Client Report :

Methods of reducing the consumption of energy on wood drying kilns

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Executive Summary

This report reviews instances where possible energy savings can be made during the wood drying process. The review was funded by the Forestry Commission under contract number PPD 12/02.

Wood drying is an energy hungry process. The economics of which form a significant cost of the overall sawmilling process. This review investigates instances in the kiln drying process where energy savings are possible. These include energy recovery systems specifically designed for use on wood drying kilns (systems which recover heat from the moist/hot air vented during the wood drying process), the use of frequency inverters on kiln fans, general kiln maintenance and insulation capability. There is a great potential for energy saving systems to be incorporated onto UK wood drying kilns, not only for the cost benefits, but to aid the environment and pre-empt government directives on energy usage.

The main conclusions and recommendations drawn from this review were:

- A simple kiln check and maintenance regime will detect breakdowns and other potential problems and ensure that they are quickly rectified, thus saving energy and money.
- When choosing a new kiln, thought should be given to the type of insulation being specified, and its ability to withstand temperatures with which the kiln will be used now and in the future.
- The addition of a speed controller to the kiln fan system when purchasing a new kiln can provide significant energy savings during drying.
- From the evidence reviewed, it should be possible for significant savings to be made using a heat recovery system on softwood kiln drying operations based in the UK.
- When minimising the overall costs of timber drying, effort should be directed into energy efficiency and the avoidance of drying defects. As a guideline these goals are achieved by the proper selection of kiln type and in the longer term adequate kiln maintenance.

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Introduction

In the UK, research and development into the drying of softwoods is an ongoing process. Active research programmes are in place to investigate the optimisation of the drying process, reducing drying times and increasing the quality of dried material.

Kiln drying is a necessary part of producing UK softwoods for the construction industry. This process is often a bottleneck in the production chain and also a serious consumer of energy.

The cost of drying timber for the UK markets consists of four main elements, capital investment, raw material cost, energy consumption and labour (load and un-load the kiln). The energy requirements can be further split into four components to:

- Generate heat
- Generate airflow
- Run the control unit and associated switch gear
- Run the forced extraction fans (if fitted)

All four can utilise electricity, although most UK softwood sawmills use a combination of energy types including, electricity, fuel oil, gas and sawmill waste residues to run their kilns. Because of the different sources and the variability of dimensions and moisture contents required from the final product, it can be very difficult to place a specific price on the cost of drying a m^3 of softwood harvested in the UK. However, any possible reductions in energy consumption will result in significant savings being made in producing dry material.

This report reviews instances where energy savings can be made in relation to some of the aspects of kiln drying. These include energy recovery systems specifically designed for use on wood drying kilns (systems which recover heat from the moist/hot air vented during the wood drying process), the use of frequency inverters on kiln fans, general kiln maintenance and insulation. There is potential for energy saving systems to be added onto UK heat and vent kilns, especially if new government directives on energy and the environment come into force, or energy costs rise substantially.

In today's economic climate, any savings possible during the manufacturing process can only help increase profit margins, in what is, a low value commodity.

Wood Drying Kilns

A wood drying kiln (batch kiln) is basically an insulated box with the facility to produce heat and to humidify and circulate air. These three variables (heat, humidity and airflow) are essential elements of the drying process and are controlled via sensors within the kiln to optimise the removal of moisture from wet timber at a controlled rate.

Most UK softwood producers have relatively modern wood drying kilns (figure 1) which have the main fans and heat exchangers situated above the kiln load in the roof space, above a false ceiling. Top and side flaps or rubber partitions reduce the size of gaps around the parcels of timber, ensuring the heated air is directed through the load as efficiently as possible. Several types of kilns have forced air extraction units to remove moisture laden air, whilst vents introduce fresh air. Most of the modern kilns used in the UK softwood industry have their operation controlled by computer.

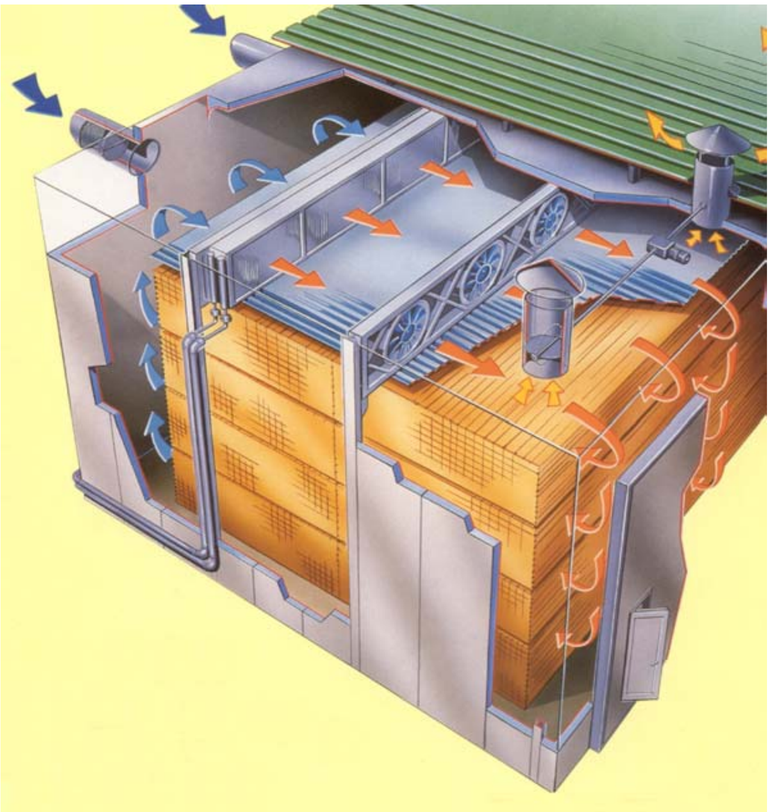

Figure 1. Exploded diagram of a wood drying kiln (over-head fan batch kiln)
(taken from HB Koeltechniek Drying Systems, Almelo, Holland promotional material)

Most wood drying kilns (batch) are not efficient users of heat energy. Essentially, wet timber is placed into the kiln and the air within heated and circulated through the stacked timber by a number of fans. In order to regulate the loss of moisture from the drying timber (to prevent drying degrade), the atmospheric condition is regulated by the introduction of moisture (steam or atomised spray) to prevent the timber drying too rapidly (to prevent distortional problems and various types of drying degrade). As the hot air is passed through the kiln, the wet timber absorbs heat, resulting in the movement of moisture to the surface, where it is absorbed by the circulating air. When the circulating air becomes saturated with moisture, the vents, located on the kiln roof are opened and the saturated air is vented to the atmosphere. Fresh air is then drawn into the kiln, heated, and the wood drying process continues.

In a number of northern European countries, notably Finland, Sweden and Norway, heat recovery systems are regularly incorporated into the construction of new build, heat and vent kilns, mainly to heat the fresh air drawn into the kiln when moisture laden air is being vented. Heat recovery systems are quite common in these countries due to the fact that winter temperatures can drop below -20°C. These low air temperatures require large inputs of heat energy to raise the temperature of the fresh air being introduced into the kiln, prior to the drying cycle being continued.

From the information gathered during this study, only one heat recovery system has been located on a wood drying kiln in the UK.

Drying Costs

A number of studies have been undertaken dealing with drying costs in different kiln types. The direct cost of timber drying consists mainly of energy consumption, capital investment and personnel costs.

The relative importance of the above factors depends strongly on the dimension of timber to be dried. For thin boards with high initial moisture content, the cost of energy is dominant. For thicker dimensions, drying defects play an important role although the total cost of drying is also much higher. A study undertaken by Hukka (2001) compared four types of modern kiln (batch, single stage continuous, optimised two stage continuous and high temperature), drying Nordic softwood species. The batch type kiln was the most versatile to use and the initial investment cost was the lowest. The two types of continuous kilns were the most expensive (nearly twice the price of a batch type kiln) and could only be used economically to dry specific dimensions. The high temperature kiln had an approximately 25% higher initial cost than the batch kiln (size for size) and its use was limited to drying material to a lower moisture content.

The most economical choice of kiln found by Hukka was the high temperature kiln. This result was based on its high capacity and its low use of energy. Energy consumption was lower due to the low ventilation required during this type of drying process. The limiting factor in this type of kiln was the need for steam and a heat energy source with a temperature exceeding 140°C

The main conclusions drawn by Hukka were that, when minimising the overall costs of timber drying, effort should be directed into energy efficiency and the avoidance of drying defects. As a guideline, these goals are achieved by the proper selection of kiln type and, in the longer term, by adequate kiln maintainance.

Due to the variability in kiln type, size, timber dimension, species, final moisture content and the energy resource being utilised, the actual cost of drying can only be calculated accurately by the sawmill undertaking the drying.

Simple measures to reduce energy costs

A number of simple measures can be undertaken by sawmill personnel to reduce the waste of energy on wood drying kilns. A maintenance programme can be devised whereby all working wood drying kilns are checked for defects and problems on a regular basis. Steps can then be implemented to instigate repairs. Areas which often require attention include:

- **Door seals** - If steam can be seen escaping from any part of the kiln structure (other than the vents, when open), the seals should be replaced or repaired.
- **The gaskets** (seals) on the in-let and out-let vents - Check these seal correctly when closed, and that the vents close completely.
- **The effectiveness of the door and wall insulation** - If you can feel warm spots on the external fabric, your insulation is not doing its job.
- **The main heating system** - Does your kiln struggle to reach or maintain temperature ? If so, the heat supply pipework may be of the wrong diameter, not insulated sufficiently or your boiler may be under-capacity.
- **The main fans** - Although many computer control systems will highlight if a kiln fan has a fault, it is important that the fans are checked by a qualified electrician to ensure the fans start-up and run correctly. A fan which has developed a fault may appear continue to run due to the turbulence caused by the remaining fans.

A simple check and maintenance regime will ensure any problems are quickly located and rectified, thus saving energy and money.

Kiln Insulation

The insulation type and specification used in a wood drying kiln is an important aspect of energy consumption and future work practices. The main fabric of a modern kiln is composed of three layers with either aluminium or stainless steel inner and outer surfaces sandwiching a central core of insulation material.

The type, thickness and specification of the core material will regulate the effectiveness of the overall thermal capacity. The insulation core is usually expanded polystyrene or mineral wool (rock or glass). As well as regulating the thermal capacity of the kiln, the type of material utilised can have a direct bearing on possible future changes in work practices. Expanded polystyrene normally has a maximum working temperature restriction. If the stated temperature is exceeded, the insulation material will break down rapidly and therefore lose its insulation properties.

Therefore, it is very important when choosing a new kiln that thought is given to the type of insulation being specified, and its ability to withstand the temperatures at which the kiln will be used, now and in the future.

Kiln Air Circulating Fans

The two major consumers of energy used in wood drying kilns are for the production of heat, and the movement of air.

There may be as many as 10 fans present in a medium/large size batch kiln (190 m^3). Based on a presentation by Groupe Schneider, 3kW fans running at 100%, 90 hours per week, 48 weeks per year, with an electricity price of 4p (£0.04) per kWh, indicate that the running costs can be quite considerable (table 1).

Power	**x**	**Hrs**	**x**	**kWh**	
30	x	4320	x	0.04	= £5184 per year

Table 1. Air circulating fan running costs (fans running at 100%)

This cost can be significantly reduced by fitting a speed controller (frequency inverter). Although this may increase the initial capital outlay (by approximately £2500), the savings made within the first year should more than pay for this addition.

If the speed controller was set to run the fans as described above at 80% of their full power, considerable savings could be possible (table 2).

Power	**x**	**Hrs**	**x**	**kWh**	**x**	**speed^3**
30	x	4320	x	0.04	x	0.8^3 = £2654 per year

Table 2. Air circulating fan running costs (fans running at 80%)

If the speed controller was set to run the fans at 60% of their full power, even greater savings are possible (figure 3).

Power	**x**	**Hrs**	**x**	**kWh**	**x**	**speed^3**
30	x	4320	x	0.04	x	0.6^3 = £1120 per year

Table 3. Air circulating fan running costs (fans running at 60%)

Most modern kilns (batch kilns constructed within the last 10 years) are generally supplied with slightly oversize fans to ensure the correct air velocity is achieved. During a normal kiln schedule, higher air velocities are generated during the earlier stages of the schedule (large movement of moisture), gradually reducing in the later stages of drying as the moisture content decreases. Most computer controlled drying operations have a variable fan speed unit built into the programmed schedules and is generally available as part of the operating system. As the calculations above illustrate, the addition of a speed controller when purchasing a new kiln can provide significant energy savings.

Heat Recovery Systems

Introduction

Wood drying kilns regularly exhaust hot saturated air to the atmosphere and substitute this with fresh air to continue the drying process. This ‘air changeover’ reduces the temperature within the kiln until the substituted fresh air is re-heated. Heat recovery systems pre-heat the in-coming air using energy from the saturated out-going air.

How Heat Recovery Systems work

Most heat recovery systems supplied by the major kiln manufacturer’s work in a similar way. In simple terms, the hot, humid air exiting the kiln via the vents is passed through an aluminium heat exchanger heating it as it passes. At the same time, incoming air is passed over the other side of the exchanger, thereby warming it up. Heat is therefore removed from the exiting moist air and is used to warm the incoming fresh air. Since the incoming air is now substantially warmer, less energy is required to heat the incoming air to the temperature required for the drying operation to continue. The whole process is not thought to influence or improve the drying process.

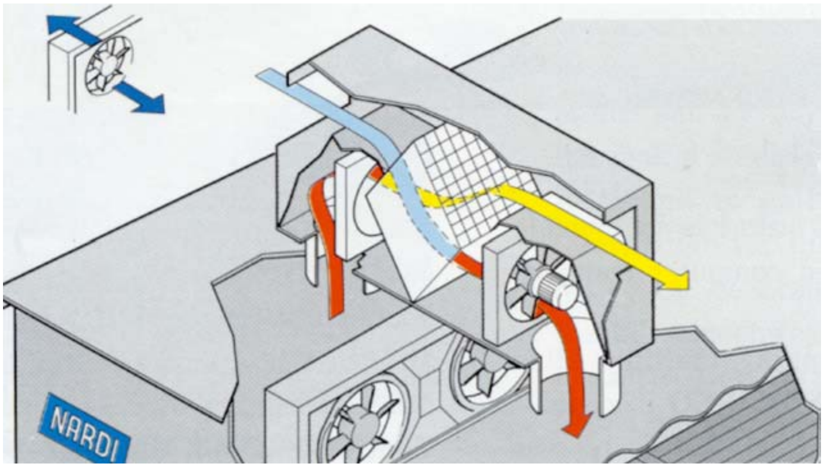

Figure 2. The workings of a heat recovery unit (picture kindly supplied by NARDI SpA)

Costs

The cost of a heat recovery system depends on a number of factors. It is more economical to fit heat recovery systems on new build kilns, than to manufacture and fit to existing kilns. It is also more economical to fit the system to a number of kilns rather than to a single kiln. The price of a unit will also vary depending on the manufacturer and the kiln dimension.

Valutec® kindly supplied figures on the cost of manufacturing and installing a new system on four existing batch kilns. The cost of the system was approximately £55,420.00. The housing unit for the system was made and paid for by the client. The client also installed an energy meter to calculate savings. The installed system paid for itself in a little over two years. The client then placed a further order for its three remaining kilns to be converted.

The main European kiln manufacturers who market heat recovery systems state a number of different percentage savings through the fitting of a heat recovery system. These range from:

Brunner-Hildebrand	10%
BES Bollmann Gmbh	15% - 20%
Valutec	15% - 20%
Nardi	18% - 23%

Heat recovery systems marketed by a number of other global manufacturers quote possible savings of up to 60%.

All heat recovery systems provide energy savings throughout the year. The greatest energy savings are made during the winter months, especially when the air temperature drops below freezing. Dr Travan of Nardi® SpA has reported on the use of energy recovery systems to reduce energy costs (Travan, 2000). This study indicated that energy savings were variable throughout the year, although savings were possible even in climates which do not exhibit severe winter conditions. As energy costs are closely associated with kiln size and the species being dried, the following cost indications should be taken as indicative only.

The case study by Dr Travan related to a 90 m^3 batch kiln fitted with a heat recovery unit, drying 30 mm pine and heated with fuel oil. The full schedule was calculated as taking approximately 120 hours.

The study indicated that the energy recovery unit provided different savings depending on the external conditions. These conditions were split into three main categories, winter: extreme, winter: average and summer average. The following examples give an indication of the approximate savings made during one kiln run during the different climatic conditions.

Winter: extreme

Outside air temperature:	-5ºC
Saving	£75

Winter: average

Outside air temperature:	10ºC
Saving	£50

Summer: average

Outside air temperature:	30ºC
Saving	£25

Generally, the mean temperature averages for Scotland (where most of the softwood sawmills are located) are lower than those used for the examples given above. They also vary between different regional areas. A mean summer average temperature would be around 12ºC to 15ºC. A mean winter average temperature would be around 5ºC. A mean winter extreme average temperature would be around -5ºC.

From the evidence reviewed, it should be possible for significant savings to be made using a heat recovery system on softwood kiln drying operations based in the UK.

New Technology

Heat pumps

Closed-cycle vapour compression heat pumps work in a similar way to a heat engine in reverse. A heat engine takes high grade heat, converts it to work and rejects the energy balance at a lower temperature than the heat source. A heat pump takes waste heat, applies work to the operating fluid and provides heat at a higher temperature than the waste heat source. Heat pump technology has been applied mainly to the manufacturing and mining industry. Although the technology is now attracting research from the wood drying sector. A heat pump's evaporator can be used to extract any condensable substance, such as water in air. This leads to a number of applications in the recovery of heat during wood drying.

A study in New Zealand on the use of heat pump de-humidification for drying sawn timber indicated that energy savings of between 40% and 60% should be possible when compared to conventional kiln drying. Although, heat pump technology is fairly new, it may not be long before this type of system is applied to energy recovery systems on conventional kilns.

Dissemination

Copies of this report will be distributed to BRE's industrial partners (main UK softwood sawmillers) listed below.

- BSW Timber Plc (Mr Tom Smith & Mr David Mills)
- James Jones and Sons Ltd (Mr Francis Wilbur)
- Howie Forest Products Ltd (Mr Ian Murchie)
- Balcas Timber Ltd (Mr Andrew Kidney)
- Adam Wilson and Sons Ltd (Mr Darryl Francis)
- James Callander and Sons Ltd (Mr Gordon Callander)
- John Gordon and Sons Ltd (Mr Ronald Gordon & Mr Ronnie Stevens)

Conclusion and recommendations

The main conclusions and recommendations drawn from this review were:

- A simple kiln check and maintenance regime will detect potential problems and ensure that they are quickly rectified, thus saving energy and money.
- It is very important when choosing a new kiln that thought is given to the type of insulation being specified, and its ability to withstand the temperatures at which the kiln will be used, now and in the future.
- The addition of a speed controller to the kiln fan system when purchasing a new kiln can provide significant energy savings during drying.
- From the evidence reviewed, it should be possible for significant savings to be made using a heat recovery system on softwood kiln drying operations based in the UK.
- When minimising the overall costs of timber drying, effort should be directed into energy efficiency and the avoidance of drying defects. As a guideline these goals are achieved by the proper selection of kiln type and, in the longer term, adequate kiln maintenance.

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Brunner-Hildebrand

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