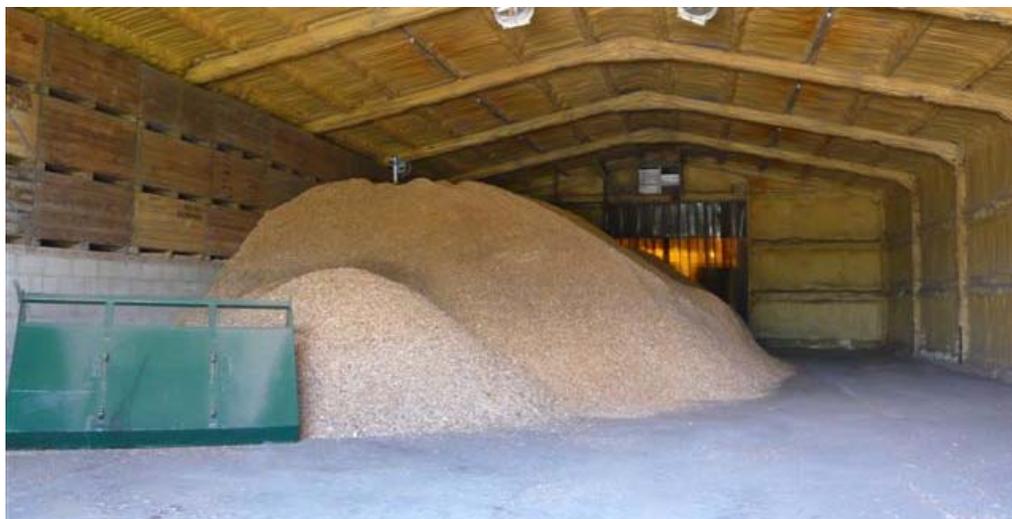


# Woodchip Drying

## Summary

Increasing the use of wood as fuel and the proportion of woodlands under management are both FC objectives for Great Britain. Production of woodchips for fuel is increasing and the sector is developing quickly. Interest in woodchip drying has increased as many suppliers have run short of seasoned timber and chips during trading through recent winters, requiring unseasoned wood to be chipped. There is also a desire to reduce the capital and space tied up in timber seasoning. Active drying would allow chip suppliers to be more reactive to markets whilst minimising the need to hold large stores of drying timber. In a review of the literature covering commercial chip drying, this report has identified a shortfall of operational information and guidance. Whilst the mechanisms of chip drying are well understood, particularly those associated with short rotation coppice (SRC), information on operational drying is scarce. Large scale drying occurs on an industrial scale of tens or hundred of cubic metres per hour and has a large demand for infrastructure. Small scale drying often uses converted trailers and buildings, using fans to force air through chip piles. Data suggests that green chip can be dried relatively quickly (2–3 days) to 25–30% with minimal energy input, using fan and ambient air. Further reduction of moisture content to below 20% requires longer drying time if energy input is not to be excessive. Reduction can take place in around 6 days for warmed air or over several weeks for ambient air. Reduction of moisture content from 34 to 7.5% was found to be possible in 24 hours, but the energy used far exceeded the energy gained by a factor of 3–4. Case studies are required to confirm drying rates for these approaches and calculate energy balances.

**Figure 1** Woodchip storage and drying using forced ambient air



## Introduction

Interest in woodchip drying has risen due to wood suppliers throughout the country having run short of seasoned timber and chips during recent winters. This has required unseasoned wood to be chipped, creating high moisture content woodchip. In addition, there is a desire to reduce the levels of capital “tied up” in stacks of timber seasoning throughout the year. Many suppliers also have insufficient covered storage space to meet the needs of their annual supply. Using active drying would allow chip suppliers to be more reactive to markets whilst minimising the need to hold large stores of drying timber.

The development of wood as a fuel is an objective across the FC in Great Britain (DECC, 2009; FC, 2007) to support the growth of the woodfuel industry and markets, meet challenging targets to reduce carbon emissions, and that could lead to an increase in the area of woodland in active management.

The woodfuel supply sector is still developing and there is a shortfall of information and guidance on woodfuel supply chain organisation. To address this, Technical Development will collect and analyse information to develop and promote accurate guidance on the woodfuel supply chain.

## Objectives

1. Complete a desk study on woodchip drying.

## Literature Review

Woodchip drying has a number of benefits for fuel quality, transport and storage.

### Effects of Moisture Content

Moisture content directly affects calorific value as the water contained within woodfuel must be evaporated during combustion. The energy input required to evaporate water is known as the latent heat of evaporation. The latent heat of evaporation is provided as a cost from the overall heat output from combustion. The net calorific value of a fuel will therefore decrease with increasing moisture content as the latent heat required will increase but the dry matter content of the fuel remains the same. The heating value of an oven dry tonne of spruce wood is 5.4 MWh. For each percent of moisture content increase, the heating value linearly decreases by 0.0594 MWh. The energy content in MWh/t,  $Q_{net}$ , can therefore be calculated by:

$$Q_{net} = 5.4 - 0.0594 \times MC$$

(Laurila & Lauhanen, 2010)

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The latent heat of evaporation is 686 kWh per tonne of water, but dryers will require in the order of 950-1400 kWh/t as they are not 100% efficient (Francescato et al., 2008; Swigon & Longauer, 2005; Nellist et al., 1993). Higher fuel moisture content also lowers the combustion temperature, leading to incomplete combustion and increased gaseous emissions. Smaller boilers are more susceptible to lowered efficiencies caused by high moisture content and are generally most efficient using fuel with values of between 20% (w.b.) and 30% (w.b.) (Francescato et al., 2008; Helin, 2005).

Fuels with higher moisture contents are also more costly to transport as for a given volume, the weight to be moved will be greater. For a given weight, larger volumes of dryer fuels can be transported, either in larger containers or at a higher bulk density.

Drying woodchip also has the benefit of reducing fungal spore build-up, loss of dry matter and the self heating problems associated with longer-term storage of green chip (Andersson et al., 2002; Jirjis, 1995).

## Drying Process

Drying occurs in two stages, the first is known as the constant drying rate, which is the evaporation of water on the chip's exterior. The second stage is known as the falling drying rate and is governed by rate of diffusion within the chips themselves as water travels along a moisture gradient from the centre towards the chip surface (Gigler et al., 2000; Jirjis, 1995; Nellist et al., 1993).

Drying can occur through various methods including passive evaporation from airflow and from active heating. Air drying will occur if the ambient air passing through has a lower relative humidity than the equilibrium relative humidity of the chip. Evaporation of water can also be achieved through heating, generally with forced hot air, although chip piles can also self dry where compacted piles reach temperatures above 40°C through microbial action (Nellist et al., 1993).

Drying can be classified in two ways: passive or active.

- Passive drying consists of stacking or piling timber, residues or chips and relying on ambient temperatures and air flow to reduce moisture content.
- Active drying uses an assisted flow of air to remove moisture from piles.

Active drying air flow can be created by using fans to move ambient air, or air heated by solar or boiler heat exchangers, or directly from flue gasses. Solar conveyors also fall into this category as they use a temperature gradient to cause air flow (Francescato et al., 2008; Helin, 2005). Helin (2005) suggests ambient air flow rates of 400–500m<sup>3</sup>/h per m<sup>3</sup> chip are required for fan use in bed depths of 0.8–1.5m.

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Drying will take place in a layer progressing from the heat source. Water evaporation will maintain a low temperature in the chips until dried, at which point the next layer will start to dry. This effect creates what is known as the *drying front* and will lead to a variation of moisture content through the depth of the chip pile. Air pressure from the fan must force moisture laden air out of the pile, otherwise moisture will start to condense within higher, cooler layers. The “back pressure” is the reaction to the fan air flow caused by the relative porosity of the material. Back pressure for grain is c. 1000 N/m<sup>2</sup>, however woodchip is more porous and so the pressure will be lower; in the region of 250–280 N/m<sup>2</sup> (McGovern, 2007). The strength of the fan must be sufficient to cope with the back pressure and to deliver sufficient air flow.

## Operational Research

A great deal of the published literature on chip drying and air flow has stemmed from SRC research in the 1990s. The work centred on developing models based on a large number of variables such as chip size fractions, relative humidity, bed porosity, wood density and water concentration on the chip surfaces. Whilst the models have been found to describe heavily regulated empiric data adequately (Gigler *et al.*, 2000; Fløjgaard Kristensen and Kofman, 2000; Nellist *et al.*, 1993), their complexity makes them more suited to the general understanding of processes.

Application of these models in real-world operations where many of the variables will be unknown is unlikely. The tendency for a great deal of contemporary woodchip to be of mixed source and species is only likely to complicate matters further.

## Large Scale

There is little information on the energy inputs associated with commercial chip drying operations. Larger scale dryers are expensive and commonly run using waste or by-product heat in larger installations. Dryer types are high temperature flash-dryers and drum dryers and the lower temperature conveyor dryers. Dryer cost varies between € 360 000 for smaller drum dryers to € 1500 000. Larger installations tend to be more efficient and energy usage is in the region of 990 kWh/t for moisture content reduction from 55% (w.b.) to 10% (w.b.) (Price, 2009).

Larsson (undated) describes extremely high throughput chip drying in Sweden used in a municipal combined heat and power station. The plant was originally run entirely on fossil fuels but has been converted to use biomass. The lower calorific value of the biomass required co-firing with fossil fuels at peak loads. Biomass pre-drying using heat produced in the plant has been introduced to improve calorific value of the feedstock. The large continuous flow dryer uses super-heated steam produced in

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generation processes to deliver heat. The dryer uses the fluid bed principle<sup>1</sup> to cope with the difference in particle size classes on the continuous feed conveyor. The operation dries 300 m<sup>3</sup> of chip per hour from a moisture content of 50% (w.b.) to 15% (w.b.). Whilst no energy usage was specified, the improved calorific value of the woodchip was such that fossil fuel co-firing was no longer needed and overall energy costs dropped.

Smaller industrial drying conveyors are also available. An example of this product type is a vibrating drying conveyor unit produced by Rudnick & Enners. The unit uses industrial steam as a power input with claimed throughput of 3–15 m<sup>3</sup>/h, using 1.0–1.1 MWh. Both feed and temperature can be adjusted to suit the infeed type, drying temperature being variable between 20 and 150 °C (IFI, 2009).

## Small to Medium Scale

Details of small to medium scale drying are also scarce. Francescato *et al.* (2008) give an example of a converted farm trailer that uses 80 °C input air to dry chips to 30% (w.b.) in 2–3 days, however no energy or financial running costs are given.

Jirjis (1995) describes chip piled 3 m deep, dried with continuous ambient air flow but does not provide any costs. Moisture content dropped from 57% (w.b.) to 19.3% (w.b.) in 11.5 weeks.

Nordhagen (2010) provides some energy costs for a trial in Norway. A 4 kW fan was used to supply hot waste air to a trailer and a container. A summary of the 4 trial runs is presented in Table 1.

Wet basis moisture contents for the 4 trials initially ranged from 66.1–52.1% and were reduced to 9.6–6.9%. Calorific value rose from 1340–2170 kWh/t to 4710–4860 kWh/t; a gain of around 3000 kWh/t for a cost of 486–556 kWh fan electricity. The heated air was treated as a free by-product from other operations.

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<sup>1</sup> The fluid bed principle uses a moving bed of material (chips) to progress particles according to their size. Light and small particles dry quicker and are allowed to pass through faster than larger and heavier pieces.

# Woodchip Drying

**Table 1** Summary of drying trial by Nordhagen (2010)

Study	Chip Volume (m <sup>3</sup> )	Pile Depth (m)	Air temp (°C)	Drying Time (hours)	Fan Energy (kWh)
Trailer	11.5	1.2	14–18	139	556
				139	556
Container	29.0	1.9	25–26	121.5	486
				67.5	270

## British trials and practice

British examples of chip drying are also sparse as most woodfuel suppliers use passive drying techniques; generally drying timber in the round (Webster, 2007).

Webster (2008) describes 3 floor drying setups for woodchip. The first forced ambient air with a tractor-powered fan, reducing wet basis moisture content from 45% to 25% in 48 hours, however, no energy information was available. The second detailed a grain dryer, reducing the wet basis moisture content of 450 m<sup>3</sup> of chip from 45–30% down to 30–25% at 2% per day. Again, no costs or energy consumption could be provided. The third used forced air that was heated using solar energy. A reduction in wet basis moisture content from 39% to 14% in 8 days was recorded. The drying cost was recorded as £0.87–1.44/m<sup>3</sup> with an energy input of 649 kWh (to power the forced air flow), providing a gain of c.2880 kWh for 90 m<sup>3</sup> of chip.

The most comprehensive study was by McGovern (2007), investigating energy use of drying woodchip in grain dryers. The study used non-roofed tray grain dryers with a capacity of around 25 tonnes of grain. McGovern describes the drying of 20.96 t of chip piled to 1.25 m in depth within the tray. Drying air flow at 60°C was produced from a kerosene burner and supplied by a 37 kW fan at 11 m<sup>3</sup>/s. Chip moisture content was reduced from 34% (w.b.) to 7.5%<sup>2</sup> (w.b.). Initial weight of 20.96 t reduced to 15.3 t in 21 hours of active heating and 4.5 hours of fanned ambient air flow. Bulk density reduced from 326 kg/m<sup>3</sup> to 248 kg/m<sup>3</sup>. Calorific gain was calculated as 4033 kWh for the entire load. Energy cost for the study was estimated as 17,097 kWh of kerosene and 943 kWh of fan use, although McGovern notes that drying did not progress after 18 hours, so 20% of fuel and 25% of power could have been saved. Energy input was therefore 3-4 times the energy gained in chip calorific value. Drying cost was calculated as £36 per wet tonne or £1.47 per dry tonne per % moisture reduction, perhaps reducible to £1.00.

<sup>2</sup> This very low moisture content represents over-drying. Boilers do not require chip this dry and may be damaged if fed with it.

# Woodchip Drying

## Summary of Experience

Information on small to medium scale drying is limited, particularly with regard to energy costs. Table 2 summarises available examples.

Data suggests that green chip can be dried relatively quickly (2-3 days) to 25 – 30% with minimal energy input, using fan and ambient air. Further reduction of moisture content to below 20% requires longer drying time if energy input is not to be excessive. Reduction can take place in around 6 days for warmed air or over several weeks for ambient air. Reduction of moisture content from 34 to 7.5% was found to be possible in 24 hours, but the energy used far exceeded the energy gained (59.4 kWh/t per percent decrease in moisture content) by a factor of 3-4.

**Table 2** Summary of small scale drying trials

Study	Air temp (°C)	Chip MC% change	Drying Time	Energy
Trailer	80	Green – 30	24 – 36 hours	
Building	ambient	57-19	2000 hours	
Trailer	14-18	Green – 10	139 hours	556 kWh (fan) Heat free
Container	25-26	Green – 10	67.5 – 121.5 hours	486 kWh (fan) Heat free
Building	ambient	45 – 25	48 hours	
Building	ambient	45 – 25	240 hours	
Building	Solar heated ambient	39 – 14	192 hours	649 kWh (fan)
Building	60	34 – 7.5	25.5 hours	943 kWh (fan) 17,097 kWh (heat)

## Conclusions

The benefits of drying woodchips are well known; increase of fuel quality, improvement in storage capability, and reduced transport costs.

Moisture content reduces the net calorific value of chips as the water must be evaporated using energy from combustion, lowering combustion temperature and combustion efficiency. Net calorific value can be seen to increase linearly with decreasing moisture content, each percentage decrease providing a net increase of 0.0594 MWh/t.

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Storage of dried chip is less problematic, there is reduced fungal spore build-up, reduced loss of dry matter through microbial action and the self heating problems associated with longer-term storage of green chip.

Drying of chip relies on air flow, either forced or passive, removing water vapour from chip surfaces. Drying rate is linear at first as surface moisture evaporates and then slows as water is pulled from inside the chips. Forced drying normally uses fan-blown air through the chip pile. Active heating of the air increases chip drying rate.

A large amount of operational research concerning woodchip drying was published in the 1990s. The research concentrated on SRC drying and has limited use for today's commercial chip producers, due to different feedstock characteristics of roundwood, and different chip specifications.

Woodchip drying is used on large industrial scales in Scandinavia, pre-drying large volumes of green chip to as low as 15% (w.b.). The chip throughput of these operations is very large, some drying 300 m<sup>3</sup> per hour. Infrastructure and power requirements are also on a large scale, dryers using industrial waste heat or steam.

For commercial chip suppliers who sell chip for boiler use at moisture contents of around 20%, fan-blown warmed air appears to be able to dry chips within 3–6 days. Ambient air will take considerable longer. Further case studies with assessment of energy inputs are required to confirm drying rates for these approaches and calculate energy balances.

## Recommendations

### Operational/working practice

No implications.

### Cost/output

The lack of information found in the literature highlights the need for up to date empiric data from viable commercial operations in the GB context. Energy and financial balances are required to confirm approach validity.

### Health and Safety

No implications.

## Country policy

No implications.

## Existing FC publications

No implications.

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