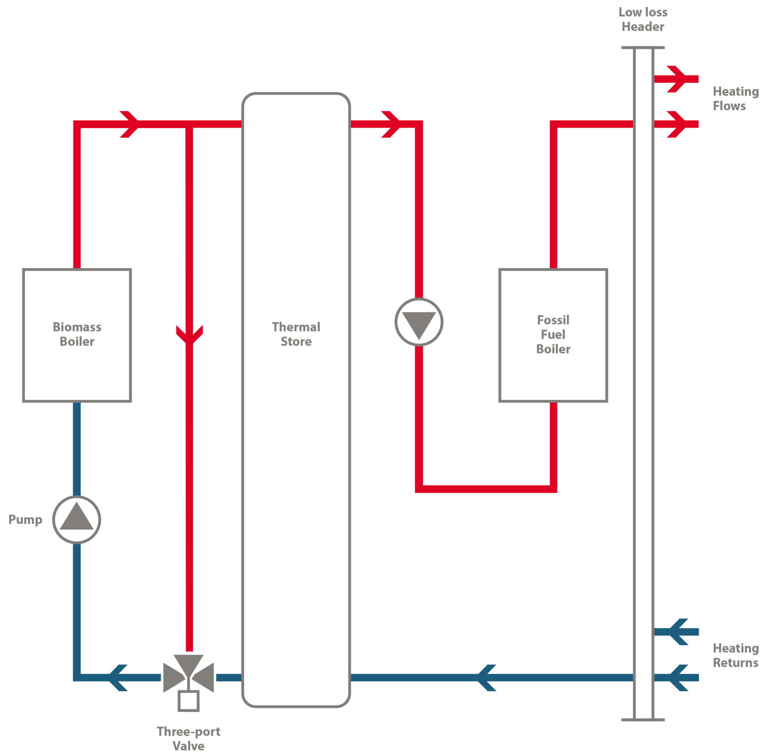


Figure 4.2: Biomass boiler and its thermal stored connected in series with fossil fuel boiler



4.2 Buffer vessels and thermal stores

The terms buffer vessel and thermal store tend to be used interchangeably, but they have different functions. The term accumulator is also used interchangeably with the other terms, particularly with log boilers.

4.2.1 Buffer vessels

Buffer vessels are used in most biomass boiler systems to receive the residual heat from the biomass boiler when there is no heat demand. Biomass boilers tend to have a higher thermal capacity and much longer response times than fossil-fuel boilers because of more refractory material. The resulting residual heat usually is removed from the boiler through the heating medium when there is no heat demand. Capturing and re-using this residual heat will improve overall efficiency and prevent boiler overheating, and reduce the risk of high pressure within the boiler's water circuit. Buffer vessels are used for this purpose. The heat stored within buffer vessels can then be used when the boiler is restarted (if the downtime is not too long).

Most biomass boilers need a buffer vessel. The manufacturer of the boiler will specify the minimum buffer vessel sizing requirements. The capacity of a buffer vessel will depend on:

- whether the boiler has automatic ignition,
- the type of grate,
- whether the feed auger needs to be emptied onto the grate and the fuel burned off prior to shut down, the type of fuel
- and the mass of the ceramic lining within the boiler.

Depending on these factors, the capacity ratio of buffer vessels can vary from 5 litres/kW to 60 litres/kW of boiler capacity. Buffer vessels tend to be relatively small compared to thermal stores.

4.2.2 Thermal stores

Thermal stores smooth out variable heat demand. This means a smaller boiler can be used, that can run for longer at peak efficiency. Thermal stores are often configured to also function as buffer vessels. Thermal storage depends on the stratification of the heating medium (mainly water) and hence tend to have a large height to diameter ratio. Water inlets to thermal stores are designed to minimise turbulence and maintain stratification.

Figure 4.3: Thermal storage vessels

Using thermal storage changes the operational demands on biomass boilers and any back-up fossil-fuel boilers, changing the design economics of a biomass system. This is because thermal stores enable smaller biomass boilers to operate continuously for longer periods than larger boilers that must vary output significantly or even start-up and shutdown frequently. This means improved efficiency and use of the biomass boiler. A smaller biomass boiler will also be cheaper.

Given the number of variables (heat load, size and number of biomass boilers, size and number of top-up and back-up fossil-fuel boilers, and size of any thermal store), a detailed analysis is necessary to design the optimum system. There are publications and design tools available (see section 4.3).

4.3 Design and sizing

One of the first steps in sizing and design a system is to determine the heat load profiles in terms of daily and seasonal heat load variation and the peak heat demand. The variability in heat demand will depend on the type of heat demand.

Heating for industrial processes will tend to be the least variable. Hospitals, care homes and leisure centres (particularly those with swimming pools) are usually of medium variability. Where heat is used primarily for space heating, there will be significant variability of demand between day and night, and seasonally.

Therefore, heat-demand profiles need to be produced for (at least) winter and summer days. It can also be helpful to produce annual heat-load duration curves.

Looking at a typical demand profile for space heating and hot water services, for example (see Figure 4.4 and Figure 4.5), the demand will be mainly during the winter months and for commercial buildings might only be during weekdays and office hours. In summer, the heat load will mainly, if not exclusively, be to provide hot water.

Figure 4.4: Illustrative daily heat consumption annual profile

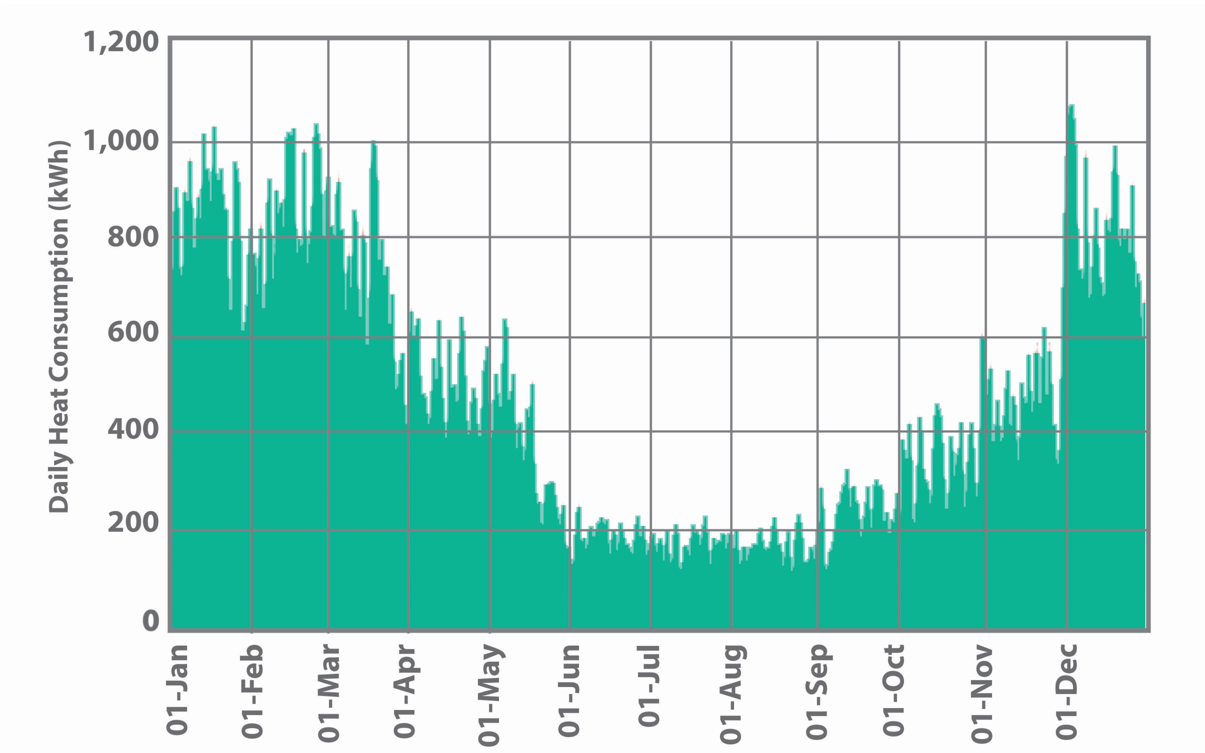
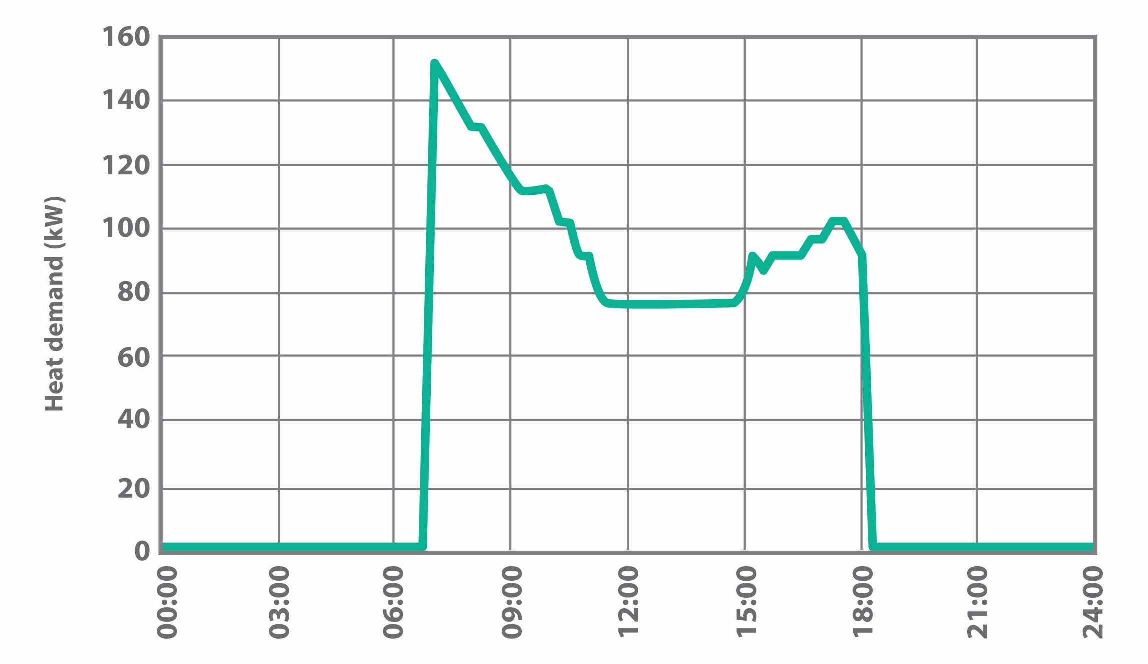


Figure 4.5: Illustrative heat load profile for a winter day



This illustrates the problem of designing a system to operate efficiently over a wide range of heat demand that is beyond the capabilities of a biomass boiler without thermal storage and/or fossil-fuel boiler capacity. The system design should aim to maximise the running hours of the biomass boiler capacity within its range of turndown (ideally as near to full-load running as possible). This is achieved by shifting in time the peaks in load by using the thermal store, ensuring that the biomass boiler 'sees' a more continuous and steady demand.

The size of the thermal store depends on:

- the size of the boiler,
- the difference between the peak load and the boiler capacity,
- the timing and duration of loads higher than the boiler capacity.

The sizing of the boiler relative to the thermal store may need to be a trade-off between available physical space and optimising capital costs. This can result in some fossil-fuel boiler capacity to make up for any shortfall.

Clearly, a detailed analysis is required for each situation by an appropriately experienced person such as a chartered building services engineer or the installer. There are also design tools available.

- The Carbon Trust's biomass sizing tool is available to download at www.carbontrust.co.uk/emerging-technologies/current-focus-areas/biomass/pages/biomass-tool.aspx

Such tools will only produce reliable answers if the heat load data inputs are sufficiently detailed and accurate. It is strongly recommended that readers refer to the Chartered Institution of Building Services Engineers (CIBSE) publication available at www.cibse.org 'Biomass Heating, AM15: 2014' for a detailed explanation of biomass boiler and thermal store sizing, and the principles of operation of thermal stores and buffer vessels.

4.4 Connection to the heat-distribution system

The biomass boiler and heat load systems can be more easily matched when designing a completely new heating system. However, many biomass boiler systems are fitted to existing heating systems to displace oil or gas-fired boiler capacity. Fitting to existing systems will more likely require some form of hydronic separation between the biomass boiler system and load system.

4.4.1 Heat exchangers

Heat exchangers are used to provide isolation between the biomass boiler and load systems; plate heat exchangers are most commonly used. Heat exchangers are used for various reasons, including to:

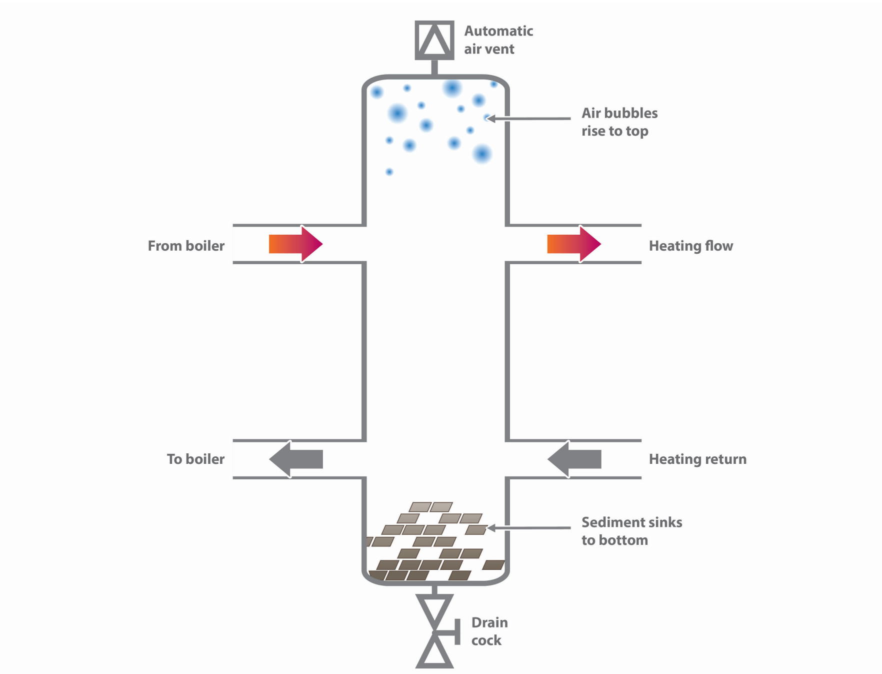
Figure 4.6: Typical plate heat

- Separate systems that operate at different pressures or temperatures.
- Prevent possible contamination or debris in an older existing distribution system from entering the boiler circuits (although systems should be fully cleaned and flushed at commissioning).
- Facilitate maintenance of individual load (secondary) circuits without affecting the heat supply to other loads.
- Ensure that a failure of the biomass system does not affect back-up fossil-fuel boilers (on the secondary side of the heat exchanger) or the loads.
- Provide a boundary where responsibilities for the operation/maintenance of biomass plant and the load distribution system are with different parties.

4.4.2 Low loss headers

These enable boilers to be controlled at their own flowrate (compared to the flowrate of load systems which may be different). Low-loss headers allow multiple boiler connections and multiple load connections. The design of headers can be complex and should be undertaken by an experienced heating system design engineer. Some existing systems may already have a low-loss header to which the biomass system can be connected.

Figure 4.7: Diagram of a low-loss header



4.5 System monitoring and control

4.5.1 Biomass boiler efficiency

Heat output from the biomass boiler should be heat metered so that, along with fuel records, the boiler efficiency can be calculated. Also, depending on the system, the heat output data may be required by financial support schemes.

If there are fossil-fuel boilers within the installation, then it is good practice to monitor the heat output and fuel use of these as well so that the relative contributions from biomass and fossil fuels can be analysed.

4.5.2 Boiler primary circuit

Flow rate will usually be constant through the primary circuit, and temperature sensors will measure the boiler flow and return temperatures.

If there is a buffer vessel or thermal store in the system, then more temperature sensors are used to monitor combined flow temperatures. In addition, two or more sensors will monitor temperatures within the thermal store to determine whether the biomass boiler should be started up or shut down.

4.5.3 Secondary circuits

Secondary circuits will have their own measurement and control systems including variable speed drives to allow the system to respond to demands for heat.

5. Heat metering

5.1 Meter types and principles of operation

It is good practice to measure heat output and heat use, and most biomass boiler installations will require some heat metering. There are many reasons for measuring heat in biomass installations including:

- To determine heat output of the boiler and monitor boiler efficiency.
- To determine the heat use of particular loads.
- To provide diagnostic information in the event of a system fault.
- To provide control signals for the firing of top-up and standby boilers.
- To bill heat users, particularly for systems where there are multiple users.
- To meet the requirements of financial support schemes.

There are various manufacturers providing heat meter systems suitable for biomass boiler systems. Selecting an appropriate heat meter depends on the working fluid (heat transfer medium), the operating ranges for flow rate and temperature, pipe diameter, whether the meter is battery or mains-powered, whether the flowmeter is installed in the flow or return pipe, and the ambient temperature.

A heat meter normally comprises a flow sensor (flow meter), a matched pair of temperature sensors and an integrator (or calculator) with display.

5.1.1 Flow sensors

There are various types of flow sensor available, the most commonly used in heat meters being:

- Ultrasonic flow sensors, which measure the transit time of the ultrasound in the moving fluid between an upstream and downstream sensor. They are non-invasive and low maintenance. However, they need relatively long unimpeded upstream pipework to ensure accurate measurement.
- Fluid oscillatory flow sensors, which fall into two groups: vortex shedding flow sensors and fluidic oscillatory flow sensors. In the former, a bluff body in the fluid stream causes the shedding of vortices on alternate sides of the body, the frequency of which is proportional to the fluid velocity. In fluidic oscillatory flow sensors, a jet enters a separate chamber and oscillates between two feedback channels, the frequency being proportional to the main fluid flow velocity.

The choice of flow sensor will depend on the heating medium, the accuracy required, and the cost and practicalities of fitting the flow sensor within the installation.

5.1.2 Temperature sensors

Temperature sensors are supplied as matched pairs and are calibrated to minimise the error in measuring the temperature difference between flow and return streams. Temperature sensors are normally of the platinum resistance temperature detector (RTD) type Pt100 or Pt500[23].To maintain accuracy, it is important that the temperature sensors are installed correctly, usually within thermal pockets and that their cables (as provided by the manufacturer) are not altered.

5.1.3 Integrators

The heat meter integrator determines the instantaneous heat flow, by using the flow rate of the heating fluid, the temperature difference between the flow and return, and the specific heat capacity of the heating fluid. Integrating this over time gives the cumulative heat consumption of the heating circuit (in kWh, MWh or GJ).

[23] Pt100 means that the RTD has a resistance of 100Ω at 0ºC. A Pt500 RTD has a resistance of 500Ω at 0ºC. Higher resistance RTDs have lower errors for the same cable types, which is important where longer cable lengths are needed.

As well as displaying the heat consumption, most integrators can provide other useful parameters such as the instantaneous rate of heat use, flow and return temperatures, and the flow rate of the heating fluid. Furthermore, many integrators can store historical data (e.g. 18 months of month-end cumulative heat data), and output/download data to other monitoring systems such as building management systems (BMS).

Depending on the manufacturer, heat meters can be configured for a number of communications protocols (such as Meter-Bus [M-Bus] and RS 232) by adding modules to the integrator.

Heat meter calibration, depending on meter type, is specific to the heat transfer fluid in the circuit measured. This is normally water, but can be water with anti-freeze and/or a corrosion inhibitor. Generally, corrosion inhibitors do not require meter recalibration, but glycol anti-freeze mixtures do.

In either case, the heat meter supplier or manufacturer should be consulted. If additives are present for which meters have been specifically calibrated, then it is important that the level of concentration is maintained through regular checking and topping up. Automatic systems are available to achieve this.

Some meters are specifically manufactured for use with water-glycol mixtures and the glycol concentration can be entered directly into the meter rather than having to be specifically calibrated by the manufacturer or authorised agent.

5.2 Meter classifications

Heat meters should meet the requirements of the Measuring Instruments Directive (2004/22/EC) (MID). If they comply, then they will have a CE mark. IS EN 1434:2007 Parts 1 to 6 is the Irish implementation of EN 1434:2007, which is harmonised to MID. 'Part 1: General requirements' and 'Part 6: Installation, commissioning, operational monitoring and maintenance' will be of most value to readers of this guide.

In addition, heat meter accuracy is specified by the MID class notation, where accuracy is defined in terms of Class 1, 2, or 3, with Class 1 being the most accurate. The accuracy of the meter in practice will also depend on it being installed in line with the manufacturer's instructions. A poorly installed meter will not be accurate.

When selecting and installing heat meters, consider:

- The accuracy class of meter.
- The need for the flow sensor, temperature sensors and integrator to be matched.
- Suitability for the static pressures and flow rates of the circuits where they are to be installed.
- For open vented systems, low pressure and the presence of air can mean that an ultrasonic flow sensor is not appropriate.
- Whether a glycol-based additive is required in the hydronic circuit to be metered.
- Correct positioning of flow sensors in relation to pumps, bends, etc. and flow sensor orientation in accordance with the manufacturer's guidance.
- Installation of temperature sensors in accordance with the manufacturer's guidance.

5.3 Installation

Generally, heat meter integrators need to be protected from outside elements. This can be done by installing them on pipework in buildings or, if outside installation is necessary, housing within weatherproof boxes (unless the heat meter integrators are suitably IP[24] rated).

[24] IP stands for International Protection, but is commonly referred to as Ingress Protection

Heat meter components must be installed correctly to ensure accurate measurement of the target heat flow. Manufacturers will specify the requirements for each meter. Failure to observe these may lead to inaccurate measurements. For example:

- In horizontal pipe runs, ultrasonic flow meters must normally be installed with the sensor head orientated within +/- 45° to the horizontal.
- Flowmeters may also be sensitive to the direction of flow. In such cases, the flowmeter will have direction marks on the body of the meter. These should match the direction of flow.
- Heat meter manufacturers will specify whether the flow sensor should be installed in the flow or return pipework.

There may be restriction on where flowmeters can be fitted in the pipework system. Examples are:

- Mechanical meters should not be located within five pipe diameters of bends or other disturbances.
- Ultrasonic meters should not be placed where there is a risk of air build-up, such as at high points in the distribution system, or near to a pump inlet or discharge.

Temperature sensors are supplied as matching pairs, and the serial numbers on the hot and cold temperature sensors should match. Temperature sensors should be correctly installed within their thermal pockets. Thermal paste can be used to ensure good contact between sensor and the wall of the thermal pocket. The sensors should not be able to move once installed. It is good practice for the meter installer to fit the temperature sensors and calculators with security tags. This shows that the meter has not been tampered with. Such good practice may be required by a financial support scheme.
Temperature sensors and their leads are particularly susceptible to mechanic damage; care should be taken in the siting of the thermal pockets and in the positioning and securing of the sensor leads.

The detailed design and installation must ensure that the temperature sensors are sited to measure the intended heat flow. Incorrect siting of one or both sensors will lead to erroneous measurements.

5.4 Maintenance and calibration

Heat meters should be supplied with calibration certificates. Ideally, these calibration certificates are valid for a set time period. However, manufacturers do not always state recalibration intervals or expected meter lifetimes, even on their calibration certificates and there is no requirement in the MID or EN1434 to do so. In the absence of guidance from the manufacturer, a period of no more than five years between recalibrations would be considered good practice.

The calibration should be appropriate to the heating medium. For example, if it is to be used to measure the flow of a water/glycol mixture then the flowmeter should have been calibrated for that mixture.

It is the flow meter that is the most likely to become less accurate over time. Recalibration usually requires that the flowmeter is removed and returned to the manufacturer or the test house approved by the manufacturer. This will result in downtime for the installation (drain-down, refill and re-pressurisation) unless there is a way of bypassing the meter. It may be more economical to buy a new meter, perhaps as an exchange with the manufacturer.

Records of all meter calibrations, repairs and changes should be maintained.

6. Ash handling

Ash produced from the combustion of solid biomass should ideally just consist of the non-combustible mineral components of the fuel. In practice, ash will have some organic content from unburnt combustibles and, depending on the fuel source, contamination such as sand and soil.

Boiler ash falls into two types: bottom ash and fly ash:

- Bottom ash makes up around 98% of the ash from a biomass boiler. It collects at the grate and, as more fuel is introduced, falls from the grate into an integral ash pan.

- Fly ash is fine ash that is entrained in the combustion gas flows and is collected via a fly-ash drop-out chamber within the boiler and as part of separate flue-gas cleaning. Fly ash is finer than bottom ash and contains toxic particulate matter from volatised metals and metal salts. Fly ash is a hazardous waste and should be disposed of appropriately.

Bottom ash from contaminated fuel (such as waste wood) and bottom ash from poor combustion should also be treated as hazardous waste. Where completely combusted, bottom ash from clean biomass is generally safer than fly ash. The normal disposal route for ash is to landfill. Ongoing arrangements will need to be made with a licensed waste company for disposal. Unless specifically approved by the Environmental Protection Agency (EPA), ash must not be disposed of to land.

In smaller boilers, bottom ash and fly ash collect in the boiler's ash bin, which requires regular manual emptying. Larger boilers are usually equipped with augers that convey the ash into a separate metal ash container (see Figure 6.1), which may be external to the boiler house.

Ash handling gives rise to several health and safety risks that must be managed. Further information is provided in the accompanying Operation & Maintenance guide.

Figure 6.1: Conveying ash to a separate container within the boiler house

6.1 Clinker

Clinker (or slag) is a glassy material that forms when ash is raised above the ash-fusion temperature. The ash-fusion temperature depends on the constituents of the fuel. In particular, high levels of chlorides can reduce the ash-fusion temperature significantly and lead to clinker formation. Similarly, if the temperature at the grate becomes too high, for example through a drier than normal fuel or heat not being removed sufficiently quickly from the boiler, then clinker will form.

Clinker can cause problems with the grate and ash-handling components, such as augers, leading to downtime and repairs. Boilers are designed to avoid clinker formation under normal conditions by managing the temperature on the grate. Some boilers are fitted with water-cooled grates and/or flue gas recirculation to limit grate temperature.

7. Flues and emissions

7.1 Flues

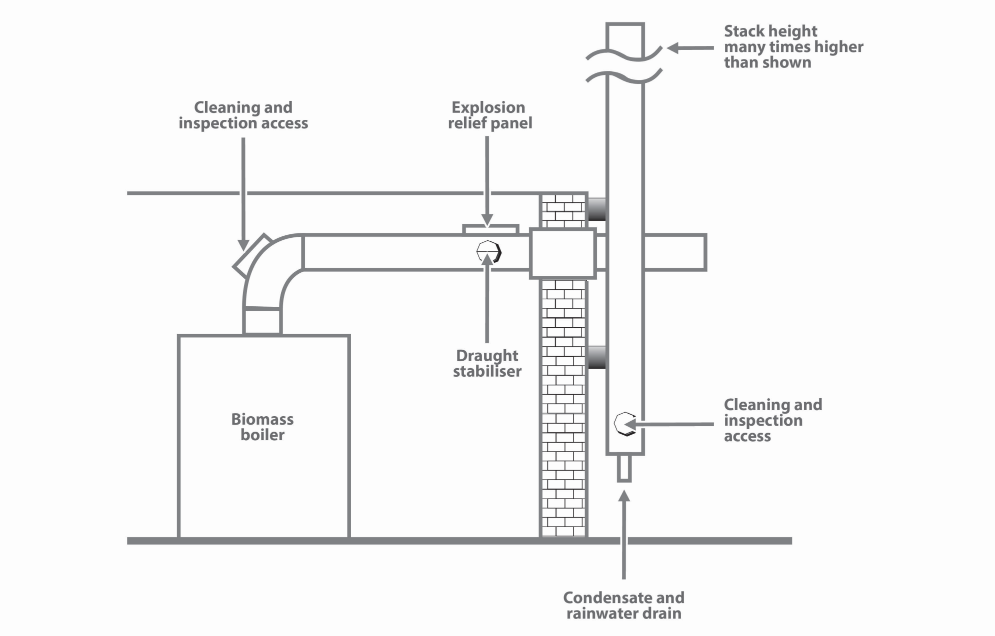
The flue system for a biomass boiler system must perform three functions:

- Provide sufficient draught to remove combustion gases from the boiler under all operating conditions.
- Disperse the combustion gases in compliance with air quality regulations. The EPA and the local authority monitor air quality. Compliance with air quality regulations may also require flue-gas abatement systems in addition to that provided as an integral part of the boiler (see section 7.2).
- Ensure that combustion gases do not enter occupied (or potentially occupied) spaces and thereby cause a health hazard. These spaces include the boiler house itself and nearby buildings.

Biomass flue systems normally have more components than the equivalent oil or gas boiler systems. Flue design and installation should only be undertaken by those with the necessary capability and experience. Technical Guidance Document Part J of the Building Regulations and the associated 'Technical Guidance Document J, Heat Producing Appliances' cover the requirements for flues and chimneys. However, the following bullet points summarise the main technical issues: (The relevant regulations should be read in full).

- Biomass boilers must always operate with a negative combustion chamber pressure relative to atmospheric pressure so that the combustible gases and combustion products within the boiler cannot escape into the boiler house. This negative pressure is created by the buoyancy of the combustion products in the flue stack and is dependent on the flue design, particularly the effective height of the vertical stack (see Figure 7.1). It is not normally recommended to use induced draught fans over and above those fitted within the boiler, or as part of emissions abatement equipment (such as cyclone grit arrestors) installed within the flue.
- The length of the flue between the boiler and the vertical stack should be minimised.
- Cleaning and inspection access points should be sufficient for the flue system to be cleaned.
- A draught stabiliser should be fitted.
- The flue terminal should not be fitted with a cowl of any type.
- The vertical stack should have a drain for condensate and rainwater.
- An explosion relief panel should normally be fitted

Figure 7.1: Typical biomass boiler flue components



7.2 Emissions

In addition to carbon dioxide (CO2) and water vapour, the main emissions that biomass boilers give rise to are:

- Carbon monoxide (CO).
- Oxides of nitrogen (NOx).
- Particulate matter (PM), including fly ash, salts, volatile organic compounds, soot and condensable organic compounds.

These emissions can be limited mainly by carefully controlling combustion conditions. However, there is a trade-off between limiting combustion temperatures to lower NOx emissions (e.g. by flue gas recirculation) and ensuring complete combustion to limit emissions of CO, soot and organic compounds. The chemical reactions and interactions between the various pollutants are complex. A good starting point for further information is the Chartered Institution of Building Services Engineers' (CIBSE) publication 'Biomass Heating, AM15: 2014'.

Boilers up to and around 300kW capacity are usually not equipped with any post-combustion abatement equipment. Larger boilers are often equipped with cyclone grit arrestors, either integral with the boiler or as a separate unit fitted in the flue system prior to the vertical stack. Other methods to reduce emissions of particulate matter include bag filters, ceramic filters and electrostatic precipitators.

Additional control of NOx can be achieved in large boilers through selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR). This is generally only used with biomass boilers using contaminated waste wood and which therefore must be (i) compliant with the Industrial Emissions Directive (previously the Waste Incineration Directive), and (ii) permitted by the competent authority (i.e. the EPA or local authority).

Emissions monitoring is usually done when it is required by a permit from the competent authority. Typically, this would apply to contaminated waste wood combustion or plant falling under the Medium Combustion Plant Directive (rated thermal input of 1MW or more). The monitoring could be continuous or periodic, depending on the pollutant to be monitored and the detailed requirements of the competent authority. Continuous emissions monitoring (CEM) will require a permanent monitoring system. Periodic monitoring requires samples to be taken by an accredited emissions monitoring service provider.

Emissions monitoring of other biomass boiler plant is unlikely, except where there are concerns about performance, complaints from the public, etc. In these instances, monitoring is likely to be temporary and done by an accredited specialist provider.

8. References and other sources of information

A substantial amount of guidance on biomass systems has been published over recent years. This guidance will not all remain fully correct or accurate, several factors and variables referred to in this guide are likely to change over time, such as technology, costs, fuel availability, financial support schemes, legislations and standards. It is important to cross-reference these factors against the latest publications.

8.1 General

Chartered Institution of Building Services Engineers (CIBSE) (2014). *AM15 Biomass Heating*
https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I76dAAC

Carbon Trust (2012). *Biomass Heating: A Practical Guide for Potential Users*
https://www.carbontrust.com/media/31667/ctg012_biomass_heating.pdf
It should be noted that the costs and Renewable Heat Incentive (RHI) are mainly UK specific.

Invest Northern Ireland (2014). *Biomass: A Best Practice Guide for Businesses in Northern Ireland*
http://www.elementconsultants.co.uk/wp-content/uploads/2018/02/biomass-a-best-practice-guide-for-businesses-in-northern-ireland1.pdf

Biomass Energy Centre, Forest Research (2011). *Biomass Heating: A Guide to Feasibility Studies*
https://www.forestresearch.gov.uk/tools-and-resources/biomass-energy-resources/reference-biomass/documents-downloads/best-practice-guidance/

Biomass Energy Centre, Forest Research (2011). *Biomass Heating: A Guide to Medium Scale Wood Chip and Wood Pellet Systems.*
https://www.forestresearch.gov.uk/tools-and-resources/biomass-energy-resources/reference-biomass/documents-downloads/best-practice-guidance/

Deutscher Energieholz- und Pellet-Verband e.V. (DEPV) (German Wood Fuel and Pellet Association) (2012). *Recommendations for Storage of Wood Pellets* (English translation produced by COFORD, Department of Agriculture, Food and the Marine).
http://www.dimnikarstvo.si/files/GRADIVA/recommendations_for_storage_of_wood_pellets.pdf
(See also:
http://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/pp12_pelletstoragefacility.pdf and www.r-e-a.net/upload/enplus_pellet_storage_guideline_ukpc-v1.pdf)

Conversion factors for energy units of oil and liquefied petroleum gas (LPG) from SEAI
https://www.seai.ie/resources/seai-statistics/conversion-factors/

8.2 Sustainability legislation

The EU Renewable Energy Directive (under revision at time of writing) will come into effect in 2021, extending the scope of the existing EU sustainability criteria for bioenergy to cover biomass and biogas used for heating, cooling and electricity generation.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0767R%2801%29

8.3 Energy efficiency

Excellence in Energy Efficiency Design (EXEED) Certified Program
https://www.seai.ie/grants/business-grants/exeed-certified-grant/

8.4 Health & Safety

Combustion Engineering Association (CEA) (2011). *Health and Safety in Biomass Systems, Design and Operation Guide*
https://cea.org.uk/wp-content/uploads/2018/07/Biomass_HS_final_071211.pdf

Health and Safety Authority (HAS) (2013). *Safety, Health and Welfare at Work (Construction) Regulations 2013* http://www.hsa.ie/eng/Legislation/Regulations_and_Orders/Construction_Regulations_2013/.

Details of the duty holders and responsibilities are included on this website.
http://www.hsa.ie/eng/Your_Industry/Construction/Construction_Duty_Holders/

8.5 Procurement and contracts

Carbon Trust (2012). *Biomass Installation Contracting Guide, Practical Procurement Advice*
https://www.carbontrust.com/media/88611/ctg073-biomass-contracting-guide.pdf

Carbon Trust (2012). *Template Contracts for Supply of Biomass Fuel, Supply of Heat Energy, Operation and Maintenance Agreement and Services Agreement*
https://www.carbontrust.com/resources/guides/renewable-energy-technologies/biomass-heating-tools-and-guidance/

Energy network (produced by North Karelia University of Applied Sciences) (2003). Heat Sales Contract
http://elearn.ncp.fi/materiaali/kainulainens/nwh/heat_energy_entrepreneurship/business_models/material/Contract%20for%20supplying%20district%20heat.pdf

9. Glossary

Ash content	Percentage of a biomass fuel's mass, on a dry basis, that will be produced as ash upon complete combustion of the fuel.
Auger	An Archimedean (a rod with a helical projection) screw used to transfer material that is in a particle form.
Bioenergy	Renewable energy from living (or recently living) plants and animals e.g. wood chippings, crops and manure
Biomass	Any organic matter that can be burned for energy. Typically derived from solid wood into wood chips and pellets. Also, from short rotation coppice, miscanthus, sawdust and straw.
Buffer vessel	A form of thermal storage used to capture residual heat on boiler shut-down to improve system efficiency and to protect the boiler. Must be sized to have sufficient thermal capacity to absorb residual heat on boiler shut-down. Smaller than a thermal store.
Bulk density	Measure of the mass of the fuel divided by its volume (e.g. kg/m^3)
Calorific value (CV) – net	The net calorific value of a fuel is the total energy released during combustion excluding that needed to evaporate any water arising as a combustion product and the moisture content of the fuel. Also known as the Lower Heating Value (LHV) of the fuel.
Calorific value (CV) - gross	The gross calorific value of a fuel is the total energy released during combustion including that needed to evaporate any water arising as a combustion product and the moisture content of the fuel. Also known as the Higher Heating Value (HHV) of the fuel.
Capital costs	Initial setup costs of plant or a project, after which there will only be recurring operational or running costs.
Combined Heat and Power (CHP)	The simultaneous production of heat and electrical power from a single fuel source for useful purposes. Fuel typically combusted in a reciprocating engine or used to generate steam to be expanded in a turbine.
Commissioning	The process of verifying that a new heating plant meets the performance specifications as per design; called for in the installation contract.
Consultant	Professional person or organisation appointed to provide assistance of an advisory nature under a predetermined contract.
Contractor	Person or organisation appointed for the task of executing the scope of works.
Energy crops	Crops grown specifically for energy production purposes e.g. miscanthus
Energy density	Measure of the energy contained within a unit of fuel in MJ/m^3
Feedstock	The raw biomass material subsequently used as a fuel.
Firebed	The mound of fuel undergoing combustion within a boiler's combustion chamber.
Flue	The passageway between combustion device and terminal of a chimney which acts as a duct to exhaust combustion gases to a position and height where they will not cause annoyance or health hazard.
Flue Gas Recirculation (FGR)	FGR is the feeding of a proportion of the cooled flue gases back to the combustion chamber to reduce the temperature of combustion at the grate with the aim of reducing the production of nitrous oxides. Sometimes referred to as exhaust gas recirculation (EGR).
Heat demand	The demand of heat of a site at any one time, typically expressed in kW or MW.
Heat exchanger	A device that transfers heat between two fluid systems e.g. water flows from boiler system and heating pipework. Many different configurations available but plate-heat exchangers most commonly found.
Heat meter	Device that measures the rate of heat transferred by a system by monitoring the flow rate of water and temperature difference between flow and return pipes.

Installer	Organisation or person contracted for the installation of equipment. May also be the supplier.
Lambda (λ)	Denote the ratio between the actual amount of combustion air (oxygen) and the minimum theoretical (stoichiometric) amount of combustion air (oxygen) required for complete combustion of the fuel.
Liability	A person or organisation's legal responsibility to pay debts or fulfil obligations.
Moisture content (MC)	Percentage, by weight, of biomass fuel that contains water. For example, wood pellets typically have an MC of less than 10%. Wood chips and logs are likely to have a more variable MC of between 20% and 60%.
Peak load	The maximum heat demand of a site across a year, typically expressed in kW or MW. Used to size heating systems.
SEAI	Sustainable Energy Authority of Ireland
Short rotation coppice	Dense growth of small trees or bushes regularly trimmed back for re-growth. Willow or poplar grown as an agricultural crop on a short (2-5 year) rotation cutting cycle and at a planting density of 10-20,000 cuttings per hectare.
Stoichiometric combustion	Combustion of a fuel with the theoretical minimum quantity of air (oxygen) that is required for full combustion of the fuel.
Sub-stoichiometric	Combustion of a fuel with less than the stoichiometric amount of air, leading to incomplete combustion.
Super-stoichiometric	Combustion of a fuel with more than the stoichiometric amount of air, normally to ensure complete combustion.
Supplier	Organisation or person contracted for the delivery of a goods or assets.
Thermal store	A reservoir of heat energy provided from the boiler to enable the heating system to meet the majority of energy demands. Allows the boiler to be of a smaller size as well as improving its operating efficiency by allowing running for longer continuous periods. May also perform the role of a buffer vessel.
Turndown ratio	The turndown ratio of a boiler is a measure of its ability to operate at heat outputs less than the full rated output. It is the ratio of the maximum heat output to the minimum level of heat output at which the boiler will operate efficiently or controllably. For example, a boiler with 2:1 turndown ratio will be able to operate down to 50% of its full rated output.
Virgin wood	Wood as cut or harvested prior to any treatment
Warranty	Agreement provided by an organisation such as a contractor or manufacturer that it will remedy, without additional charge, deficiencies in their service or goods that have arisen within a stated period after their installation.

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