CWA Information Sheet No 19: Woodfuel and woodfuel Heating Systems

This information note is one of a series produced by the Community Woodlands Association. It gives an overview of the different types of woodfuel, the equipment and the processes required to produce a quality product and the types of equipment used to burn it. It signposts to sources of more detailed information: other CWA information notes or external websites and publications. Many of the general principles are applicable everywhere but references to funders and regulators are for Scotland only.

Introduction

Wood is one of humanity's oldest fuels, but in recent years it has come back into vogue. The many benefits of woodfuel include:

- Sustainably-produced wood can provide heat for homes which is carbon neutral: modern wood heating systems are cost-effective and environmentally sound;
- Communities and the local rural economy can benefit from a diversified income through woodfuel production. Income is retained in the local economy and local jobs can be created;
- Income from selling small-diameter or low-grade logs as woodfuel helps support sustainable woodland management;
- Space heating with wood can be more cost effective than using other forms of energy;
- The waste gases from an efficient system, using an appropriate fuel are virtually smoke-free and the ash can be used as a fertilizer.

Woodfuel supply

Woodfuel is one of most common trading areas for community woodland, for a number of reasons. It is in many respects a "simple" product, it doesn't necessarily require specialist equipment or skills (beyond chainsaw certificates), it is relatively straightforward to produce, and there are existing, albeit not always well developed, markets.

Woodfuel is also relatively undemanding with respect to feedstock: almost any species / quality can be used, and once dried and stored well, the product is slow to depreciate. These limited barriers to entry mean that it is possible for businesses to start small and grow organically, which may suit community groups with limited investment capital or appetite for risk.

There are some broader advantages for community and social business: woodfuel enterprises tend to have a limited (geographic) sphere which reduces the potential to displace existing businesses. Selling woodfuel is an effective way to engage with the local community and can help deliver a range of other objectives: enabling otherwise uneconomic woodland operations and helping mitigate climate change by substituting for fossil fuels.

There are however, some significant constraints and issues to be addressed:

- Woodfuel production takes time between felling and selling, requiring good forward planning and the maintenance of stocks, which then require large storage areas for raw material (log stacks) and processed firewood;
- Woodfuel is a low value (per tonne) product and profit margins depend on efficient working, notably on minimising multiple handling. Consumers are increasingly focussed on quality and reliability of supply;
- Delivery (cost and method) can be the most difficult aspect to get right.

Firewood processor at Abriachan © AFT

There is a range of options as to how best to organise supply chain logistics for woodfuel businesses and no single "best solution". Community woodland groups and woodland social enterprises have developed a variety of models according to local conditions and historical circumstances (such as access to funding opportunities for machine acquisition).

Funding for firewood log processors is currently available from the Forestry Grant Scheme under the Harvesting & Processing option. A range of other lottery, statutory and charitable funding sources have been accessed by community woodland groups in the past.

The scale of production is often critical as this will determine the viability of investment in machinery. The annual sustainable harvest from a woodland will depend on species and growth rates; but only a proportion of the total harvest may be suitable for woodfuel as in almost all cases it will be more profitable to sell large-diameter material as sawlogs.

CWA info note 8 describes the forest inventory process and the calculation of annual harvest volumes.

Woodfuel Systems

Commercial, small- to medium-scale woodfuel systems currently focus on 3 fuel types: firewood logs, woodchips and wood pellets. Various factors need to be taken into consideration when deciding on the type of heating system and type of fuel you will use:

- Scale: how much heat do you need?
- Do you want the heat for directly warming a room, for cooking on or for heating hot water for radiators and taps?
- What space do you have for the stove/boiler and associated fuel stores?
- What types of woodfuel do you have readily and reliably available to you?
- Do you want to supply your own fuel from your own woodland?
- How much time do you have to produce your fuel and look after your system?
- Is there a service engineer available in your area for the type of installation you would like?
- Do you want a fully automated system?

Firewood Logs & Stoves

Logs are the cheapest form of woodfuel, but they are bulky and the hardest option to automate. For efficiency and clean combustion, logs should be burnt at a moisture content of 20% or less in a woodburning stove or boiler.

Logs can be processed manually, with chainsaw and axe, but for larger volumes mechanisation will be more efficient (and may be easier and safer for appropriately trained volunteers). If you expect to process more than $20m^3$ annually it will be cost effective to invest in a vertical, petrol-driven log-splitter, whilst for larger volumes (>$100m^3$ /year) it may be worth acquiring a firewood processor: these are usually tractor-mounted and can cut and split roundwood into logs, although they are limited in the diameter of material they can handle.

Loose bark should be riddled out after processing to improve drying. Any shards will make great kindling. Mechanical handling can be used if the processed logs are contained by wire cages on a pallet (Intermediate Bulk Containers with all plastic removed are a good option). Manual handling is required to stack the firewood at home and load it into stoves.

Vertical log splitter at Dunnet Forest

To optimise the seasoning (drying) process:

- Fell trees in the winter when the moisture content is lowest;
- Process logs so that they can start to season in the dry months of the spring;
- Store logs off the ground, perhaps on old pallets and in a location where the wind can blow through the stacks;

- Get the logs under cover before the onset of autumn / winter, storing them in a well-ventilated and sunny location. Expect to store logs for 2 summers before they are ready for burning.

Well-ventilated poly tunnels can speed-up the drying process and kilns will provide a very uniform product in terms of moisture content. Bark keeps moisture in, so even small logs should be split at least once.

Logs take up a lot of space and it is important to develop systems and locations that minimise the amount of handling. If you are relying on air-drying, you need space to stack and store 2 years' supply of logs. One solid cubic metre of wood requires around 1.6m^3 of storage space when neatly stacked, around 2 to 2.5m^3 when loose in a box, bag or heap.

Hardwood logs are generally more energy dense than softwoods, but the key thing for buyers and sellers is to know the moisture content. Different species will season (and rot) at different rates and the slower the logs are allowed to dry, the more chance fungus has to grow and reduce the calorific value of the logs. Oak may need to be split into smaller logs to dry at the same rate as birch or ash. Lady Congreve's firewood poem outlines the virtues and shortcomings of various species.

The most reliable method to check the moisture content of firewood is an oven drying test; however, pin meters are now widely available at a low cost (from around £15) and these will provide you with a reasonable average moisture content reading for your firewood. Burning wet wood even in a wood stove is bad for the stove and bad for those inhaling the smoke.

Log burners come in a range of options, from open fires to wood gasification boilers. Wood burns efficiently when the fuel is dry, the fire is hot, air can be directed to burn off flue gases and heat recovered before it goes up the chimney.

An open fire may only have 20% efficiency whereas a good, metal wood-burning stove may reach 85% efficiency. Wood gasification boilers can achieve close to 95% efficiency with the heat drawn from the flue by water filled heat exchangers rather than from the firebox which cools the fire and reduces efficiency. Heat from the boiler is stored in a hot water accumulator and from there, further heat exchangers take hot water to radiators/underfloor heating or water taps. NB. when calculating your fuel requirement for any boiler system, always allow for heat losses from the pipe-work.

If the aim is to provide backup heat in a house that already has central heating, the simplest and cheapest option is to install a wood-burning stove fuelled by logs. A woodstove can provide extra heat and a focal point in a room and backup heat in the event of a power cut or central heating breakdown. It may also provide domestic hot water, if the necessary plumbing arrangements can be made. Heat outputs for wood-burning stoves range from 2 to 25 kilowatts (kW), whereas log-boilers generally range from 18 to 100 kW.

Log burners can be made to be used as cookers and some are even combined with automated pellet-burning units so that there is a means of heating the home when no one is on hand to fill the log firebox. Masonry and ceramic stoves work efficiently with a single, continuous, hot burn, with the heat captured in a stone/ceramic mass to be gradually released into the home environment.

Important considerations when installing a wood-burner into a building are the flue and the air source. Existing chimneys need to be lined to ensure they warm up quickly and stay warm to ensure a good draw and to vent water vapour and particles that might otherwise condense out as tar, which could seep into the masonry of an unlined chimney, or collect and become a fire hazard.

If the air source for the stove in your living room is in the same room, you will create a draft of cold air around door frames as the fire sucks in air for combustion. An alternative is to pipe in the air from the outside, which may only be possible for built-in stoves rather than free-standing stoves. Reputable stove installers and suppliers should be able to advise on these issues. With air pollution a significant concern, consider DEFRA and Ecodesign standards when purchasing a wood-burning stove.

Fuel requirements

A reference figure for all tree species is that they provide 5.32 kilowatt-hours (kWh) for every 1 kilogram of <u>completely</u> dry wood. At 20% moisture content, 1 kg of firewood will yield 4.2kWh. Burned in a stove with 75% efficiency, the final energy output will be 3.2kWh for every 1 kg.

So if, for example, the power output of your stove is 10kW and you run it for 5 hours on average each day, your energy requirement is 18,000kWh per year. If your firewood delivers 3.2kWh per kilogram you will need 5.6 tonnes of logs each year. A range of indicative scenarios are presented in the table below, with tonnes of logs required and an estimate of stack volume, if the firewood is birch at a density of 625kg/m^3 at 20% moisture content.

Property	Peak Heat output kW	Annual weight of logs (tonnes)	Stacked volume (m^3) birch
Living Room Stove	4-10	2.5-6	5.5-14
3-4-bedroom house	10-20	6-11.5	14-27
Larger house	15-35	13-20	20-47

The energy requirement will depend on the volume of the rooms, the level of insulation, the location and level of exposure etc. It may be advisable to oversize a wood stove so that it is not running too hot for too long.

For buildings with greater heating requirements you might consider installing two log boilers (to run in sequence) or one log boiler combined with an automated pellet boiler. For a building that currently uses approximately 3,000 litres of oil per annum (30,000kWh) you would need about 9 tonnes of wood at 20% moisture content. Neatly stacked this might occupy 25-30m^3.

Woodchips

Woodchips are commonly used in medium to large automated boilers for larger buildings and district heating systems (where individual buildings draw heat from hot water pipes running between them with the hot water generated by a central boiler). Chips must be fairly regular in size and within a specified moisture content to ensure reliable operation of the boiler and automated feed system. Chips are produced from small to medium sized logs using mechanical wood chippers: these can be stand-alone or tractor-driven.

Woodchips are also used in some combined heat and power units, where they are burnt to generate steam for driving an electrical turbine and surplus heat is distributed to adjacent homes or industrial processes.

Chip made from arboricultural and tree harvesting residues (branches, lop-and-top) often cannot be used in smaller boilers as it contains a lot of bark and green material and might better be described as 'biomass' suitable for large-scale, power generation boilers or used as garden mulch. If you manage woodland with large, accessible, conifer clear-fells, brash recovery could be considered if it generates additional income or is cost neutral as it leaves a brash-free site for easier restocking.

Logs for chipping are generally stored for a summer to dry them to a suitable moisture content. Most chippers work more efficiently with a wood moisture content greater than 30% - less than this can cause problems.

Wood-chippers are expensive, especially those that can handle large diameter material, and it may be more cost-effective to hire in a chipping contractor. This has multiple benefits: reduced capital outlay, no idle equipment when you are not chipping, whilst a good contractor will bring experience and provide you with a consistent product.

Woodchips are ideally stored in a weather-proof, concrete floored drying shed - these may incorporate fans to reduce drying times - and are a significant investment. Moving woodchips efficiently from the drying shed to the boiler's woodchip store needs specialist equipment, at least a bulk loading bucket and a bulk trailer.

Woodchip transport at Tormore © Sleat CT

Chip boilers will specify the required moisture content: this information should be provided by the installer and can also be found on the Ofgem Emissions Certificate. Most chip boilers require a moisture content of 30% or less. Some larger boilers have a drying system integrated into the boiler and can take higher moisture contents.

Woodchip moisture content can be assessed using a humimeter. Alternatively, take samples from inside the woodchip pile and dry them in an oven, checking the weight at intervals until they stop losing weight.

Woodchip heating systems are fully automated and start at outputs of 35kW, (suitable for a larger house, e.g. a farmhouse). Woodchips are delivered to a chip store adjacent to the boiler by a tipping trailer or blown in from a lorry. They are fed into the boiler by a rotating auger and heat is stored in an accumulator or put straight into a district heating network.

Woodchips provide approximately 3.5kWh per kg, with 3t wood providing about 12m^3 of chip. As with log boilers, the volume of chip required will vary depending on the energy requirement of the property (see table below for indicative values). Good insulation, reducing drafts, capturing solar radiation and sheltering buildings with trees will all reduce fuel demand.

Property Type	**Boiler Size (kW)**	**Annual woodchip (tonnes (m^3))**
Large House (4-5 Bedrooms)	35	20-30 (80-120)
Small District heating scheme - workshops	150	75 (300)
Large Industrial business	850	1200 (4800)

Other factors to be taken into consideration when planning a woodchip system include:

- Space for chip feed-store;
- Access for woodchip delivery suitable for small lorry or tractor/trailer unit;
- Matching the type of boiler to the readily available woodchip supply;
- Higher installation costs than some alternatives;
- The cost and security of supply of chips.

Wood Pellets

Wood pellet heating systems can be fully automated and only small, domestic units require manual handling to load the feed hopper.

Wood pellet stoves generally start around 7kW output and can be modulated down to around 2.5kW. These are suitable for heating single rooms, or for smaller properties as full central heating systems. Pellet stoves can be installed in the living space of a home, in a utility room, in an outhouse or as an external, self-enclosed unit. Pellets require less handling than logs. The feed-hopper of the stove can hold sufficient pellets for several days burning.

Stoves require an electricity supply as they are controlled by microprocessors and the heat is distributed by electric fans: they would not, therefore, operate during a power cut.

Because pellets are a uniform size, shape and moisture content the systems can be very efficient. Pellets are made from compressed sawdust with a moisture content of around 8%, so they have a high energy value per cubic metre and take up much less space than a chip boiler of equivalent size

Pellet manufacture can be done at a small scale using wood-workshop waste, but in the UK pellet supplies are largely from large-scale industrial processors often using wood fresh from the forest. There are several pellet producers in Scotland, although much of our demand is met by imported pellets. If the pellets are made in Ireland they might have been made from wood exported from Scotland, so whilst pellets might be efficient and convenient, they do not have the smallest carbon footprint compared with other woodfuel options.

Pellets are supplied loose in bulk for larger boilers and in bags for hand-filling domestic hoppers. Loose bulk pellets will be delivered by a lorry and either blown or tipped into the boiler hopper. Bagged pellets need somewhere dry and weatherproof for storage. The table below gives indicative boiler size and fuel requirements for various properties.

Property Type	**Boiler Size (kW)**	**Annual pellets (tonnes)**
House (3 bedrooms)	22	4
Cafe	27	4.5
School	50	7-9

As with other woodfuel systems it is important to size your stove/boiler correctly so that it is working efficiently. To ensure consistency and quality of the pellets, it is best to buy ENplus pellets.

Units and definitions

The **Moisture Content** of a piece of wood is the weight of water in the wood expressed as a percentage of the weight of the wood. MC_w (%) = $(m_w-m_d)/m_w \times 100$ (where m = mass).
For example, if the solid wood elements in a piece of wood weighs 50 kg and the water in that piece of wood weighs 50 kg, the total weight is 100kg and thus the moisture content is 50%.

Wood density is the weight (mass) of wood for a given volume of wood. It varies considerably between species; e.g. 1m^3 of “green” (freshly felled) beech weighs 1030kg, whereas similar volumes of birch and Sitka spruce weigh 930kg and 920kg respectively. Once wood has been completely dried out the variation between species becomes even more marked with 1m^3 of beech weighing 570kg, birch 500kg and spruce 380kg.

Power and Energy: The kilowatt (kW) is a unit of power, approximately equal to 1.34 horsepower. A kilowatt-hour (kWh) is a unit of energy equal to one kilowatt (kW) of power sustained for one hour.

Energy content may also be measured in joules (1kWh = 3.6 megajoules). Wood has a typical calorific value of 19.2 megajoules/kg dry matter. Values for wet wood can be calculated using the formula MJ/kg = 19.2 - (0.2164*MC), where MC is the moisture content in percent of total weight, i.e. 1 kg of wood fuel with a moisture content of 45% has a calorific value of 9.42 megajoules.

Comparisons with other fuels

The table below shows the energy content in gigajoules and megawatt-hours of various fuels (figures from Forest Research)

Fuel	Units	GJ	MWh
Heating oil	1000 litres	42.5	11.8
Natural gas	1000 m^3	38.1	10.6
Coal	1 tonne	27-31	7.5-8.6
Electricity	1000 kWh	3.6	1
Wood pellets @ 10% MC	1 tonne	17	4.8
Logs @ 20% MC	1 tonne	14.7	4.1
Wood chips @ 30% MC	1 tonne	12.5	3.45

Thus 1000 litres of heating oil has the same energy content as 2.5t of pellets, 2.9t of logs (20% MC) or 3.4t of woodchips (30% MC)

Resources

Community Woodlands Association (advice and support for community woodlands)
http://www.communitywoods.org
Making Local Woods Work (advice, tools and resources for woodland social enterprises)
https://makinglocalwoodswork.org

Scottish Forestry: Use Woodfuel Scotland
https://usewoodfuel.co.uk/
Forest Research: Biomass energy resources
https://www.forestresearch.gov.uk/tools-and-resources/fthr/biomass-energy-resources/
Reforesting Scotland: WoodfuelScotland / Scottish Woodfuel News
https://woodfuelscotland.wordpress.com/

Department for Environment Food & Rural Affairs (guide to wood-burning stoves)
https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1901291307_Ready_to_Burn_Web.pdf
HETAS (Ecodesign regulations explained)
https://www.hetas.co.uk/ecodesign/
EN*plus*® (independent certification for wood pellets)
https://enplus-pellets.eu/en-in/

Norwegian Wood – chopping, stacking & drying wood the Scandinavian way. Mytting, L, MacLehose Press, 2015.
https://www.waterstones.com/book/norwegian-wood/lars-mytting/robert-ferguson/9780857052551

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