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Project: **Woodfuel: Relating Quality and Specification to Burner Types**

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Summary

This Internal Project Information Note describes the factors affecting the quality of woodfuel and links woodfuel specification to the range of wood burning appliances currently available in the UK. The quality and specifications for the two main types of woodfuel in use in the UK (log wood and wood chips) are discussed in detail.

Introduction

The use of renewable resources to produce heat and electricity is now stated Government policy. This policy aims to reduce fossil fuel emissions by producing 10% of GB energy requirements from renewable resources by 2010 and 20% by 2020.

Woodfuel can be a viable alternative to using fossil fuels for the production of heat and electricity, particularly in rural and semi-rural areas. The wood burning appliances currently in use vary in size and capability; for example, burners capable of producing less than 1000 kW (1 MW) of energy commonly produce heat only, while those with an output greater than 1000 KW can supply both heat and electricity. Indications are that future development in combustion technology will result in the production of both heat and electricity from burners with outputs of less than 1000 KW. To ensure economic competitiveness, i.e. that woodfuel quality and specification is accurately related to burner requirements, it is essential that all the elements in the production and supply of woodfuel are fully considered and integrated.

In addition to log wood and wood chips it is evident that there is growing interest in the production of wood pellets (densified wood residue materials) for use particularly in domestic appliances and as a replacement for fossil fuels in some larger sized burners. This Technical Note includes only basic information on wood pellet fuel, as this is still an emerging technology in the United Kingdom.

When relating woodfuel specification and quality to burner types, several main factors need to be taken into account:

- The type, species and volume of the supply required.
- The availability and proximity of the woodfuel resource.
- The selection of the most appropriate readily available supplies in relation to wood burning appliances.
- Processing and storage of the woodfuel.

Factors affecting woodfuel quality

Primary factors

The primary factors affecting woodfuel quality are:

- the part of the tree to be used as woodfuel.
- moisture content.
- wood density.
- fuel dimensions of comminuted product.
- contaminants.
- storage and drying.

Moisture content

Generally there is more water in softwoods than hardwoods, and within tree species a greater amount is present in the sapwood than in the heartwood. The amount of moisture in wood varies for different tree species, regions of the country and in different parts of individual trees. The moisture content (MC) of a piece of wood is defined as the weight of water expressed as a percentage of the weight of the wood. This can be expressed either on a dry basis or a wet basis.

Dry-basis moisture content. A dry-basis MC is expressed as a percentage of the oven-dry weight of the wood. For example, if the wood in a piece of timber weighs 50 kg and the water also weighs 50 kg, the moisture content is 100%. Because freshly felled timber can contain a large amount of water it is possible for MC expressed in this way to exceed 100%. The main reason for using this method to express MC is that the oven-dry weight of the timber is constant, thus MC is expressed as a percentage of a constant value. This method is the established way of expressing moisture content used by the Forestry Commission.

The wet/green weight and oven-dry weight of the wood must be expressed in consistent units of either grams, kilograms or tonnes.

Wet-basis moisture content. A wet-basis MC is expressed as a percentage of the weight of the timber including any moisture. For example, if the wood in the piece of timber weighs 50 kg and the water also weighs 50 kg, the moisture content would be 50%. Because the timber weight includes both the moisture and wood in the timber, MC on this basis can not exceed 100%, and is extremely unlikely to exceed 75%. This way of expressing MC is often used in the bioenergy industry as it gives a more direct impression of the amount of water in the timber, which is of great importance in estimating the net energy available.

MC is commonly estimated by taking measurements of the wet and dry weight of samples of wood. Having measured the wet weight, the dry weight is determined by putting the sample of wood in an oven (usually laboratory or industrial type) for 24 hours at a constant temperature of 103 ± 2 ^{o}C and then weighing it (Desch and Dinwoodie, 1996).

MC is directly related to the net calorific (heat) value, usually expressed as megajoules per kilogram (MJ/kg) or gigajoules per tonne (GJ/t). The higher the MC, the lower the net calorific value, because heat energy is required to evaporate the water from the wood. For example, a piece of wood with a MC of 10–12% (wb) has a net calorific value of about 17 GJ/t, compared with about 7.5 GJ/t for wood with a MC of 50% (wb). Thus it follows that reducing MC can lead to greater burning efficiency. MC varies in different tree species, regions of the country and in different parts of individual trees.

Practical methods to reduce moisture content

If the primary objective is to manage crops for energy production, there are several methods for reducing the moisture content of standing or felled timber:

- **Ring barking.** Removing a thin continuous band of bark and cambium from around the circumference of the main stem prior to felling. This kills the tree by preventing the uptake of soil water and nutrients.
- **Chemical thinning.** This method involves applying chemical into a small cut in the stem to kill the tree prior to felling.
- **Sour felling**. Trees are felled, usually as part of a thinning operation, and left *in situ* for between 6 and 18 months (Technical Development Branch, Forest Research, 1998). Moisture is lost through the needles or leaves in the transpiration process.
- **Dead and dying trees**. Compared to living trees and depending on the degree of mortality these have a reduced MC and can be felled for woodfuel. However, it is important to retain a proportion of deadwood in the woodland due to its important value to woodland ecosystems (Forest Enterprise, 2002).
- **Stacking residues and/or roundwood on site.** Residues or wood are stacked in situ after felling. Consideration should be given to timing of subsequent extraction and comminution to minimise ground damage.

- **Stacking timber at roadside (covered or uncovered).** Timber should be stacked on bearers[1] and positioned in a place of low humidity and high air temperature and movement. (Code of Practice, Road Haulage of Round Timber, 3rd Edition, 2003)

Before adopting any of these methods, consideration must be given to tree/crop health, timing of operation, economics, health and safety aspects and resulting aesthetic changes.

Wood density

Wood density is an expression of the amount wood mass per unit volume. Density can be expressed in different ways, depending on whether or not MC is accounted for. Two relevant expressions are green density and basic density.

Green density. Green density is defined as the weight of a piece of freshly felled wood divided by its volume and is usually expressed in units of g cm^{-3}, kg m^{-3} or t m^{-3} (tonnes per cubic metre).

Basic density. Basic density is defined in a similar manner to green density, except that the weight of wood does not include any moisture.

The volume is usually measured on the freshly felled piece of wood so that basic density is the ratio of oven-dry weight to green volume. Occasionally, basic density is calculated using volume as measured on wood that is not freshly felled.

Higher density wood will have more energy per unit volume. Density varies between species; generally a hardwood log or chip will contain more potential energy than an equivalent sized softwood log or chip at the same moisture content.

Density of a particular species can vary within trees in the same stand and even in sections within a tree. Typically the green density within a single tree is greater at the base, thereafter decreasing gradually to the tip (Desch and Dinwoodie, 1996). The rate of drying is slower in species that have a high density and dense wood requires more energy to process into logs or chips.

Fuel dimensions

Many woodfuel combustion systems require woodfuel of specified dimensions. Often wood logs have to be processed (communinuted) to produce chips or chunks of the right size. The piece or particle size of any high quality woodfuel should remain consistent, with the minimum amount of variation. This is of particular importance when using wood chips in a burner with an automated delivery system where a screw type auger is being used to manage the fuel. Wood chip size and composition can vary greatly. Before acquiring any chipping or shredding equipment or taking wood chips from a supplier the optimal chip size required and acceptable amount of variation should be ascertained from the burner manufacturer.

The production of consistent high quality wood chips is directly related to the type of raw material used and maintenance of the cutting edges of the knives or screw of the chipper. The size of wood chip produced by chippers can be determined by:

- In-feed roller speed (disc and drum chippers).
- Number of knives (disc and drum chippers).
- Knife settings (disc and drum chippers).
- Pitch of screw (screw cone chippers).
- Rotational speed of disc, drum or screw

Information on the range of particle sizes a chipper is capable of producing is provided by the manufacturer. Further chip quality evaluation work is being undertaken by Technical Development.

[1] Two long lengths of roundwood placed at roadside to ensure the stack of timber doesn't come into contact with the ground.

For log wood to burn efficiently the width/thickness should not exceed 15 cm; logs of a greater size should be split. Round and split logs that are uniform in size are easier to transport and store.

Storage and drying

One of the primary aims of storing woodfuel is to reduce the MC. Seasoning (drying time) is dependent on the wood density, wood dimensions, presence of bark, method of storage and stacking and the required MC. The rate of drying is strongly influenced by air movement, temperature and humidity.

To maximise the rate of drying, logs should be stacked on bearers using a method that exposes a large proportion of their surface area to warm air. Stacks should be positioned to take full advantage of air movement and sunlight and provide easy uplift for secondary processing and transport. The tops of the stacks should be covered to prevent reabsorption of water, particularly during the wetter periods of the year. The most practical way of covering is likely to be with waterproof sheeting.

Wood chips should be stored in a built structure such as a Dutch barn; alternatively relatively dry wood chips can be protected by covering with waterproof sheeting. The small size of the wood chips presents practical problems in terms of air circulation around the bottom of the heap. Storage on a concrete floor is therefore recommended, and this can also facilitate future mechanical handling. To minimise the possibility of combustion, it is necessary to manage the heap size and formation carefully, and to ensure that storage as chips does not exceed 12 months. In Denmark the recommendation for wet wood chips is that heaps should not exceed 10 metres in height. The width of the heap is usually governed by width of available covers and/or access requirements.

Chipping wood creates a greater bulk density[1] when compared to other fuels. The higher the moisture content, the greater the weight. Both of these factors have implications for handling and storage, and also for transportation.

Respiratory protection against small particles and airborne mould spores is required when handling woodchips, particularly those with a high moisture content.

Transport

The cost of road transport is high and the haulage distances and method of transport have a direct effect on the delivered price of woodfuel. In the UK road haulage is likely to remain the primary method of transporting woodfuel from the forest to the processing site and as the final delivery method to the burner site. Current economic indicators are that chipping at point of use is the preferred option due to bulk density i.e. the greater bulk density after chipping the less efficient the handling. Transporting wood chips over distances greater than 32km (20 miles) is seen to be uneconomic. As far as transportation of logs is concerned, the logs should be square stacked and of similar size and uniform length to enable more solid volume per unit area.

Brash bales (composite logs) are compressed stem and branch wood made from forest residues. In the UK, brash bale production is relatively new and trials are ongoing to establish the economics of production (costs and outputs), methods of reducing moisture content and their potential for use in medium to large scale burner units. They can be transported in the same way as logs.

Secondary factors

The most important secondary factors affecting woodfuel quality are:

- The species and quality of trees used for woodfuel production.
- Woodfuel that has twisted grain or a high proportion of knots requires an increased amount of energy to process into logs or wood chips.

[1] The mass per unit volume of a material, including solids and voids, commonly expressed as kilograms per cubic metre, e.g. the bulk density of fresh wood chips is *c*. 320–380 kg m^{-3}.

Further information on these secondary factors can be found in *Timber, Its structure, properties and utilisation* (Desch and Dinwoodie, 1996).

Woodfuel specifications

It is important for both producers and users that a consistent size and quality of woodfuel is achieved. The development of a simple, common standard for producers and burner manufacturers is important, particularly for the production and burning of wood chips.

Developing a common European standard

A major factor restricting the development of international trade in woodfuel is the absence of a common standard between countries. The European Union (EU) is currently preparing a European Standard (CEN/TC 335) for the various types of biofuels which includes woodfuel in various forms. This is due to be released mid 2005 and is likely to be accepted by the majority of the woodfuel industry throughout Europe. The current draft can be viewed on the CEN website: www.cenorm.be.

A synopsis of the Central European Norm (CEN) draft standard CEN 335 Standardisation of Solid Biofuels is shown Tables 1, 2 and 3 below

Table 1 Classification of origin and sources of woody biomass

Wood origin	Wood source
Forest and plantation wood	Whole trees
	Stemwood
	Logging residues
	Stumps
	Bark (from forestry operations)
	Landscape management woody biomass
Wood processing industry by products and residues	Chemically untreated wood residues
	Chemically treated wood residues
	Fibrous waste from the pulp and paper industry
Used wood	Chemically untreated wood
	Chemically treated wood
Blends and mixtures	Combination of any of the above

Wood Chips and Hog Fuel

An example of high quality wood chips recommended for household usage should be sourced from stem wood with the following specification:

Moisture Content <20 or <30 % (wet basis)

Dimensions P16, P45 or P63 (see Table 2)

Energy density E 0.9 (net calorific value > 900 kWh/bulk m^3)

Table 2 Particle size for wood chips and hog fuel

Type of wood fuel	Main fraction (> 80%)	Fine Fraction (<5%)	Coarse fraction, max. particle length
P16: Wood chips	3.15≤Particle≥16 mm	<1 mm	<1% >45 mm all <85 mm
P45: Wood chips and hog fuel	3.15≤Particle≥45 mm	<1 mm	<1% >63 mm
P65: Wood chips and hog fuel	3.15≤Particle≥63 mm	<1 mm	<1% >100 mm
P100: Hog fuel	3.15≤Particle≥100 mm	<1 mm	<1% >300 mm
P300: Hog fuel	3.15≤Particle≥300 mm	<1 mm	<1% >400 mm

Table 3 Dimensions for wood logs

Wood logs	Diameter (D) and Length (L) mm
P200-	L < 200 mm and D <20 mm ignition wood
P200	L = 200 ± 20 mm and 40 ≤ D ≤ 150 mm
P250	L = 250 ± 20 mm and 40 ≤ D ≤ 150 mm
P330	L = 330 ± 20 mm and 40 ≤ D ≤ 160 mm
P500	L = 500 ± 40 mm and 60 ≤ D ≤ 250 mm
P1000	L = 1000 ± 50 mm and 60 ≤ D ≤ 350 mm

The benefits of a European standard are to:

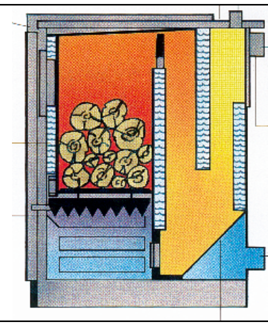
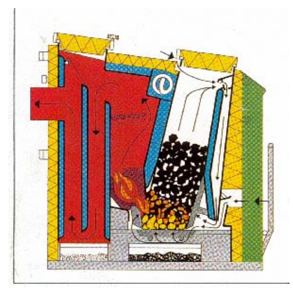
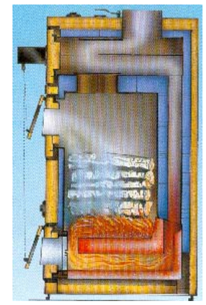
- Simplify the communication between fuel suppliers and customers.
- Assure that woodfuel and burner technology complement each other.
- Assure that the delivered woodfuel has the quality that is specified.

Woodfuel burning systems

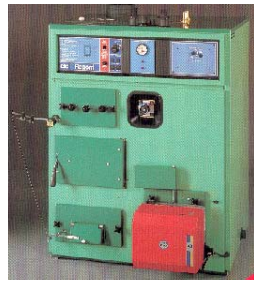
The following charts show current information on woodfuel burning systems and identify the fuel specification for each. They range from small, simple warm air systems to modern commercial sized systems producing heat, electricity, or a combination of heat and energy called combined heat and power (CHP).

Domestic sized systems. Traditional appliances 2 –25kW			
Name	**Box stove**	**Tiled stove**	**Cooker/boiler**
Brief description	Fire is within a freestanding metal container with adjustable air inlets.	Intense intermittent firing within a large ceramic or stone heat store. Slow release of stored heat between firings.	A 'Range' cooker that also supplies 'wet' central heating.
Fuel type (s)	Logs	Logs	Logs
Combustion type and maximum efficiency guide	Simple ' over-burning' technology *c*. 65–70%	Simple 'over-burning' technology *c*.85–90%	Simple 'over-burning' technology *c*.50–60%
Heat output range	2 to 20 kW	Up to 10 kW	10 to 25 kW
Suitability	Small domestic, direct air heating or supplementary to other background heat.	Small/medium domestic, direct air heating, high aesthetic appeal.	Small/ medium domestic, cooking and CH/DHW supply.
Service requirements	Woodfuel storage capacity. Some operational expertise		
Installation parameters	Insulated chimney. Direct heat production.	A large and heavy construction.	Insulated chimney. Large hot water storage.
'Best practice' fuel characteristics	MC *c*. 20 –25 % (wb) and assured supply of suitable fuel.		

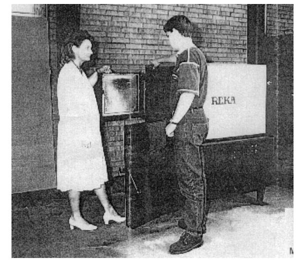
CH: central heating; DHW: domestic hot water.

Domestic sized systems. Freestanding boilers, log fired 11 – 200kW			
Name	Freestanding boiler. ‘Over-fired’ type	Freestanding boiler. ‘Under combustion’ type	Freestanding boiler. Reverse combustion type
Brief Description	Top or side loading boiler unit		
Fuel Type (s)	Prepared wood logs	Prepare wood logs. Options for supplemental oil/gas burners.	Prepare wood logs. Options for supplemental oil/gas burners.
Combustion type[2] and max. efficiency guide	Simple ‘over-burning’ technology *c.* 60 –70%	Efficient under combustion design *c.* 65-75%	Very efficient reverse combustion design *c.* 75 – 90%
Heat output range	11 – 30 kW	15 – 200 kW	15 – 75 kW
End-use suitability	Small/medium domestic or small commercial premises		
Service requirements	Wood fuel storage capacity. Some operational expertise.		
Installation parameters	Insulated chimney. Large CH hot water storage tank, usually incorporating DHW provision & additional electric immersion heater		
‘Best practice’ fuel characteristics	Refer to manufacturers specification, MC *c.* 20 – 25% (wb) and assured supply of suitable fuel	Refer to manufacturers specification, MC *c.*20 – 30 % (wb) and assured supply of fuel	

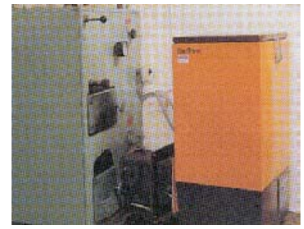
[2] Under combustion, fire burns sideways and away from the fuel, placed on top. Reverse combustion, fire burns downwards and away from the fuel, placed on top.

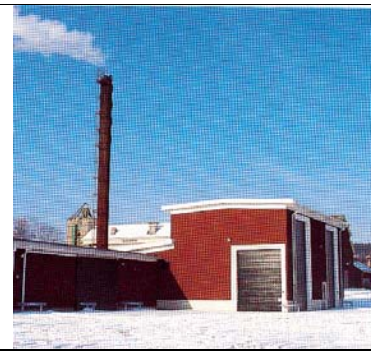
Domestic sized systems[3]. Free standing boiler variants, log fired			
Name	Multi-fuel boilers	Combination boilers	Wood pre-burners
Brief Description	A boiler designed to run on a wide variety of fuels	A main wood, plus a separate oil/gas boiler in one unit	A wood pre-burner furnace designed to convert another, e.g. a fossil fuelled boiler
Fuel Type(s)	Primarily wood logs, but also coal, coke, wood or peat briquettes. Also supplementary oil or gas burner options.	Wood logs mainly, plus the programmable fossil fuel option.	Prepared wood logs[4]
Combustion type and max. efficiency guide	Under or reverse combustion type *c*. 60 – 65% wood logs; *c*.60 – 80% fossil fuel alternatives.	Under or over combustion type *c*. 60 – 70 % wood logs; *c*. 75 – 85% fossil fuel alternative.	Reverse combustion. Up to 90%.
Heat output range	20 – 600kW	15 – 25 kW	20 – 50 kW
End use suitability	Small/ medium domestic or small commercial premises		
Service requirements	Wood fuel storage capacity. Some operational expertise		Wood fuel storage capacity. Operational expertise required.
Installation notes	Insulated chimney. Large CH hot water storage tank		
'Best practice' fuel characteristics	Refer to manufacturer's specification. MC *c*. 20 – 30% (wb) and assured supply of suitable fuel.	Refer to manufacturer's specification. MC *c*. 20% (wb) and assured supply of suitable fuel.	MC *c*. 20% (wb) Fuel **quality** is critical and assured supply of quality fuel as per manufacturer's specification.

[3] Photographs courtesy of Baxi and Masugnen
[4] Refer to CEN/TC 335 specification.

Domestic to medium sized systems[5]. Free standing boilers, chip fired.			
Name	Pre-furnace burner	Stoker-burner	Inclined moving grate
Brief Description	A hopper and a feeder tube to a small ceramic lined burner. Flames are injected into a separate boiler unit. Basically a 'chip fired blow lamp'	A hopper and feed tube, but into a smaller containment vessel placed inside the boiler. Combustion air is supplied via a separate pipe.	A hopper and fed tube, but onto an in clined moving grate which lies inside the boiler, at its base. Combustion air is supplied from beneath the grate.
Fuel Type (s)	Fuel grade wood chips		
Combustion type and max. efficiency guide	Turbulent air combustion[6]. Up to 85% (may be greater for larger units)	Over fired combustion with air feed from sides. 70 – 85%	
Heat output range	20 – 300 kW	30 – 300kW	20 – 500 kW
End use suitability	Domestic to large commercial	Large domestic to large commercial	Domestic to large commercial
Service requirements	Appropriate hopper size and assured supply of suitable fuel. Operational expertise.		
Installation parameters	Require professional installation to ensure safety and efficiency		
'Best practice' fuel characteristics	Refer to manufacturer's specification. MC 20 or 30% (wb)		MC up to *c*. 50% (wb)

[5] Photographs courtesy of Veto.
[6] Fuel mixes with the air during burning. All chip fuelled appliances can be operationally adjusted.

Domestic to medium sized systems. Re-constituted fuels – pellets **2 – 400 kW**			
Name	Small domestic space heating	Central heating boilers	Retrofit pellet burners for boilers
Brief Description	A 'stand alone' unit similar in appearance to a modern 'box stove' design. The fire is electrically ignited and thermostatically controlled, so heating can be electronically programmed	Small boilers have an integral hopper, which is usually manually filled. Larger boiler units have an attached hopper similar to a chip unit. If large enough the hopper can be filled by a fuel delivery tanker, like an oil fired system	Units designed to replace external burner equipment on fossil fuel boilers, (e.g oil). Units are similar to a pre-furnace chip unit. If large enough the hopper can be filled by a fuel delivery tanker, like an oil fired system
Fuel Type(s)	Quality grade extruded pellets refer to manufacturers specifcation.	Quality grade extruded pellets or lower grade 'rolled' pellets for larger units, refer to manufacturer's specification	
Combustion type and max. efficiency guide	Automatic fuel feed from integral hopper, usually dribbled down a small feed spout from above fire. High efficiency (up to 90% +) due to dense and very consistent fuel.	Automatic feeding from a hopper, (see footnote). High efficiency, (up to 90 %+) due to dense and very consistent fuel	
Heat output range	2 – 12 kW	60 – 185kW	40 – 400 kW
End-use suitability	Small dwelling/single rooms	Domestic and commercial central heating systems	
Service requirements	Undemanding due to high fuel quality		
Installation parameters	As for other 'box' stoves	Similar to fossil fuelled boilers	
'Best practice' fuel characteristics	Essential to keep stored fuel dry. Poorer quality pellet supplies are characterised by pellet disintegration and woody dust.		

District Heating Systems 100Kw – several megawatt		
Brief Description	A small pre-fabricated or larger site constructed system that provides piped heat to a community or part of a larger community. Individual dwellings and businesses can draw upon the circulated district heat via metered heat exchangers. In that way, retaining control of their heating and hot water use. The district heating plant may also produce electricity by a co-generation system, (see below).	
Fuel Type (s)	Some form of comminuted fuel, e.g. wood chips or shredded wood fuel, suitable for medium to large scale automated feeding systems.	
Combustion type and max. efficiency guide	A variety of combustion systems may be used, either singly or in combination to increase overall efficiencies, (see Commercial Boilers below). Efficiencies up to 90% may be attained for some systems.	
Heat output range	From about 100kW up to several megawatts. The upper limit depends on the distribution pipe work length, more by economics than heat loss.	
End-use suitability	Piped heat is supplied as a "service" to customers, like Gas or Electricity.	
Service requirements and installation parameters	The system gives several advantages to the consumer but requires a large initial investment, and a few specialist people to run and maintain it. If combined with electricity generation, heat supplies may be particularly competitive with other systems. Problems may arise from low summer heat loadings, but can be designed out if suitably recognised at the initial stages.	
'Best practice' fuel characteristics and other	Larger scale boiler plant tends to dictate its own specifications of wood fuel supply. It is then advantageous for potential suppliers to fit in with this. Also larger plant can be designed to be less sensitive to variations in fuel quality. Although they are designed to manage a wider variation of chip quality the burning efficiency is reduced. Adjustments to burner settings and in-feed systems may be required for consistent variations in fuel quality or specifications.	

Conclusions

- The correct choice of raw material, harvesting system, comminution or processing machinery, storage, transport and burner will promote the continued development of a sustainable woodfuel market.

- To achieve high quality woodfuel from green timber (trees recently felled and having a MC of *c*. 45% (wb) or more), MC should be reduced to between 20 and 30% (wb). This improves the calorific and monetary value and reduces the costs of handling and transportation.

- It is important for both the producers and users of woodfuel that a consistent size and quality of woodfuel is achieved and the standards being drawn up should help to achieve this.

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