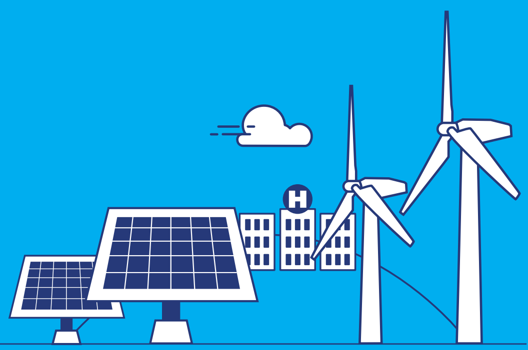
ENERGY GENERATION

STAGE 1

- Biomass Boilers
- Combined Heat and Power



ENERGY GENERATION - STAGE 1

Biomass Boilers

KEY FEATURES

- Can provide steam, HTHW, MTHW or LTHW
- Well established, mature technology in use worldwide across many sectors
- Eligible for Renewable Heat Incentive payments
- Typical carbon saving potential up to 25%
- Plant life circa. 20 years.

1. Introduction

The term biomass refers to a broad range of fuels that are derived from matter that was once living, such as energy crops, sewage sludge, wood, straw and animal litter. The technology used to convert the fuel to useful heat varies significantly depending on the fuel itself. This guide focuses on the most popular biomass heating technologies that have been deployed on NHS sites, namely wood pellet and wood chip fired biomass boilers. It is also possible to operate standard boilers on biogas (bio-derived methane). This requires adjustment to the burner as the fuel typically has a different calorific value to standard natural gas. Biogas is also covered in the section on CHP.

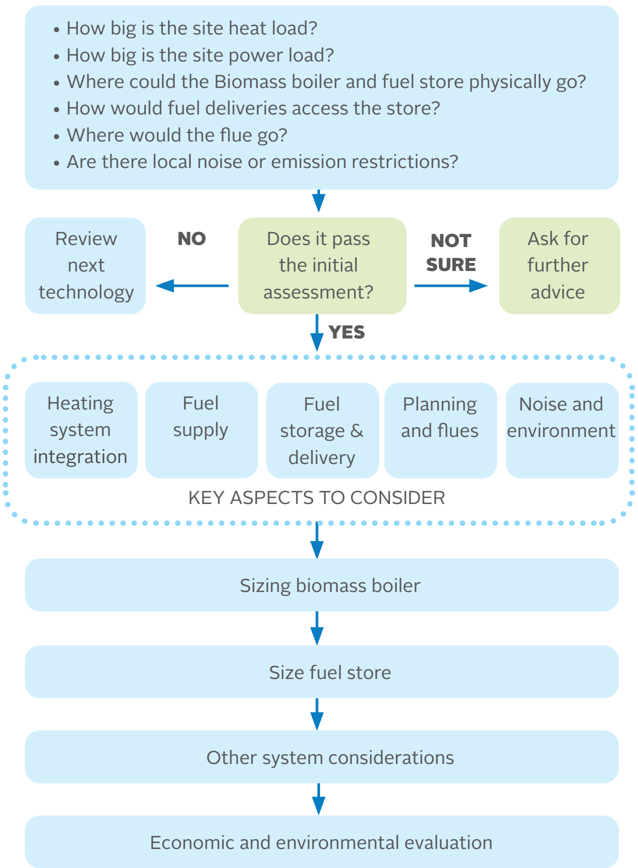
Biomass boilers use a well-established, mature technology, and have been deployed in other countries and sectors with great success. They are available in a range of sizes from a few kilowatts to several megawatts. There is a range of biomass installations in UK hospitals, although actual numbers of installations remain relatively low. Although 25 sites across the NHS are reporting use of renewable heat (2015/16 ERIC report), not all will be using biomass technologies.

Currently biomass is financially supported by the UK Government through the Renewable Heat Incentive (RHI), whereby operators are paid per kilowatt hour of useful heat produced. This mechanism helps to balance out the increased cost of biomass installations compared to gas, and the differential in fuel cost. The RHI payments are index-linked and guaranteed for 20 years from the date of accreditation.

Different types of wood chip and wood pellet boilers are available, depending on whether the site requires steam, HTHW, MTHW or LTHW. Biomass boilers can also significantly reduce site carbon emissions, even after accounting for the carbon footprint in fuel transport. Importantly, NHS experience has generally shown that biomass boilers, particularly larger installations, require more operator intervention than equivalent gas-fired plant. Biomass boilers also cannot rapidly adjust heat output like gas fired plant, so need be sized to the site heat baseload, with other heat generators providing the remainder. Some installations will benefit from the inclusion of thermal storage, although this needs to be considered on a case-by-case basis.

Engaging with fuel suppliers at the start of the project is essential, since the type and specification of available fuels and the vehicles available for fuel deliveries will set important engineering design criteria for the project. In this respect biomass is unusual, since the technical solution is determined by both site and fuel supplier requirements.

2. Initial assessment of feasibility



The chart above shows the process of establishing whether the project is likely to be viable and if it is worth proceeding to a detailed feasibility study. More details are provided in the table below.

Q How big is the available site heat load?

A Generally, biomass boilers will be used to supply heat for space heating or domestic hot water. Biomass boilers are available in a wide range of sizes, so can supply small heat loads, but multiple small biomass boilers could present operational challenges.

Q Where could the biomass boiler and fuel store be physically located?

A Smaller size units (circa 200kW) can be supplied packaged in a shipping container sized form that includes the boiler, thermal buffer and integrated fuel storage. Larger systems will require a plant room. A 1MW steam wood chip boiler would require a plant room around 7m x 4m x 4m (l,w,h) and a separate fuel store of around 150m^3. See section on fuel store types for typical arrangements.

Q How would fuel deliveries access the store?

A Fuels are delivered by either rigid or articulated lorry. Consideration needs to be given to how the vehicle could access the site, including any overhead obstacles. Bear in mind that, for convenience, the site might prefer deliveries outside of core hours.

Q Where would the flue go?

A A biomass boiler will need a flue, the height of which will depend on boiler size and local dispersion requirements. If possible, an existing chimney with a disused or spare flue is ideal.

Q Are there local noise or emission restrictions?

A Biomass plants, whilst significantly reducing carbon emissions, can be restricted or prevented in certain air quality management areas or smoke control zones. Before developing any project, it will save time and money to establish at an early stage whether it will achieve local authority planning approval.

3. Implementation: heating system integration

Biomass boilers are available in a range of sizes and heat outputs including Steam, HTHW, MTHW and LTHW. Heating system integration is therefore relatively straightforward.

For LTHW, MTHW and HTHW systems, boilers can be integrated into existing distribution headers to share loads with other heat plant. The boiler will need to be integrated into the existing boiler sequencing and BMS systems to ensure optimum efficiency.

For biomass steam boilers, consideration needs to be given to the interaction of the boiler with other steam-raising plant, to ensure the controls enable the biomass boiler not to be set back when working alongside much larger steam boilers. As with non-steam boilers, integration with boiler sequencers and BMS systems is essential to ensure effective and efficient operation of all plant.

4. Choice of fuel type

It is important to establish the availability of different fuels. The chosen fuel needs to be available from a range of suppliers and, as best as can be established, available for the life of the boiler operation (circa 20 years). Selecting a fuel only available from one supplier risks the hospital being held to ransom during later stages of the project, unless the price can be locked in.

The table below compares key features.

	Wood pellet	Wood chip
Consistency	Wood pellets are a very consistent fuel type available in 6-8mm diameter for smaller systems and 10-12mm diameter for larger systems. Fuels are covered by EU standard EN14961-2.	Wood chip is a more variable fuel source, particularly with sizing and moisture content. Care must be taken if purchasing by weight to systematically check fuel moisture content at point of delivery and for objects in the fuel that could jam feed mechanisms. Wood chip is normally supplied to a given particle size (G30, G50, G100) and a maximum moisture content (20%, 30%, 40%); the greater the moisture content the lower the energy density and the price, but more product is required to produce the same heat. Boilers will be designed to operate within a given range of fuel specifications.
Space required	The volumetric density of pellets is ~650kg/m3 and their energy density is ~4.8kWh/kg, so a 1MW boiler running at full output for three days would require a store of approximately 23m3, which could be configured as 2.5m x 2.5m x 3.7m (l, w, h).	Typical wood chip volumetric density is ~250kg/m^3 and energy density ~3.5kWh/kg (depending on moisture content), so a 1MW boiler running at full output for three days would require a store of approximately 82m^3, whjch could be configured as 3.5m x 3.5m x 6.7m (l, w, h). This is roughly 3.5 times the size of the equivalent pellet store.
Dust and aspergillus	Pellets can create dust, so this needs to be controlled during deliveries. Some delivery vehicles can extract and contain dust during delivery. Pellets are virtually dry, so are a lower aspergillus risk when compared to fuels with a higher moisture content.	Wood chip does not generally contain large quantities of dust. However, the comparatively high moisture content can present a risk of aspergillus and management methods for delivery and extraction must be considered, particularly if the installation is located close to critical care units. This could even include reviewing arrangements for AHU plant feeding nearby buildings.
Cost	Pellets are more expensive than chip. Prices observed in NHS hospitals in the last two years have been around 4.0 to 4.5p/kWh.	Wood chip is cheaper, in part due to the simpler production and greater variability in the fuel. Typical prices seen in NHS Trusts range from around 3.4 to 4.9p/kWh.

When the above points have been reviewed, it may still be possible that both fuel options can be included within detailed feasibility. It is worth noting that the cost of the fuel is not necessarily critical to the success of the project. Depending on the specific site requirements, it might be much simpler to install a wood pellet system, which saves significant capital cost and, compared to a more complex wood chip solution, may represent better value for money over the life of the project.

5. Fuel storage and delivery

There is a wide range of biomass fuel storage systems. System design depends on four main criteria:

- Type of fuel
- Site space constraints
- Delivery vehicle access and offloading
- Dust or aspergillus containment

The main systems that have been installed at UK hospital sites are as follows:

Blown pellet stores. The simplest storage system, in the form of simple silos, rooms, or prefabricated boxes. Pellets are blown into the store from equipment on board a delivery vehicle from up to 30 metres away, although to minimise fuel damage, a maximum distance of 20 metres is generally recommended. The boiler extracts the pellets from the store using a vacuum delivery system.

Wood chip silos. The wood chip silo can be constructed in a variety of forms. Fuels are typically delivered by tipper, hook-bin tipper, or walking floor articulated trailer. The simplest solution is for the silo to be located below the delivery point, but this is not often possible. More commonly, the wood chip will be tipped gradually into a hopper from which a variety of mechanisms such as augurs, bucket lifts and conveyors transfer the fuel to the silo. The mechanisms depend on the proximity of the offloading station to the silo and should be designed with simplicity in mind to ensure maximum reliability. Consideration must be given for the containment of aspergillus during delivery, where this is a site requirement. The bottom of the store will usually have a sweeping arm and an augur to transport the fuel from the silo to the boiler, usually via a small day storage bin.

Ro-ro hook bins. Roll-on, roll-off Hook Bins, typically 30m^3 to 35m^3 are used as a combined delivery and storage system. The bin is delivered onto a framework containing an augur. Once the bin is depleted it is removed and another delivered. The system has the advantage that the fuel remains in the container until it is required and therefore helps to minimise risks associated with dust or aspergillus. Where space permits, twin bins enable continuous operation and speed of delivery. If this is not possible, consideration needs to be given to loading and offloading space. This system is usually best suited to medium sized boilers (circa 500kW), as larger boilers will require high delivery frequencies. However, hook-bins have been coupled with larger silo systems on NHS sites.

Walking floor trailers. The fuel is delivered in a walking floor articulated trailer and the walking floor mechanism is connected to the boiler plant management system, which then controls the offloading. The trailer still offloads into a hopper, which usually transports the fuel to a day store, but there is none of the additional complexity seen with a silo system. Deliveries are faster, but space needs to be provided for trailer changeover. The system also usually requires a standing charge for the trailer hire.

Other storage and delivery considerations. A key requirement with any fuel storage system is the ability to remove the fuel back into a lorry, for example if a faulty load of fuel has been delivered, or boiler is shut down for an extended period (perhaps during the summer) and the store needs to be emptied.

Reliability issues with biomass are often associated with the fuel transport systems, so care in design is important to ensure that the system is robust and that it is simple to diagnose and remove blockages when they occur. Procedures for safe offloading of fuel must also be considered during design.

All biomass fuel transport systems must also be fitted with a system that prevents burn-back into the store from the boiler.

6. Planning considerations

Most hospital-scale biomass plants will exceed the permitted development criterion of 45kW. Key aspects for planning consent will be required flue height and dispersion and external features, such as stores or the entire biomass plant. Many trusts have ongoing communications with local planners, and early stage engagement when considering a biomass project will identify any specific constraints and enable these to be considered at feasibility stage.

7. Noise and environmental issues

Biomass plant are not particularly noisy, although consideration must be given to the proximity of delivery and fuel transportation mechanisms to other site activities and neighbours, as well as likely delivery times. The planning authority will also consider environmental impacts from biomass boilers, especially exhaust emissions. Where the proposed installation is within an air quality management area or smoke control zone, the local authority may impose certain requirements such as exhaust gas clean-up technologies such as cyclone particle removal.

8. Biomass boiler sizing

Biomass boilers cannot respond to rapid changes in demand, so are usually sized to meet heat base load requirements. However, as the summer heat load can be very low, it can sometimes be attractive to operate a biomass boiler only during the heating season (October to April) and this can still provide an attractive business case. This is because there are higher incentives in the RHI for the first 3,066 full load running hours.

A graph of the hourly heat demand over a 12-month period can be used to establish the heating base load. If this is not available, then scaling the site monthly demand to an hourly heating profile of a similar site can be effective. Data should be adjusted for degree days to ensure the analysis is robust.

Depending on the heating profile, it may be advantageous for LTHW biomass boilers to be fitted with a thermal store to enable the boiler to supply more of the heating load and enable it to operate a consistent rate.

9. Fuel store sizing

Fuel stores should be sized to suit operating regimes and frequency and size of fuel deliveries. Consideration should also be given to preventing fuel degradation and enabling fuel to be safely removed and transported from site if necessary. A sample calculation for an initial estimate of fuel store volume is:

Fuel store size = (((Boiler_Size x (Peak_Del * 24 * 1.25)) /Energy _Density)/Volumetric Density)

Where:

Boiler_size = Peak thermal output of the boiler.

Peak_del = Maximum permissible number of fuel deliveries per week in peak heating season.

Energy_density = Energy density of the fuel in kWh/kg.

Volumetric_density = Volumetric density of the fuel in kg/m^3.

Note: the 1.25 factor allows a 25% safety factor, which should be revised during detailed design.

For a pellet boiler of 1,000kWth with maximum permissible deliveries of three per week, this would equate to:

Fuel store size = (((1000 x (3 * 24 * 1.25))/4.8)/650)
Fuel store size = $28m^3$

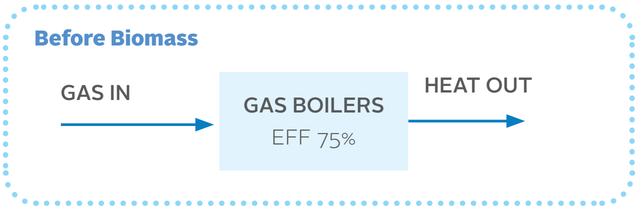
10. Other considerations

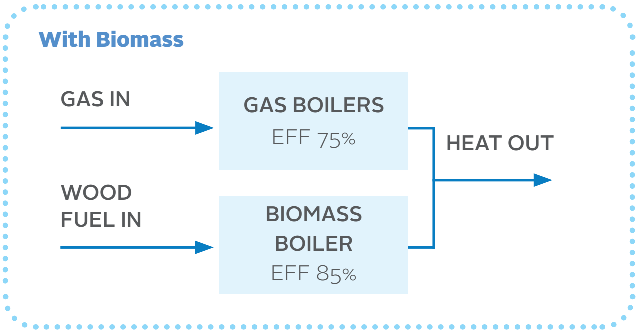
Boiler ignition systems vary between manufacturers, with some being powered by electricity and some by small natural gas burners. Consideration must be given to how suitable services can be made available to the boiler.

Biomass plant present specific aspects of health and safety that must be considered to ensure the plant is designed, constructed and operated in a safe manner. The Combustion Engineering Association has published guidance on biomass health and safety, details of which are noted in the reference section.

11. Economic and carbon evaluation

The financial case for biomass is usually made in comparison to the existing heat appliances it will offset and is shown in the diagrams below.





The financial savings associated with wood fuelled boiler plant are therefore based on a comparison between the operating cost of the gas boilers it offsets and the operating cost of the biomass boiler plus the income from the available incentives.

Renewable Heat Incentive (RHI). The Renewable Heat Incentive is a payment for qualifying renewable heat plant, with which wood chip and wood pellet usually are compliant. The scheme is administered by Ofgem and the current rates, at the time of publication, are shown in the table below. However, the rates are subject to regular review, so the latest rates should be confirmed on the UK Government website (see web address in the reference section, below).

Tariff name	Eligible technology	Eligible sizes	Tariffs
Small commercial biomass	Solid biomass including solid biomass contained in waste From 20 September 2017 the tiering threshold for small and medium biomass will change from 15% to 35% of heat load. From this date large biomass will move from a single, untiered tariff to a tiered tariff with the same 35% threshold.	Less than 200kWth Tier 1	2.96
		Less than 200kWth Tier 2	2.08
Medium commercial biomass		200kWth and above and less than 1MWth Tier 1	2.96
		200kWth and above and less than 1MWth Tier 2	2.08
Large commercial biomass		1MWth and above Tier 1	3.15
		1MWth and above Tier 1	2.21

Following changes on the 20th of September 2017, all biomass plants receive the same tariff level. Tier 1 covers the first 3,066 hours of operation and all further operation is paid at Tier 2. Once accredited, the RHI tariff is index-linked for 20 years. Biomass steam systems can be accredited through the RHI, but accreditation can be complex and early engagement with Ofgem is recommended.

12. Calculating savings

A worked example of the cost and carbon savings is shown below.

Cost savings	Without biomass	With biomass
Site heat demand (kWh)	20,000,000	20,000,000
Site heat provided by biomass (kWh)	-	5,000,000
Site heat provided by gas (kWh)	20,000,000	15,000,000
Gas boiler efficiency	75%	75%
Annual gas consumption (kWh)	26,666,667	20,000,000
Unit cost of gas (p/kWh)	2.30	2.30
Unit cost of biomass heat (p/kWh)	4.00	4.00
Total cost of gas	£613,333	£460,000
Total cost of biomass heat	£0	£200,000
Biomass boiler size (kWth)	-	990
RHI Tier 1 Revenue	£0	**£95,613**
RHI Tier 2 Revenue	£0	**£43,419**
Total cost	£613,333	**£558,468**
Total cost saving	**£54,866**	

Carbon savings	Without biomass	With biomass
Total gas consumed (kWh)	20,000,000	15,000,000
Total biomass heat consumed (kWh)	-	5,000,000
Carbon factor for gas (kg/kWh)	0.18387	0.18387
Carbon factor for biomass (kg/kWh)	0.0025	0.0025
Total carbon emitted (tonnes)	3,677	2,771
Carbon saved	**906.85**	
Carbon saved	**24.7%**	

References

- ***Planning Portal , Flues for Biomass and CHP Power Systems*** *https://www.planningportal.co.uk*
- ***Institute of Air Quality Management , Biomass and Air Quality Information for Developers*** - *http://www.iaqm.co.uk*
- ***Biomass Energy Centre*** - *www.biomassenergycentre.org.uk*
- ***Carbon Trust , CTG012 – Biomass Heating*** *www.biomassenergycentre.org.uk*
- ***Carbon Trust , Biomass Sizing Tool*** *https://www.carbontrust.com*
- ***Combustion Engineering Association, Health and Safety in Biomass Systems*** - *http://www.hetas.co.uk*