HEAT NETWORK PARTNERSHIP FOR SCOTLAND

District Heating Strategy Factsheet

Application of Biomass Boilers in district heating systems

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1 Introduction

The Scottish Government, through the Renewable Heat Action Plan for Scotland, has set a target of 11% of heat consumed in Scotland to be generated by renewable sources by 2020. Biomass can play an important role in achieving that goal.

The Climate Change (Scotland) Act 2009 introduced ambitious targets and legislation to reduce Scotland's emissions by at least 80% by 2050. All public sector bodies in Scotland have duties under the Act to reduce carbon emissions in line with the emissions reduction targets. Heating accounts for a large element of the direct carbon emissions of many public sector bodies, so biomass can make a significant contribution to achieving these targets. Correctly managed, biomass can deliver a significant reduction in net carbon emissions when compared with fossil fuels as well as a possible income stream from Renewable Heat Incentives where applicable.

2 Learning Objectives and Outcomes

2.1 Learning Objectives

At the end of this e-module, the reader will:

- Know how to carry out their own evaluations on the suitability of biomass boilers in various applications; and
- Understand how to evaluate the financial viability of projects utilising this low carbon heating technology.

2.2 Learning Outcomes

On completion of this e-module, the reader will be able to:

- Describe the main biomass boiler technologies;
- Outline the benefits of biomass;
- Assess site suitability for biomass;
- Consider all fuel and technology requirements for installing a biomass boiler; and
- Understand the key issues in relation to biomass boiler projects that are needed to build a business case.

3 Rationale for Biomass Boilers

The Scottish Government, through the Renewable Heat Action Plan for Scotland[1], has set a target of 11% of heat consumed in Scotland to be generated by renewable sources by 2020. Biomass can play an important role in achieving that goal.

The Climate Change (Scotland) Act 2009[2] introduced ambitious targets and legislation to reduce Scotland's emissions by at least 80% by 2050. All public sector bodies in Scotland have duties under the Act to reduce carbon emissions in line with the emissions reduction targets. Heating accounts for a large element of the direct carbon emissions of many public sector bodies, so biomass can make a significant contribution to achieving these targets.

There are several reasons why an organisation may consider installing a biomass boiler:

- Financial reasons;
- Carbon reduction;
- Boiler replacement;
- Access to a locally sourced fuel.

3.1 Financial Reasons

The cost of heat from biomass can be lower than the cost of heat produced by an existing fuel source such as electricity, oil or LPG.

In the future, the price of biomass is likely to inflate at a lower rate compared to fossil fuels to further enhance this financial benefit.

The market for biomass has been transformed by the introduction of the Renewable Heat Incentive (RHI). This is the world's first incentive scheme for renewable heat. For eligible installations, the RHI offers a payment for each unit of eligible renewable heat (see section 8.2).

3.2 Carbon Reduction

Correctly managed, biomass can deliver a significant reduction in net carbon emissions when compared with fossil fuels. The amount of carbon reduced will depend on the efficiency of the biomass system.

There are financial rewards for saving carbon including:

- Reduction of the Climate Change Levy (CCL) which is charged on purchases of gas, LPG and electricity by public bodies[3];
- Reduction of payments under the Carbon Reduction Commitment Energy Efficiency scheme (CRC)[4]. The CRC scheme is a mandatory carbon emissions reporting and pricing scheme to cover all organisations in the UK using more than 6,000MWh per year of electricity. The scheme is managed on behalf of the UK Government's Department of Energy & Climate Change (DECC), by the Scottish Environment Protection Agency (SEPA); and

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[1] Please refer to http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/Heat/RHUpdate11 for more information [accessed 03/05/2017]

[2] Please refer to www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/climatechangeact for more information [accessed 03/05/2017]

[3] Please refer to www.gov.uk/green-taxes-and-reliefs/climate-change-levy for more information [accessed 03/05/2017]

[4] Please refer to www.scotland.gov.uk/Topics/Environment/climatechange/international-action/uk/CRC-1 for more information [accessed 03/05/2017]

- Reduction in the quantity and cost of emission allowances purchased by very large energy users who are part of the EU Emissions Trading Scheme (EU-ETS)[5].

3.3 Boiler Replacement

Biomass systems are often considered as an option at the point when life-expired boiler systems are being replaced. Capital options need to be assessed and the financial and carbon impacts of different boiler systems need to be evaluated.

Biomass systems can be designed to generate heat at a range of temperatures, pressures and flow rates. This means that biomass can be integrated within existing heating systems without major modification of the heat distribution system.

3.4 Source fuel locally

Biomass fuel can be sourced locally from within Scotland, on an indefinite basis, contributing to security of supply[6].

Some organisations consider it a benefit to source fuel close to where it is used, providing local economic benefits through the fuel supply chain. In addition, sourcing fuel locally allows for the financial and environmental costs of fuel transportation to be minimised.

Biomass suppliers are based all over Scotland and it is possible for most sites to purchase fuel locally.

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[5] Please refer to www.scotland.gov.uk/Topics/Environment/climatechange/international-action/eu/EUETS for more information [accessed 03/05/2017]

[6] Please refer to http://www.woodfueldirectory.org/ [accessed 03/05/2017] for more information on biomass suppliers in Scotland.

4 Biomass Boilers

Biomass boilers are very similar in design to boilers used to burn coal. Biomass has been successfully used across a wide range of public sector buildings. There are a number of different biomass boilers available. The major differences between them relate to the type of fuel that they can burn, the size of the boiler, how the fuel is fed into the boiler and whether the boiler is continuously fired or batch fed.

Successful installations will recognise that biomass systems behave differently to fossil fuel systems. The key features of biomass systems include:

- Biomass fuels are organic products. This means that their physical and chemical characteristics vary, with wide variations in combustion performance across the range of different biomass fuels available and smaller variations within the same type of fuel. Boilers are designed to operate efficiently with a specific fuel specification. This makes matching and checking that the fuel supply meets the boiler specification crucial;
- Biomass fuel needs to be stored on site and transferred to the boiler. A biomass scheme will need adequate fuel storage and handling systems. These take up space and need to be designed to match the physical characteristics of the fuel chosen. This is to avoid blockages in the fuel delivery system and to take into account health and safety issues; and
- Biomass boilers do not react to rapid changes in heat demand, as combustion of the solid fuels cannot change as rapidly as the combustion of gas or oil. Consequently biomass boilers are best operated in continuous operation with steady or slowly changing levels of output. This should be considered at the design stage. The biomass boiler may be sized to match base load demand, with a backup fossil fuelled system for peak demand; or a buffer tank may be used to provide a heat store.

4.1 The main elements of a biomass boiler

Biomass fuels all have some degree of moisture within them. To deal with this a biomass boiler has a refractory lining and the combustion chamber is designed such that the fuel entering goes through a drying zone created by reflected heat before it is burnt. This means that it is possible to burn even very wet fuels (50% moisture or more) by using a large combustion chamber with a large drying zone and extensive refractory lining. As the drying process uses energy this leads to lower overall boiler efficiency when wetter fuels are used.

This need for space within the combustion chamber for fuel drying combined with the low energy density of biomass compared to fossil fuels is the reason why biomass boilers are considerably larger than similarly rated fossil fuelled systems.

The combustion of wood involves initial gasification of the fuel such that combustion occurs above and not within the fuel bed. Oversupply of air is essential to ensure complete combustion occurs.

The fuel feed process requires addition of the fuel in response to the heat demand. Screw augers can provide accurate control of fuel feed and are most often used in smaller systems where fuel feed rate is critical. Larger systems use chain or conveyor feed systems as used in coal boilers. All fuel feed systems incorporate devices to prevent fire spreading into the fuel feed system and then into the feed hopper.

Many biomass boilers include automatic ignition. This usually involves heating an electric element and blowing the hot gases into a small area of fuel until it combusts.

4.2 System Overview

The key elements of a biomass heating system are:

- Access to the site for fuel delivery;
- Fuel reception and dry storage;
- A fuel delivery mechanism for getting the fuel from the store to the boiler;
- The biomass boiler itself; and
- Ancillary equipment, such as the flue, ash extraction, buffer tank, pipework and the control system.

The choice of boiler, fuel store and delivery system all depend predominantly upon what type of biomass fuel is being burned. Other decisions such as whether or not an automatic system is required, the need for a heat buffer tank and the complexity of the heating system will depend on the nature of the site, the heat load and the type of fuel. This means that one of the first and most important decisions you will have to make when considering a biomass boiler system is what fuel to use. In this section we will first examine biomass fuel types and then discuss boiler sizing and the use of ancillary equipment.

4.3 Biomass Fuel Types

As shown in Table 4.1, biomass has a lower energy density than solid or liquid fossil fuels. This means that biomass fuels are required in larger volumes to satisfy a given heat output.

A biomass boiler burns organic matter, grown either as a fuel or derived from a clean waste stream such as the unwanted branches when a tree is harvested. For small and medium installations (up to around 1MW) there are three main types of fuel:

- Unprocessed fuel such as wood logs[7] or straw bales;
- Wood chips; and
- Wood pellets.

For large installations, wood chip or wood pellets are the most commonly used fuels.

Forestry Commission Scotland has created a website dedicated to providing information on the use of wood fuel[8].

There are many types of energy crops that can be used as biomass fuel such as miscanthus grass and short rotation coppice grown as a farm crop. Most biomass in Scotland will come from wood that is co-produced when woodland or forestry trees are harvested. This so called 'brash' comprises branches and tree tops, which has few other markets. Other sources are from thinning operations undertaken as part of woodland management, or from the removal of poor quality trees prior to replanting.

These biomass sources are either made into fuel by processing it into pellets by first drying and grinding the material prior to compression, or are simply chipped and used. Pellets can also be produced from residues collected in timber processing, i.e. sawdust from sawmills or from manufacturing plants.

Alternative fuels can come from diverse sources such as seaweed or other biomass waste steams such as crop by-products. Before considering one of these alternative fuels it is important to ensure that the biomass boiler and fuel handling system is designed for them. Any long-term fuel supply risks must also be taken into account.

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[7] Wood logs are usually used on small scale boiler, <150kW output.

[8] Please refer to www.usewoodfuel.co.uk for more information [accessed 03/05/2017]

This is important as each boiler will be tested and a certificate produced which sets out what type of fuel it can burn in order for UK Air Quality Standards to be met. The RHI scheme will require you to use a fuel which meets the specification for your boiler set out in the emissions certificate. For instance, it is typical for a log boiler to need a fuel of below 20% if it is to meet air quality requirements.

Table 4.1 - Bulk and Energy density of different fuels[9]

Fuel (as received)	Calorific value		Energy density by volume	
	kWh/tonne	kWh/litre	kWh/m³ (low-high)	
Wood chips (30% MC)	3,500	–	694	868
Log wood (stacked – air dry: 20% MC)	4,100	–	1,419	2,028
Wood (solid – oven dry)	5,200	–	2,067	3,100
Wood pellets	4,700	–	2,833	3,306
Miscanthus (bale – 25% MC)	3,400	–	471	605
House coal	8,100	–	6,847	
Anthracite	8,900	–	9,808	
Oil	11,500	11.2	9,972	
Natural gas	–	–	10.13	
LPG	1,300	7	6,520	

Different biomass types have different processing requirements to turn it into useful fuel and these have different costs associated with them. Wood logs are cheaper than wood chips for example and chips are cheaper than wood pellets. While there is an obvious advantage in buying cheaper fuel, this has implications elsewhere in the process. For instance, pellets are in effect an engineered fuel that comes in a standard size and at a standard moisture content. As a result the biomass systems to use them can be cheaper. Chip is more variable in both size and moisture content leading to more costly boiler and fuel feed systems. Logs have the same variation in terms of size and moisture content and in addition they almost always need some form of hand feeding or batch loading, but the boilers to use them are usually simple and low cost.

As a result, these are the practical considerations that must be made:

- Do I want an automatic or manual fuel feed system?
- If I chose automatic fuel feed do I want a lower cost pellet system and a high cost fuel or a higher cost chip fed system and cheaper fuel?
- If I chose chip or logs, can the fuel be sourced at a low enough moisture content to meet air quality requirements or will it need to dry further?
- How will the fuel be delivered to site?
- How will the fuel be stored?
- How will the fuel be fed to the boiler?
- How often will the boiler need manual input?

4.3.1 Wood Chips

Biomass boiler systems that burn wood chips require less manual intervention than those that burn wood logs. Generally wood chip is characterised by variable moisture, mineral content, ash and calorific value. It may also have variable size. This means that it is important to specify wood chip that is suitable for the boiler to be used.

Wood chips can be produced from virgin timber, from sawmill offcuts, waste wood or from brash. The type of feedstock material will influence the combustion properties of the fuel. For example, sawmill offcuts and brash may contain more bark than fuels produced from

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[9] The Carbon Trust (2012). Biomass Fuel Procurement Guide.

small round wood, logs or forestry thinnings. This increases the amount of ash produced; and it may also increase the level of trace components that can impact on combustion such as chlorine.

The type of ash produced is important: ash with a lower melting temperature than the boiler is designed for can cause clinker to form. Clinker is ash that melts or fuses. Clinker can block or damage the inside of the boiler by coating surfaces and allowing hot spots to form. This is particularly important for waste wood. Waste wood is generally classified into four classes: the highest grade (often denominated 'A') is the cleanest grade and should not contain contaminants and should have low trace components. Grades B and C are progressively more contaminated. Grade C waste wood is classified as waste and should be treated as such. Grade D is hazardous

Wood is chipped to a specified maximum size. Smaller particle sizes are an inevitable consequence of the nature of the feedstock going into the chipping process. Brash or sawmill offcuts may lead to more size variation compared with chips made from more uniform round wood. The size of the chips is important, as oversized wood chips can block fuel delivery mechanisms. The wood chips are then dried to a moisture content that meets the boiler specifications. This is dependent upon the design of the boiler but a maximum moisture content of 30% is typical for many installations of 500kW or less.

<u>Delivery</u>

Delivery of chips to the site may be done in a number of ways:

- A common delivery method for wood chips is a tipper lorry or trailer. These vehicles require either an underground fuel store or a store at a lower level than the road supporting the vehicle.
- A front loader may be used to take the chips from the delivery vehicle to the store or the chips can be tipped directly into a store which might be a shed or barn type structure.
- For self-supply it is also possible to chip the wood on site and blow the chips directly from the chipper into a hopper.

The impact of climate change is likely to result in different weather patterns and conditions in Scotland over the next few decades. This may lead to increased and new risks from flooding within the lifetime of a biomass plant. Consequently, the following should also be considered for an underground fuel store:

- The distances from the boundary of the site to waterways and water bodies;
- The existence of groundwater, coastal water or nature protection areas in the area;
- The geological or hydrological conditions in the area; and
- The risk of flooding or subsidence on the site.

Above ground reception hoppers can also be used to store wood chip above ground, without the requirement for there being a change in level on site.

For larger plants (>500kW) it is also possible to use mechanisms such as a walking floor. Here, the wood chips are tipped onto the floor of a large shed and a moving floor carries the chips to a conveyor, which delivers the chips to the boiler. The high cost of such plant dictates the scale at which it can be economically used.

<u>Stores</u>

Wood chips are often stored outside at the point of production and as a result can have relatively high moisture content and a tendency for microbial degradation. This may cause self-heating if stored in large piles or simply fuel deterioration in small quantities; and in addition may result in the presence of microbial spores. Rain may increase this issue, so it is important that the chips are stored and handled properly. There are Swedish recommendations for storage piles between 7 metres and 15 metres depending on the nature of the chips[10]. Stores for wood chips must have a flat solid base. Wood chips can form overhangs and cavities when fuel delivery mechanisms take fuel from the base of the store, with the overlapping wood chips effectively forming a bridge over the gap created. For this reason it is not appropriate to design fuel stores for wood chips with a V-shaped base.

Fuel Store to Boiler

The fuel needs to be transferred to the boiler. For wood chips this typically involves automatic fuel delivery mechanisms, controlled in relation to the demand from the boiler.

The most common mechanisms for taking the fuel from the store to the boiler in larger systems are conveyor belts (including drag-link conveyors). These can be fed by a rotary agitator or walking floor. A rotary agitator consists of four arms which extend out of a central hub. As the hub rotates the arms push the wood pellets onto the conveyor or auger. The arms extend as the fuel store becomes empty.

In smaller systems a screw auger conveyor is more commonly used. This comprises a mechanism that uses a rotating blade, usually within a tube, to move the wood chips.

4.3.2 Wood Pellets

Wood pellets are the most straightforward form of wood fuel to work with and allow the greatest degree of automation. However, they also tend to be more expensive than other wood fuels and therefore are more suitable for boilers <200kW or where large quantities of fuel need to be transported long distances. They are available supplied in bags or loose in bulk, the latter being cheaper per tonne.

Pellets are manufactured from compressed sawdust (which can be produced from a variety of feedstock[11]) and are produced to a specified size and moisture content. The pellets are usually 6mm or 8mm in diameter for small systems while larger systems can use pellets of 10mm or 12mm. The length of the wood pellets is generally less than 40 mm. Moisture content is between 6-10% with a net calorific value of 16.3-19 MJ/kg. There are standards for the production of pellets (EN14961), which is represented by the ENplus Quality Certification in Europe[12]. This ensures the quality for wood pellets, including factors such as the length of the pellet, the moisture content and the amount of ash generated. Wood pellets are commonly produced to the ENplus-A1 or ENplus-A2 standards. A1 pellets incorporate very little bark, have a low ash content and a higher ash melting point than the A2 pellets. A2 fuel is more commonly used by larger installations and produces more ash. No chemically treated wood is included in these wood pellets.

Table 4.2 outlines the quality standards for pellets.

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[10] Please refer to IEA Bioenergy: Health and safety aspects of solid biomass storage, transportation and feeding. Found at http://task32.ieabioenergy.com [accessed 03/05/2017]. The Environment Agency has also proposed standards for fuel storage. Please refer to Technical Guidance Note 7.01: Reducing fire risk at sites storing combustible materials.

[11] The majority of wood pellets are produced from wood chips, bark, wood processing shavings or sawdust.

[12] Please refer to www.enplus-pellets.eu/pellcert/enplus-handbook for more information

Table 4.2 Quality standards for pellets

Unit	ENplus A1	ENplus A2
Length	< 40mm	< 40mm
Fines by weight	< 1%	< 1%
Ash content by weight	< 0.7%	< 1.5%
Ash melting temperature	> 1,200°C	> 1,100°C

The EN 14961-2 standard was agreed upon by the European Pellet Council in January 2011 and has gained extensive support within the European pellet sector. ENplus enables the customer to identify pellets that fulfil EN14961-2, the European standard for wood pellets.

Stores

Wood pellets are dry fuels and must be stored under cover. They do not degrade as readily as chips due to microbial degradation because of the low water content and heat used during processing. Poor quality pellets are prone to break up if handled frequently or incorrectly. This should not be a significant problem with certified pellets.

Wood pellets flow more readily than wood chip and this property can be used to ease the handling and movement of pellets around the site, making automatic feed easier. As a result, wood pellet fuel stores typically have a V-shaped base, falling to a central auger. This arrangement allows the pellets to flow towards the auger, which then takes the pellets directly to the boiler. This angle of drain should be designed to ensure that the pellets flow well and do not become interlocked. It is also possible to use augers to lift pellets vertically, on an incline or horizontally.

On smaller sites, pre-fabricated fuel silos can be erected inside a building with the fuel delivery connections mounted on the outside wall of the building. On larger systems an external fuel silo is more appropriate. Health and safety issues are also important in the consideration of the handling and storage of wood pellets, particularly in large quantities. Dust may be a particular issue. Large stores will be subject to self-heating issues and should be monitored carefully[13].

Delivery

Wood pellets are often delivered pneumatically directly from a lorry into a fuel store, negating the need for a reception mechanism.

It is important that the wood pellets are not damaged during delivery. Pellets can be damaged when delivered at high pressure. This causes them to split when they hit the inside of the store, which results in sawdust being fed into the boiler instead of the pellets. It takes longer to deliver the wood pellets at the correct velocity, instead of the maximum velocity a delivery vehicle is capable of. It is therefore important to monitor deliveries to ensure the pellets are delivered correctly.

The Scottish Government has developed a Biomass Wood Fuel Pellet Supply Framework for public bodies who are purchasing biomass wood pellets. The framework only covers wood fuel in the form of pellets. Biomass woodchip, animal biomass and plant biomass are not included in the scope[14].

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[13] Please refer to www.ieabcc.nl for more information [accessed 03/05/2017]
[14] Please refer to www.scotland.gov.uk/Topics/Government/Procurement/directory/Utilities/Biomass for more information [accessed 03/05/2017]

4.3.3 Wood Logs

In their most simple form as harvested, wood logs come in 3 metre lengths of stemwood. These are usually delivered by lorry, in loads of around 25 tonnes. The moisture content is variable and can be 60% or higher at the time of harvest. As burning wet wood is very inefficient it is usual to store logs for several months to dry or 'season' them before fuel use. Some log boilers need a fuel of below 20% moisture content if they are to meet air quality requirements. For these types of boilers the feedstock must be dried, usually by seasoning for a lengthy period.

Round logs must be handled using heavy machinery and the boiler will invariably need to be started manually. Log based systems tend to be small scale only (20-500kWth) and involve batch fed boilers. There are semi-automatic systems, where logs can be loaded into a hopper and automatically loaded into the boiler when required. In these systems heat may be transferred to a buffer or storage tank allowing hot water to be used on demand.

Wood is typically only used "in the round" (i.e. whole wood logs) on agricultural sites where there is a large amount of space available, the machinery is already on site to handle whole logs and personnel are on site who can service the boiler.

Larger sites can often burn bales of brash from timber harvesting, provided the boiler is designed to do so.

Small or medium sized installations use split logs, cut into lengths of 300mm to 500mm. It is common for wood to be delivered after it has been seasoned or kiln dried, however the moisture content of split logs can be quite variable and achieving a moisture content of less than 20% needs either a long time to season (up to around 24 months) or kiln drying. Once the wood is sufficiently dried it will require careful storage.

Split logs need to be taken from the log store to the boiler manually, and the boiler will need to be started manually.

4.3.4 Other fuels

Other common fuels include energy crops, waste wood or straw. Some important differences between these fuels and those described above are:

- Energy crops: these fuels include short rotation coppice, producing a wood fuel with similar properties to those described above. One difference is the amount of bark that may be included in the fuel, with a higher mineral content than debarked wood fuel. It will be important to ensure that the boiler can take this fuel and that the mineral content will not impact on ash production or lead to fouling of the boiler. An alternative energy crop is miscanthus grass. This is similar to bamboo in nature and it is important to understand the moisture content, mineral content and handling requirements of this fuel.
- Straw tends to come in bales, although there are ways to pelletise straw. As an agricultural crop based feedstock it will include a higher mineral content than wood, resulting in a higher slagging and fouling potential than wood fuel. In addition handling of the bales will need to be considered. There are systems available that are designed to take straw.
- Waste wood represents a range of fuels. For most systems of the scale under consideration here the higher quality fuels (Grade A and B, see 4.3.1) should be used. Properly handled this fuel should not be classed as a waste fuel. If the material is classed as a waste fuel then permitting requirements will take this into account and emissions limits will need to be met. Waste wood tends to be dry and handling and storage should take this into account.

4.3.5 Summary of biomass feedstock

Table 4.3 provides a summary of the different options for biomass feedstock.

Table 4.3 Summary of biomass feedstock options

Feedstock type	Derived from	Moisture content (%)	Chemical composition	Mechanical handling
Virgin wood chips	Forestry management residues such as thinnings and felling residues Sawmill by-product and clean untreated waste wood Short rotation coppice	25-30	Low mineral and trace components Nitrogen content important to emissions Fuels containing bark will contain more trace components	Yes
Wood pellets	Sawmill residues, sawdust, untreated waste wood	6-10		Yes
Wood logs	Round wood, thinnings and woodland or estate management	20-60		Batch fed
Agricultural Bales	Straw (wheat, barley)	10-30	Trace components may include alkali metals, silica and chlorine. For miscanthus this will depend on harvest time	Yes, in designed systems
Energy crop bales or pellets	Miscanthus	<10 to >20		Yes, in designed systems

4.3.6 Biomass Fuel Sustainability

There are concerns about the sustainability of biomass feedstock production, relating to land use and to inappropriate forestry practice. Both of these may decrease the carbon benefits of biomass use. It is therefore important that biomass fuels are grown, harvested, processed and transported in ways that minimise carbon and other impacts.

From Spring 2015 all biomass fuel used by organisations claiming the RHI must meet a lifecycle greenhouse gas emissions target of 60% savings against the EU fossil fuel average and land criteria. For woodfuel use this is set out in the UK Timber Standard for Heat and Electricity[15]. Meeting these standards de-risks the chance that biomass energy will be unsustainable.

The Biomass Suppliers List (BSL) was launched by the UK Government on 30th April 2014. This is a list of accredited woodfuel suppliers who have demonstrated that their fuel meets the sustainability criteria required under the RHI. Recipients of the non-domestic RHI may use the BSL as the easiest way to demonstrate compliance; however, they may also demonstrate the sustainability of their fuel by submitting quarterly sustainability reports to OFGEM[16].

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[15] Please refer to www.gov.uk/government/publications/timber-standard-for-heat-electricity for more information [accessed 03/05/2017]
[16] Please refer to www.ofgem.gov.uk/environmental-programmes/renewables-obligation-ro/information-generators/biomass-sustainability for more information [accessed 03/05/2017]

4.4 Health and Safety Issues

The Combustion Engineering Association has produced a design and operation guide for health and safety considerations for biomass systems[17].

4.4.1 Carbon Monoxide

Biomass boilers can be a source of carbon monoxide and flammable gases. These gases can, on occasion, feedback into the fuel store. This causes both a risk of suffocation and a risk of explosion. The design of a biomass fuel store and the working procedures for those operating the plant must consider these risks[18].

4.4.2 Fuel Deliveries

Fuel deliveries are usually carried out by lorry. It is important that these fuel deliveries take place safely. This can be particularly challenging on some sites where there is a considerable amount of pedestrian traffic or the presence of vulnerable people.

4.4.3 Compost

If biomass fuel (e.g. wood chips and wood pellets) is allowed to get wet or is stored wet for long periods, then there is a risk that it will start to compost, resulting in the release of heat. If left unchecked, the fuel pile could spontaneously combust. To prevent this, the fuel must always be kept dry.

4.4.4 Dust Fires

Incorrect handling of wood pellets can cause them to break down into fine wood dust which presents the potential for dust fires or explosions. This risk can be managed by ensuring that systems are designed to avoid the breaking-up of pellets and accumulation of wood dust. In addition good housekeeping measures should be taken to avoid sources of ignition.

5 Boiler Sizing and Buffer Tanks

Biomass boilers take longer to heat up and cool down than fossil fuel boilers and are less able to modulate their output. It can take 45 minutes to 2 hours for a medium sized biomass boiler to heat up, and up to 24 hours for a large biomass boiler to reach maximum output. The time taken depends on the fuel used and the boiler design. As a general rule, those boilers which are designed for dry fuel such as wood pellets have less refractory lining and therefore take less time to heat up. The higher the moisture content that a boiler can handle, the longer it is likely to take to heat up and cool down

The design of a system that uses a biomass boiler must consider this. If the biomass boiler is required to start up frequently and operate for short periods then it will be inefficient, more likely to breakdown and will require more regular maintenance. There are two strategies to address inefficiency in biomass systems:

- On sites where there is fossil fuel available, the biomass boiler and fossil boilers can be designed to work together with the biomass boiler meeting the base load for the site and fossil boilers modulating to meet remaining demand; or

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[17] Please refer to www.cea.org.uk/index.php/policy/existing-policy/health-and-safety-biomass-systems for more information
[18] Please refer to www.hetas.co.uk/wp-content/mediauploads/health_and_safety_in_biomass_s.pdf for more information [accessed 03/05/2017]

- On sites where the biomass boiler is the only heat generating plant, a buffer tank can be used to even out the peaks and troughs of heat demand. A buffer tank is a large and highly insulated water tank that acts as a heat store.

Both of these strategies require an assessment of the peak heat loss in the building and assessment of the heat demand during the year.

5.1 Biomass and Fossil Fuel Backups

Biomass boilers are often used in conjunction with fossil fuel boilers. The fossil fuel boiler is used as a backup system when the biomass boiler and buffer tank cannot provide enough heat.

This configuration has two main benefits:

- If a fossil fuel backup system is used then the kW rating of the biomass boiler can be reduced accordingly as it will not be the sole source of heat; and
- It ensures that the biomass boiler operates as efficiently as possible, supplying base load heat. The heat load is sufficient most of the time for the biomass boiler to operate between 30% and 100% of its maximum output.

5.2 Role of a Buffer Tank

A buffer tank can be a useful means of extending the output of a biomass boiler. This can help to meet part of the peak load requirements and to overcome the initial inertia of a biomass system starting from cold for instance at the start of a day.

It can be possible for a biomass boiler providing 30% of peak output to meet 95% of total annual consumption by the use of a sufficiently large buffer tank.

An intelligent control system can manage the output of the boiler and the storage capacity of the buffer tank to ensure maximum system efficiency. Such a system would typically have five or more sensors at different heights in the buffer tank. A controller with only two sensors will be cheaper but less capable of controlling the biomass boiler output as accurately.

When specifying a biomass system, the boiler, buffer tank and control system must be selected to work together to meet the heating requirements of the system they serve.

5.3 Peak Heat Load

Fossil fuel boilers are traditionally sized by calculating the maximum heat requirement of the building they serve and selecting a boiler which is capable of providing at least this much heat. The calculation of the maximum space heating requirement of a building generally involves selecting a design outside temperature (the temperature which is exceeded 98% of the time would be typical) and a design inside temperature, for example 20^{o}C.

The insulation properties of the building then need to be assessed. This is done by measuring the area of each building element such as the walls, windows and roof. The insulation value for each element is known as the U-value. The U-value will be specified for new buildings. For recently constructed properties it is often assumed that the property was constructed to meet building regulations[19]. The National Calculation Method has a database

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[19] Please refer to www.scotland.gov.uk/Resource/0045/00450556.pdf for more information [accessed 03/05/2017]

of U-values for different construction types[20]. The total heat lost through all these building elements is referred to as the Fabric Heat Loss.

The Ventilation Heat Loss calculation takes into account the volume of the building and the ventilation rate. For new buildings, the ventilation rate may be specified (for healthcare facilities refer to SHTM 03-01 Ventilation for Healthcare Premises) or a test may have been done for the infiltration rate for building compliance and the performance of the known ventilation systems. For older buildings the ventilation rate will usually be assumed, taking into account the building's age, building use and ventilation system.

Finally, thermal bridging needs to be quantified. This is where heat is lost through the join between two building elements such as around a window or a doorframe.

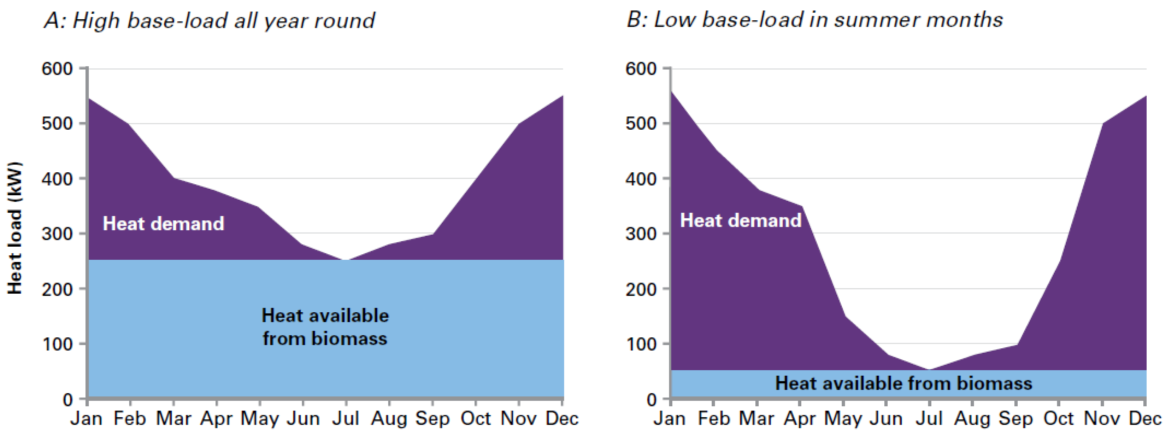
5.4 Biomass Boiler Sizing for Peak Load

Sizing of a biomass boiler is different because, as indicated earlier, biomass boilers are more efficient when operated continuously. Thus, although it is essential to understand the peak load requirements when sizing a biomass boiler for space heating, it is also important to understand that simply selecting a boiler to meet the peak load requirements will result in an inefficient system. This is because the heat load is likely to be much lower for most of the time.

Consequently it is preferential to use a smaller biomass boiler sized to supply average heat load, with a conventional fossil fuel boiler or appropriate heat store to enable the peak heating requirement to be met.

Figure 5.1 shows how the relative sizing of the biomass and conventional boiler will be determined according to the heat load profile for the buildings served. In Figure 5.1 the blue heat load is met by biomass and the purple heat load by a secondary fossil fuel boiler.

Figure 5.1 – Relative sizing of biomass boilers according to heat load profile for buildings served[21]



To understand the heat load profile, consider how a care home and an office are heated. A care home is kept at a constant temperature all day and all night. The amount of heat required will depend on the outside temperature and how much heat is generated inside the building by other sources.

[20] Please refer to www.ncm.bre.co.uk/download.jsp for more information [accessed 03/05/2017]

[21] The Carbon Trust (2009). Biomass heating: a practical guide for potential uses CTG012.

Consider an office with working hours from 09:00 to 17:00. The heating system comes on at 06:00 to heat up the building from cold. Between 06:00 and 09:00 the building gradually heats up, absorbing heat in the process. From 08:30 the building will fill up rapidly with people. Computers, lights and other equipment are turned on and heat is generated. These sources of heat are referred to as internal gains.

This means that the building may need less heat during the day. During the winter months the building will need heat all day, during the spring and autumn months the building may require a limited amount of heat and the building may overheat during the summer months. The building will require no heat between 17:00 and 06:00 and has an intense period of heat consumption between 06:00 and 09:00. The building will have a lower requirement for heat (dependant on the time of year) between 09:00 and 17:00.

A care home is well suited to a biomass boiler due to the continual need to heat the building and the slow changes in heat demand. The office is less suitable for a biomass boiler. In this example if a biomass boiler was installed, a buffer tank would be required and the boiler size would have to be carefully selected.

6 Maintenance

Biomass boilers are likely to require more maintenance than oil or gas boilers. For example, biomass boilers burn solid fuel and therefore generate more ash than an oil or gas boiler. This ash must be removed from the boiler to ensure that the heat is efficiently transferred. If the ash mixes with condensate in the boiler then acid deposits may form, which cause corrosion. Additionally, if ash is allowed to build up this may result in hot spots that can damage the boiler.

As they burn solid fuels, biomass boilers have more moving parts than gas or oil fired boilers and this also leads to a higher maintenance requirement.

It is important to keep the boiler clean. This can be automated to some extent, although it will always require more work to operate than fossil fuel boilers.

In addition the boiler, the fuel store and fuel handling machinery are mechanical systems that will incur wear and tear and will also require maintenance from the supplier or other qualified providers.

To ensure that the plant is maintained and operated correctly it is advisable to integrate routine checks on the system. These can include daily visual inspection; weekly checks (e.g. on ash level); monthly checks (e.g. on handling equipment); and annual servicing. In addition fuel monitoring is important to ensure that the fuel meets the specification required for the boiler. This should include monitoring of fuel consumption and batch testing of quality (e.g. for moisture content, particle size, visual inspection for stones, plastic etc. and laboratory testing for chemical contaminants if the fuel is not certified).

6.1 Biomass Boiler Cleaning

The heat exchanger in a boiler consists of a series of tubes through which the hot combustion gases pass, heating the surrounding water. Many wood pellet and wood chip boilers use items known as turbulators to keep these tubes clean. These function by inducing turbulent flow of combustion gases to reduce the rate at which ash is deposited onto the tube walls.

For larger systems, compressed air is used to remove ash deposits from the heat exchangers. Such systems can reduce the frequency of ash removal but do not eliminate the need for it. Boilers which are consistently operating at low outputs will tend to need more frequent cleaning than those which operate between their minimum and maximum output most of the time.

6.2 Flue Design

Biomass boilers require a flue or chimney to draw flue gases through the plant and disperse these gases to atmosphere at a safe height. When designing a biomass boiler system it is essential to consider the flue that will be required. Generally these will need to be higher (and wider) than equivalent flues for oil or gas boilers. The flue will need to provide a draught to meet the requirements of the boiler and ensure that the emissions of the boiler are sufficiently dispersed. A flue will often require planning permission, which will consider appearance and impact on local air quality.

Environmental Health Officers will assess the impact on the local air quality. There are some areas where air quality is a specific concern and additional requirements may be in place to manage air pollution. These are known as Air Quality Management Areas, usually referred to as AQMAs. Not every AQMA has the same restrictions in place.

In making a decision, the Environmental Health Officer will require evidence that the flue has been designed to sufficiently disperse gases such as nitrogen oxide, nitrogen dioxide (also referred to as NOx) and particulates. Wood contains nitrogen and by burning wood more nitrogen compounds are generated than would be the case from an equivalent fossil fuel boiler. In considering permitting for a boiler, the Environmental Health Officer may require particular measures to be incorporated into the scheme (e.g. ceramic filters or electrostatic precipitators, designed to reduce particulate emissions).

6.3 Removing Particulates

Since biomass is a solid fuel it generates more particulates than natural gas or oil. Ensuring the appropriate dispersal of these requires a combination of actions that may include:

- Ensuring that the velocity of the flue gases is more than six metres per second;
- Making the flue higher than any surrounding structure by at least two meters; and
- Use of devices to remove particulates from the flue gases.

Cyclones are the cheapest and most common way to remove particulates from exhaust gases. These operate by spinning the flue gases very quickly, causing the heavier particles to migrate to the outside of the cyclone vessel before being deposited in the base of the cyclone.

The disadvantage of such systems is that they do not remove the smallest particles; this requires the addition of a ceramic filter or an electrostatic precipitator. These add considerable cost to a system but may allow a biomass boiler to be installed where it would usually not be permitted.

The requirements for biomass flues are different for each Local Authority area so it is important that these are checked.

6.4 Space Requirements

Biomass boilers are generally larger than gas boilers, although the size does not increase linearly with increases in the output capacity of the boiler. Most manufacturers produce a range of boilers housed in the same or similar size of enclosure (for example 100kW to 200kW); with only the next range of boilers likely to be significantly larger in terms of both footprint and height.

It is important to leave sufficient space around the boiler to allow it to be maintained. Again, each boiler is different and while some only need access on two sides for maintenance, there are others which require access on all sides.

Buffer tanks also take up a lot of space. Even the smallest biomass system will likely require a tank of 2,000 litres. It is not uncommon for larger systems to require a buffer of more than 10,000 litres and district heating schemes may require a buffer of more than 100,000 litres (normally in the form of multiple buffer tanks).

The fuel you choose to burn, and how much fuel you wish to store on site will affect how large a fuel store you need. The most important consideration when deciding how much fuel you need to store on site is the length of time between deliveries. Rural sites need particular consideration.

Finally, you should consider how the size of fuel delivery you are able to order will affect the amount paid for the fuel. A delivery of wood pellets of more than 10 tonnes is often considerably cheaper than a delivery of less than 10 tonnes.

Figure 6.1 provides a guide to typical plant sizes. This only includes the boiler. The fuel store, fuel delivery and control equipment will also need to be taken into account.

Figure 6.1 –Typical biomass plant sizes [22]

Plant size (kW)	Footprint (m^2)	Length (m)	Width (m)	Height (m)
250	22	5.5	4	2.1
320	33	8.2	4	2.5
400	33	8.2	4	2.5
500	42.5	8.5	5	2.7
700	42.5	8.5	5	2.9
900	45	9	5	3.6
1500	47.5	9.5	5	4.3
2500	55	10	5.5	4.7
3500	60.5	11	5.5	5.6
4500	69	12.5	5.5	5.9

6.5 Containerised Plant Rooms

Many sites lack sufficient space to install a biomass system within an existing building. This may be overcome by the use of a pre-fabricated plant room, delivered ready to be connected to your existing system. Often such systems are in the form of modified shipping containers or pre-fabricated buildings.

These pre-fabricated units can also include a fuel store, or can be connected to a fuel silo.

As a guide, a plant room for a 200kW biomass boiler, buffer tank and a 20m^3 fuel store would typically be around 3m x 3m x 9m. The size of plant rooms that can be delivered is limited to about 4m x 4m x 12m due to road haulage restrictions. A ballpark cost for a containerised plant room with a 199kW biomass boiler, buffer tank and fuel store is £100,000 including installation.

[22] The Carbon Trust (2009). Biomass heating: a practical guide for potential uses CTG012.

These pre-fabricated units still require some preparation work on site, such as a building structural slab, connecting pipework, control cables and an electricity supply ready for connection.

6.6 Planning Consent

In 2009 and 2010, the Scottish Government introduced a relaxation on planning controls, called "permitted development rights" on properties for many of the more common types of renewable technologies. This relaxed, and in some cases, removed the need for planning permission for many renewable systems[23].

There are permitted development rights for biomass systems under $45kW_{th}$. These may allow the installation of a biomass system without applying for planning permission, however there are a number of conditions attached. Permitted development rights do not extend to listed buildings and scheduled monuments, which are covered by other planning regulations. In such cases, listed building consent is required for most works. Even if the biomass boiler is $45kW_{th}$ or less, it may not be possible to comply with the limitations associated with the permitted development, in which case planning permission would be required.

Elements of a biomass system can be designed for minimal visual intrusion. Boilers and fuel stores can be installed internally, provided there is sufficient space, or in external plant rooms with an attractive cladding.

It is often more difficult to disguise a biomass flue. The height of the flue is determined by the boiler's requirements and the height of surrounding buildings. It is often not possible to make a flue shorter so that it falls within permitted development, or is visually unobtrusive, without causing operating problems, or failing to meet air quality requirements.

It can be difficult to reach agreements on biomass flues in conservation areas or listed buildings, where the visual obtrusion is of particular concern but the height of the flue cannot be reduced due to operating concerns. For more information refer to the Historic Scotland Short Guide on the installation of micro-renewable systems in historic buildings[24].

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[23] Please refer to www.scotland.gov.uk/Publications/2010/07/15092031/0 for more information [accessed 03/05/2017]

[24] Please refer to http://conservation.historic-scotland.gov.uk/short-guide-8.pdf for more information [accessed 03/05/2017]

7 Building the Business Case

Depending on the fossil fuel, the cost of operating a biomass boiler can be lower than the cost of operating a fossil fuel boiler due to the lower cost of the fuel. This even taking into consideration the higher operating costs associated with biomass. The Government incentives available under the RHI further increase the attractiveness of biomass.

7.1 Fuel Price

Table 8.1 outlines the approximate prices for different biomass fuels, natural gas and heating oil.

The price of biomass is highly dependent upon the transport cost. It is usually uneconomic to transport fuel more than 50 miles from a depot. Many suppliers give discounts for larger deliveries (e.g. pellet deliveries of 10 tonnes or more). These prices are an indication only, transportation costs and the amount of notice provided to a supplier will have a significant effect on the price of fuel.

Table 8.1 Fuel costs comparison

Fuel	Price per unit	kWh per unit	Pence per kWh
Wood chips (30% MC)	£110/tonne	3,500 kWh/tonne	3.1p
Wood pellets	£210/tonne	4,800 kWh/tonne	4.4p
Natural gas	4.9p/kWh	1	4.9p
Heating oil	58p/litre	10 kWh/litre	5.8p
LPG (bulk)	43p/litre	6.6 kWh/litre	6.5p
Electricity	15.0p/kWh	1	15p

7.2 Renewable Heat Incentive

The information below is correct as of 1st July 2014.

The Renewable Heat Incentive (RHI) is a government scheme which makes a payment for generating heat from a renewable source. Table 8.2 shows the amount of money paid for each unit of heat depending upon the boiler used.

For smaller biomass boilers, the RHI tariffs are tiered; this means that a lower rate is paid for each unit of heat beyond a set amount. In each year the Tier 1 tariff is paid until the system has operated up to 15% of the annual rated output (i.e. the equivalent of 1,314 hours at the rated capacity of the installation). For the rest of the output in the year, the Tier 2 tariff will apply.

When a boiler is being sized it is worth considering the structure of the RHI tariffs to ensure that the financial benefits of biomass are optimised. It is important not to oversize the boiler, however, as this may cause problems highlighted in the maintenance section.

Table 8.2 Biomass RHI tariffs for new boilers (April 2017)[25]

Type	Tier	Tariff (p/kWh)[26]
Small biomass (<200kW)	Tier 1	2.85
	Tier 2	0.75
Medium biomass (200 – 999kW)	Tier 1	5.32
	Tier 2	2.31
Large biomass (≥1,000kW)	-	2.08
Solid Biomass CHP (all capacities)	-	4.29

OFGEM have responsibility for administering the RHI[27]. As well as sustainable fuel supply, the RHI has a number of requirements for eligibility. Eligibility requirements include:

- The heat produced must be used for an eligible purpose;
- The heat produced is metered using an approved meter and metering system; and
- For small boilers below 45kW output the boiler and the installer must be accredited under the Microgeneration Certification Scheme (MCS)[28].

7.3 Operation and Maintenance Costs

As described above, biomass boilers need regular maintenance. The maintenance costs will depend upon who carries out the maintenance and how the biomass boiler is operated. An oversized boiler will incur higher maintenance costs.

Figure 8.1 provides an indication of these costs relative to fossil fuel boilers. The costs for biomass boilers assume annual maintenance costs of £600/year, monthly labour requirements of 0.75 days for chip based systems and 0.3 days for pellet based systems, annual plant servicing and a daily labour charge of £100 per day.

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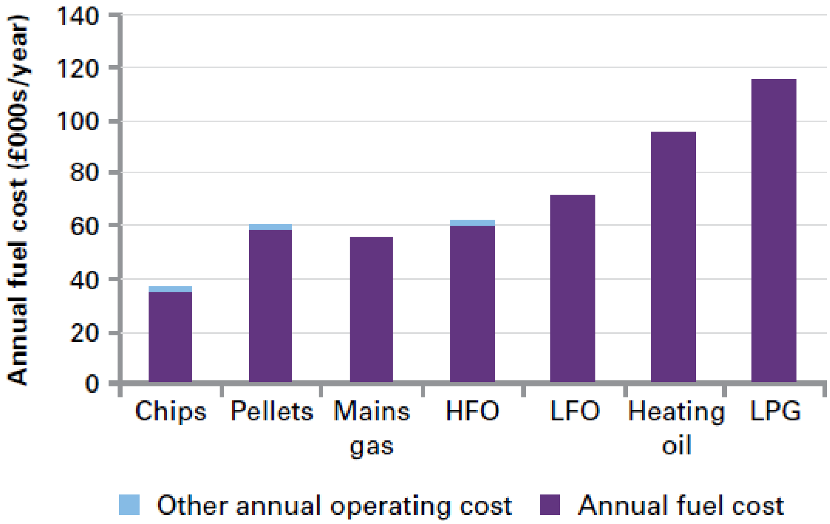
[25] Please refer to www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi/tariffs-apply-non-domestic-rhi-great-britain for more information [accessed 03/05/2017]

[26] From 01/04/2017

[27] Please refer to www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi for more information [accessed 03/05/2017]

[28] Please refer to www.microgenerationcertification.org [accessed 03/05/2017]

Figure 8.1 –Annual fuel costs including maintenance[29]



This shows that while biomass boiler maintenance is higher than with other fuels, it still has little impact on the financial performance of biomass relative to other fuels.

9 Assessing Site Suitability for Biomass

This guide has covered a number of the key issues that should be considered when assessing the suitability of biomass. Prior to investing in biomass it is important that a detailed assessment is undertaken by an experienced biomass supplier or consultant. The key principles and key issues that need to be included in this assessment are:

- The heat load (and whether the heat is needed constantly or intermittently);
- The level of automation required;
- The most suitable fuel type and matching fuel requirements to local supplies;
- The type of biomass boiler and fuel store;
- The required space for fuel delivery and storage;
- The required space for the biomass boiler;
- Any planning issues such as listed building consent and conservation areas; and
- Air quality issues (especially if the site is within an AQMA).

[29] The Carbon Trust (2009). Biomass heating: a practical guide for potential uses CTG012.

10 Further Useful Links and References

Title	Source	Description	Link
The Biomass Suppliers List	The Biomass Suppliers List	This list is to provide participants in the RHI with a way to demonstrate that their fuel complies with the RHI standards. Suppliers registered on the list will be audited by the BSL Administrator to ensure they meet these standards and will be allowed to display the logo of the scheme. The list will be available from Spring 2015.	www.biomass-suppliers-list.service.gov.uk
The Renewable Energy Association (REA) Biomass Power Group	The Renewable Energy Association	The Renewable Energy Association has been representing the biomass sector since its launch in 2001. The REA's Biomass Power Group leads on all issues relating to power generation from 'clean' biomass. A further group (the bioenergy forum) leads on non-Waste Incineration Directive (WID) exempt biomass. The group combines with other REA groups to work on combined heat and power systems as required	www.r-e-a.net/member/biomass-power
National Biofuel Supplier Database	The Carbon Trust	This database is designed to identify local and national wood fuel suppliers	www.woodfueldirectory.org
Biomass Energy Centre		This is a map based listing of more than 300 fuel suppliers operating across the UK is available on the Biomass Energy Centre website.	www.biomassenergycentre.org.uk

The Carbon Trust – Initial assessment tool	The Carbon Trust	This design tool helps you to assess the optimum size of biomass boiler and heat storage and the control strategy for a proposed biomass system and then to make an initial economic assessment of a proposed biomass plant based on site information	www.carbontrust.com/resources/guides/renewable-energy-technologies/biomass-heating-tools-and-guidance
Biomass heating - A practical guide for potential users	The Carbon Trust	Helps organisations adopt best practice approaches and avoid common errors when installing biomass heating systems	www.carbontrust.com/media/31667/ctg012_biomass_heating.pdf
Biomass installation contracting guide - Practical procurement advice	The Carbon Trust	Explores a range of different options for setting up contracts for biomass boilers	www.carbontrust.com/media/88611/ctg073-biomass-contracting-guide.pdf
Biomass fuel procurement guide - Key considerations for successful procurement	The Carbon Trust	Covers specification and procurement of biomass fuel	www.carbontrust.com/media/88607/ctg074-biomass-fuel-procurement-guide.pdf
Renewable energy sources - Opportunities for businesses	The Carbon Trust	Introduces the main sources of renewable energy and helps readers to assess whether renewable energy is a viable option for their business	www.carbontrust.com/media/7379/ctv010_-_renewable_energy_sources.pdf
Power play - Applying renewable energy technologies to existing buildings	The Carbon Trust	Provides advice and tips to help plan, build and manage cost-effective low carbon buildings	www.carbontrust.com/media/81373/ctg050-power-play-renewable-energy-technologies-existing-buildings.pdf
Taking the heat - Lessons learned from using biomass heating in low carbon buildings	The Carbon Trust	Lessons learned from using biomass heating in low carbon buildings	www.carbontrust.com/media/81385/ctg061-taking-the-heat-biomass-heating-low-carbon-buildings.pdf

Renewable Heat Incentive - About the Scheme and How to Apply	OFGEM	Provides an overview of the RHI scheme	https://www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi
Technical guidance note 7.01	Environment Agency, Chief Fire officers Association	Provides guidance on the health and safety issues in the storage and handling of biomass fuels.	http://www.cfoa.org.uk/16192