GUIDANCE DOCUMENT 3

WOODFUEL PROCESSING

FOREST FUELS

Forestry Commission England

South West of England Regional Development Agency

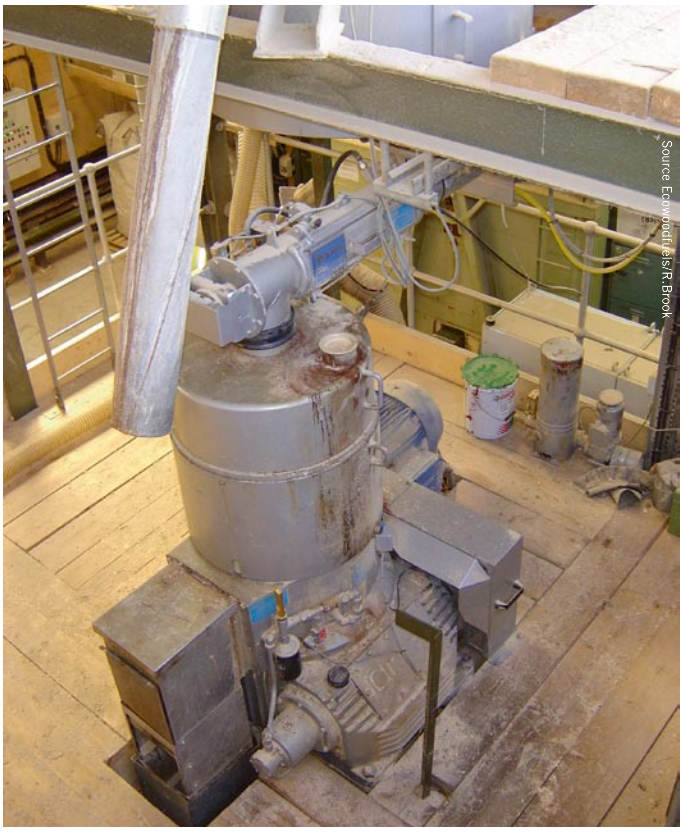
regensw sustainable energy agency

WOOD PELLETS

The pellet industry complements all stages of the wood production industry by taking the by-products, such as sawdust, grinding dust, shavings and joinery off cuts, as its raw material. The feedstock must not contain heavy metals or halogenated compounds, or treatments which may include such compounds following the manufacturing process, as the resulting pellet would then be subject to the Waste Incineration Directive.

Pellets are also manufactured from energy crops such as Miscanthus and Short Rotation Coppice. Both crops will feature increasingly as the biomass market develops; however, Miscanthus is likely to be at the forefront of these developments.

Miscanthus is currently being pelletised into "nugget" size pellets to improve transport logistics and economics by increasing the fuel density. The pellets are being supplied to large energy end users like Drax Power Station in Selby Yorkshire where several thousand tonnes of pellets are being co-fired with coal to reduce CO_2 emissions.



Khal pellet press

PREPARING THE FEEDSTOCK

The first stage in pellet production is the storing and pre-treatment of the raw material. Sawdust, or other mixed feedstock, should be screened to remove sand, gravel or other impurities, and passed over a metal detector to remove metal contamination. Screening also allows larger material to be removed for sale as other products, such as de-dusted horse bedding, or for re-grinding to produce satisfactory feedstock for pelletisation.

Next, material is pre-treated to ensure that it achieves uniform moisture content. Most feedstock derives from kiln-dried timber, but it is feasible to take primary production sawdust which is wet, with a moisture content of around 50%. This wet material must be dried to about 10 to 16% moisture content, then it can be blended with already dry material. Drying sawdust must be done with extreme caution as airborne sawdust can create an explosive air and dust mixture.

Shredder used for pellet production, material can be re-circulated to improve the quality of the finished product

PROCESSING THE PELLETS

The pre-treated feedstock is then passed into a dosing feeder. This creates a smooth flow of material and portions the material into suitable quantities for feeding into the pellet presses.

A pellet die may be a plain or a ring-shaped matrix: a large heavy roller forces feedstock through a metal casing with pellet-shaped holes. The casing may be flat, curved or ring shaped and the holes are chokered in form: they taper towards the outside of the matrix. Forcing material through the die generates pressure causing the wood to heat, allowing the natural resins and binders (lignin) momentarily to liquefy and glue the pellets together.

Occasionally lignin or starch is added in fractional quantities to aid this process. Steam is occasionally added to reduce the energy requirement and decrease wear in the pellet die.

Pellets emerge from the die like "spaghetti" and are cut to length by a mounted knife typically 10mm to 30mm in length. Cooling then stabilises their form before being bagged or stored in large hoppers for onward transportation and delivery by either pneumatic or bulk lorry.


Source Ecowoodfuels/R.Brook


Source Ecowoodfuels/R.Brook

Khal pellet press and die with emerging pellets

COSTS

It is important for producers to minimise the cost of feedstock to offset the relatively high manufacturing and capital costs of the plant. This being one of the principal reasons for the development of pellet production in conjunction with large scale sawmilling. It has been estimated that the embedded energy costs of pellet production are around 2.5% when using dry sawmill co-product rising to 20% when using green.*

A small-scale pellet press suitable for a joinery company may cost from around £10,000 but generally, pelletisation equipment starts at around £50,000 for a machine capable of producing 300kg per hour, and costs rise with output.

Considerable ancillary equipment is usually also required, such as a hammer mill, feedstock preparation and conveyor equipment, pellet cooling equipment and a bagging plant. This can easily double or triple the final total cost of the plant. In addition, maintenance and operation of the equipment is expensive, so that although there are significant advantages to pellets, their productions costs are much higher than those for woodchips.

*OBERNBERGER, I. and THEK, G. 2005

PROBLEMS

Pellet production has been described as a black art, because it is extremely difficult to maintain uniformity of feedstock, and moisture content, and a great deal of skill, knowledge of sources of feedstock and care is required to ensure optimal blending and a uniform and consistent finished product.

Frequent problems include poor binding, leading to very high fines or dust contamination of the finished product, and failure to produce a product of uniform length.

WOODCHIP

In some ways, woodchip production can be just as complicated as pellet production:

- Unlike pellets, chips may be produced in various locations.
- While pellets are made from relatively uniform feedstock, woodchips can be made from far less homogenous feedstocks.
- Achieving a satisfactory moisture content and particle size requires careful control and knowledge of the feedstock, and of its storage, handling and processing.

Heizohack Chipper 14–800 purpose built lorry mounted chipper with seven metre reach grab–working with whole trees at roadside

Baler producing log bundles of harvesting brash, ready for transportation and then chipping

LOCATION

Woodchip can be produced in forest terrain chipping, at a landing or roadside, at a depot or yard remote from the forest, or at the point of use.

In forest or terrain chipping involves chipping material where it was felled. This requires specialist machinery capable of travelling over poor terrain, which may be wet, steep, rocky or covered in brash material. The chipper must be fed by crane or other machinery, and can use waste wood left on site, brash, or even stump material excavated from the ground.

It is hard to keep material clean while terrain chipping because, during the harvesting which created it, vehicles often drive over it, consequently, it is hard to avoid including stones and soil when feeding the chipper.

The grade of chip may also be poor because brash, twiggy material, lop-and-top, needle and leaf are often included. This need not be a problem if the end user's boiler is set up to use this material effectively (i.e. a moving– or step–grate boiler with a large diameter in-feed mechanism).

The specialist nature of and substantial investment required for terrain chippers means that they are little used in Europe today. However this method of harvesting can be highly appropriate in sites where such specialist machines are operated in a very large area of forest where there is continual harvesting, and where the customer is nearby.

An alternative to terrain chipping is to bale brash and forestry residues, such specialist equipment produce a "log like" bale which can forwarded and hauled in conventional way. Tilhill Forestry currently operates such a machine in Northern England supplying bales for chipping to a large CHP plant at Shotton Paper Mill in North Wales.

Chipping at roadside is carried out on material which has been felled, snedded and cross-cut in the forest. Material is then stacked at the roadside by product category: saw log material, fencing material, etc. A separate stack is made of material for energy production. This material is usually smaller in diameter, forked, twisted or bent and too poor for other uses.

It may be stacked and left at the roadside (with signage) to dry, chipped at the roadside, or transported for processing elsewhere by standard crane-mounted self-loading timber lorry. Normally, it makes more sense to transport the material as logs before chipping if it is to travel some distance, because it is far denser as timber than chips. Chip occupies approximately twice the volume of solid timber.

Direct chipping into fuel store – useful option where noise of chipping and timber storage is acceptable or as in this case where no other option is available due to limited delivery access via pedestrian door.

LOCATION CONTINUED

Roadside chipping can be done with mobile chipping equipment. The material can be crane–or manually–fed into the chipper and blown into a road going vehicle or tractor and trailer. This method is most common where the end user is close to the site because of the reduced density of the material once it has been chipped.

This system can also be used for whole tree material extracted to the roadside. Forwarder extraction for small diameter roundwood or whole tree material–common in the UK–means that the resulting chips should be cleaner and less contaminated. A major advantage of chipping whole trees is the cost saving of not snedding or cross cutting. Chipping a whole tree also produces a far greater volume of chip by including branches and needles. In a hardwood species such as birch there can be an increase of 16% (where 100% is the volume of harvestable stem wood). For a pine species the branch wood can add 21%, and a species such as spruce can add up to 54%.

It is best not to use material which has been extracted from a forest site by winching or dragging because of the high risk of contamination by soil, grit or stones, which get under the bark. This would risk damage to the chipping equipment and to the boiler.

Chipping at a depot or yard area may be appropriate where the depot or yard is surrounded by a number of boilers or CHP plants within a reasonable distance. Transporting the roundwood to the yard in traditional timber lorries reduces the haulage costs because of the timber's higher density. Other feedstocks can be brought to the yard too, such as recycled timber and slabwood waste from sawmills.

Chipping in the depot can give greater scope for organising the production of different grades of fuel, dry storage undercover of finished chip, holding substantial stocks and reducing moisture content. It also allows the use of static chipping equipment and a range of processing machinery.

Chipping at point of use may be useful when the point of use is a relatively industrial location where it is acceptable to deliver stock (such as solid timber or slabwood) by large lorries and to carry out noisy, dusty and potentially dangerous processing on site. Seasoning of roundwood timber may take place at the roadside in the forest, and/or at the point of use, or potentially at an intermediate storage site.

Stock brought directly from the forest will save on intermediate haulage and result in a saving on the cost of the finished chip. However, the site must either have a fixed or permanent chipper, or be capable of holding substantial stocks of roundwood in preparation for regular visits from a mobile chipper.

Slabwood stacked for drying in an open exposed location orientated to allow the prevailing wind through the stack at 90 degrees

Roundwood stacked adjacent to fuelstore on steel bearers, sheeted to prevent rain ingress, a near perfect design providing all-round air circulation.

FEEDSTOCKS FOR WOODCHIP

The five main categories of woodchip feedstock are:

- Roundwood from forestry or whole tree material – £14–22 per cubic metre at roadside
- Sawmill residues in the form of off-cuts, slabwood, sawdust, etc. £5–10 per tonne
- Arboricultural arising in either chipped or solid form £0–10 per tonne
- Purpose-grown energy crops such as short rotation coppice or forestry (SRC or SRF) £15-20 per tonne.
- Recycled timber £20–25 per tonne

Each has features determining its price and quality.

Forestry Residues

Forestry frequently produces co-product which is too knotty, bent, forked or small in diameter for use as timber for fencing or sawmilling, the two primary uses for timber. This virgin forestry waste has long been used in pulp, paper or chipboard production. Now the growth of recycling means that companies and consumers choose instead to use recycled paper, or recycled chips for fibreboard. In their place, woodfuel producers have seized the opportunity to use the virgin timber for energy production.

A significant advantage of using roundwood for chip production is its relative consistency and uniformity, which enable producers to make a high grade of chip and to control particle size. The high density of storage, whether at roadside, in-forest or at a depot or point of use, also allows material to be stacked correctly to reduce moisture content. (See Guidance Document 4 for stacking methods).

Sawmill Co-product

The sawmilling industry produces a large volume of waste material. This may be reject roundwood material, similar to that described above, or more commonly sawdust, off-cuts and slabwood waste. Slabwood is produced when cutting square sawn timber from roundtimber. Slabwood is the outer curve of the log that has to be removed. Sawmills often bundle slabwood, strapping it with metal or material bands, so that it can be stacked to allow rapid drying. This can then be transported using traditional timber lorries.

A disadvantage of using slabwood is that its size can vary considerably, depending on the recovery rate of the sawmill, slabwood often consists of very small stick-like pieces of varying length which are very slow to feed manually into a chipper. It is better to use a crane to feed such material.

An advantage of slabwood is that its high surface area to volume ratio means that it dries much more quickly than roundwood: in summer material can go from 55% moisture content to below 35% in under three months, if the weather is suitable and the material is stored appropriately in an open exposed and preferably sunny location with good ventilation, on bearers. Because slabwood comes from the outside of the log there can be a high proportion of bark in the finished chip, which has two main implications:

- the chips will be browner, and so will produce more ash than a whiter chip
- there may be grit in the bark from it being skidded or winched out of the forest; however some sawmills debark their logs before milling to reduce the damage done by grit on their sawing equipment

The bands strapping slabwood together should be removed before chipping to avoid damage to the chipper, or clinkering in the boiler.

Excavator feeding chipper with arboricultural arisings of all shapes and sizes which would be difficult to crane feed with a conventional timber grab. Oxford City Council Tree Station

Slabwood is often cheaper than forestry roundwood: if the market price for forestry roundwood is too low, it may not be economic to extract it from the forest and therefore it commands a higher price. Slabwood however, is a waste product which builds up in sawmills, so it is in the mills' interest to have it removed from the site, hence the relatively low price. However, with a growing woodfuel market the stocks of slabwood are ultimately limited by sawmill output.

Other sawmill residues such as sawdust or offcuts can be included in chip production. However they must be limited in order to control the ratio of fines (see Guidance Document 1). Small loose offcuts can be very difficult to feed into a chipper, and this needs to be done by a grab crane or conveyor.

As slabwood is frequently tapered, the tail end of a piece is often dragged through the chipper and not cut successfully by the knives, producing shards or slithers. Some chipper mechanisms are better at limiting this, and some are fitted with slither breakers, but slabwood does tend to produce a lower graded chip. Consequently, producing G30 chip from slabwood can be unreliable. Slabwood also has a higher proportion of bark compared to roundwood and therefore can result in clinkering in some boilers.

Arboricultural Arisings

A substantial by-product of tree surgery. They may be already chipped, solid timber or roundwood.

Chips produced on site after tree surgery have a high moisture content because they are chipped immediately following felling and the handling storage and transport processes limit the opportunities for drying. Wet fuel with a high leaf and bark content arising from a wide variety of species is only suitable as fuel in a boiler designed to cope with wet fuel i.e. a moisture content greater than 35%.

Contamination is also likely from soil, sand, grit, and stones. This occurs when contractors sweep up at the end of the day and throw their sweepings in with the chip. Contaminants produce clinker in a boiler affecting both the performance and longevity of the boiler.

Arboricultural waste will contain a very wide range of species and many evergreen species such as laurels and rhododendrons. The thick waxy leaves of these species can lead to chemical damage within boiler systems. Chip material produced in this way should only be burnt in equipment with large robust in-feed augers or mechanisms able to take relatively non-homogenous particle sizes with high extremes, ideally with a moving or step-grate or with exhaust gas re-circulation capable of reducing clinker output.

Tree surgery also produces larger roundwood or timber sections which are too big to pass through the surgeon's chipper and so are hauled back to the depot. If dried out they can produce a higher grade of woodfuel but as they are often lumps or rounds they are difficult to chip without specialist chipping machinery.

Despite these issues a number of potential advantages can accrue from the use of arboricultural waste, and the material can attract a gate fee, allowing the relatively greater costs of fuel production to be offset. Central processing means the raw material is gathered and often delivered to site as a waste product for processing. This minimises haulage costs.*

*See Croydon Tree Station Study – http://www.bioregional.com/programme_projects/forestry_prog/urban_forestry/urbfor_woodchip.htm

Short rotation coppice.


Recycled Timber – clean pallets can produce good quality woodchip

FEEDSTOCKS FOR WOODCHIP CONTINUED

With careful handling, storage, sorting and processing, arboricultural waste is an obvious fuel source but beware, a number of UK operations have learnt painful lessons when using material from gardens and parks, which is far more likely than forest material to be contaminated: They have found metal railings, stakes, tree ties and even plough shares, bottles and bicycles– with catastrophic results for both chipping equipment and boilers.

Purpose-grown energy crops (Short Rotation Coppice and Short Rotation Forestry) are increasingly popular as users choose them to replace ever more expensive fossil fuels.

Short rotation coppice or forestry crops are grown on agricultural sites and regularly cut (typically on a three year cycle) for woodfuel production. To date these crops have been made up almost exclusively of Willow and Poplar varieties and clones. They can be mechanically harvested and chipped in a single pass operation by specialist equipment similar to a forage harvester.

Such material is of a high moisture content, and particle size is variable. Single-pass harvesting creates a very low cost woodfuel of a lower grade, suitable for larger industrial consumers such as power stations–particularly where crops are grown close to the point of use and can be hauled directly to site. Such woodfuels have a higher leaf, twig and bark content than others, depending on the time of year they are harvested, so produce a browner chip. This may have implications for ash or chemical exhaust gas production within the boiler.

Miscanthus has historically been favoured by farmers considering energy crops and consequently is established more widely than short rotation coppice. Miscanthus is a perennial grass harvested each year using conventional agricultural equipment.

Unlike Short Rotation Coppice, miscanthus is largely dry at harvesting and as a monoculture it provides a consistent feedstock for pellet production and other end uses such as animal bedding. Miscanthus has the potential to provide large volumes of a low cost but highly productive biomass ideally suited to co-firing and other large scale energy production. Bical is working with landowners to develop co-operative models with centralised pelletising plants to service large energy contracts.

http://www.bical.net/

Recycled timber is a useful low-cost feedstock with an extremely low moisture content–often less than 20%– which gives a high energy value. Clean recycled timber comes in many forms such as joinery off-cuts and pallet wood. Its biggest disadvantage is the likelihood of contamination. Normally such material is chipped by a hammer mill or shredder and as part of this process, metal is removed by an overband magnet.

Where treated feedstock is used, the resulting woodchip may contain chemical contaminants such as paints, glues, preservatives, metal and plastic.

The combustion of contaminated woodchip will be subject to the Waste Incineration Directive and can only be burnt in regulated appliances.

Baled miscanthus being fed into pellet plant for conversion into fuel cubes.

CHIPPING EQUIPMENT

It is important to distinguish between chippers designed to reduce the volume of waste on a site, as typically used by tree surgeons, and those designed to produce woodfuel. Woodchips, which meet the quality and standards required for woodfuel, can only be produced on purpose-built chippers.

In addition, high quality chip production can only be achieved by correct maintenance of the machinery. In particular, knives must be kept in a sharp, correctly-set state, and should be changed frequently and ideally each time the chipper is used.

Using the right machinery with the appropriate feedstock enables the contractor to produce material of uniform particle size and of the correct grade. Contractors most effectively control moisture content by choosing appropriate feedstock and by correct storage methods before and after processing.

Fixed or mobile

Chippers may be fixed or mobile (on a towed trailer unit or lorry-mounted). A fixed chipper is best for a depot where material is brought in for use on site or for processing and transporting to local boilers. The density of boiler installations is still low in the UK, so it may be better to use mobile equipment.

Power source

Chippers may have a built-in engine or be driven by the power take off (PTO) from a traditional agricultural tractor. Inbuilt engines have the disadvantage that they are much heavier and cost more to maintain, so they are usually only suitable on a small portable chipper such as those used in tree surgery. A PTO drive is preferable for larger purpose-built woodfuel chippers as tractor units are widely available and produce high power output. Large-scale three phase electrical chippers are manufactured for static factory processes such as joinery workshops.

There are three main types of chipper, categorised according to the way they operate: cone, drum or disk. All three can be manual or crane-fed. Crane-fed chippers have a shorter, more open in-feed area and no safety stop wire or bar: though it is possible and legal to crane-feed a manual-fed chipper, it is a contravention of health and safety law to manually feed a purpose-built crane-fed chipper.

Cone chippers

Have an extremely high throughput, but are limited as to the feedstock they can use: ideally they process solid roundwood only, and in wet form to lubricate the cutting action. If fed with slabwood or brush these machines produce non-uniform chip with extremes of particle sizes.

Cone chippers have an internal cone rotating at high speed, with spiral-set knives. Material feeds in at the cone's point and is chipped by the knives against the outer casing. These machines need a relatively high-power in-feed. By changing the internal cone they can produce different particle sizes, up to large chunks for "hogwood" boilers (or also for cattle corral bedding).

Drum chippers are currently the most popular as they can take in whole tree material, such as branchwood, brash, slabwood or solid roundwood timber, and still produce a uniform chip. Separation of the cutting and blowing functions means that drum chippers can produce varied particle sizes according to the screen size. They also use relatively little power and can operate on an engine as low as 80hp.

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Drum chippers

Contain a high-speed rotating drum which has knives mounted in its side. Rollers feed material against the drum at 90°. The cut material will then pass through a screen, or if oversized, pass round the drum again for re-cutting. Screened material falls (directly or through an auger) to a fan, to be blown out of the chipper.

Heiziohack Drum Chipper – Heizomat are a German biomass boiler manufacturer who began manufacturing chippers under the brand Heizohack because of the limitations of many chipper in the market to produce Fuelwood.

Internal view of drum chipper showing blade settings.

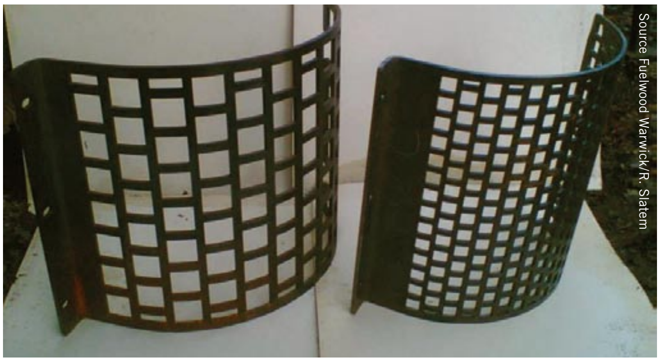
Disk chippers are more simple in construction and working, so are cheaper than drum or cone chippers. However because the cutting and blowing functions are not separated, material is not screened, and therefore the resulting chip is less uniform than from drum chippers. Disk chippers have a large heavy flywheel around whose circumference knives are set. The fans of the blowing unit are mounted on the back of the flywheel. A disk chipper may have an in-feed at 45° rather than at 90° to the knives, to increase the throughput of the machine; however this limits the feedstock to solid roundwood as opposed to brash or slabwood.

In addition to the equipment described there are some other large scale mechanical systems with potential for woodfuel production.

Shredders are typically used as part of a manufacturing process to produce very specific finished products, such as shavings for equine use or as part of the pellet manufacturing process. Low grade material unsuitable for these products could be used for woodfuel however the material may need further processing (i.e. hammer mill) or its supply limited to specific boiler types capable of handling such material.

Hammermills are used in similar manufacturing processes to shredders and at times as part of the same process, material may be both shredded and then passed through a hammer mill. They are also used by large scale recyclers to breakup recycled timber, arboricultural waste and green domestic waste. The resulting material has the potential for woodfuel use, however due to potential contamination, markets are currently limited unless the material is carefully sorted prior to processing.

Tub grinders are used to break down all sorts of "woody residues" from stumps including soil and stones, through to recycled timber. Such machines are often used as part of site clearance work on construction projects. Ultimately, the mulch material produced is largely unusable in the current UK woodfuel market but has potential once a number of large CHP plants come online that have robust in-feed mechanisms.



Screens for G30 and G50 chip.

Disk chipper – most common type of chipper on the market today, used widely by tree surgeons

SUMMARY

It is important when considering whether to become a fuel processor to research the following key areas;

- What types of feed stock are available and its geographic spread and suitability in relation to the potential boiler sites to be supplied.
- What is the value and size of the potential market to be served.
- When considering the purchase of processing equipment, take into account, likely feedstock, processing capacity, maintenance requirements, and budget. Trial and view machinery before purchase and speak to other fuel suppliers.
- Another option may be to hire in equipment before committing to purchase and wait for the woodfuel operation to be up to a viable capacity. For woodchip it is likely that around 2500 tonnes of supply will be required to sustain a viable woodfuel supply company.
- Look at the haulage and delivery options and the investment required to service potential boiler sites which may require several different delivery methods and therefore vehicles. Is it possible to contract this part of the fuel supply process to a third party?

There is a very wide range of assessable web based information and many websites dedicated to woodfuel. However, it must be borne in mind when reviewing this information that woodfuel in the UK is still an emerging market and the information available, and the experience upon which it is based, is limited.

Jenz Shredder being loaded with recycled wood waste at waste transfer station

This document is part of a series – other guidance documents available include Woodfuel Standards, Woodfuel Supply Contract Options, Woodfuel Storage and Woodfuel Distribution

Further Information
Biomass Energy Centre
www.biomassenergycentre.org.uk

Bioenergy Group
www.bioenergygroup.org

Rural Development Initiative
www.ruraldevelopment.org.uk

The South West Woodfuel Advice Line
08450 74 06 74

The South West Woodshed
www.southwestwoodshed.co.uk

Forestry Commission Technical Notes and research
tinyurl.com/3rzklf
tinyurl.com/3ffn97

For more information on processing equipment for logs and chip production visit
www.fuelwood.co.uk
www.westconuk.com
www.mus-max.at/en/land-forsttechnik/news

For more information on pellet production and to find equipment suppliers visit
www.nef.org.uk/logpile/pellets/production.htm
tinyurl.com/5mbd3z

References
Woodfuels Basic Information Pack 2000

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Herstellung und Nutzung von Pellets, Volume 5 of the Thermal Biomass Utilization series, Institute of Resource Efficient and Sustainable Systems, Graz University of Technology, Austria.

Credits
Bent, E – Midlands Wood Fuels
Brook, R – Ecowoodfuels
Hogan, G – Biomass Energy Centre
Halcro-Johnston, A – Regen SW
Corker, M – Bical
Slatem, R – Fuelwood Warwick
Murray, I – John Deere
Frost, W – Silvanus Trust
Gill, M – Greenwaste Management Services
Rickwood, D – Forest Fuels
Whatmore, S – Forest Fuels
Wilding, J – Clinton Renewables

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