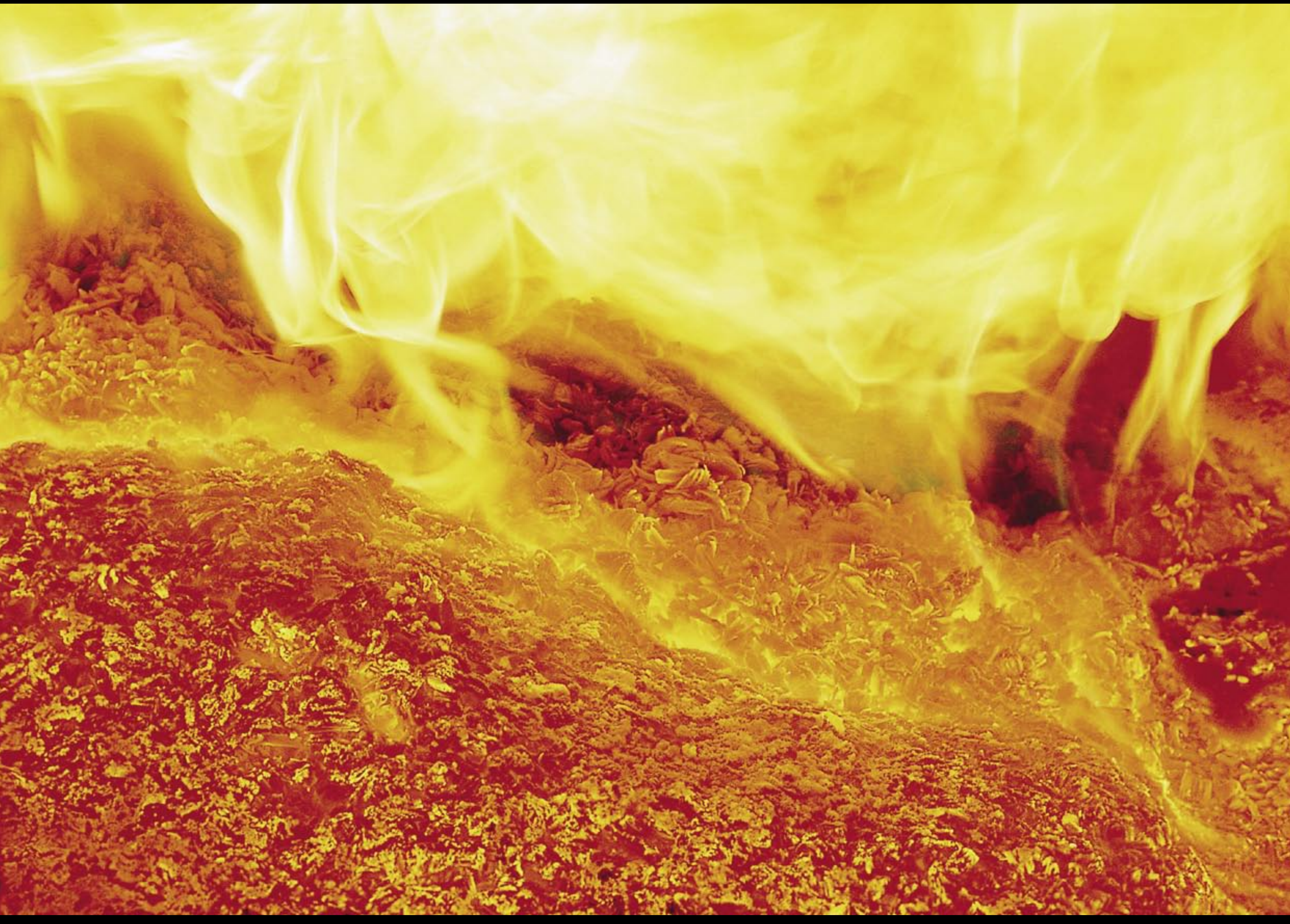
FEBRUARY 2005

the association for British Furniture Manufacturers

Benchmarking wood waste combustion in the UK furniture manufacturing sector



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The organisation provides a variety of sector specific services, with environmental management being a key area of service provision. Further details of BFM Environment Ltd are provided at the rear of this publication.

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Biffaward Programme on Sustainable Resource Use

Objectives

This report forms part of the Biffaward Programme on Sustainable Resource Use. The aim of this programme is to provide accessible, well-researched information about the flows of different resources through the UK economy based either singly, or on a combination of regions, material streams or industry sectors.

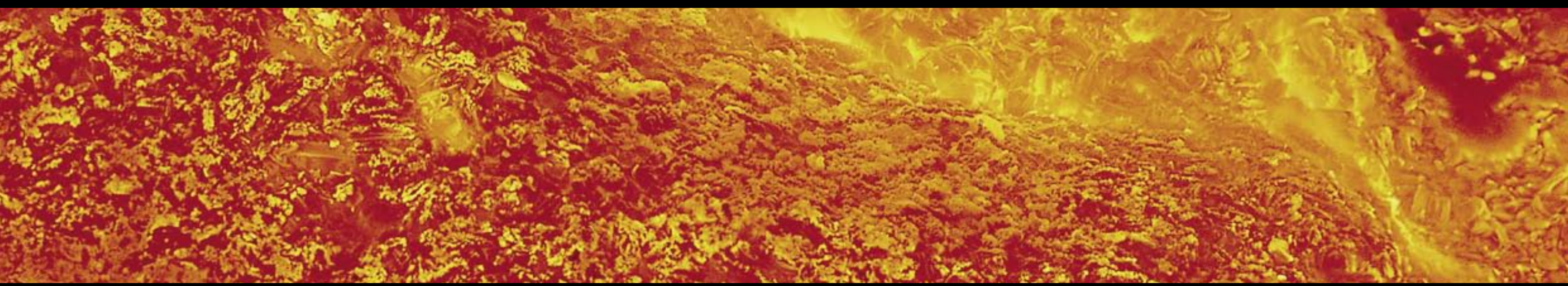
Background

Information about material resource flows through the UK economy is of fundamental importance to the cost-effective management of resource flows, especially at the stage when the resources become 'waste'.

In order to maximise the Programme's full potential, data will be generated and classified in ways that are both consistent with each other, and with the methodologies of the other generators of resource flow/ waste management data.

In addition to the projects having their own means of dissemination to their own constituencies, their data and information will be gathered together in a common format to facilitate policy making at corporate, regional and national levels.

More than 30 different mass balance projects have been funded by Biffaward. For more information on the Mass Balance UK programme please visit www.massbalance.org



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Contents

Foreword

This Biffaward sponsored project represents an important milestone for wood waste combustion in furniture manufacturing. It is the first large-scale survey of combustion plant authorised under PG1/12(04), the wood combustion guidance note, as well as being the first impartial guide for the sector on the issue of wood combustion and the associated economics.

The guide shows how important wood waste combustion is to the sector, especially to the increasing number of manufacturers using board material. Combustion enables such companies to utilise unavoidable wood waste for the generation of heat, thereby reducing reliance upon fossil fuels. The process also eliminates upwards of 95% of the road journeys which would otherwise be associated with the collection of wood waste for off-site disposal.

The financial pay-back from combustion projects is typically derived from the savings on waste disposal and the reduction of fossil fuel for heating. The economics of the process have recently been further improved by the availability of interest free loans of up to £100,000 for four years from the Carbon Trust.

Valuable though the energy from wood waste can be, it is not properly utilised in the UK. Much of the heat generated in this manner is simply dissipated to atmosphere. Demonstration projects would be a useful method of transferring technology from the Continent into UK industry regarding the potential for combined heat and power, district heating schemes and the potential for the sale of process heat &/or cooling to neighbouring factories. Many feel that Government funding to promote the growth of renewable energy would be better spent in such areas to utilise waste materials which are freely available and might otherwise have a negative environmental impact, rather than funding the growth of biomass crops.

Such innovation could provide an important economic boost to forward thinking furniture manufacturers at a time of economic hardship. It is a sad reflection of the state of UK manufacturing that 10% of the combustion plants participating in this study had closed during the two year period of the project.

I sincerely hope that the current economic climate, coupled with the compliance difficulties already experienced by 60% of “existing” authorised combustion users, will persuade the Department for Environment, Food and Rural Affairs to abandon suggestions regarding the tightening of the carbon monoxide limit for “existing” boiler plant. The imposition of a 150 mg/m^3 limit, as proposed in earlier drafts of PG1/12(04), would render 94% of such boilers non-compliant. Given that this plant was compliant at the time of purchase and has an expected life-span of 20-30 years, the retrospective imposition of such a tight limit would be extremely unhelpful. It would simply lead to the closure of many usable combustion plants, an increased amount of wood waste going to landfill in the shorter term and the further encouragement of imports in the future.

Finally, my thanks go to Biffaward for their continued support. The Biffaward programme on sustainable resource use has provided very valuable research funding for this study and its predecessor regarding solvent benchmarking. Unfortunately, the funding which was provided through landfill tax credits has since been abolished by Government.

Roger Mason - BFM Ltd Managing Director

Executive summary

On-site combustion is the single most important management option for wood waste from the furniture manufacturing sector. This study suggests that combustion in authorised wood burning boilers accounts for 223,500 tonnes of waste wood from the furniture sector each year. The option is particularly attractive for companies which process board material, due to the lack of off-site uses for the associated waste coupled with the cost of landfill which can be in excess of £70 per tonne.

Plant specified at 0.4 MW to 3 MW thermal input, requires authorisation by the local regulator. Such plant typically consumes between 90 and 675 kg/hour of wood waste and this study estimates that there are probably around 275 such units in the UK. Initial installation costs normally range between £100,000 and £500,000 for a complete package and a lifespan of 20 to 30 years can be expected.

Controls are laid out in process guidance note PG1/12(04). Half of the authorised companies participating in this study were compliant with their emission limits. Of particular significance were the emission limits applicable to carbon monoxide and particulate matter, compliance with the latter limit running at 51.9%. Other limits apply to formaldehyde (85.7%), hydrogen chloride (94.9%), hydrogen cyanide (74.3%) and organic compounds (72.2%). Scope exists to improve these emissions through attention to fuel consistency, combustion temperature, residence time, turbulence and oxygen.

Although the compliance rates were low, they would be even worse in the event of a change to the carbon monoxide limit. At present, the latter is agreed on a site specific basis for “existing” plant. If a retrospective limit of 150 mg/m^3 were imposed upon “existing” plant, as proposed by the Department for Environment, Food and Rural Affairs during the review of PG1/12(95), the compliance for the sector would fall to 26%.

The study noted that there is potential to make better use of the energy generated by this combustion. All of the systems in the study generated heat rather than heat and electricity. The lack of process heat requirements typically meant that the majority of the energy was simply dissipated heat to atmosphere during 7 or 8 months of the year. Examples have been provided of Continental initiatives for combined heat and power plants, district heating schemes and the opportunity for the sale of process heat &/or cooling to neighbouring factories.

1: Introduction

1.1 Background

Wood combustion forms an important element of the wood waste management strategy of the furniture sector. Earlier work by BFM Ltd (2003) suggested that around 137,000 tonnes or 28% of the wood waste produced by the sector each year was used for on-site combustion, making it the single most important outlet. The results of this study on combustion suggest that the option is even more significant, accounting for 223,500 tonnes each year of wood waste from the furniture sector.

It is recognised that wood waste incineration with heat recovery is not the best environmental and economic option. In accordance with the Government's waste management hierarchy, the sector needs to look at the reduction of waste at source followed by reuse and recycling. Much work has been undertaken on such issues for example BFM (2003), Bromhead (2003) and Envirowise (2001). However, the furniture industry is involved in the processing of highly variable raw materials such as solid timber and will always generate dust and off-cuts, a proportion of which will have limited minimisation, reuse and recycling potential.

In addition, the industry is using increasing amounts of reconstituted board material such as chipboard, melamine faced chipboard (MFC) and medium density fibreboard (MDF). Consequently, around 75% of the sector's wood waste consists of board based off-cuts and sawdust which are much less appealing to off-site recyclers than solid timber wastes.

1.2 Aims and objectives

Very little information has previously been generated regarding wood waste combustion in furniture manufacturing, despite the fact that the option provides the single largest outlet for the sector's wood waste. This project aimed to:

- Collect data from a large number of authorised wood combustion operations
- Produce benchmarking and best practice information on boiler use and control
- Quantify the mass balance associated with the on-site wood combustion units, generating information on issues including the inputs of material burned by the sector and the outputs associated with energy generation.
- Contribute to the revision of the relevant process guidance note: PG1/12 - combustion of fuel manufactured from or comprised of solid waste in appliances between 0.4 and 3MW (see section 6.4).

In addition, the opportunity has been taken to document some basic information about the process of combustion, relevant equipment, legislation, costs and benefits to provide a guide for those companies considering the potential for combustion. Detail has also been provided regarding the optimisation of existing boiler plant.

By encouraging the proper utilisation of energy and the minimisation of emissions, the project has sought to make wood combustion a more sustainable waste management option.

1.3 Project structure

The project centred upon the collection of detailed combustion audits at 50 wood combustion operations. Information was gathered from a further 41 units through telephone discussions. Consultation was also undertaken with wood combustion equipment manufacturers and a fact finding mission was undertaken to seven wood combustion installations in Austria to evaluate the potential for more advanced wood combustion schemes and technologies.

2: Wood waste in furniture manufacturing

2.1 Introduction

Work by BFM Ltd (2003) for the Government's Waste and Resources Action Programme (WRAP) suggested that the UK furniture sector generated 525,199 tonnes of wood waste during 2001. Some 68.2% of this total was accounted for by board material.

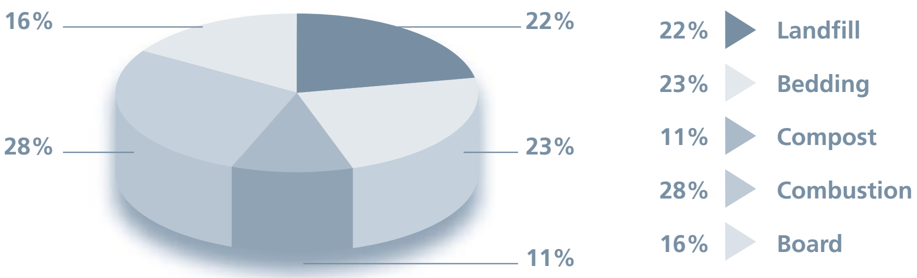
Figure 1: Furniture sector wood consumption and waste in 2001

	Consumption		Waste	Raw material waste	
	£ mil	Tonnes	%	£ mil	Tonnes
Hardwood	£115	214,297	35.82%	£41	76,757
Softwood	£62	213,527	20.17%	£12	43,061
Board	£425	1,829,789	19.57%	£83	358,081
Veneer	£18	81,000	58.42%	£10	47,300
Total	£619	2,338,613		£147	525,199

Source: BFM Ltd (2003)

Five main options were identified for the management of the sector's wood waste. Combustion accounted for the largest amount of material (28%) followed by animal bedding (23%) and landfill (22%). The manufacture of board material accounted for 16% of wood waste with the remaining 11% being used for composting and land remediation.

Figure 2: Furniture wood waste management (2001)



Source: BFM Ltd (2003)

2.2 The waste management hierarchy

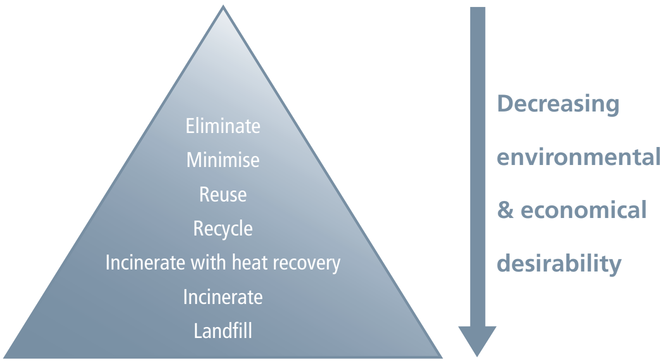
The waste management hierarchy is a series of options in decreasing order of environmental and economic desirability as shown in figure 3. When faced with a waste stream of any sort, the hierarchy provides a template to review the opportunities available.

Ideally, wood waste should be reduced at source. For example, if the dimensions of a board based desk top are determined by the measurements of standard sheets of board, it is possible to avoid the generation of sizeable off-cuts with each panel. If the design can be kept to simple straight lines, the shape can be generated through the use of a circular saw which will create sawdust from

2: Wood waste in furniture manufacturing

the 2 mm width of the blade. Conversely, a complex shape will typically be generated using a CNC router which generates a 20 mm channel of sawdust along with a sizeable off-cut.

Figure 3: The waste management hierarchy



After waste has been minimised at source, attention should turn to the potential for reuse. The economics of resizing off-cuts to make smaller components depends upon a range of factors such as the size of the smallest components relative to typical off-cuts, the range of wood types and colours along with the value of components relative to labour and machinery costs. Typical forms of reuse include the production of pedestal tops from off-cuts resulting from the production of office furniture and the use of solid wood off-cuts to create support blocks for chairs.

Recycling is the next option on the waste management hierarchy and it involves the reprocessing of wood waste for reuse. For example, softwood off-cuts might be chipped with the removal of dust to create high quality animal bedding.

Incineration with heat recovery is the option below recycling. The technique has the benefit of generating heat from a renewable source, thereby reducing the use of fossil fuels such as gas and oil and the associated emissions of carbon dioxide. In addition, the process significantly reduces the volume of the waste material. Ash typically accounts for just 0.5% of the volume of the original wood waste, leading to a massive reduction in off-site transport requirements. However, most furniture companies do not have a heat requirement for much of the year. Consequently, much wood waste is incinerated without heat recovery.

Finally, the least desirable option is that of landfill which still accounts for 22% of the sector's wood waste, some 107,000 tonnes (BFM, 2003). Much of this waste is composed of board material which is not attractive to options further up the waste management hierarchy such as reuse and recycling. Consequently, the material is well suited to combustion, a process which has the potential to play a much greater role within the sector.

Off-cuts of MFC have limited uses other than for combustion with heat recovery

3: The wood combustion process

3.1 Introduction

In order to appreciate the significance of combustion emissions and how they can be controlled at source, it is necessary to understand the combustion process. This section explains the basic principles of wood combustion and the potential that exists for UK furniture manufacturers to move from conventional combustion for heat generation to more advanced options such as combined heat and power plants.

> **"In order for wood to burn efficiently, it is necessary to control the temperature, turbulence and time of combustion"**

3.2 The process of combustion

Wood is composed of a complex mixture of components which result in particular properties that influence its use as a fuel:

- Volatiles: a range of compounds that are driven off by heat and burn with the characteristic yellow/orange flame
- Carbon: results in the ash which remains after combustion
- Water: wood used in furniture manufacturing typically has a moisture content around 10%

In addition, timber based products may contain compounds which have been deliberately added by man. For example, MDF and chipboard will contain binding resins such as urea-formaldehyde. MFC will be coated in melamine, whilst PVC or ABS based edge-banding may also be included. Occasionally, waste may contain a small amount of coated timber, i.e. that which has had stains and lacquers applied.

With a conventional wood combustion unit, the wood is introduced into the combustion chamber along with primary air. The temperature of the chamber causes the moisture within the wood to boil, expand and evaporate. Once sufficient moisture has been removed, the wood itself will heat up and begin the process of thermal decomposition. This process releases organic vapours which are burned in the presence of oxygen.

In order for wood to burn efficiently, it is necessary to control the temperature, turbulence and time of combustion.

3.2.1 Temperature

The temperature is typically maintained at around 850°C to 1,050°C for wood combustion. Inadequate temperature will lead to incomplete combustion and high carbon monoxide (CO) levels. Excessive temperature will allow the formation of clinker, a solid residue which forms from the melting of ash. Clinker can stick to the walls of the combustion chamber interfering with air flows and circulation patterns.

The temperature at which clinker begins to form largely depends upon the nature of the material being burned. Solid timber has a low ash content of 0.4 to 0.5% and clinker does not form until a temperature of around 1,100°C is reached. At the other end of the scale, melamine faced chipboard (MFC) has an ash content of around 1.5% and the temperature of combustion is typically kept to 850°C to prevent clinker formation. Pure MDF might be burned at around 1,050°C.

The main method of temperature control is the variation of air circulation. For example, the addition of greater amounts of excess air will lower the combustion chamber temperature.

3: The wood combustion process

3.2.2 Turbulence

The generation of high levels of turbulence within the combustion chamber enables the mixing of fuel, volatile gases and oxygen without having to introduce unnecessary amounts of air which would cool the process (thereby encouraging incomplete combustion due to low temperature). The degree of turbulence depends upon variables such as the diameter of the combustion chamber, gas velocity, viscosity and density.

Turbulence is achieved by various means. Where the fuel is blown into the boiler, the transport air provides the oxygen for primary combustion as well as creating turbulence through the mechanical effects of the swirling air coupled with the thermal movement of gases. Where the fuel is screw-fed into the boiler, turbulence is created through the use of fans to introduce the primary air. The latter provides the oxygen used for the initial combustion of the volatiles from the fuel. Secondary air is also usually introduced to the process to enable complete combustion.

3.2.3 Time

The residence time of gases in the combustion chamber must be sufficient to allow them to mix with enough oxygen to achieve complete combustion. The time is typically around 1⁄2 to 3⁄4 of a second for solid timber. Longer residence times are used in systems burning more hazardous materials than those used within the furniture industry. Smaller particle sizes need a shorter residence time and process control will typically suffer when there is significant fluctuation in fuel particle size and moisture content.

3.2.4 Incomplete combustion

Incomplete combustion occurs when the volatile compounds are not broken down fully, resulting in the generation of a variety of pollutants. It may result from:

- Insufficient temperature
- Inadequate residence time
- Lack of available oxygen

Incomplete combustion typically leads to high CO levels and the generation of a range of other pollutants:

- Polyaromatic hydrocarbons: cancer causing compounds which should be broken down as long as there is a residence time of >1.5 seconds at a temperature of >800°C (Obernberger, 2003).
- Polychlorinated dioxins and furans: highly toxic compounds which are formed at low temperatures between 180°C and 500°C where chlorine is present in the fuel, e.g. due to PVC edgebanding.
- Nitrogen oxides (NOx) contribute to environmental problems such as acid rain and photochemical smog formation. NOx limits are not imposed by PG1/12(04) but they do feature in the European Waste Incineration Directive. NOx levels can be reduced through the control of air in the primary and secondary combustion chambers, with low excess air ratios in the secondary chamber (Obernberger, 2003)

In an ideal situation, the combustion process would occur with the exact proportions of air and fuel. In practice, combustion processes occur with varying proportions of fuel and air due to issues such as inadequate mixing and fluctuating fuel characteristics. In order to ensure sufficient oxygen, it is usual to inject excess air, i.e. more air than the minimum required to obtain complete combustion. However, excess air will lower the combustion temperature.

3: The wood combustion process

3.2.5 Solid residue

Solid residues from combustion can be split into three types according to Obernberger (2003) and will typically be composed of between 0.5% and 5% of the original waste weight.

Bottom ash is the material which is left in the combustion chamber which will account for 60% to 90% of ash production with wood fuel. Cyclone fly ash consists of the smaller particles which are carried out of the combustion chamber and are retained by the cyclone filters. This material typically accounts for 10% to 30% of the total ash. Lastly, a proportion of the ash (typically 2% to 10%) will pass through the filter and be emitted from the stack.

Depending upon the design of the wood combustion plant, bottom ash might be removed automatically or manually, with manual extraction typically occuring every 1 or 2 weeks. After removal, the ash is normally left to stand in a metal bin for a week or two in order to allow the heat to dissipate.

3.3 Alternative ways of generating energy from wood

There are a number of alternative ways of deriving energy from wood. These processes may produce energy in the form of charcoal, oil, gas or heat.

Pyrolysis is conducted at temperatures ranging from 300°C to 600°C in the absence of oxygen. Conventional slow pyrolysis results in the production of charcoal through the slow heating of the wood to a temperature between 300°C and 400°C (Venderbosch et al, 2001).

Flash pyrolysis involves very rapid heating of wood up to 600°C and a rapid cooling of the resulting vapours to produce a dark brown liquid or bio-oil with a heating value roughly half that of conventional fuel oil. The process of effectively liquidising the calories contained within the wood has a number of potential benefits over traditional wood feed stocks. The increased density of the material reduces storage space and transport costs as well as potentially producing a more uniform feed stock.

At present, the main use of Bio-oil on a commercial scale is the smoking of food. The oil has a strong burnt wood odour and is sometimes referred to as “liquid smoke”. However, from an energy perspective its use as a straight diesel substitute is much more exciting, though further research is needed to counteract problems associated with acidity and abrasive particles.

Gasification is the conversion of a solid fuel such as wood into a gaseous fuel which can be used for electricity generation.

3.4 Combined heat and power plants

The potential to generate electricity as well as heat from wood waste is an attractive one. During the months of the year when heat is not required, the thermal energy can be converted into electricity for use on site or sale to the National Grid.

A variety of technologies can create electricity from wood waste. Steam turbines are powered by steam generated from the heat given off by the combustion process. Turbines are well established and can range in size from 0.5 MW_e to 500 MW_e (Van Loo & Koppejan, 2003)[2] . However, in smaller plants <2 MW_e the electrical efficiency is low at 8% to 18% (Obernberger, 2003).

A newer version of the traditional turbine is offered by the process of the organic Rankine cycle (ORC) which uses organic oil instead of water as the process medium, thereby enabling operation at relatively low temperatures. ORC processes can operate at partial load and efficiencies of 13%

[2] MW_e denotes megawatts of electrical energy

3: The wood combustion process

to 17% have been achieved. The technology appears promising for plant between 0.4 MW_e and 1.5 MW_e (Obernberger et al, 2003).

Steam engines offer a cheaper way to generate small amounts of electricity. Units are typically less than 1 MWe in size and they have electrical efficiencies of 6% to 20% MW_e (Van Loo & Koppejan, 2003). The technology is less sensitive to contaminants and is suited to boiler plant with a varying work load.

Stirling engines are closed systems which use air, helium or hydrogen as a medium. Heat is transferred to the medium, which is subsequently subjected to forced cooling. The expansion and contraction inside a chamber is used to power a piston and efficiencies of 15% to 30% are claimed (Van Loo & Koppejan, 2003). The best efficiency is obtained where the temperature in the hot heat exchanger is as high as possible without leading to the formation of clinker in the boiler. Therefore, it is necessary to preheat the combustion air with the flue gas leaving the hot heat exchanger by means of an air pre-heater. The temperature of the combustion air is typically raised to 500°C to 600°C, resulting in very high temperatures in the combustion chamber (Obernberger et al, 2003).

Burg Hotel, Oberlech, Austria

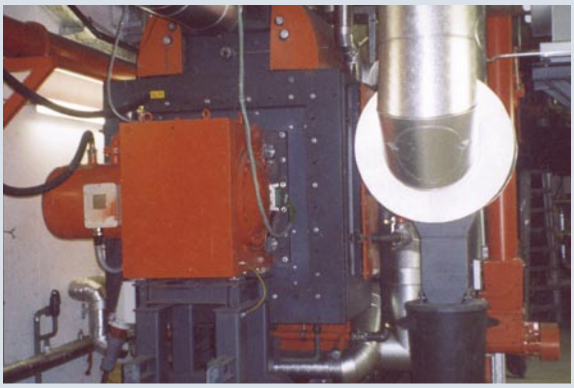
The potential of the Stirling engine technology is demonstrated by the Burg Hotel, Oberlech in Austria. The hotel operates in an exclusive ski resort and must ensure that energy creation has a minimal impact on the environment. In 2003, the hotel installed two 440 kW Mawera boilers.

One has a ceramic filter, allowing it to burn a variety of wood waste types. The other has a 35 kW Stirling engine attached for electricity generation.

The heat is distributed through 3 km of pipe work to 25 hotels at a cost of 5.5 to 7 cents per kWh. Around 40-50 tonnes per week of wood is consumed in winter and a bunker has been hewn out of the rock to provide around 4 months capacity.

Three chambers can be identified on the wood burning boiler to the right. The top, curved section contains the air pre-heater. The middle section is the secondary combustion chamber with primary combustion occurring in the lowest section.

Above: The Burg Hotel, Oberlech



The picture on the left shows the other end of the boiler. The Stirling engine is contained within the orange box mounted half-way up the boiler.

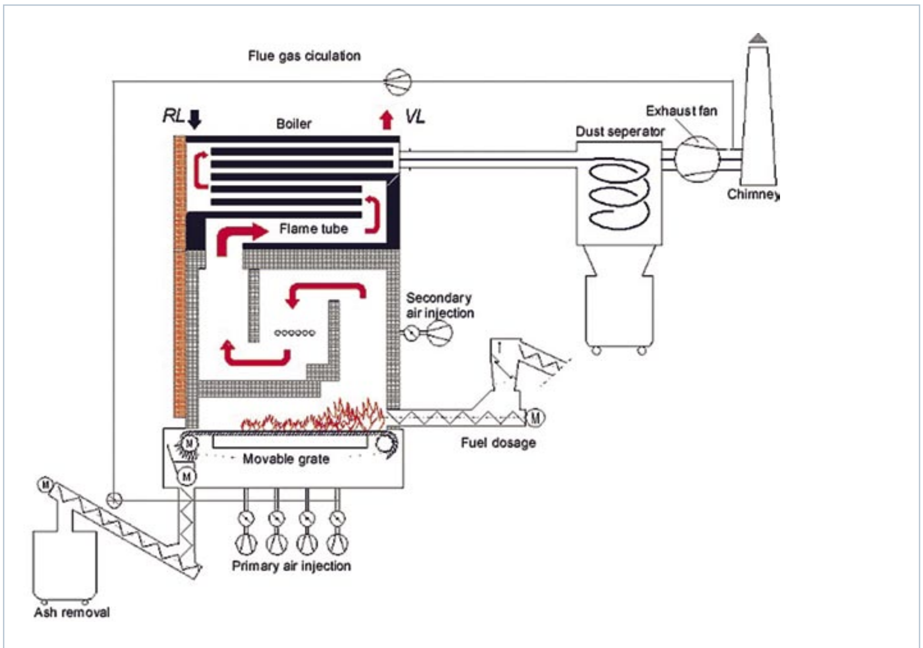
4: Wood combustion systems

4.1 Introduction

A number of key elements make up a typical wood combustion system:

- Silo and extraction / hogging system
- Feed mechanism
- Combustion chamber and grate
- Particulate removal and monitoring equipment
- Heat exchange and distribution system

Figure 4: The main components of an underfeed stoker wood combustion system



Source: Moldow-Mawera (UK) Ltd

4.2 Silo and extraction / hogging system

Extraction systems remove wood dust from the working environment through capture hoods placed on and around woodworking machines. The extracted air typically passes through a system of bag filters which remove the particulates from the air stream. The wood dust is then transported to a silo for storage until it is required for combustion.

Solid off-cuts of material can be passed through a hogger or chipping unit to break the material down into small chips which are suitable for storage in the silo. A variety of hogger designs are available, some of which will also process veneer off-cuts and cardboard.

Particles of wood waste from the dust extraction and hogging systems need to be stored prior to use to smooth out the fuel supply and demand. The silo provides this buffering capacity.

It is recommended that the silo is sufficient to cope with two weeks worth of production. This allows a level of 50% to 70% to be maintained giving enough fuel for the boiler to allow burning

4: Wood combustion systems

during typical non-production times such as from Friday lunchtime to Monday morning. In addition, if there is a problem with the boiler plant, the spare capacity in the silo acts as a 1 week buffer to allow repairs to be undertaken.

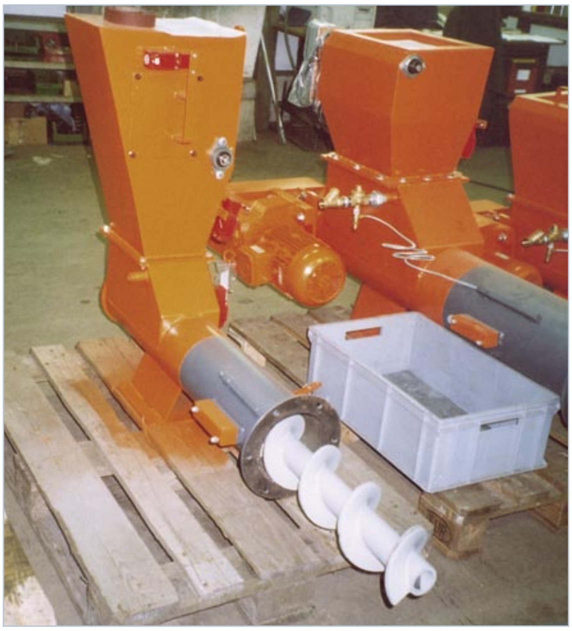
A plant of 1.1 MW to 1.4 MW would typically have a silo of around $100m^3$ to $150m^3$, whilst a 3.0 MW unit would have a silo between $350m^3$ and $400m^3$. Similar plant in countries with more severe winters such as Austria, would have silos several times larger to enable waste from summer production to be stored for winter heating.

4.3 Feed mechanism

A number of different feed mechanisms are used to carry fuel from the silo into the combustion chamber. The best mechanism for a specific site is determined by the nature of the fuel coupled with the scale of the plant.

Manual fuel feeding is only encountered in plant above 0.4 MW which is several decades old. Such feed systems are labour intensive and generate higher emissions due to the peaks and troughs of operation associated with the input of batches of fuel. The presence of an opening to the combustion chamber allows unregulated doses of oxygen to enter the plant causing drops in operating temperature.

Fans can be used to deliver dry material with relatively small particle sizes, e.g. <20 mm and 20% moisture content (Van Loo & Koppejan, 2003). This method also has the benefit of introducing primary air and contributing to the turbulence required for complete combustion.



Screw feed systems waiting to be installed in new boiler plant

Screw feeds are more common in the furniture industry and simply rotate to feed fuel from the base of the silo into the combustion chamber. Bridging in the silo can be a problem for such systems, with the screw turning in a void created by a bridge of wood dust above. Bridging can be minimised by ensuring that fuel is kept relatively dry and the discharging system from the silo should be robust and maintained.

Hydraulic rams may be used for feeding boiler plant which uses wood chips of more variable length and wetness. However, these systems would be more commonly found in timber mills and biomass operations rather than furniture manufacturers.

4.4 Combustion chamber and grate

Fuel is delivered to a combustion chamber to undergo thermal decomposition. A number of chamber designs can be used for wood waste:

- Dust combustion: dry material with relatively small particle sizes can be injected into the system with combustion taking place while the material is in suspension, with complete combustion occurring after the addition of secondary air.

4: Wood combustion systems

- Fixed bed combustion: primary air passes through a fixed bed in which drying, gasification and charcoal combustion takes place (Van Loo & Koppejan, 2003). The combustible gases are burned after secondary air is added. There are a variety of fixed bed systems and grates may be water cooled to prevent the formation of clinker:
  - Fixed grate: the sloping grate allows gravity to move the fuel across the grate from the in-feed to the ash collection system
  - Travelling grate: the grate is formed by a band of bars which moves continuously across the grate to give a smooth passage of fuel. The speed can be varied to achieve complete combustion
  - Underfeed stokers: fuel is fed into the combustion chamber by a screw conveyor from below.
- Fluidised bed combustion: the fuel is burned in a self-mixing suspension of gas and solid material into which combustion air enters from below.

4.5 Particulate removal and monitoring equipment

Wood combustion plant >0.4 MW will usually include a multi-cyclone filter to remove particulates from the waste gases. Such systems can typically ensure that particulate emissions are kept below 150 mg/m^3, thereby meeting the requirement of PG1/12(04) as outlined in section 6.4.

More advanced systems of particulate removal are available. Electrostatic precipitators can meet limits as low as 25 mg/m^3 but will cost £80,000 to £120,000 (Moldow-Mawera (UK) Ltd, *pers comm*). Ceramic filters can be used to reduce particulates to 5 mg/m^3 and they are typically used by plants which burn treated timber.

Authorised wood combustion plant will normally include monitoring equipment to measure the key emissions. This will consist of a number of probes in the discharge stack which will monitor a range of compounds (see section 6.4.3).

A ceramic filter unit with discharge bin for a wood combustion unit burning treated timber

4.6 Heat exchange and distribution system

The vast majority of wood burning systems in the UK make use of the energy from their combustion system to provide space heating. Small systems (typically <0.4 MW) may simply blow hot air into the immediate vicinity. Longer distance transport of heat can occur through the generation of medium pressure hot water which can supply radiators and taps. Older systems may generate steam. This has a potential benefit in terms of utilisation for process heat, but few furniture sites would require such an energy source.

4: Wood combustion systems

Orama Fabrications Ltd

Orama Fabrications Ltd is a Derbyshire based manufacturer of worksurfaces, e.g. for kitchens and bathrooms. In 2003, the company installed a Talbott C8 (2 MW) hot water boiler which meets the space heating requirements for the entire site. The system also supplies process heat to a heated-platen hydraulic laminating press. The latter accounts for a 25% base-load, reducing the need to dissipate excess heat to atmosphere under low summer loading conditions. The system provides 100% peak demand during winter months.

The combustion installation is mainly fuelled by chipboard, with some MDF and a minimal amount of softwood, all of which is stored in an existing 100m3 silo. The system is expected to have a pay-back of just two years.

Significant potential exists to make better use of heat from wood combustion in the UK. Space heating is only required for 4-5 months of the year leading to the dissipation of heat between April to October. Some furniture sites have a process heat requirement, e.g. a timber kiln or wood coating shop, but these often require only a small amount of the available energy.

Much of the energy from wood waste combustion is simply dissipated

The generation of electricity as well as heat appears to have greater potential as discussed in section 3.4 on combined heat and power plants. These systems have the benefit of generating electricity at times of the year when space heating is not required. The technology is much more popular on the Continent, where different economic parameters have been set. For example, in Austria it is possible to sell green electricity to the grid for up to 15 cents per kWh compared to the standard tariff of 7 cents per kWh (Moldow-Mawera (UK) Ltd, *pers comm*). This premium, coupled with landfill charges of €80 to €100 per tonne for general waste and a high rate of carbon tax on fuels such as coal, provides an incentive for the initial investment.

Another initiative much more frequently encountered on the Continent is the selling of heat to third parties. District heating schemes are a common way to provide heating to communities in countries such as Denmark, Holland and Austria. A central wood combustion operation pumps heated water through an underground network of pipes and the householders are charged per kWh used.

Alternatively, a site with combustion can provide heat for the process of a neighbouring factory. More advanced options also exist, such as the use of an absorption chiller so that heat from wood burning can provide cooling for a neighbouring process. The case study of the Biostrom plant in Austria shows the potential for advanced energy utilisation from wood combustion systems.

4: Wood combustion systems

Biostrom plant, Hard am Bodensee, Austria

The potential utilisation of energy from a wood combustion operation is demonstrated by the Biostrom plant in Austria.

The plant cost £4.2 million and was finished in March 2002. It processes 22,000 tonnes p.a. of wood waste each year. This material is mixed and includes pallets, furniture and treated timber.

By taking in treated timber or "condemned wood", the plant can charge a gate fee of up to €150 per tonne. In order to burn off the associated contaminants, the plant has a combustion chamber which is 20 m high to ensure a residence time of 2 seconds at 1,100°C. A ceramic filter is also used to clean the gases at the rear of the process.

The plant can produce 10 MW total heat, of which 2 MW is kept in reserve (this is destined for a future district heating scheme). 6 MW of heat energy is used to produce green electricity, 1.2 MW of which is sent into the grid. Further revenue is generated through the sale of heat to a neighbouring bottling plant for use in absorption chillers. These provide cool water at 5°C to the operation which not only reduces the operating cost of the bottling plant but saves electrical energy normally used in absorption chillers.

The careful control of the combustion process coupled with the ceramic filters leads to very low emissions, e.g. CO <30 mg/m^3 and particulates <3 mg/m^3.

Above: A vehicle loading wood waste into the Biostrom plant

The electricity generating section of the Biostrom plant

5: Wood combustion costs and benefits

5.1 Introduction

The primary concern of furniture companies is the manufacture and sale of the finished goods. Waste management is a secondary consideration resulting from the production process. Consequently, waste combustion will only be specified where it makes economic sense.

The pay-back of a system depends upon a number of variables, the most important of which are the costs associated with the boiler installation and those resulting from the existing wood waste disposal and heating fuel arrangements. Significant pay-back improvements can be achieved through the use of the interest free loans of up to £100,000 available from the Carbon Trust as detailed in section 5.3.3.

5.2 The cost of combustion projects

The installation and commissioning of a wood burning system on a furniture site can range in price from £10,000 to £1 million depending upon the scale and complexity. At the lower end of the cost scale are simple hand fed units generating hot air. These small units of 0.05 MW or 0.1 MW are suited to small workshops generating a low volume of wood waste such as 20 kg per hour. Such systems save on heating fuel and reduce landfill costs for companies which do not generate sufficient quantities of wood waste to make segregation, collection and recycling viable.

Slightly larger units around 0.35 MW and 75 kg/hr feed rate are more likely to include automatic feeding systems for dust collected by a central extraction system. A disproportionate number of units of this size exist within the UK as they fall just below the threshold for local authority control (see section 6.4).

"The pay-back of a system depends upon a number of variables, the most important of which are the costs associated with the boiler installation and those resulting from the existing wood waste disposal and heating fuel arrangements"

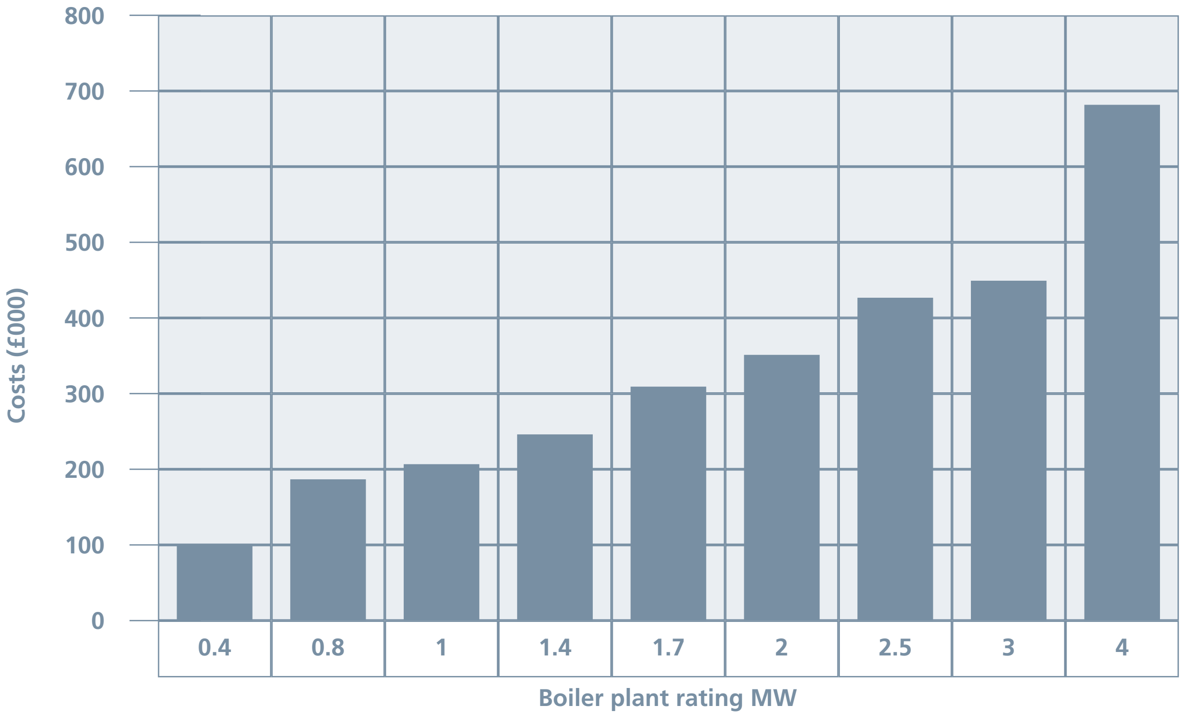
Exceeding the 0.4 MW threshold incurs a need for registration and the payment of an annual fee to the regulator. More significantly, continuous monitoring becomes a requirement which will typically add £20,000 to £30,000 to the price of the installation. Such an amount is generally considered to be disproportionately expensive on plant rated at less than 1.0 MW, hence the low numbers of plant in the UK specified between 0.4 MW and 1.0 MW.

The largest wood combustion plants in widespread use within the UK furniture manufacturing sector are rated at 2.5 MW to 3.0 MW, with the latter having a feed rate of around 675 kg/hr. Project costs are typically in the range of £400,000 to £500,000. It should be noted that the actual combustion chamber itself is typically only one quarter to one thirds of the project cost. Other items of significant expenditure being the extraction modifications, boiler house, silo, monitoring equipment, hogger, heat distribution system and installation.

Combined heat and power projects will typically involve double the capital cost of the conventional heat producing systems (Moldow-Mawera (UK) Ltd, *pers comm*).

5: Wood combustion costs and benefits

Figure 5: Authorised wood combustion project costs



Source: Moldow-Mawera (UK) Ltd

5.3 The pay-back of combustion projects

Payback is typically derived from savings on energy purchases and wood waste disposal.

5.3.1 Energy savings

Space heating is the most common use for the energy derived from wood waste combustion. The level of wood waste generation (and to a lesser degree the pattern of generation) will determine the size of boiler plant required, which in turn dictates the amount of heat available. Existing sites know the cost of their annual heating bill and it is a relatively straight-forward calculation to estimate the saving associated with the reduction in fossil fuel based heating.

Further cost savings can accrue if heat can be used for a year round process requirement. For example, the water borne and high solids coatings encouraged by process guidance note PG6/33(04) typically have a longer drying time than their traditional high solvent counterparts. Consequently, forced drying is often used to ensure complete curing of the lower solvent coatings in a short period. There are also examples of furniture manufacturers using process heat in kilns, presses and veneer wash down filtration systems.

Chairs passing through a drying tunnel heated by wood waste

5: Wood combustion costs and benefits

The investment in a combined heat and power plant requires a longer term view. Capital costs will be in the order of double those of conventional systems, but year round energy benefits will accrue through the production of electricity. This can be used on site or sold to the National Grid at around 6.5 pence per kWh (2004 prices). This figure is around 3 times the price of conventionally generated energy due to the green premium. However, grid connection is an expensive process in the region of £200,000 to £1 million (Moldow-Mawera (UK) Ltd, *pers comm*).

5.3.2 Wood waste disposal savings

Work conducted by BFM Ltd (2003) showed that wood waste generated on furniture sites could cost up to £70 per tonne to dispose of to landfill (2002 prices). This cost has since risen and will continue to do so. Such waste was normally at least partly derived from board material, which lead to very little demand from constructive uses. At the other end of the scale, furniture manufacturers generating segregated softwood waste were able to command revenue of up to £60 per tonne. Consequently, on-site combustion is most likely to appeal to furniture sites which use at least some board material.

It should be remembered that the cost of landfilling continues to increase as do the savings associated with the diversion of waste to on-site combustion. The landfill tax was £13 per tonne for active waste in 2002 and rose by £1 each year to 2004. From April 2005 to 2010, there will be a £3 per year increase resulting in a tax of just over £30 per tonne. Furthermore, the operating costs of waste management companies continue to rise as they implement controls required by European legislation. These costs are passed onto the waste producer, thereby improving the pay-back of alternative outlets.

Sundeala Ltd

Sundeala Ltd is a Dursley based manufacture of notice boards. The company has installed a Talbott 1MW Steam Raising System to provide the process heat required by the specialised drying process which needs steam over a long period. The system is fuelled by the dust generated during the sanding of the notice boards. The wood fuel significantly reduces the site's use of natural gas as well as reducing landfill costs.

5: Wood combustion costs and benefits

5.3.3 The Carbon Trust

The Carbon Trust is an independent, non-profit company set up by the Government which provides practical advice to businesses to help reduce their energy use. Energy-Efficiency Loans from the Carbon Trust are available to help companies fund energy saving projects such as the upgrading or replacement of lighting, boilers or insulation. Eligible companies can borrow from £5,000 to £100,000 interest free, unsecured for up to 4 years, without arrangement fees. These loans are available to small and medium sized enterprises (SMEs) which have been trading for at least 12 months.

Each application is assessed individually, based on the specific energy usage and processes involved, for example, a number of companies have successfully used the loans scheme to contribute to the cost of a new wood burning boiler installation.

Projects must have an energy saving with a payback period of less than five years. If the project produces a payback within this period then the savings made will cover the loan repayments. After the loan is repaid the customer will see the full benefit of the savings. Further details can be obtained from www.thecarbontrust.co.uk/loans

Figure 6: Definition of small and medium sized enterprises

- <250 employees
- <40 million Euros Turnover (approximately £25m) or <27 million Euros assets (approximately £17m)
- No controlling interest more than 25% by a non-SME (i.e. not part of a larger organisation)

A wood burning boiler plant with a compact footprint showing the stack, silo and combustion unit.

6: Controls on wood combustion

6.1 Introduction

The degree of control imposed upon boiler plant by environmental legislation is dependent upon the size of the plant. Combustion equipment rated at less than 0.4 MW is simply subject to the general controls of the Clean Air Act 1993 and the Environmental Protection Act 1990, Part III.

Plant rated at 0.4 to 3 MW is subject to Local Air Pollution Prevention and Control (LAPPC) with a much more specific set of requirements outlined in process guidance note PG1/12(04). Wood combustion plant rated at >3 MW on furniture manufacturing sites should fall under the Integrated Pollution Prevention and Control regime (IPPC). However, in reality LAPPC requirements are typically applied as the combustion on a furniture manufacturing site will invariably be linked to an authorised woodworking process[3].

More recently, wood combustion plant of any size has become subject to the controls of the European Waste Incineration Directive, but only if certain types of wood waste are burned.

6.2 Clean Air Act 1993

This Act makes it an offence to emit "dark smoke" from any trade premises except where a furnace is being lit from cold and all reasonable steps have been taken to minimise emissions. Dark smoke is defined as smoke darker than shade 2 of a Ringelmann Chart which is a paper based chart with a number of progressively shaded boxes against which emissions can be visually compared.

Therefore, the Act imposes some degree of control on small wood burning boilers with a net rated thermal input <0.4 MW. This is equivalent to a wood feed rate of <90 kg per hour.

6.3 Environmental Protection Act 1990, Part III

Statutory nuisance can be defined as an unlawful interference with someone's enjoyment of their land. Particulate and odour emissions are likely to be the main forms of statutory nuisance with regard to wood combustion operations. Most complaints about particulates occur when they land on cars and washing etc. where they may cause damage to the outer surface due to the acidic nature of the particles.

6.4 PG1/12(04) Combustion of fuel manufactured from or comprised of solid waste in appliances between 0.4 and 3MW

Part I of the Environmental Protection Act 1990 originally established the Local Air Pollution Control regime under which the wood combustion guidance note was brought into effect. The regime has now been converted to Local Air Pollution Prevention and Control (LAPPC) established by the Pollution Prevention and Control Act 1999, though there has been little in the way of practical implications resulting from the change.

Wood combustion plant with a thermal input between 0.4 and 3 MW is subject to regulatory control in accordance with process guidance note PG1/12(04). These thresholds roughly equate to a wood feed rate of 90 to 675 kg/hour.

[3] Sites which process >1,000m³ of wood p.a. or purely saw >10,000m³ p.a. are subject to LAPPC control under PG6/2(04) "Manufacture of timber and wood based products". A boiler plant >3.0MW linked to such a process will remain under local authority control

6: Controls on wood combustion

The guidance note can also apply to wood combustion plant <0.4 MW where two or more plants are used together and the aggregate thermal input exceeds 0.4 MW. When determining whether or not two small boilers are operating "together," the guidance note suggests that regulators consider questions such as:

- Could the function be undertaken by a single larger unit?
- Are the units fed from the same storage silo?
- Are they connected to a common heating system?

PG1/12(04) sets a range of emission limits for wood burning boilers, depending upon the type of wood waste which is passing through the system. Authorised processes are expected to upgrade to meet these emission limits.

Figure 7: Emission limits from PG1/12(04)

Total particulate matter	200 mg/m^3
Organic compounds	20 mg/m^3
Carbon monoxide for existing processes for new appliances <1MWth for new appliances >1MWth	* 250 mg/m^3 150 mg/m^3
Formaldehyde	5 mg/m^3
Hydrogen chloride	100 mg/m^3
Hydrogen cyanide	5 mg/m^3
*Agreed on a site specific basis.	

Source: DEFRA (2004b)

6.4.1 Carbon monoxide

The carbon monoxide (CO) value has been the most contentious emission limit in the process guidance note. The original note set a limit at 100 mg/m^3 to be attained by 1st October 1995. However, this limit was subsequently revised upwards to 400 mg/m^3 before AQ12(95) dated 16.08.95 stated that the CO limits should not be applied as:

> "the Departments have obtained further evidence as to the high costs of upgrading existing processes to comply with these emission limits. Having regard to this evidence and the fact that the CO limit serves principally to demonstrate good combustion and that the notes contain emission limits for the main pollutants, the Departments have concluded that these two PG notes should no longer specify that existing processes comply with the CO limits by 1st October 1995." DoE (1995)

Therefore, CO limits for "existing" processes (those which were installed in December 1995 and before) have since been agreed on a site specific basis according to the level which can be achieved, whilst "new" plant >1MW has had a limit of 150 mg/m^3.

6: Controls on wood combustion

Early drafts of the 2004 revision of the guidance note proposed that a CO limit of 150 mg/m^3 should be brought in for existing combustion plant >1 MW. However, this figure was removed from the revised note with the issue to be revisited upon the publication of this combustion study by BFM Ltd.

6.4.2 Other emission limits

Limits on formaldehyde, hydrogen chloride and hydrogen cyanide are only relevant to sites burning board based products, e.g.:

- Formaldehyde from chipboard, plywood, fibreboard and similar material
- Hydrogen chloride where painted or PVC coated wood is burned
- Hydrogen cyanide from melamine faced wood

6.4.3 Monitoring

The guidance note contains a range of monitoring requirements which vary according to whether a site is burning purely raw timber / dust or it is burning board material and other wood based products.

Raw timber (e.g. uncoated, untreated hardwood and softwood):

- Particulate matter: continuous quantitative monitoring with a visible and audible alarm
- Carbon monoxide and organic compounds: annual test

Other wood based products (e.g. MDF, MFC and chipboard)

- Particulate matter: continuous quantitative monitoring with a visible and audible alarm
- Carbon monoxide: continuous quantitative monitoring with a visible and audible alarm. Results may be discarded when taken within 30 minutes of start-up or during periods of idling
- Oxygen or carbon dioxide: continuous indicative monitoring
- Annual testing for particulate matter, carbon monoxide, organic compounds and where appropriate for formaldehyde, hydrogen chloride and hydrogen cyanide
- Daily visual and olfactory assessments

Monitoring imposes a significant cost on wood combustion plant. A full set of continuous monitoring equipment will generally cost £20,000 to £30,000. Furthermore, the equipment tends to be unreliable especially with regard to carbon monoxide. Other industries would test for CO using an infra-red beam with a 3 meter light path. However, the stacks used by furniture sites to achieve the required efflux velocity (speed of air discharge from the stack) are much too narrow. Therefore, extractive sampling is used which takes a sample from the stack via a feed tube. The presence of moisture from the fuel coupled with particulate matter results in a need for the equipment to be cleaned, repaired and recalibrated on a regular basis. Re-calibration alone will typically cost between £500 and £1,000 per visit.

Consequently, the cost of monitoring is disproportionately high for a new boiler installation in the 0.4 MW to 1.0 MW range. This has led to many companies either specifying plant of 0.35 MW to fall outside of the control regime or opting for 1.3 MW plant in the hope that they grow into it. Under-specification means that the boiler plant cannot handle all of the wood waste and

6: Controls on wood combustion

landfill is typically used for the surplus. Over-specification results in higher emissions as boiler plants perform poorly when they are frequently stopping and starting due to a lack of fuel or a lack of heat demand.

Discussions with local regulators may allow an alternative approach to monitoring for authorised plant. For example, some argue that an oxygen trim system is preferable to standard monitoring kit. The latter typically performs no active role, but simply records performance. However, oxygen trim mechanisms involve the monitoring of temperature and oxygen with a feedback mechanism which can control the fuel feed rate and oxygen levels. If the temperature and oxygen levels are maintained within specific parameters, it is argued that carbon monoxide is effectively destroyed.

Such a theory can be tested using a relatively inexpensive (£1,000) hand-held device as illustrated. These units are only designed for occasional use, e.g. weekly checks on combustion performance. They are self calibrating and simply require the insertion of the monitoring probe into the stack. Such units may have the potential to take the place of continuous monitoring, either with or without oxygen trim.

A hand held monitoring device (in this case attached to a metallic panel) is shown on the right of the picture with the grey probe visible on the left

6.5 European Waste Incineration Directive

The European Waste Incineration Directive (2000/76/EC) has been transposed into UK law and its requirements are incorporated within PG1/12(04). The Directive contains an exclusion for “wood waste” except that containing “halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coating”.

Current understanding suggests that this excludes all wood and timber based products e.g. solid timber, MDF, MFC, plywood and chipboard except where they contain:

- Halogenated organic compounds: these are substances which contain chlorine, bromine or fluorine, e.g. polyvinyl chloride (PVC). Consequently, companies with wood combustion equipment should ensure that no PVC edge-banding enters the wood waste stream, e.g. through switching to an ABS alternative
- Heavy metals: these compounds are unlikely to feature in furniture manufacturing operations and are more likely to occur in products such as CCA (copper, chrome, arsenic) treated timber.

The Waste Incineration Directive imposes emission limits which are around 1/10th of those contained in PG1/12(04) and no standard wood burner could achieve them. Therefore, furniture companies should remove all PVC from their wood waste stream to ensure that they remain excluded from the Directive requirements.

7: Wood combustion in the furniture sector

7.1 Introduction

One of the key aims of this project was to collect information on authorised wood combustion plants in the UK. The following section provides a breakdown of the results of the on-site audits with additional information included from telephone discussions with other combustion plant operators.

7.2 Characteristics of audited companies

This study contacted the operators of 91 wood combustion units, 83 of which were authorised. This combustion plant was being operated on 72 sites. The majority of operations had a single boiler, but some of the larger operations had multiple units with as many as 8 on a single site.

The majority of site audits were conducted during 2003 and early 2004. Eight of the authorised boiler plants included within the study had closed by the end of 2004 due to company closure or an increased reliance on imported components, with a consequential decrease in the amount of on-site woodworking and wood waste generation.

63 of the 72 participating companies were furniture manufacturers. The remainder were involved in a variety of timber related industries included joinery, timber supply and flooring manufacture.

The size of individual participant companies varied greatly. The smallest operation with an authorised plant had a turnover of just £1 million with the largest exceeding £100 million. The average turnover was £31.4 million.

7.3 Wood combustion plant

7.3.1 Size of plant

The combustion units which participated in the study ranged in size from 0.35 MW to 4.7 MW. Although boiler plant of 0.35 MW falls below the authorisation threshold for PG1/12(04) when operated in isolation, it will still be subject to the regime where it operates in conjunction with other combustion units with a combined rating above the threshold of 0.4 MW.

The average size of the plants participating in this study was 1.8 MW and the combined net rated thermal input was 141 MW.

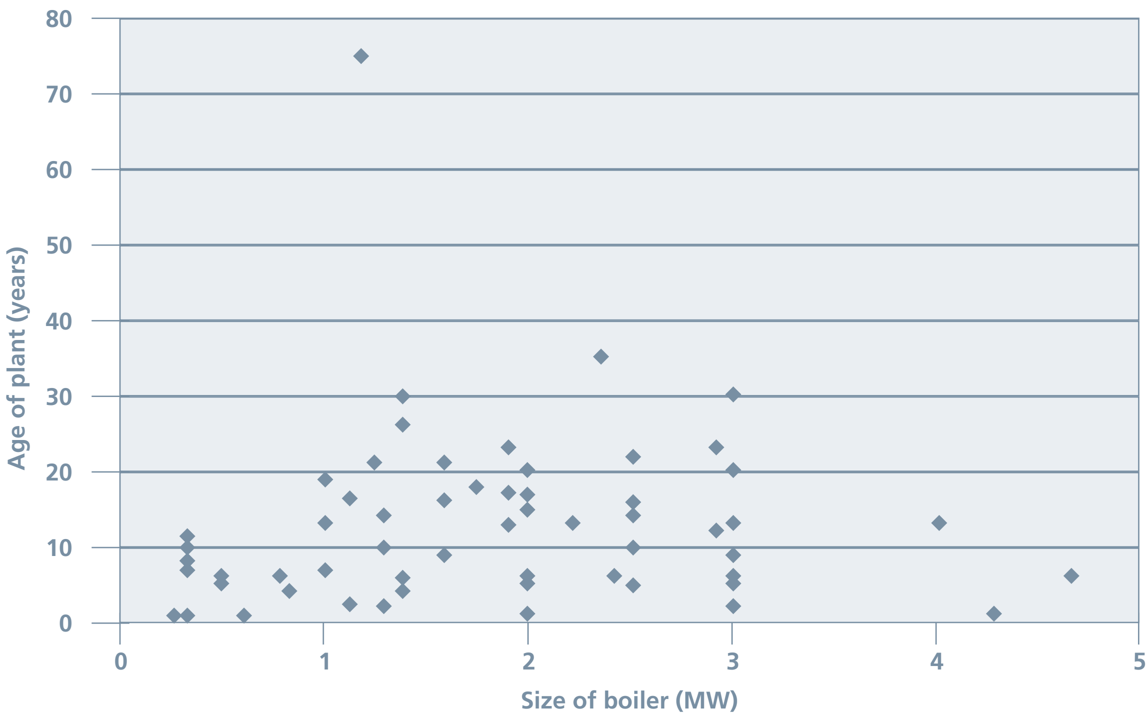
7.3.2 Age of plant

The average age of the plant was 14.5 years old, i.e. installed around 1990. The range of ages was significant with a selection of recently installed units through to one boiler with a declared age of 75.

Of the 62 plants with a known age, 55% were installed in 1995 or before, i.e. they were deemed to be "existing" plant according to the process guidance note definition.

7: Wood combustion in the furniture sector

Figure 8: Correlation of size and age of wood burning boilers



7.3.3 Fuel type

59% of companies were purely burning board material whilst just 8% were purely burning solid timber. The remainder were burning a mix of wood based fuel but this was dominated by board material, at least some of which was being burned by 92% of sites. Of the board material users, some 61% were processing at least some melamine faced chipboard.

Such figures regarding the dominance of board material in the sector correlate closely with those generated previously in work by BFM Ltd (2003). This showed that board material was in use by 92% of furniture manufacturers, with 61% using hardwood and 17% using softwood. The latter has excellent recycling opportunities and is less likely to be burned, whereas the alternative options for board dust and off-cuts are extremely limited. Therefore, it is not surprising to find that board material is the dominant fuel for wood combustion in the UK.

Only 32% of sites were able to quantify the amount of wood waste consumed by their combustion plant. This reflected a general neglect by the industry to quantify its waste streams as noted in previous studies (BFM Ltd, 2001; BFM Ltd 2003). On those sites which could provide figures, the average plant consumed 283 tonnes of solid timber and 646 tonnes of board material each year.

There was a wide variation in fuel consumption levels between boilers of similar sizes. For example, the amount of fuel consumed by operators of 1.4 MW boilers varied from 125 tonnes to 800 tonnes p.a. A number of factors contributed to this variation such as:

- Availability of fuel and the associated operating pattern, especially at night and over week-ends.
- Requirement for space heating and process heat
- Age and efficiency of boiler and heat distribution / dissipation system

7: Wood combustion in the furniture sector

7.4 Energy utilisation

All of the companies were using energy from their wood combustion process to provide space heating. 5% were also using heat to provide drying in their wood coating shop and a further 5% were using the heat for kilning purposes.

Only 7 of the sites had calculated the saving on fossil fuel associated with the boiler plant. This averaged £24,286 p.a. with a range from £10,000 to £50,000 p.a. The scale of saving reflected the size of the heat demand coupled with the nature of the previous heating source, i.e. gas or oil.

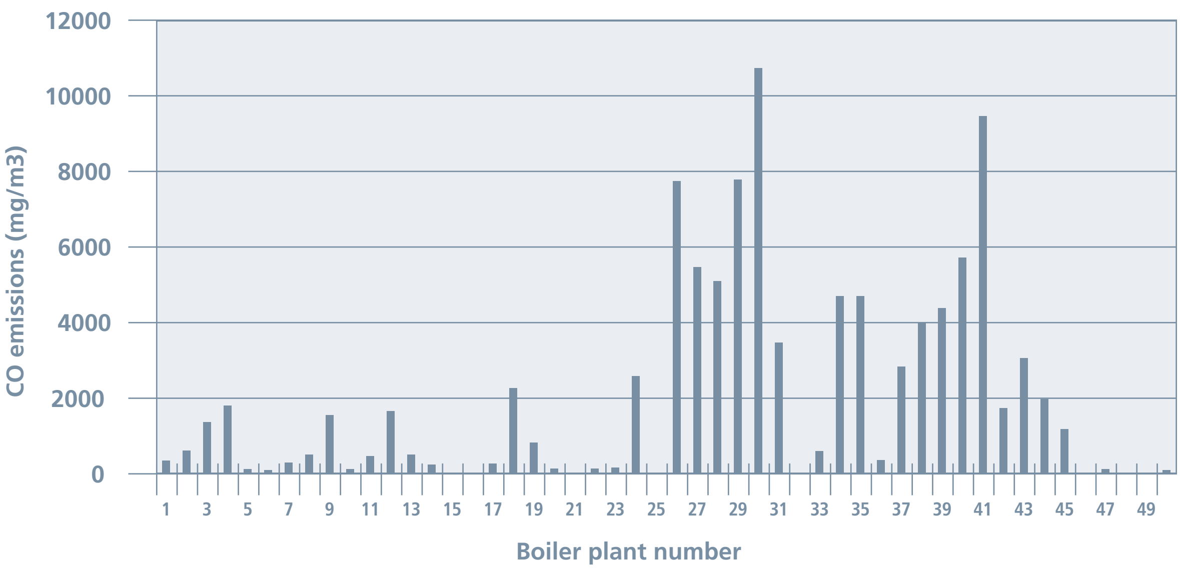
Further savings accrued through the diversion of wood waste from landfill. 6 sites had performed this calculation and annual savings ranged from £1,800 to £50,000 with an average of £21,467 p.a.

7.5 Carbon monoxide emissions

Emission details were provided by 50 authorised wood combustion plants. Information was collected from the most recent set of annual monitoring results, typically conducted in 2002 or 2003.

There was a sizeable range of CO emissions with figures ranging from 3 mg/m^3 to 10,775 mg/m^3 as shown in figure 9.

Figure 9: Carbon monoxide emissions 2002/03



The average of these readings was 2,023 mg/m^3. However, this result was skewed by a number of exceptionally high readings, seven of which exceeded 5,000 mg/m^3 as shown in figure 10.

34.0% of companies were achieving CO emissions of 150 mg/m^3 or better with a further 10.0% having readings of 150-400mg/m^3.

7: Wood combustion in the furniture sector

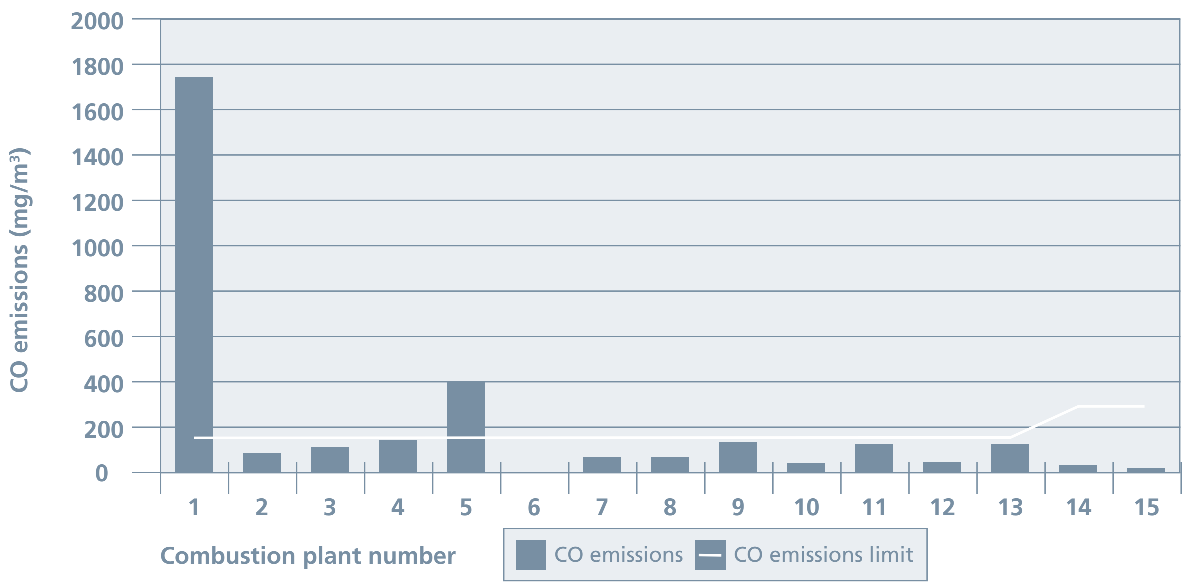
Figure 10: Carbon monoxide emission bands

Emissions (mg/m^3)	Number of companies (actual)	Number of companies (%)	Cumulative percentage
0-150	17	34.0%	
150-400	5	10.0%	44.0%
400-1000	5	10.0%	54.0%
1000-2000	6	12.0%	66.0%
2000-5000	10	20.0%	86.0%
>5000	7	14.0%	100%
Total	50	100%	

The compliance implications of the above results are determined by the age of the combustion plant. "Existing" plant installed in December 1995 or before, has CO limits set on a site specific basis. Plant which was installed after this date must achieve 150 mg/m^3 unless it is rated at less than 1 MW in which case the limit is 250 mg/m^3.

Figure 11 shows the CO emissions from the 15 "new" plants which provided monitoring data. Of these, numbers 1 to 13 were rated above 1.0 MW, whilst boilers 14 and 15 were <1 MW. Somewhat surprisingly, two of the larger new plants exceeded their limit of 150 mg/m^3, with readings of 400 mg/m^3 and 1,773 mg/m^3. The latter reading was exceptionally high for a two year old boiler. The plant had been installed by an overseas manufacturer which is not widely known in the UK and the emissions appeared to be a reflection of the very low price.

Figure 11: Carbon monoxide emissions from "new" plants

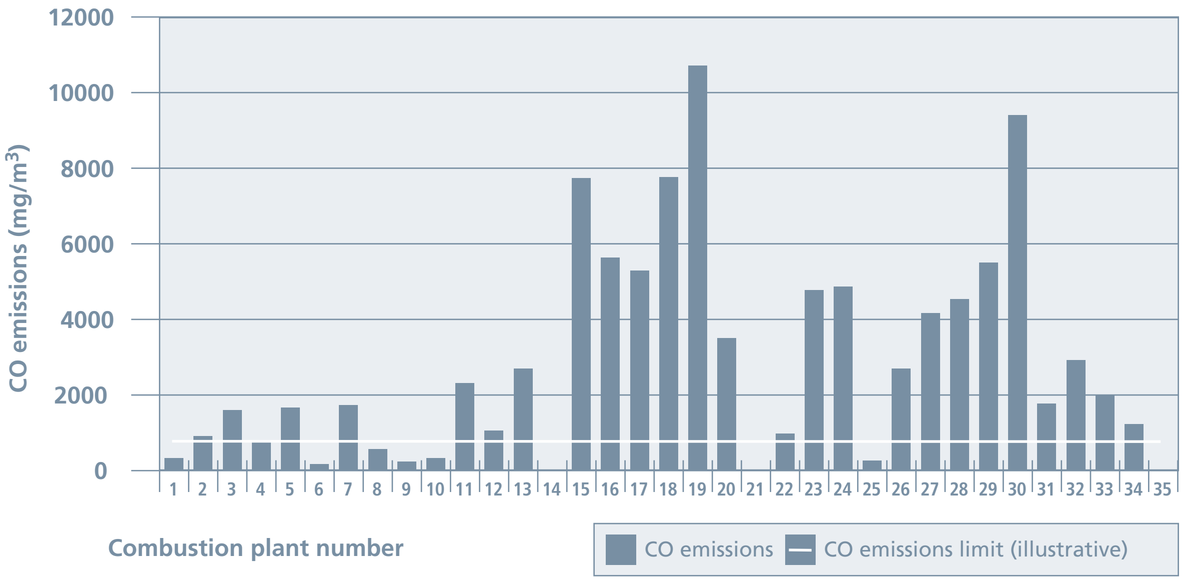


Analysis of the results from 35 "existing" plant is shown in figure 12. Such plant has a CO limit set on the basis of what can be achieved, but an illustrative figure of 400 mg/m^3 has been included as this was one of the previous limits.

The results show that just 4 of the plant (11.4%) had CO emissions below 150 mg/m^3, with a further 4 plants below 400 mg/m^3 and 5 plants (14.3%) in the 400 mg/m^3 to 1,000 mg/m^3.

7: Wood combustion in the furniture sector

Figure 12: Carbon monoxide emissions from "existing" plants

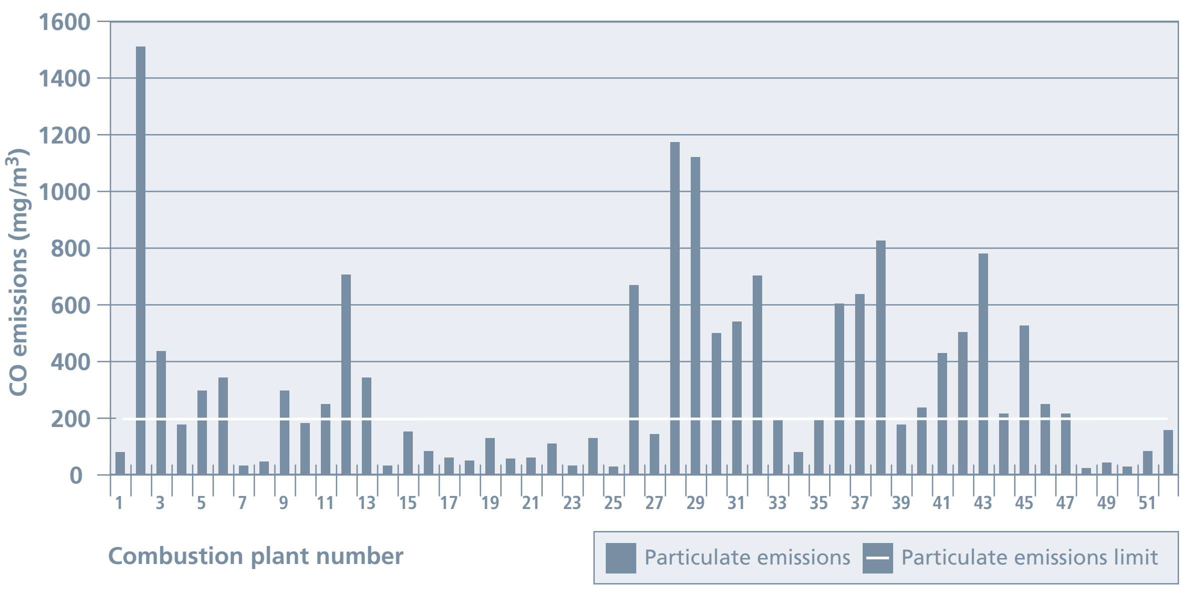


7.6 Particulate emissions

Particulate emission data were collected for 52 of the participating wood combustion units. Again, the figures were largely derived from the 2002/03 period and the results are shown in figure 13 which also includes the emission limit of 200 mg/m^3.

Particulate emissions ranged from 20 mg/m^3 to 1,500 mg/m^3 with an average of 321 mg/m^3. The emission limit was achieved by 27 (51.9%) of the respondents.

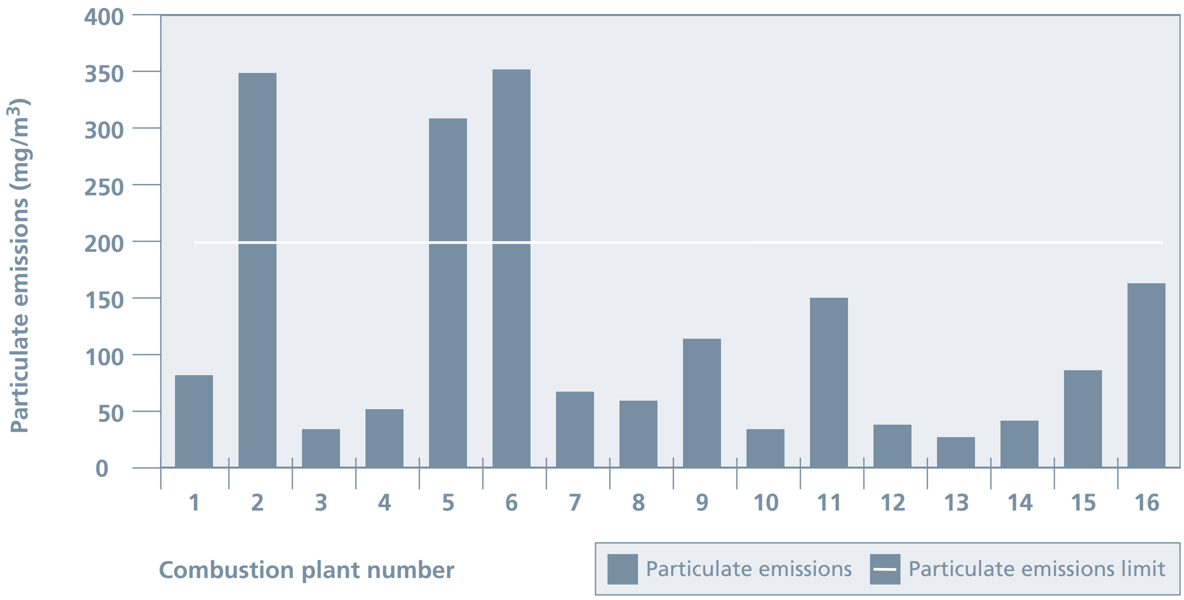
Figure 13: Particulate emissions 2002/03



7: Wood combustion in the furniture sector

It can be seen from figure 14 that a much lower level of particulate emission was generated by new combustion plant, with an average of 118 mg/m³. The emission limit was achieved by 81.2% of such companies.

Figure 14: Particulate emissions from "new" plant



7.7 Other emissions

Companies which burn board material are required to conduct annual monitoring of formaldehyde emissions. Hydrogen chloride and hydrogen cyanide monitoring may also be required, depending on the nature of the material being burned. In addition, volatile organic compound monitoring is required.

7.7.1 Formaldehyde

The formaldehyde emission limit is 5 mg/m³. Monitoring results were obtained from 41 companies with an average of 2.54 mg/m³ and a range from "not detectable" to 18 mg/m³. Compliance was achieved by 85.7% of companies.

7.7.2 Hydrogen chloride

The hydrogen chloride limit of 100 mg/m³ was met by all but two of the 39 respondents. One of the non-compliant companies had an emission level of 150 mg/m³, but subsequent action to identify and remove PVC from the waste stream led to a marked reduction.

The average level of emission was 26.4 mg/m³. Although this is well within the limit set by PG1/12(04), the level is of concern as it suggests that PVC is still entering the furniture wood waste stream for combustion. The subsequent generation of hydrogen chloride and associated hydrochloric acid, leads to the rotting of the internal fabric of the boiler plant with increased maintenance cost and decreased performance. Furthermore, the presence of halogenated organic compounds in the wood waste stream leads to the risk that the plant will fall under the much stricter control of the Waste Incineration Directive.

7: Wood combustion in the furniture sector

7.7.3 Hydrogen cyanide

39 companies were able to provide data regarding hydrogen cyanide emissions. Their average reading of 6.42 mg/m^3 was above the 5 mg/m^3 limit set by PG1/12(04). Results ranged from "not detectable" to 41.5 mg/m^3 and compliance was achieved by 74.3% of companies.

7.7.4 Volatile organic compounds

The limit set by PG1/12(04) for organic compounds is 20 mg/m^3. This level was exceeded by 27.8% of respondents whose results ranged from "not detectable" to 465 mg/m^3 with an average of 35.7 mg/m^3.

7.8 Compliance

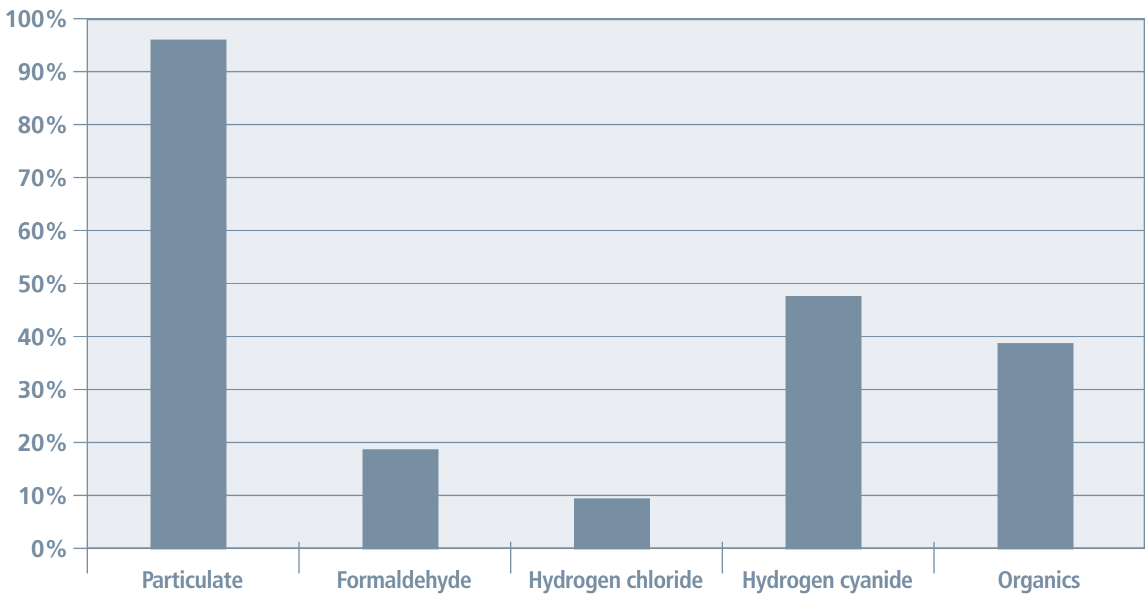
50 sites provided sufficient information regarding their emissions to enable a judgement to be made as to whether they were compliant with the emission limits set by the process guidance note and the conditions of their site authorisation. Half of these companies were compliant.

Of the 15 "new" processes, 11 were fully compliant, whilst the other 4 were non-compliant. One plant failed on CO, one on particulate and one on formaldehyde, with the remaining plant failing on all three pollutants.

Of the 35 "existing" processes, 14 (40%) were compliant and 21 were not. The main reasons for non-compliance are shown in figure 15. Most companies failed on particulates (95%) and at least one other pollutant such as hydrogen cyanide (48%) or organic compounds (38%).

In the event of a reduction in the CO limit for existing plant to 150 mg/m^3, just 2 "existing" companies (6%) would be deemed compliant and the compliance rate for the whole sector would be 26%.

Figure 15: Emission limits exceeded by non-compliant "existing" processes



7: Wood combustion in the furniture sector

7.9 Extrapolation of project results

The extrapolation of the project results into sectoral figures on wood combustion is problematic due to the uncertainty which surrounds the number of wood combustion units operating in the UK.

The Department for Environment, Food and Rural Affairs (DEFRA) publishes figures on the number of processes authorised under each guidance note, but wood combustion authorisations are normally combined with those for the manufacture of timber and wood based products. Thus, 536 authorised timber processes were recorded in 2002/03 (down from 571 in the previous year), whilst just 36 separate combustion processes (down from 41) were recorded (DEFRA, 2004a).

Discussions of the PG1/12(95) working group[4] which participated in the review of the process guidance note suggested that there might be around 300 authorised combustion plants in the UK. However, these discussions were held in 2002, since which time more plants have closed than have been commissioned. As discussed, 8 of the 83 authorised combusting plants participating in this study had closed before the publication of this final report. Therefore, a figure of 275 may be a realistic estimate of the number of authorised wood combustion plant.

Based on the analysis of the project participants, it is possible to make some suggestions regarding the plant which operates under PG1/12(04):

- 275 authorised plants are likely to consist of 151 (55%) "existing" units with 124 classed as "new"
- Average size of boiler is 1.8 MW giving a total authorised combustion capacity of 495 MW
- The plants burn an average of 283 tonnes of solid timber and 646 tonnes of board material each p.a. This equates with 77,825 tonnes of solid timber and 177,650 tonnes of board material p.a. giving a total of 255,475 tonnes p.a.
- If 87.5% of authorised combustion plant is associated with furniture manufacturing as was the case in this study, the sector could be expected to burn 223,500 tonnes of wood waste p.a. Such a figure is nearly 61% higher than the 137,000 tonnes suggested by previous work (BFM Ltd, 2002). This variation is likely to be due to the fact that the 2002 study involved the survey of 72 companies using a range of waste management options. Consequently, the combustion data was based upon responses from 19 authorised wood burning plants. In addition, there may also be errors due to the assumptions about the number of authorised plants.
- Sites with authorised combustion plant save an average of £24,286 p.a. on fossil fuel purchases, equivalent to £6.7 million for all authorised users
- If the 255,000 tonnes of wood waste consumed by authorised wood combustion were to be sent to landfill, it would incur a cost of £13.5 million at an average price per tonne of £52.50.

> **"A figure of 275 may be a realistic estimate of the number of authorised wood combustion plants"**

[4] Working group consisted of wood combustion equipment manufacturers, trade bodies, regulators and a number of process operators

8: Best practice

8.1 Introduction

The levels of emissions generated by a wood burning boiler in large part reflect the physical design and build of the unit. However, there are a number of physical and operational considerations which can help to optimise combustion performance.

8.2 Minimising combustion emissions

CO and particulates tend to be the most problematic emissions for authorised wood combustion plant. It is possible to reduce particulate emissions at the rear end of the process through the retrofitting of more efficient capturing systems, though of course, this does not solve the underlying problem.

The reduction of CO emissions can be more problematic as it is not possible to simply bolt-on a piece of arrestment equipment. Emission levels are in large part a reflection of the design of the combustion chamber and this limits the scope for change. However, there are a number of considerations which can improve the level of CO emission.

The mix of wood particles into the combustion chamber should ideally be kept as consistent as possible in terms of size, moisture content and material type.

A particularly wet batch of fuel will require more energy to drive off the moisture prior to the commencement of thermal decomposition. Consequently, it will burn more slowly and generate less heat than its drier counterpart. In addition, the higher the moisture content of the fuel, the greater the danger of bridging in the silo leading to intermittent fuel feeding.

Particle size is also important. If 1 kg of wood chips are introduced to a combustion chamber, they will burn more slowly than 1 kg of sanding powder. The latter will effectively explode and combust instantly leading to a sudden peak in oxygen demand if complete combustion is to be achieved. Conversely, the wood chips will burn in a more controlled manner leading to a lower but longer oxygen demand.

The switch from dust to chips and back again will occur if there is layering in the silo. This may result from batches of activity undertaken on a furniture site such as:

- Turning off the extraction system during a lunch-break, leading to the shakedown of the filters and the generation of a volume of fine dust.
- The hogging of a batch of off-cuts during the lunch-break to empty the bins in the workshop, leading to a layer of coarser chips
- Resumption of normal working after the break leading to a mixture of particle sizes as long as the afternoon production schedule is not heavily biased towards a particular process (e.g. fine dust from sanding machines).

8: Best practice

Combustion characteristics also vary between different types of timber and wood based products. As discussed in section 3.2.1, MFC will typically be burned at 850°C to prevent clinker formation whereas solid timber might ideally be burned at 1,100°C to ensure complete combustion. Emissions will be subject to greater fluctuation if batches of one material are followed by a different one.

The automatic detection and correction of oxygen levels is known as oxygen trim. Such a mechanism will help to ensure that sufficient oxygen is available for complete combustion whilst reducing the likelihood of introducing too much excess air which will lower the combustion temperature and increase the level of particulate emissions.

Alstons Cabinets Ltd

Alstons Cabinets Ltd is a manufacturer of bedroom cabinets which employs around 230 staff at its site in Ipswich. Production centres upon MDF and chipboard panels to which foils are applied.

The company has a 3.0 MW Omnical boiler which was installed in 1995 and is classed as an "existing" process. The boiler operates for 10 hours per day, 5 days per week and consumes around 1,000 tonnes of board material p.a.

Alstons Cabinets together with Moldow-Mawera (UK) Ltd, have worked closely with the local authority to optimise the performance of the boiler plant. A number of physical changes have been made to the plant including the insertion of a feedback loop to maintain a constant pressure in the combustion chamber and a change of bricks to improve the air circulation. In addition, hourly checks are made on the type of material being fed into the system to ensure the consistency of the fuel.

These changes have helped the site to reduce CO emissions from 773 mg/m^3 in 2000 to 197 mg/m^3 in 2003, whilst particulates have fallen from 116 to 81 mg/m^3. Emissions of formaldehyde, hydrogen chloride, hydrogen cyanide and organics are all <1 mg/m^3.

9: Conclusions

This project suggests that around 275 plants operate wood combustion processes authorised under process guidance note PG1/12(04). These units consume 255,000 tonnes of wood waste p.a., around 69.5% of which is board material. Around 87.5% of the authorised combustion units are thought to be associated with furniture manufacturing and these plants could be expected to burn 223,500 tonnes of wood waste p.a.

Combustion is an attractive waste management option for board material waste due to the lack of constructive outlets coupled with the high cost of landfill, which can be up to £70 per tonne at 2002 prices.

Much greater potential exists to make use of the energy generated by this combustion. All of the participant companies generated space heating during winter, but the vast majority simply dissipated heat to atmosphere during 7 or 8 months of the year. Only 5% used the heat for kilning and 5% for drying tunnels in wood coating operations.

Demonstration projects would be a useful method of transferring technology from the Continent into UK industry regarding the potential for combined heat and power, district heating schemes and the opportunity for the sale of process heat &/or cooling to neighbouring factories.

Compliance with the requirements of the wood combustion guidance note remains problematic. Full compliance is only being achieved by 50% of plant and this figure would drop to 26% if CO limits were tightened significantly for "existing" plant. Operators of such plant would have the following options:

- Attempt to persuade the local authority to use their discretionary powers to allow the combustion plant to continue in operation
- Replace the combustion plant with a newer and cleaner version
- Close the combustion plant and dispose of wood waste off-site &/or import a greater amount of product

The latter is probably the route which the majority would pursue. The economic problems of the sector mean that many companies would not have the capital to replace existing plant. The rise in operating costs associated with a switch from combustion to off-site disposal would act as further encouragement for companies to increase the import of components and finished goods, thereby avoiding the need for woodworking and wood waste disposal. The importing of goods from economies lacking in fundamental environmental controls would lead to a greater global environmental impact of furniture production in addition to significant economic loss for the UK.

Such change is not just idle speculation, as illustrated by the fact that 8 of the 83 authorised combustion plant contacted as part of this study during 2003 had closed by the end of 2004, either due to the winding-up of the company or a switch to importing.

Glossary of terms

Authorised combustion plant: one which falls under local authority or Scottish Environmental Protection Agency control as it has a net rated thermal input of >0.4 MW, thereby bringing it into control by PG1/12(04)

BFM Ltd: the trade association of British Furniture Manufacturers

Bottom ash: residual material which is left in the combustion chamber after burning

Clinker: a solid residue which forms in the combustion chamber of a boiler due to the from the melting of ash when temperatures become excessive (typically >1100°C for solid timber and >900°C for MFC

DEFRA: the Department for Environment, Food and Rural Affairs

Excess air: in order to ensure sufficient oxygen for the combustion process, it is common to inject excess air, i.e. more air than the minimum required to obtain complete combustion

Existing plant: a boiler installation dating from December 1995 or before

Fly ash: small particles which are carried out of the combustion chamber and are retained by the cyclone filters or emitted through the stack

MDF: medium density fibreboard

MFC: melamine faced chipboard

New plant: a boiler installation dating from after December 1995

Nitrogen oxides (NOx): gas formed by the combustion process which can be reduced through the control of air in the primary and secondary combustion chambers

Oxygen trim: the automatic detection and correction of oxygen levels

PG1/12(04): process guidance note for the combustion of fuel manufactured from or comprised of solid waste in appliances between 0.4 and 3MW

PG6/02(04): process guidance note for the manufacture of timber and wood based products

PG6/33(04): process guidance note for wood coating processes

Glossary of terms

Polyaromatic hydrocarbons: cancer causing compounds which should be broken down as long as there is a residence time of >1.5 seconds at a temperature of >800°C

Polychlorinated dioxins and furans: highly toxic compounds which are formed at low temperatures between 180°C and 500°C where chlorine is present in the fuel, e.g. due to PVC edgebanding

Polyvinyl chloride (PVC): substance found in certain types of edge-banding. PVC should be kept out of boiler plants as its combustion leads to the generation of hydrogen chloride which rots the internal fabric of the boiler. In addition, wood waste containing halogenated organic compounds such as PVC is not exempt from the European Waste Incineration Directive

Primary air: air which provides the oxygen used for the initial combustion of the volatiles from the fuel

Secondary air: air which is introduced to the process to enable complete combustion.

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BFM Environment Ltd research projects

A number of environmental research projects have been conducted previously by BFM Environment Ltd. Final project reports can be downloaded at www.bfmenvironment.co.uk

Benchmarking solvent use in the UK furniture manufacturing sector

This Biffaward sponsored research project involved 41 solvent audits to develop a benchmarking publication concerned with good solvent practice on a sub-sectoral basis. The work showed the degree of solvent reduction progress which has been achieved by the industry. For example, between 1998 and 2000, the project participants reduced their solvent consumption from 1,475 to 870 tonnes a saving of 41% or 605 tonnes p.a.

Evaluation of the market development potential of the waste wood and wood products reclamation and reuse sector

Sponsored by the Waste and Resources Action Programme (WRAP), this project quantified the end-of-life (EOL) wood waste arisings from a variety of sectors including furniture. Barriers hindering further utilisation of material were identified and solutions were suggested. The guide estimated that around 2 million tonnes p.a. of wood waste is generated through EOL furniture alone, around 90% of which is landfilled.

Implications of sustainable development for reproduction furniture manufacturers

Sustainable Technologies Initiative sponsored project designed to identify the key variables associated with sustainable development in reproduction furniture manufacture. The project identified a number of barriers to more sustainable development, one of which was the need to consider end-of-life furniture recovery and associated design for environment.

Promotion of timber waste recycling in the furniture manufacturing sector

This project, sponsored by WRAP, involved the most detailed analysis of timber waste undertaken with the UK furniture manufacturing sector. It resulted in the production of a guide containing waste benchmarks together with guidance on the recycling options available for timber waste. The guide estimated that around 500,000 tonnes of process wood waste is generated by the sector each year, around one quarter of which is landfilled.

Envirowise best practice guidance

BFM has written a number of guides for Envirowise and has made a major contribution to other publications. These include:

- GG177: Reducing Solvent Use in the Furniture Industry
- GG289: Furniture – the Essentials Guide
- GG290: Savings from waste minimisation in furniture manufacturing
- GG308: Furniture workbook: cut waste cut costs
- GG340: Savings through low solvent coatings

BFM Environment Ltd

BFM Environment Ltd provides a range of environmental, health & safety services to the furniture sector.

Key environmental management services include:

- Advice line: provides advice to members (free of charge) on any areas of EHS management such as legislation, technical issues and best practice
- Site reviews: Available to members (free of charge) to review operations and assess current levels of EHS performance, with the provision of a summary report including recommendations.
- Update: a monthly publication available by e-mail which contains news of EHS developments relevant to the sector as well as details of forthcoming environmental conferences and guidance etc.
- Training: various courses are offered to the industry including the 3 day BFM Certificate in Environmental Management and the 1 day Introduction to Environmental Management
- Policy level representation: BFM Ltd works closely with regulators and policy formers such as DEFRA and DTI to ensure that member views are represented during the formation and revision of policy.
- Research: work has been undertaken to develop and document best practice advice in key environmental management areas

Additional health and safety services include:

- Health and Safety Certification: BFM Ltd operates a H&S certification scheme which has been assessed and approved by the Association of British Insurers under the “Making the market work” initiative. Certified companies should obtain reduced rates of Employers Liability insurance. Certification is available to companies which can demonstrate a genuine commitment to H&S along with continual improvement of performance.
- Monitoring: BFM Ltd provides a range of H&S monitoring services including:
- Wood dust personal exposure
- Solvent personal exposure
- Noise surveys
- Local exhaust ventilation testing for wood dust and solvent extraction systems

Further details with regard to health, safety and environmental issues can be obtained from www.bfmenvironment.co.uk or by contacting BFM Ltd’s Environmental Consultant Alistair Bromhead (tel: 07932 674707): alistair@abromhead.freeserve.co.uk

Sponsor information

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Moldow-Mawera (UK) Ltd is a manufacturer of wood waste combustion equipment including combined heat and power plant.

Talbott's Ltd is a manufacturer of wood waste combustion equipment.

The GMB general union represents workers in several production and service sectors including furniture making.

The Snowflake Group is the UK's largest woodshavings contractor.

FFINTO is the Furniture, Furnishings and Interiors National Training Organisation.

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