Final Report

Demonstration of end uses for recovered MDF fibre

Project code: MDD005
Research date: September 07 to March 08
Date: September 2009
WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.
Executive summary

The production of Medium Density Fibreboard (MDF) in the UK generates 131,000 tonnes of waste. Furniture manufacturing creates an additional 150,000 tonnes. Just over half of this total waste stream is sent to landfill with the remainder being burned both with and without, energy reclamation.

WRAP’s (Waste & Resources Action Programme) review of wood waste arisings and management in the UK (2005) estimated that just over 1,000,000 tonnes of wood waste were processed, post consumer, at civic amenity sites in 2003/4 (excluding furniture). There do not appear to be any published figures for MDF waste alone. However, in a 2005 statistical review of the timber industry (Timber Trade Federation), MDF represents 7% of the UK’s total wood consumption. Thus, by extrapolation, and assuming that there is a direct correlation between consumption and waste arisings, it can be estimated that an additional 70,000 tonnes of waste MDF is generated by consumers.

The same WRAP report indicated that 602,000 tonnes of furniture was also sent to waste, but it did not break this figure down into its material components. However, it is clear that this source will account for significant additional post consumer MDF waste.

The wood panel production sector is facing increasing competition for its raw material resources. The rise in importance of wood as a fuel for the production of heat and power has led to price rises and interruptions to supply. Identifying new sources of raw materials may be one method for the MDF manufacturers to help alleviate the supply chain pressures that they face.

The current disposal practices for MDF waste have environmental and economic burdens associated with them, therefore alternative approaches for the disposal of this waste need to be considered, such as recycling into other uses or re-use in MDF manufacture.

One approach to the reclamation of the wood fibres from MDF is the use of Microrelease technology, which is a patented process that utilises electromagnetic radiation in the form of microwave energy to swell and liberate the fibres without causing any physical damage to them. Contamination removal is simple as this process does not cause breakdown of any grit, laminates and inorganic/organic particles.

Laboratory trials have already demonstrated that fibres recovered in this process (rMDF) can be used in the production of new MDF boards and a variety of other applications but this has yet to be proven on an industrial scale.

This report demonstrates that rMDF can be incorporated in whole, or in part, into the commercial production of the following products:

- Medium Density Fibreboard
- Wood Plastic Composites (WPCs) for decking
- Insulation fibres
- Oil spill absorbers

Each of these has been investigated in terms of ease of manufacture, product performance and economic viability, with comparisons being made between standard production and products containing recycled MDF fibres.

The cost benefit analysis carried out for this report was based on the best available data at the time of writing. However these calculations may need to be revisited to take into account the current uncertainty in the economic situation.

Re-use of fibres in the production of MDF offers a promising solution both technically and financially. The fibres (up to 20% by dry weight) can be incorporated into the existing production with negligible effect on the manufacturing parameters and no significant drop in product performance. 900,000 tonnes of MDF is produced each year in the UK and by utilising 20% recycled fibres, there is potential to utilise 160,000 tonnes of waste (greater than the annual landfill waste stream currently generated by MDF and furniture manufacture).
addition, reductions in processing costs might be demonstrated with a potential additional benefit being the reduction in the amount of binder (resin).

The incorporation of rMDF into Wood Plastic Composites is shown to pose greater problems including the need to develop the front end of the production process to better incorporate the fibres into the product. In addition, the performance of the rMDF product was found to be lower than for its non-recycled fibre counterpart in these trials. A cost benefit analysis also reveals that an rMDF based product using the Microrelease technology currently costs more to manufacture than the standard product which uses wood flour as its primary raw material. Despite these results from these trials, manufacturers consider that the use of rMDF still has potential in the manufacture of WPCs, in particular those that require greater structural capability.

A number of positive performance results are identified when using rMDF as a partial substitute for recycled paper fibres used in cavity wall insulation. The settlement under mechanical load and shock is improved by the addition of rMDF with the overall potential for using less insulating material. In addition, there is potential for rMDF to compete on price with recycled paper fibres. Under these circumstances, the overall cost reduction to the manufacturer, combined with potential benefits passed on to the consumer, make for a positive cost benefit analysis. However, some technical issues still need to be addressed including ways of counteracting the recorded drop in thermal performance of the rMDF product.

The use of rMDF fibres (either on their own or mixed with paper fibres) for cleaning up oil spillages is also considered. Whilst the ability to absorb oil is greater than that of recycled paper the rMDF products also have a tendency to absorb much more water than existing products on the market which is considered to be disadvantageous.

The environmental impacts of each of the processes discussed within this report were also assessed and the results of the study investigating the closed loop recycling of MDF fibre are presented within a separate Life Cycle Analysis (LCA) document ‘Life Cycle Assessment of Closed Loop MDF Recycling: Microrelease Trial’ (ISBN: 1-84405-417-9). Publication of this report was held pending the results of the Life Cycle Assessment.
Contents

1.0 Introduction........................................................................................................................................... 1
  1.1 Project partners................................................................................................................................. 2

2.0 Aim and scope....................................................................................................................................... 2
  2.1 Objectives........................................................................................................................................ 2

3.0 Current disposal of MDF waste ......................................................................................................... 2

4.0 Market opportunities for recycled MDF.............................................................................................. 4
  4.1 Medium density fibreboard (MDF) manufacture ............................................................................... 4
     4.1.1 Background to MDF manufacture ...................................................................................... 4
     4.1.2 Technology - drivers & barriers ......................................................................................... 4
     4.1.3 Market .................................................................................................................................. 5
  4.2 Wood plastic composites ................................................................................................................. 5
     4.2.1 Background to wood plastic composites .............................................................................. 5
     4.2.2 Technology - drivers & barriers ......................................................................................... 5
     4.2.3 Market .................................................................................................................................. 6
  4.3 Oil spill applications ......................................................................................................................... 8
     4.3.1 Background to oil spill applications .................................................................................... 8
     4.3.2 Technology – drivers and barriers ..................................................................................... 8
     4.3.3 Market .................................................................................................................................. 9
  4.4 Other industrial applications ........................................................................................................... 9
     4.4.1 Thermal insulation ................................................................................................................ 9
     4.4.2 Horticultural growth mediums .......................................................................................... 10
     4.4.3 Asphalt/bitumen additives .................................................................................................. 11
  4.5 Products assessed in this study ....................................................................................................... 11

5.0 Microlase ............................................................................................................................................. 11
  5.1 The process ..................................................................................................................................... 11
  5.2 Economic considerations ............................................................................................................... 12

6.0 Case study Glunz (Sonae) - Medium Density Fibreboards ................................................................. 13
  6.1 The process ..................................................................................................................................... 13
  6.2 Fibre specification .......................................................................................................................... 14
     6.2.1 Specification ......................................................................................................................... 14
     6.2.2 Input method ........................................................................................................................ 14
     6.2.3 Chemical composition ........................................................................................................ 14
  6.3 Trials using rMDF ........................................................................................................................... 15
  6.4 Results ........................................................................................................................................... 17
     6.4.1 Manufacturing ..................................................................................................................... 17
     6.4.2 Product performance ........................................................................................................... 20
     6.4.3 User trials ............................................................................................................................ 22
  6.5 Conclusions ................................................................................................................................... 24

7.0 Case study Vannplastic Ltd. - Wood Plastic Composites (WPCs) ......................................................... 25
  7.1 The process ..................................................................................................................................... 25
  7.2 Fibre specification .......................................................................................................................... 26
  7.3 Trials using rMDF ........................................................................................................................... 27
  7.4 Results ........................................................................................................................................... 28
     7.4.1 Manufacturing ..................................................................................................................... 28
     7.4.2 Product performance ........................................................................................................... 29
     7.4.3 End use ................................................................................................................................ 32
  7.5 Conclusions ................................................................................................................................... 32

8.0 Case study Excel Industries - Insulation fibres and oil spill absorbers ............................................... 33
  8.1 The process ..................................................................................................................................... 33
  8.2 Trials using rMDF ........................................................................................................................... 34
  8.3 Results ........................................................................................................................................... 35
     8.3.1 Manufacturing ..................................................................................................................... 35
     8.3.2 Product performance - Insulation ...................................................................................... 35
     8.3.3 Product performance – Oil spill absorber ........................................................................... 37
  8.4 Conclusions ................................................................................................................................... 38

9.0 Economic benefits of using recycled MDF fibre................................................................................ 38
9.1 Introduction ........................................................................................................................................38
9.2 Glunz – Sonae Indústria ................................................................................................................39
  9.2.1 Influence of% rMDF content and fibre costs on cost of production ...........................................39
  9.2.2 Effect of raw material costs on production ..............................................................................41
  9.2.3 The effect of reducing resin content on board production costs ............................................42
9.3 Vannplastic Ltd ................................................................................................................................42
9.4 Excel .............................................................................................................................................43
10.0 Conclusions ................................................................................................................................45
Appendix 1 Cost benefit analysis ........................................................................................................47
1.0 Introduction

Board materials, such as Medium Density Fibreboard (MDF) and particleboard, represent approximately 23% by volume of all wood based raw materials used in the UK (8% and 15% respectively). Over 80% of these materials are used in the construction and furniture sectors with the use of MDF and particleboard continuing to expand\(^1\).

It is estimated that up to 90% of the 940,000tonnes of MDF manufactured in the UK is used in the furniture sector with the material's stable, flexible and homogenous nature being the key to its increasing popularity.

Despite this demand for their products, there is considerable competition amongst board suppliers which, combined with other factors, has led to the creation of a highly price sensitive market. As such, margins are tight and manufacturers tend to focus the majority of their attention on fulfilling orders and generating new business. However, environmental issues are becoming increasingly important and manufacturers are constantly seeking techniques that will generate environmental improvements whilst not compromising profit.

The furniture industry also finds itself under increasing competitive pressures and as margins become tighter it is increasingly important for companies to minimise those costs that are within their control. The industry sends 107,100tonnes of MDF waste to landfill each year, plus an additional 36,720tonnes is incinerated with no heat reclamation, and as waste disposal becomes more expensive, this is an attractive area for cost management\(^2\).

For the industry as a whole in the UK, the economic impact of these waste disposal options is significant. In-house incineration of the waste would cost around £679,000 per year, (the equivalent of about £5 per tonne of waste), whilst the cost to landfill 143,874tonnes of MDF waste will be £4,390,000 per year, which is equal to about £30 per tonne. This cost is likely to increase to about £8,000,000 in 2010/2011 due to the planned increase in landfill tax and predicted increases in transportation costs.

In addition to the furniture industry waste stream, there is waste MDF generated by the board manufacturers themselves. This is either incinerated on site, with energy reclaimed from combustion being used to support the manufacturing processes, or sent for external waste disposal.

It is clear that the current disposal practices for MDF waste have significant environmental and economic burdens associated with them. Due to this, alternative approaches for the disposal of this waste need to be considered, such as recycling the waste into other uses.

One approach to the reclamation of the wood fibres from MDF is the use of Microrelease technology, which is a patented process that utilises electromagnetic radiation in the form of microwave energy to swell and liberate the fibres without causing any physical damage to them. Contamination removal is simple as this process does not cause the breakdown of laminates and inorganic/organic particles.

Previous small scale trials have demonstrated that fibres recovered in this process (rMDF) can be used in the production of new MDF boards and other products. The purpose of this work is to investigate the viability of using these reclaimed fibres for a number of different end uses and on a commercial scale.

---

\(^1\) FIRA, 2001

1.1 Project partners

The project manager, FIRA International Ltd, is the furniture industry’s research and development body and is responsible for providing independent services that improve the profitability and performance of the furniture industry and its supply chain.

Table 1.1 Project partners

<table>
<thead>
<tr>
<th>COMPANY NAME</th>
<th>PROJECT ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRA International</td>
<td>Development of supply chains, link to furniture industry wastes, product development and Cost Benefit Analysis</td>
</tr>
<tr>
<td>Biocomposites Centre</td>
<td>Research and development for wood fibre based products, link to panel industry and product development specialist and support to production trials</td>
</tr>
<tr>
<td>Glunz (Sonae Indústria)</td>
<td>Global wood based panel production company. Leaders in recycled wood usage. Commercial end user of fibre.</td>
</tr>
<tr>
<td>Vannplastic</td>
<td>Leading UK manufacturer in Wood Plastic Composites (WPCs) with a commitment to developing new products. Commercial end user of fibre.</td>
</tr>
<tr>
<td>NVIRO Cleantech</td>
<td>Investment company developing significant portfolio of UK based environmental technologies which includes Microrelease</td>
</tr>
<tr>
<td>Gnosys Ltd.</td>
<td>Leading UK practitioners of Life Cycle Analysis and carbon assessments. Responsible for all environmental assessments.</td>
</tr>
<tr>
<td>Microrelease Ltd.</td>
<td>New company formed to produce and supply rMDF</td>
</tr>
<tr>
<td>Excel Fibre</td>
<td>Manufacture and supply of cellulose fibres for industrial applications. Commercial end user of fibre.</td>
</tr>
</tbody>
</table>

2.0 Aim and scope

The aim of this work is to assess whether, via utilisation of the Microrelease technology, there are significant and real market opportunities for recycled MDF (rMDF). The technology is capable of producing fibres from different waste streams (board manufacture, furniture manufacture and post consumer). This study focuses on waste MDF generated by the manufacturing process as this is quantifiable and offers significant commercial potential.

2.1 Objectives

The overall objective is to provide sufficient and compelling evidence of the benefits of using recycled MDF to potential end users. To do this the partners carried out investigations and analyses at 3 different organisations and for 4 different products:

- Glunz (Sonae Indústria) – MDF board manufacturers
- Vannplastic Ltd – Wood plastic extruded components
- Excel Industries – Use of cellulosic fibres for insulation and oil spillage clean up materials

In each of these cases the effects of using rMDF were assessed with reference to the following criteria:

- Processing (manufacturing parameters)
- Product quality and performance
- Economic impacts (cost benefit analysis of the production processes)

3.0 Current disposal of MDF waste

The current position for disposal of waste from the MDF production process is that 72% of the total is incinerated in on-site wood burning boilers with energy reclaim for use in heating of the plant buildings and some in the supply of process heat to the MDF production processes (Table 3.1). The remaining 28% of the MDF waste produced from MDF manufacture is sent to landfill. Not all of the MDF waste produced can be incinerated as manufacturers may not always have the capacity to do so.
Paragraphs 2.27 – 2.31 of the Defra guidance on the Waste Incineration Directive\(^3\) (WID) indicate that wood waste can be incinerated in a WID exempt burner unless it contains halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coatings, or includes wood waste originating from construction and demolition waste.

However paragraph 2.29 notes that if contaminated wood waste is used for the manufacture of MDF then the final product may also be considered to be contaminated and consequently the exclusion to WID might not be applicable.

In the case of furniture manufacture, which uses approximately 90% of the MDF manufactured in the UK, incineration with energy reclaim is not widely used. In some cases small furnaces are used and the energy produced is used for space heating. However, the majority of this waste is sent to landfill (70% of the waste) while much of the remainder is incinerated with no heat or energy reclaim.

The figures presented in Table 3.1 are assumed to be a more optimistic view of the current disposal practices as information available from the furniture manufacturers tends to be skewed to those larger companies employing greener processes and who are willing to divulge their disposal practices.

### Table 3.1 Breakdown of waste streams and disposal routes for MDF manufacture and use in furniture industry\(^4\)

<table>
<thead>
<tr>
<th>Waste stream</th>
<th>Market for MDF board in the UK furniture industry(^a)</th>
<th>Total tonnage of MDF manufactured in UK</th>
<th>Waste generated from MDF board manufacture (14%)</th>
<th>Waste generated from furniture manufacture (18% minimum)</th>
<th>Total waste generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfill</td>
<td>847,500tonnes</td>
<td>941,666tonnes</td>
<td>131,336tonnes</td>
<td>152,550tonnes</td>
<td>284,336tonnes</td>
</tr>
<tr>
<td>Incineration (with no energy reclaim)</td>
<td>36,774tonnes(^a)</td>
<td>107,100tonnes(^b)</td>
<td>0tonnes(^a)</td>
<td>36,720tonnes(^b)</td>
<td>143,874tonnes</td>
</tr>
<tr>
<td>Incineration (with energy reclaim)</td>
<td>94,562tonnes(^a)</td>
<td>9,180tonnes(^b)</td>
<td>94,562tonnes(^a)</td>
<td>9,180tonnes(^b)</td>
<td>103,742tonnes</td>
</tr>
</tbody>
</table>

\(^a\) Source: WPIF (2006), Glunz(2007) and FIRA (2007) – Personal communication
\(^b\) Figures estimated using split of 70% waste to landfill, 24% waste to incineration, 6% waste to incineration with energy reclaim, from WRAP report\(^5\)

Of the total 284,336tonnes of waste MDF generated in a year, 51% is disposed of in landfill. The remaining 49% is incinerated. Of this about 104,000tonnes are combusted in on-site incinerators which provide heat for some processes in the manufacture of MDF and also for space heating. The remaining 37,000tonnes are incinerated with no energy reclaim.

---


\(^4\) F I E T (Furniture Industry Environment Trust) (2002) “Evaluation of waste production, utilisation and brokerage potential within the UK furniture industry”

Disposal of waste via these routes currently presents significant environmental and economic burdens and the costs of these are set to increase significantly with increasing landfill tax and the possibility of charges for carbon emitted, or carbon trading costs.

The environmental burdens are discussed in a separate WRAP report ‘Life Cycle Assessment of Closed Loop MDF Recycling: Microrelease Trial’ (ISBN: 1-84405-417-9). However, in terms of the economic impacts of incineration of MDF waste, the cost of operating a wood burning boiler has been considered. The calculated costs of incineration are significant with the lowest costs giving a total of £679,371 p.a., which equates to approximately £5 per tonne.

Due to the use of the energy generated from waste MDF incineration in plant processes, electricity use from the grid or gas combustion can be avoided, which would represent significant costs in terms of environmental impacts, as electricity generation based in the UK includes burning fossil fuels, coal and nuclear power as well as other greener methods. Similarly, there is a financial cost for using electricity from the grid, and through utilising heat from waste MDF combustion this is avoided. At current prices it would cost around £21M for the same amount of energy produced through the incineration of 103,742 tonnes of MDF (the portion of waste incinerated with energy reclaim) in terms of electricity purchased or £4M in terms of Gas combustion.

It is assumed that any waste diverted to the Microrelease process will be taken from the portion of waste going to landfill. If this is the case and the total 143,874 tonnes is diverted this will save the furniture manufacturing industry £4,389,778 based on proposed landfill taxes for 2007/2008 and a minimum of £7,914,779 in 2010/2011 due to the planned increase in landfill tax over the next few years and predicted increase in transportation costs in line with annual inflation targets.

It is clear that the disposal and incineration of waste MDF has a significant economic impact for both MDF producers and furniture manufacturers.

4.0 Market opportunities for recycled MDF

4.1 Medium density fibreboard (MDF) manufacture

4.1.1 Background to MDF manufacture

Medium density fibreboard (MDF) is a staple feedstock for the furniture manufacturing and shop fitting sectors. It is estimated that over 90% of the UK’s production of MDF is utilised by these industries. The material is popular because of its homogeneous appearance and structure. MDF is strong, relatively inexpensive, easy to machine and accepts a wide range of surface finishes.

The flexibility of the material means that it can be sawn and routed from standard boards into any shape that is required. This in turn leads to wastage that varies according to the requirements of the output of a particular production run. FIRA has reported that the average wastage rate within the furniture manufacturing industry is 18%\(^{(3)}\) or well over 150,000 tonnes per year. Other sources of waste include scrap boards at MDF mills and post consumer waste (including domestic and commercial).

Historically, MDF has been one of the sector’s most problematic waste streams with little option for re-use or recycling. Landfill was, and still is, the most likely disposal option available for this material with over 107,000 tonnes being disposed of in this fashion every year \(^{(4)}\). Wood recycling organisations have been reluctant to accept MDF as it had no commercial outlets and therefore offered little opportunity to add value. Although options are beginning to appear for reclaiming some value e.g. composting or supply into biomass plants, these are less than optimal in terms of the Government’s published waste management hierarchy. The Microrelease technology was developed in response to these challenges and represents an option for the recovery of MDF fibre from waste material.

4.1.2 Technology - drivers & barriers

MDF production does not lend itself readily to the re-introduction of waste MDF as a feedstock. Raw material specifications are stringent as the presence of any form of contaminant can have a detrimental affect on the aesthetics and the ease of machining of the board. Although methods for manufacturing MDF can differ, the production plants are all large scale and continuous and offer no obvious routes for the introduction of waste materials into the process. Scrap boards can be recycled by feeding them into the very beginning of the process.
Demonstration of end uses for recovered MDF fibre

(At the same point as virgin wood is chipped). However, the scrap is not added as fibre or at anything other than a very low percentage, as quality can be compromised.

Despite these technological barriers, there are considerable political, commercial, technical and environmental drivers for evaluating the potential of incorporating rMDF fibres from the Microrelease process back into MDF production.

From an environmental perspective, WRAP has identified a market sector that produces almost one 1,000,000 tonnes of product every year in the UK but that has little or no infrastructure present for the reclaiming and re-use of its resultant waste streams. Medium density fibreboard, which comprises a significant proportion of recycled material could attract a wider range of environmentally aware customers. Environmental drivers are already evident in the market place, for example the WRAP supported Olympic Development Authority (ODA) requirement that all construction work associated with the 2012 London Games should include an average of 20% of raw materials of recycled origin.

The wood panel production sector is facing increasing competition for its raw material resources. The rise in importance of wood as a fuel for the production of heat and power has led to price rises and interruptions to supply. It makes commercial sense for MDF manufacturers to be seeking new sources of raw material that could help alleviate any supply chain pressures.

Fibres recovered via the Microrelease process have, during laboratory scale trials, shown that they possess characteristics that could enable performance improvements to result from their inclusion within the production process. Although these properties are commercially sensitive at the moment it is possible that reduced production costs could also result.

4.1.3 The Market

The market size for MDF dwarfs any of the other applications that are discussed within this document. World production of MDF is of the region of 31 million tonnes (41 million m³). China and Europe are the biggest producers, each responsible for between 13 and 14 million tonnes. The UK produces over 900,000 tonnes per year.

The extent of the potential market for rMDF quickly becomes apparent when analysing these production figures. Every 1% of substitution of rMDF fibres for virgin wood fibre within the context of the world market equates to 310,000 tonnes of waste MDF being recycled and re-used to produce new boards. There is, therefore, potential to divert significant amounts of waste MDF from landfill. In the UK alone 160,000 tonnes of waste MDF could be diverted from landfill if it were possible to substitute 20% of the virgin wood material with recycled fibres.

4.2 Wood plastic composites

4.2.1 Background to wood plastic composites

A potential end use application for recycled MDF (rMDF) is in the reinforcement of Wood Plastic Composites (WPCs). Wood Plastic Composites are defined as composite materials that contain wood and thermoplastic material. WPCs are currently used in a number of applications and market sectors with all commentators suggesting that their use will grow. These markets and applications include gardens (decking, fencing, park benches, playground equipment), construction (cladding, doorframe and components, roofline products, shingles, roof tiles, stairs, windows, interior finishes blinds, kitchen cabinets), automotive (non-structural panels, parcel shelves, door linings) and industrial (handrails, pallets, rubbish bins).

4.2.2 Technology - drivers & barriers

Wood plastic is an intimate mixture of wood and resin, processed by techniques familiar to the plastic industry (e.g. extrusion). The term "Wood Plastic" is used as a deliberate attempt to highlight the scope for producing an extrudable material (with a high content of wood) to replace timber based products such as furniture or fencing. WPC products claim to demonstrate in-service performance improvements over their solid timber counterparts. Producers claim that the mechanical properties, material cost and surface quality are all reasons for using WPCs over conventional wood based materials. Resistance to rot is high and maintenance requirements are low.
Wood dust or ‘flour’ is commonly used in WPCs as a filler. This occasionally includes waste MDF dust (from sawing, drilling and routing operations) although the origin is usually waste from solid, virgin wood. Wood waste is typically available at lower cost than waste (or virgin) plastic material so advantages accrue from maximising the wood to plastic ratio. Wood dust with a fine particle size (flour) is preferred as the feedstock for WPCs as it facilitates good dispersion i.e. it mixes well with the plastic constituent before and during extrusion.

Wood flour can also be blown into coal fired power stations as a co-fuel and it is envisaged that competition for this clean wood waste will increase as more (smaller) biomass plants come on stream.

Using wood flour as a feedstock is perfectly adequate for the majority of applications mentioned above. However, there are limitations to the strength of the profiles that can be extruded using this method and it is becoming apparent that demand for structural load bearing applications will rise.

For these reasons WPC manufacture is seen as a very attractive market for rMDF. The rMDF fibres produced via the Microrelease technology are typically 1mm – 3mm in length, these are considered to be long fibres in the context of cellulosic materials. The advantage that this brings is an increase in the aspect ratio (strength to weight ratio) of a product that incorporates such fibres. It is therefore feasible that extruded WPC profiles with increased strength may result from the adoption of rMDF as a constituent raw material. Production of such a profile is a key objective of this project.

WPC manufacturers are likely to be receptive to rMDF as long as both price and technical viability (ease of processing as well as product quality) are satisfactory. Their primary driver for the use of rMDF is not to replace entirely wood flour but to seek to generate improved strength properties. This will widen the potential customer base and improve profitability through the production of higher value, load-bearing products.

The potential barriers (risks) to market adoption relate to the unknown handling and performance characteristics of rMDF fibres within the WPC manufacturing environment. There are different options available for the production of WPCs with most systems employed in the UK based upon a twin extruder technique. It is not currently fully understood how this system will respond to the use of longer cellulosic fibres.

Other issues of concern relate to appearance, creep resistance, outdoor degradation, security of feedstock supply, lack of recognised standards and lack of a brand. There are also specific risks associated with certain applications where competing technologies are under development. Thermally treated timber for instance is growing in popularity and offers performance improvements for softwoods. This could lead to solid timber frames and windows offering increased durability for outdoor applications.

4.2.3 The market

Market information for the WPC industry is difficult to come by. In 2003 WRAP published a market report on the WPC sector in the UK. The following two paragraphs are taken from this report:

The US total market for WPC products was estimated to be in excess of $350 million (£228 million) in 2001 with predictions to grow to more than $2,000 million (£1,300 million) by 2011. In contrast, WPC markets in the UK and Europe are very immature. Despite the demonstrable success of the product in the USA, market development in Europe has been slow. UK and European market growth is predicted and expected but there is a significant lack of confidence as to when this is going to occur. Market development in the USA has been particularly effective when established suppliers have introduced WPC as a more attractive product. It has been suggested that this will be the case in the UK and the rest of Europe but there are no indications as to when this will occur.

The market in Europe is expected to increase from virtually nothing at the moment to somewhere in the region of £500 million to £1 billion over the next five years. In volume terms, this equates to up to 1.3 million tonnes of WPC material. It has even been suggested that the European market for WPCs will eventually exceed that in the USA in the longer term (10 years from now). Companies are expecting to start manufacturing products in significant volumes during the course of 2003 and 2004. By 2004 these materials will become much more commonplace and will be more widely available.

---

6 Wood Plastic Composites Study – Technologies and UK Market Opportunities, WRAP 2003
UK manufacturing activity is limited thus far with volume production only just beginning to get underway. Interest in the products and technology is more widespread however and numerous pilots / trials have been, or are being, undertaken. Examples of known production include:

- Timbaplus, a company based in Birmingham, started a £2 million production of inner and outer WPC doorframes.
- WTL International, based in the Midlands, has introduced “Natraplast” compounded wood-polypropylene composite pellets to its existing range of wood floor and wood fibre products.
- Ecodec (Vannplastic), a Chester based company, developed in partnership with USPL (US Plastic Lumber Company (USA)), which has recently introduced in the market wood-plastic decking materials for garden and a railing system based on a range of hollow profiles.
- Extrawood, a subsidiary from the American firm CPI plastics, which in 2004, introduced Ezedeck, a wood plastic material with a feel like wood to be used as a decking material.

In 2006, the Hackwell Group published a report detailing the European market for WPCs\(^7\). The report claims that European production amounted to 99,000 tonnes in 2005 and forecast that this figure would rise to 145,000 tonnes by 2009. This would equate to a value of €290m. This differs significantly from the previous WRAP report and highlights the difficulty in obtaining accurate market data.

Anecdotal evidence would suggest that the UK and European markets have not grown at anywhere near the rate predicted in WRAP’s report and that the Hackwell publication offers the more representative reflection of the market – although still significantly overstated. No other relevant market reports exist although more detailed information is available on the US market.

A widely used report cited in the literature is that by the Freedonia Group Inc.\(^7\) (see Figure 4.1). This report discusses US wood-plastic composite and plastic lumber demand for the years 1992, 2001 and 2006, with forecasts for 2011.

![Figure 4.1 US markets for composites and plastic lumber demand](image)

There is also market activity in Japan although again, market data is scarce. One of the leading companies is Ein Engineering Company\(^8\). Ein claimed to have sold 22,000 tonnes of WPC in 2000. This represented an increase of

\(^7\) Freedonia Group Inc., Cleveland, Ohio, Composite and Plastic Lumber in the US – June 2002

\(^8\) WPC conference 2002-Presentation Paper, Ein Engineering Cie
50% on its 1999 figure of 14,000 tonnes. The major volume of sales (70%) was in the building materials sector (decking, signboards, stairs, handrails etc.) with the remaining (30%) sold as engineering products (e.g. acoustic boards, automotive components etc).

4.3 Oil spill applications

4.3.1 Background to oil spill applications

On average in the US alone over 100 million gallons of oil are spilled per year. Oil is transported around the globe and spills can come from tankers, storage tanks, pipelines, oil wells and vessels cleaning out tanks and even when natural oil deposits seep. Spills also occur on land by railway or truck accidents. In the 1990s, statistics indicated that worldwide oil spillage totalled over 500 million gallons. However, the true figures is much greater than as these statistics only refer to spillage incidents incidents in excess of 10,000 gallons9.

There are three main reasons for spill:

- Accidental – often through carelessness
- Unavoidable events – weather, earthquakes etc.
- Intentional spills – terrorists, war, vandalism, dumping.

It is important that to minimise environmental and economic damage, reaction measures to these spills are swift and effective. Methods currently used to clean up spillage include booms, skimmers, sorbents and chemical dispersants.

**Booms** - floating barriers to contain oil (e.g. a boom may be placed around a tanker that is leaking oil to collect the oil).

**Skimmers** - boats that skim spilled oil from the water surface.

**Sorbents** – sponge like substances used to absorb oil.

**Chemical dispersants and biological agents** – substances that break down the oil into its chemical constituents.

**In-situ burning** - a method of burning freshly spilled oil, usually while it's floating on the water.

**Washing** – removal of oil off beaches with either high-pressure or low-pressure hoses.

**Vacuum** - trucks, which can vacuum spilled oil off of beaches or the water surface.

**Shovels and road equipment** - sometimes used to pick up oil or move oiled beach sand and gravel down to where it can be cleaned by being tumbled around in the waves.

Choice of methods and tools used depends on the circumstances of each event: the weather; the type and amount of oil spilled; how far away from shore the oil has spilled; whether or not people live in the area and what kinds of bird and animal habitats are in the area.

4.3.2 Technology – drivers and barriers

Sorbents are defined as "materials that soak up liquids". Oil either penetrates into pore spaces, or is attracted to the material surface without penetrating into the material itself. Sorbents need to be both oleophilic (oil attracting) and hydrophobic (water-repellent). Use of sorbents may be solely for the clean up of small spills. However, sorbents are most often used to remove final traces of oil, or in areas that cannot be reached by skimmers.

Sorbents can be divided into three basic categories: natural organic, natural inorganic, and synthetic. Natural organic sorbents include peat moss, straw, hay, sawdust, ground corn cobs, feathers, and other readily available carbon-based products. They are relatively inexpensive and usually readily available. Organic sorbents can soak up between 3 and 15 times their weight in oil, but they do present some disadvantages. Some organic sorbents tend to soak up water as well as oil, causing them to sink. Many organic sorbents are loose particles such as sawdust, and are difficult to collect after they are spread on the water.

---

Natural inorganic sorbents include clay, perlite, vermiculite, glass wool, sand, or volcanic ash. They can absorb from 4 to 20 times their weight in oil. Inorganic substances, like organic substances, are inexpensive and readily available in large quantities.

Synthetic sorbents are man-made plastics such as polyurethane, polyethylene, and nylon fibres. Most synthetic sorbents can absorb as much as 70 times their weight in oil, and some types can be cleaned and re-used several times. Synthetic sorbents that cannot be cleaned after they are used can present difficulties because arrangements must be made for their temporary storage prior to disposal.

Further work is needed to test the oil pick up properties of rMDF fibres. It is also thought that the recycled fibres may have some improved properties over the virgin as the fibre surface could be more hydrophobic and therefore the fibre would not sink when wet. This would be of great advantage in pollution control situations. Work should now evaluate the effectiveness of the fibres to pick up oil using standard testing protocols as specified by BS 7959-1:2003 Materials used for the control of liquid spillages: Determination of sorbency.

4.3.3 The market

It is evident that there is a market for using rMDF as absorbent/adsorbent oil pick up fibre. Some existing products are based on organic materials and a natural fibre from a recycled source could be an attractive alternative.

There are no market reports available for this particular application and estimates from discussions with different players in the market vary widely. Personal communications suggest that hydrophobic products can sell for between £500 – £1000 per tonne and with hydrophilic products for about £300 per tonne. However, total volumes are believed to be relatively small with the leading UK producer manufacturing hundreds rather than thousands of tonnes.

Although the total market might be relatively small in terms of volume, the value per tonne is potentially higher than some of the other industrial applications that may exist for rMDF. The appeal of rMDF as a recycled product is also significant as the use of some plastic absorbents introduces additional environmental burdens. It has also been reported that shortages in supply of some plastics have encouraged end users to investigate, and be more receptive to, the integration of alternate materials into the supply chain.

Excel Fibre Technology has trialled the rMDF and will assess it for its suitability for this market. It is a sector that the company wishes to exploit and the ability to offer a new recycled material, together with appropriate test results would be commercially attractive to them.

4.4 Other industrial applications

4.4.1 Thermal insulation

The key driver for the insulation market in the UK is the Code for Sustainable Homes (PLANNING PORTAL 2007). Insulation will be one of the elements that will be measured and consequently, this should create greater demand for the insulation market as a whole. In addition, there is also a proposed Code for Sustainable Buildings for the commercial sector. Essentially, these codes are driven by the drive towards zero carbon developments. Additionally, there are presently over 13 million homes in the UK with inadequate insulation.

Inert mineral materials such as glass wool and Rockwool and foamed plastics have traditionally served the market. Demand for sustainable buildings has led to growth in the sales of Excel's Warmcel product – made from recycled paper fibres. It is hoped that the use of rMDF (in conjunction with paper fibre) will improve the performance properties of Excel's current product range.

The UK thermal insulation market was worth £570 million in 2003 with a prediction that this would rise to around £800 million by 2008. Excel has conducted trials for various blends of rMDF and its own waste paper fibre. The two key performance criteria are resistance to settlement and thermal conductivity. Excel is keen to widen its portfolio of raw materials as the waste paper sector can be subject to fluctuations of price and availability.
4.4.2 *Horticultural growth mediums*

Details of market size are unknown as yet and demand is expected to be highly seasonal. It is, however, thought that the moisture absorption and retention properties of cellulosic fibre (provided that the fibre is uncontaminated) will be suited to activities such as hydro seeding. Hydro seeding occurs for example in civil engineering projects whereby such constructs as roadside embankments are planted for landscaping and slope stability purposes.
4.4.3 Asphalt/bitumen additives

Strong markets exist in the use of cellulosic fibre as a filler and flow agent for industrial products such as bitumen, tile adhesive and cement. Post processing of rMDF fibres will be required to fulfil the market need as fibre size should average less than 200 microns.

4.5 Products assessed in this study

Whilst there are numerous potential markets for rMDF, the products that are considered to have the greatest potential, in terms of economics and product performance, are as follows:

- Medium density fibreboard (MDF) – mixing a percentage of rMDF fibres with virgin wood fibres to produce standard boards
- Wood plastic composites – replacing wood flour with rMDF fibres in a decking product
- Thermal insulation – substituting a percentage of recycled paper fibres with rMDF fibres

5.0 Microrelease

5.1 The process

MDF is produced from lignocellulosic fibres combined with a synthetic resin or other suitable binder, for the purpose of providing additional strength to the finished board. The mechanical refining process takes place at high temperatures. The resultant MDF panel can have a density ranging between 496 to 801kg/m³, with a uniform particle distribution throughout the board and smooth, tight edges that can be machined.

The Microrelease process utilises microwave heating to assist in the recovery of wood fibre from MDF. The fibres reclaimed from the expansion of MDF board can then be utilised in various applications, including being used to produce recycled MDF boards with a portion being recycled fibres, or potentially wholly recycled. One of the main benefits of the process is that it reclaims uncontaminated fibres. Any contaminants such as grit, laminates and coatings can be easily segregated and removed.

The Microrelease process under consideration is shown in Figure 5. and consists of the following stages:

Figure 5.1 System boundary for reclamation of fibres from waste MDF by Microrelease process
Shredding and separation
After receipt of the waste MDF by the Microrelease plant, the first stage required is shredding and sorting of the feedstock.

The preferred input material is unprocessed or raw MDF board as this is easier to recycle but the process is capable of handling MDF based products including those that have been painted or covered with another type of surface finish (melamine etc).

Shredding the waste to manageable size releases dust and also frees any metal contaminants (e.g. screws) from the MDF. These cannot be used in the Microrelease process and need to be sent for disposal.

It is anticipated that much of the feedstock will arrive as off cuts from other manufacturing processes. Sorting and shredding requirements will be minimal and, as a result, any associated energy costs will also be low.

Immersion
Waste MDF board fragments are immersed in water to allow water uptake into the board prior to microwave heating. The temperature of the water prior to immersion is 98°C and the board is immersed for 300 seconds. Energy requirements for this immersion, in hot water, are 159kW/tonne. Water uptake has been found to be 3.5kg with the initial mass of board being 2.37kg. The water used in the immersion stage will be cleaned and recycled within the process. Any slurry or solid residue removed from the water will be disposed of to landfill.

Microwave release
This stage involves heating the wet board fragments in a microwave field causing the fibres to swell, separating them for reclaim. The temperature in the microwave cavity has been measured as 101.5°C and the electrical energy consumption for the microwave process has been measured at 303kWh/tonne of board. 5.88kg of wet MDF material from the immersion stage (including the water soaked up during immersion) produces 3.5kg of dry fibre.

Separation and drying
Separation of the fibres after immersion and microwaving is achieved through non-destructive but dynamic breakdown of the board so that the fibres are not damaged or broken. Any laminate material can be removed from the fibres and discarded. There is the possibility that this material could be recycled, however current disposal practice is to ship this by-product to landfill for disposal. The fibres are then dried. This is the most energy consuming stage in the process, requiring 963kWh/tonne of board input. Any water collected from the drying process will be cleaned and recycled in the immersion stage and the dried fibres (with some residual resin content) are collected ready for shipping to the end user.

This data is based on trials run to find the best and most efficient process for fibre reclamation. The trials were run on a relatively small scale with the objective of proposing the best procedure for use in the pilot plant, where this process will be scaled up to produce 2 to 6 tonnes of reclaimed fibre per day. This process is optimised for reclaim of fibres from virgin board as lamination of board requires variation in the soak time. Using this process for mixed stream waste is seen as possible but problematic and so sourcing of clean MDF waste or sorting of waste will initially be required.

5.2 Economic considerations

Energy costs and cost of raw materials can be used to give an estimate of the expense associated with reclaim of wood fibres from MDF waste using this technique. Added to this would be the investment in plant, associated materials and other costs associated with running a business.

The final price of rMDF fibre will be a function of manufacturing costs and the financial considerations of the rMDF supplier. The cost benefit analyses within the report incorporate a range of potential rMDF fibre prices (from £80 to £160 per tonne) and these provide an easy reference tool for the assessment of the potential economic viability of using rMDF in each of the processes considered.
6.0 **Case study Glunz (Sonae) - Medium Density Fibreboards**

6.1 The process

MDF is typically produced from virgin softwood (approximately 82% fibre by dry weight) with the addition of a resin binder. A finished board will have between 5 and 7% moisture content. The manufacturing process is outlined in figure 6.1.

**Figure 6.1 Typical production line for MDF (Sunds Defibrator, 1997)**

Although some minor variations exist in the way in which MDF is produced, the feedstock would typically arrive in log form and be subjected to a debarking, chipping and washing regime. Moreover, residues from sawmills e.g. chips (4 to 50mm in size) and associated dust are used as raw materials for MDF production. Chip washing is essential for producing board with a low content of mineral impurities. The typical breakdown of raw material used at Glunz’s Meppen facility is:

- 15% softwood logs from thinnings (e.g. spruce, pine, Douglas fir, larch)
- 25% poplar logs
- 50% chips from sawmills with bark
- 10% chips from sawmills without bark
After washing, the chips are pre-steamed in a chip hopper up to a temperature of 80°C. This equalizes the moisture of the incoming raw material and softens the chips. Thereafter, the chips are pressed via a screw-feeder into the digester (cooker). Within the digester the chips are treated under thermo-hydrolytic conditions (170°C – 180°C temperature, 8bar – 9bar pressure) for a period of about 3 – 5 minutes to soften the wood.

The treated chips are then defibrated in a refiner at more or less the same temperature and pressure. This process is known as thermo-mechanical pulping (TMP-process). After defibration the wet fibres are resinated in a blowline with a resin (blowline technique) and thereafter dried in a dryer to a moisture content of approximately 8% – 10%. As an alternative the defibrated fibres can be firstly dried and thereafter resinated in a blender (blender technique). Moreover, there are plants where the blowline and blender techniques are combined.

After drying, the fibres are stored in a fibre bin.

After forming the fibre mat, efficient, continuous pre-compression is essential to enable a slow air escape from the mat. Thereafter, the precompressed fibre mat is compressed further in a continuous press into the type of board required which can vary in terms of thickness and density according to application. After leaving the press, the boards are cut and cooled.

Finally the MDF is stored, sanded, cut-to-size and packaged.

6.2 Fibre specification

6.2.1 Specification

Glunz’s fibre specification for their standard MDF products is as follows:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination</td>
<td>Free from contamination such as laminates and other surface finishes, metal (ferrous, non-ferrous) and grit*</td>
</tr>
<tr>
<td>Moisture content</td>
<td>&lt; 20%, 8-10% ideal</td>
</tr>
<tr>
<td>Shive content**</td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>Fibre length</td>
<td>0.5mm – 3mm</td>
</tr>
<tr>
<td>Dust content</td>
<td>&lt; 10%</td>
</tr>
</tbody>
</table>

* MDF is typically machined for conversion into products such as furniture. Any contamination on the fibres can cause ‘spotting’ on the board which is aesthetically undesirable but more importantly can have an adverse effect on tooling heads used to process the raw boards. This contamination is generally referred to as ‘grit’ in this context.

** Shive content in this context will refer to ‘clusters’ that have not been broken down to individual fibres. In other applications, shives might be considered simply to be fibres that are longer or wider than the maximum dimensions given within the specification.

6.2.2 Input method

For experimental purposes the rMDF was supplied in large bags in a fluffy state and was pneumatically conveyed into the recycled dosing bin before commencement of the production trial. This dosing bin is usually fed from a pit below the forming belt which is prior to the infeed of the main press. During the start up of a production run, reject mats are dumped via the pit and either recycled into the manufacturing process or diverted to the boiler plant for conversion to energy. As MDF production equipment is fast and continuous and was not designed to utilise non-resinated rMDF fibres, there are no obvious entry points for this material. The recycling bin offered the most logical route into the system.

6.2.3 Chemical composition

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal content</td>
<td>See Table 6.1</td>
</tr>
<tr>
<td>% Cellulose</td>
<td>~ 60% based on oven dry MDF</td>
</tr>
<tr>
<td>Formaldehyde content</td>
<td>average of less than or equal to 7mg/100g on an average basis (not greater than 8mg single sample)</td>
</tr>
<tr>
<td>% Lignin</td>
<td>~25 – 27% based on oven dry rMDF</td>
</tr>
<tr>
<td>Grit content</td>
<td>&lt;0.02%</td>
</tr>
</tbody>
</table>
Table 6.1 Maximum permissible contamination levels

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Limit (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>25</td>
</tr>
<tr>
<td>Cadmium</td>
<td>50</td>
</tr>
<tr>
<td>Chromium</td>
<td>25</td>
</tr>
<tr>
<td>Copper</td>
<td>40</td>
</tr>
<tr>
<td>PCB</td>
<td>5</td>
</tr>
<tr>
<td>Lead</td>
<td>90</td>
</tr>
<tr>
<td>Mercury</td>
<td>25</td>
</tr>
<tr>
<td>Fluorine</td>
<td>100</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1000</td>
</tr>
<tr>
<td>Creosote</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: Based on UK industry standard and relates to finished board

6.3 Trials using rMDF

Two trials were undertaken using the Topan 1 production line at Glunz’s manufacturing plant in Meppen, Germany. This production line is normally used for day to day board production but is also used by Glunz when they wish to undertake research and development trials on a commercial scale.

It was decided that a 16mm board would be produced with a target average density of 730kg/m³. This is a typical board (commodity product) that is sold to traders who then distribute these boards for end uses such as interior fittings and furniture production.

In trial 1 the rMDF content was 10% by weight of dry fibre. The intention had been to increase this rMDF content but this was not possible due to production issues (see results). In trial 2 stable production was achieved with 10% rMDF content and also with 20% rMDF content (Table 6.2).

Figure 6.2 Glunz’s MDF plant, Meppen, Germany
This work differed significantly from any previous attempts to recycle waste MDF back into board production as the rMDF fibres to be utilised in this trial met the specification of dry wood fibre typically produced by MDF manufacturers prior to forming into boards. The conversion process from logs / chips to dry fibre is continuous and closed therefore scrap MDF would otherwise have to be introduced at the same shredding stage of the process as logs and other wood materials. This leads to excessive dust formation and an undesirable raw material mix which would affect the board’s performance characteristics such as internal bond strength, modulus of rupture (MOR) and modulus of elasticity (MOE).

The biggest challenge to be faced by the introduction of Microrelease fibres was to ensure effective mixing with virgin fibres prior to entry to the mat forming belt. The rMDF fibres did not have resin added to them prior to their incorporation into the manufacturing process, which represented a potential risk to effective board formation. However, it also offers a long-term reward in that total resin additions to the process may be reduced thus effecting significant cost savings.

For the purposes of the trials, additional resin was added to the virgin fibre constituent (12% by dry weight compared to 11% by dry weight for normal manufacture) to maximise the opportunity for effective mixing and to accommodate the recycled fibres, which had not been treated with additional resin prior to incorporation into the mix. It was important to establish stable conditions during trial 2 and there was not enough rMDF or time to change the resin proportions. However, laboratory trials undertaken prior to this work had indicated that the use of rMDF potentially enabled slightly less resin to be added to the mix. The reasons for this are not clearly understood but it was decided that this should be tested on a commercial scale and as a result the resin content was maintained at 12% irrespective of the percentage of rMDF.

In effect the percentage resin content (by dry weight of the total fibre content) for each of the boards was as follows:

<table>
<thead>
<tr>
<th>Trial</th>
<th>Constituents</th>
<th>Approx. resin fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference board</td>
<td>Virgin fibre only (vMDF)</td>
<td>11.0% resin</td>
</tr>
<tr>
<td>10% rMDF</td>
<td>90% vMDF + 10% rMDF</td>
<td>10.8% resin</td>
</tr>
<tr>
<td>20% rMDF</td>
<td>80% vMDF + 20% rMDF</td>
<td>9.6% resin</td>
</tr>
</tbody>
</table>

The vMDF used throughout the trials had 11% resin content

Table 6.2 Boards for testing

<table>
<thead>
<tr>
<th>Approximate manufacturing parameters</th>
<th>Production time (mins.)</th>
<th>Volume produced (m³)</th>
<th>rMDF used (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference board</td>
<td>60</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>10% rMDF board</td>
<td>60</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(trial stopped – not all used)</td>
</tr>
<tr>
<td><strong>Trial 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference board</td>
<td>60</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>10% rMDF board</td>
<td>25</td>
<td>6</td>
<td>0.4</td>
</tr>
<tr>
<td>20% rMDF board</td>
<td>25</td>
<td>6</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Sample boards were assessed for quality and performance using Glunz’s laboratory and were also sent to FIRA and the Biocomposites Centre for analysis.

A sample of the production run from trial 1 was delivered to Eurotek Office Furniture in the UK who kindly agreed to offer their production facilities to assess the acceptability of the boards for furniture manufacturing.
6.4 Results

6.4.1 Manufacturing

**Trial 1**

In terms of the impact on production capacity, the trial was extremely successful. Topan 1 was able to run at full production speeds (15m$^3$ of board per hour) without any adverse effects. 15m$^3$ of boards with 10% rMDF were manufactured. The resultant boards had a feel and consistency that appeared to be very similar to the reference boards produced by the standard method. However, a fairly widespread ‘spotting’ effect was evident upon the surface of the boards produced with the rMDF content. This is shown in figure 6.3.

This was disappointing, as MDF is required to be of a consistent nature aesthetically as well as physically to be considered of the highest commercial quality. It is also likely that sub-optimal performance would be evident in secondary processing operations such as the sawing, routing and surface finishing operations commonly found in furniture manufacture.

The reason for this spotting related to the rMDF fibre specification. An amount of larger (>5mm) MDF particles remained within the rMDF supplied for trial. These particles were not immediately obvious when contained within 60 kg bags of fibre but were sufficient to lead to sub-optimal boards being produced.

At the time of the trials a Microrelease plant had not yet been fully commissioned so existing pilot equipment was modified to meet the needs of the project. This process led to poor fibre separation resulting in the presence of these larger MDF particles. Provision of adequate grading capability will overcome this problem in the future.

It is thought that differentiation within the density profile of the rMDF feedstock led to the larger particles (which were also possibly drier than the virgin fibres) ‘floating’ to the top of the mat on the forming belt. The issue was potentially compounded by exposure to the heat of the press causing a ‘singeing’ of the larger particles thereby giving them a lighter appearance than surrounding fibres. When it became apparent that this effect was unlikely to subside, the decision to terminate the trial was made.
**Trial 2**

The priority for trial 2 was to overcome the spotting problems caused by large particles and clumps of fibres as described for trial 1.

To achieve this a sample of rMDF was sent to Siempelkamp in Germany who outlined a process that utilised a vibrating sieve to remove all particles sized above 3mm. Siempelkamp is one of the world’s leading suppliers of process equipment to the wood based panel board industry and as such was well placed to construct a purpose built rig for this undertaking.

Figure 6.4 shows the set-up that was constructed at Siempelkamp’s R&D headquarters. Approximately two tonnes of rMDF fibre was processed (bags are clearly shown on the left of the photograph) in just over a week. The fibre was loaded onto an automatic conveyor and dropped down into the vibrating sieve. The graded material i.e. those particles which passed through the 3mm sieve were sucked into a bagging machine as shown on the right of the photograph. Approximately fifty per cent of the total volume processed was recovered for use within the second trial at Glunz. The rejected material was also bagged and sent for energy recovery at Glunz’s manufacturing plant (Figure 6.5).

**Figure 6.4** Sieving Process at Siempelkamp, Germany.
In terms of the impact on production capacity, trial 2 was just as successful as the first trial. Topan 1 was able to run at full production speeds without any adverse effects whilst producing boards containing 10% and 20% rMDF. Progress was significant, as the boards exhibited no obvious defects, in fact apart from a slightly lighter appearance the boards were difficult to tell apart from the reference material (Figure 6.6). This slight colour variation was also considered a bonus as this has performance benefits to producers that wish to laminate MDF.

Figure 6.5 Sieved material. Particles of less than 3mm are on the left and above 3mm are on the right.

Figure 6.6 Trial 2: Visual comparison between boards
6.4.2 Product performance

Trial 1

The following table summarises the British / European performance standards for MDF. One of the aims of the commercial scale trials was to manufacture boards with characteristics that meet these criteria.

**Table 6.3** BS EN 622-5: 1997 Fibreboards Specifications Part 5: Requirement for boards for dry process fibreboards (MDF).

<table>
<thead>
<tr>
<th>Requirements for general-purpose boards for use in dry conditions - type MDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board Property</td>
</tr>
<tr>
<td>Density</td>
</tr>
<tr>
<td>Internal Bond (Dry) BSEN 319 (N/mm²)</td>
</tr>
<tr>
<td>Thickness Swelling (24hr immersion)% BSEN 317</td>
</tr>
<tr>
<td>Modulus of Elasticity (MOE) BSEN 310 N/mm²</td>
</tr>
<tr>
<td>Bending Strength (MOR) BSEN 310 N/mm²</td>
</tr>
</tbody>
</table>

**Requirements for load bearing boards for use in dry conditions - type MDF.LA**

| Board Property | BSEN Specification | Requirement - Thickness Range >12mm to 19mm |
| --- |
| Density | Not specified | - |
| Internal Bond (Dry) BSEN 319 (N/mm²) | BSEN 622-5 | 0.60 |
| Thickness Swelling (24hr immersion)% BSEN 317 | BSEN 622-5 | 12 |
| Modulus of Elasticity BSEN 310 N/mm² | BSEN 622-5 | 2500 |
| Bending Strength BSEN 310 N/mm² | BSEN 622-5 | 25 |

Table 6.4 is a summary of the average test results determined by Glunz AG, FIRA International Ltd and the Biocomposites centre.

**Table 6.4** Summary of test results for trial 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>Density</th>
<th>IB</th>
<th>Swelling</th>
<th>MOE</th>
<th>MOR</th>
<th>Formaldehyde content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/m³</td>
<td>N/mm²</td>
<td>%</td>
<td>N/mm²</td>
<td>N/mm²</td>
<td>mg HCHO / 100g</td>
</tr>
<tr>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glunz</td>
<td>720</td>
<td>0.98</td>
<td>6.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FIRA</td>
<td>705</td>
<td>0.80</td>
<td>6.32</td>
<td>2637</td>
<td>29.42</td>
<td></td>
</tr>
<tr>
<td>Biocomposites</td>
<td>726</td>
<td>0.73</td>
<td>3337</td>
<td>32.87</td>
<td>7.5</td>
<td></td>
</tr>
</tbody>
</table>

| 10% rMDF   |         |      |          |      |      |                      |
| Glunz      | 731     | 0.61 | 6.44     | 2711 | 30.56 | 6.6                  |
| FIRA       | 730     | 0.60 | 3609     | 31.93 | 6.9  |                      |
| Biocomposites | 719 | 0.52 |          |      |      |                      |

Note 1: IB is internal bond strength, MOE is modulus of elasticity and MOR is bending strength.

Note 2: Glunz’s internal performance requirements are as follows:
- Density: \( \geq 730 \) kg/m³
- IB: \( \geq 0.9 \) N/mm²
- Swelling: \( \leq 9.0 \)
- Formaldehyde: \( \leq 8.0 \) mg HCHO single value and \( \leq 7.0 \) mg HCHO rolling average value
Table 6.4 outlines the results of assessments of different board properties by Glunz's Quality Control laboratory, FIRA's test laboratory and the Biocomposites Centre at the University of Wales. The three laboratories undertook a series of tests covering physical, mechanical and hygroscopic properties as well as formaldehyde content.

The tests at Glunz were carried out on unconditioned boards immediately after manufacture, whereas the other laboratories conditioned the boards prior to testing. In this respect it would not be unusual for there to be slight differences between the results for conditioned and unconditioned boards.

The addition of rMDF has lowered the average internal bond strength (IB) of the MDF when compared to the control samples. This is evident for all three test laboratories. The IB value for the rMDF board fell below that required of Glunz's internal quality control. In addition, the IB value for the rMDF board tested at Biocomposites was below that required by BS EN 622-5 for load bearing conditions (Table 6.3).

The density of the rMDF panels was within specification as were the swelling, MOR, MOE and formaldehyde content.

As discussed previously it was noted that white spots were evident on the surface of the panels. These white spots appeared to be fibre bundles that had not fully separated in the microwave recycling process and should not be present. These fibre bundles were the most likely cause of the low IB values in the rMDF board.

**Trial 2**

Table 6.5 outlines the results of assessments of different board properties by Glunz's Quality Control laboratory, FIRA's test laboratory and the Biocomposites Centre at the University of Wales. The three laboratories undertook a series of tests covering physical, mechanical and hygroscopic properties as well as formaldehyde content.

Once again the tests at Glunz were carried out on unconditioned boards immediately after manufacture, whereas the other laboratories conditioned the boards prior to testing. In this respect it would not be unusual for there to be slight differences between the results for conditioned and unconditioned boards.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Density kg/m³</th>
<th>IB N/mm²</th>
<th>Swelling %</th>
<th>MOE N/mm²</th>
<th>MOR N/mm²</th>
<th>Formaldehyde content mg HCHO / 100g</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glunz</td>
<td>795</td>
<td>1.36</td>
<td>6.07</td>
<td></td>
<td></td>
<td>7.8</td>
</tr>
<tr>
<td>FIRA</td>
<td>773</td>
<td>1.18</td>
<td>4.77</td>
<td>3350</td>
<td>42.58</td>
<td></td>
</tr>
<tr>
<td>Biocomposites</td>
<td>782</td>
<td>0.88</td>
<td>6.13</td>
<td>2916</td>
<td>34.23</td>
<td></td>
</tr>
<tr>
<td><strong>10% rMDF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glunz</td>
<td>766</td>
<td>1.17</td>
<td>6.16</td>
<td></td>
<td></td>
<td>7.4</td>
</tr>
<tr>
<td>FIRA</td>
<td>784</td>
<td>1.17</td>
<td>4.91</td>
<td>3505</td>
<td>42.94</td>
<td></td>
</tr>
<tr>
<td>Biocomposites</td>
<td>774</td>
<td>0.79</td>
<td>6.34</td>
<td>2929</td>
<td>34.34</td>
<td></td>
</tr>
<tr>
<td><strong>20% rMDF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glunz</td>
<td>758</td>
<td>1.13</td>
<td>6.49</td>
<td></td>
<td></td>
<td>6.9</td>
</tr>
<tr>
<td>FIRA</td>
<td>772</td>
<td>1.04</td>
<td>5.38</td>
<td>3282</td>
<td>38.84</td>
<td></td>
</tr>
<tr>
<td>Biocomposites</td>
<td>763</td>
<td>0.69</td>
<td>7.19</td>
<td>2677</td>
<td>30.56</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1**: IB is internal bond strength, MOE is modulus of elasticity and MOR is bending strength

**Note 2**: Glunz's internal performance requirements are as follows:
- Density: 730 ± 15kg/m³
- IB: ≥ 0.9N/mm²
- Swelling: ≤ 9.0%
- Formaldehyde: ≤ 8.0mg HCHO single value and ≤ 7.0mg HCHO rolling average value

The reference boards exhibited slightly higher average IB values compared with the 10% and 20% rMDF boards. This could be attributable to the slightly higher average densities of the reference boards in comparison with the
10% and 20% rMDF boards, although the differences are large enough to consider that other, unknown factors may be coming in to play.

The other strength test results (MOE and MOR) followed a slightly different pattern in that the 10% rMDF values for boards tested at FIRA were fractionally larger than those for the other boards. This pattern was not reflected in the Biocomposites results where the 10% rMDF boards exhibited slightly lower values than the reference boards. The MOE and MOR values for the 20% boards were the lowest. Once again the results from the Biocomposites laboratory were lower than those from FIRA.

The thickness swelling values of the boards are more or less on the same level, with the 20% rMDF board being slightly higher than the other boards. Once again, the thickness swell values from the Biocomposites laboratory were different to the other labs and comparatively large.

The formaldehyde contents, ascertained immediately post manufacture, were all similar, although there was a slight reduction in the 10% rMDF board and little more of a reduction in the 20% rMDF board. All of these values fell within the requirements for Glunz’s internal quality control.

The higher average density of the boards (compared with those in Trial 1) is due to the fact that Trial 2 was time-phased after several days’ production stop of the Topan 1 line. When starting MDF production after a production stop the average density has to be adjusted within the first hours of production. Nevertheless, the discrepancy of values is not substantial and the densities of the boards produced for Trial 2 are more or less the same.

Despite the variation in test results between Biocomposites and the other two laboratories, all of the samples (reference boards, 10% and 20% rMDF) that were tested in accordance with BS EN 622 Part 5 met the requirements of this standard for load bearing boards for use in dry conditions (type MDF.LA) and for general purpose boards for use in dry conditions (type MDF).

In addition, the majority of test results fulfilled the internal quality specifications of Glunz Meppen. The low IB tests from the Biocomposites laboratory (for all 3 board types) were lower than Glunz would require. In addition, some density values were slightly outside these limits (due to having to restart the line after production down time), and are higher than those experienced in trial 1.

It has not been possible to ascertain why the results from the Biocomposites laboratory were consistently different to those produced at FIRA and Glunz. Some of this could be attributable to the samples tested (for example their respective locations from within the manufactured boards). Average density values for the Biocomposites samples are, in most cases, lower than those for the FIRA and Glunz samples which will also have some effect on board properties. However, it is likely that other unknown factors have come into play.

6.4.3 User trials

The appearance of the boards produced during trial 1 was not perfect. However, the test results were sufficiently good to warrant a user assessment being undertaken. A number of boards were sent to an office furniture manufacturer in the United Kingdom (Eurotek Office Furniture) for a qualitative evaluation of how the material performed in a production environment. The majority of production at this plant is undertaken using MFC (melamine faced chipboard) although certain ranges in the company’s portfolio are based on MDF.

Two pedestal products and some desk tops were manufactured with each stage of the process being evaluated for perceived quality and ease of processing. The individual machine operators provided their opinions as to how the rMDF boards ‘behaved’ in comparison to the reference boards. A production manager was dedicated to the exercise to provide a more strategic quality control perspective.

The plan of action involved a systematic machining approach following the same route through the factory as a commercial piece of furniture. The only difference being that the trial pieces would be fast tracked and produced in a few hours. Each and every machining process would be undertaken until such point as a failure occurred or an unacceptable (non-saleable) result was witnessed. All other process parameters remained the same as for normal manufacturing conditions e.g. tolling used, staff employed and complementary materials specified.
**Sawing**

The majority of the company’s machining processes utilise automated CNC (Computer Numeric Control) equipment. Sawing is conducted on a Schelling FM CNC panel saw. The machine is not able to adapt to suit feedstock variations without operator input i.e. the speed would remain constant even through variations board density and extraction would remain consistent even if dust levels fluctuated. As such, with empirical data absent, operator perception offered the most reliable gauge of rMDF board performance. The rMDF board performed in much the same way as standard boards throughout the sawing operation. No excessive dust was witnessed and edges were cut cleanly and efficiently. This was pleasing, as the white spots visible in the rMDF boards had generated concerns over their likelihood to chip and fragment during cutting.

**Routing**

Routing is a process that enables furniture manufacturers to add design elements to board based furniture. Edges can be shaped and patterns generated on surfaces of MDF. Again, this piece of machinery is CNC based with boards held in place on an air bed through suction whilst being processed. No processing issues were noted during this phase of production.

**Edge banding (curved and straight)**

At this stage of the process raw boards are edged to provide a smooth and aesthetically pleasing finish. There were some concerns that this stage of the process would be problematic as the company usually deals with 15mm thick MDF when the rMDF samples boards were 16mm. However, both curved and straight edge banding proceeded without major problems. A slight ridge between the edge and the flat surface was noted by the production team but was considered of saleable quality. A fairly simple set up change on the equipment (optimisation of the trimmer heads) could have been made to eradicate this anomaly should a commercial scenario dictate it necessary.

Interestingly, the production team proffered the opinion that the rMDF board was exhibiting a better overall quality of finish than the reference boards by the end of this stage of the production process. Adhesion to the edging material (ABS - Acrylonitrile Butadiene Styrene) was considered stronger and the feared chipping and fragmentation around edges of boards (due to the spots in the board) had not happened.

**Drilling and fixings trials**

A Biesse Skipper 100 boring machine was used to generate a pattern of holes and profiles in the surface of the pedestal tops. A selection of standard office furniture fittings was then inserted on the assembly line. All fixings appeared to perform in a manner that would meet internal quality control. No issues were noted by the drill operator with the rMDF boards performing in much the same way as standard MDF.

Although the spotting of the board had not adversely affected the performance of the product through the production process, it was decided that applying any form of surface finish would be inappropriate. This was because production experience led the company to believe that the spotted surfaces (essentially clumps of unresinated fibre) of the boards would not lend themselves readily to the application of a professional quality finish. The clumps could be shown to flake away from the surface of the board when scratched.

The company remarked on how positive they considered the results to be. Environmental performance is a key element of its marketing and a method that the company uses to distinguish itself from competitors both in the UK and overseas. In a sector that is so price sensitive, cost of raw materials will always be important but the company would be very interested in trialling rMDF boards should they become commercially available.

User trials carried out on boards produced during trial 1 are illustrated in Figure 6.7. There were no problems for the furniture manufacturer when using the lower quality boards from trial 1. For this reason user trials were not considered necessary for the better quality trial 2 boards.
6.5 Conclusions

Production trials, performance characteristics and end user assessments all indicate that the introduction of rMDF into board manufacture will produce a commercially viable product. It is clear that substitution of at least 20% of virgin fibre with rMDF has the potential of producing boards of acceptable quality.

There is also potential for using less resin when using a proportion of rMDF fibres and the extent of this saving offers scope for further investigation at a production level.
### 7.0 Case study Vannplastic Ltd. - Wood Plastic Composites (WPCs)

#### 7.1 The process

Trials were run on the production of panels used in decking with the fibres from the Microrelease process replacing the wood flour which is used to produce this composite.

**Figure 7.1** Schematic of a wood plastic composite production process

The manufacturing process for WPC's is simple by comparison to that for MDF and can be summarised as follows

**Raw material supply**

This stage consists of supply of raw materials to the production plant and also the feeding of these materials into the process.

The raw materials considered in this stage are the plastic and wood component only. The plastic is normally recycled HDPE although fractions of other materials may be present in actual products due to mixing of plastic waste streams to intentionally alter the properties of the end product. The HDPE comes from sources within the UK.

The wood flour is sourced from Germany and is a by-product from a sawmill processing virgin wood. It is sieved and graded to ensure that the particle sizes meet the specification requirements of Vannplastic (see 7.2).

After receipt, the raw materials are placed in storage hoppers and fed into the process using an automated spiral loader. The mix ratio is approximately 65 of wood flour to 35 plastic polymer by dry weight. Additives comprise approximately 3% of the total dry weight.

**Dry blend mixing**

The plastic and wood flour are fed into the dry blend mixer along with the additive package. Additives include pigment, which is typically oxide based in an LDPE carrier, and UV inhibitors, which include a Hindered Amine Light Stabiliser (HALS) system.

The mixed components are then dropped into the extruder hopper for feeding into the next stage in the process.

**Extrusion**

The mixed feedstock is fed into a twin screw extruder that heats, mixes and melts the material. Half way through this mixing process, all volatiles (water mostly) are removed from the mix by means of a vacuum. The fully dispersed / homogenous mix is then pumped / extruded through a die into the shape required. A number of components in the extruder are heated to about 200°C to ensure full melt of the plastic component and allow thorough mixing.
**Cooling**
The panels are fed from the extruder into a cooling trough, which is water cooled to about 14°C. On removal the panels are allowed to dry without external heat. The water used to cool the panels is removed periodically for replacement and the used water disposed of to the local drainage system.

**Sawing and finishing**
Once cooled, the panels are sawn to the required dimensions and finished (loose debris brushed away) prior to packing and distribution.

**Regrinding during the trials**
In comparison to wood dust rMDF has different flow properties and compacts less easily. This had an impact on the throughput of the fibres into the production process that resulted in an uneven feed rate.

To overcome this issue an additional process step was introduced involving the regrinding of the boards after cooling and sawing so that they could be passed through the process a second time. This technique was employed to allow the trial to continue but would not be recommended for a commercial operation. It helped to achieve satisfactory dispersion of the fibre. The granulated material (approximately 8mm x 8mm) was re-fed into the process line (without the need for additional mixing) and extruded a second time.

In the raw material supply stage additional impacts need to be considered including the pelletisation of the wood fibre to increase the bulk density and feed rate requirements of the feedstock and to aid the mixing and dispersion of the fibre in a similar free-flowing form as the wood flour currently used.

It is anticipated that this step will not be needed if a compactor is installed prior to the extrusion process.

Figure 7.1 shows the fundamental elements involved in the manufacture of wood plastic composites. There is considerable flexibility available in the methods used to produce WPCs in terms of the type of extrusion employed and the potential for utilising pre-compounded pellets containing all necessary raw materials.

### 7.2 Fibre specification

Vannplastic’s products are manufactured from a mix of wood fibre and plastic materials (mainly rHDPE).

Sources of wood fibre include forestry residues and other post industrial waste streams (all softwood).

Vannplastic does not have a single technical specification for its wood fibre, preferring instead to evaluate each potential source on its merits.

The following are the parameters that form the basic requirements for the fibre specification:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination</td>
<td>Free from surface finishes (laminates, papers, foils etc), metals (ferrous and non-ferrous) and grit.</td>
</tr>
<tr>
<td>Moisture</td>
<td>Less than 8%*</td>
</tr>
<tr>
<td>Fibre Dimensions</td>
<td>Shive content less than 10%.</td>
</tr>
<tr>
<td>Fibre size**</td>
<td>200 – 500microns</td>
</tr>
<tr>
<td>Bulk density</td>
<td>120 – 220grams / litre</td>
</tr>
<tr>
<td>Special</td>
<td>Must be free flowing for good mixing</td>
</tr>
<tr>
<td>Input Method</td>
<td>Added via hopper and batch mixing vessel – fibre to be supplied in 25kg bags</td>
</tr>
</tbody>
</table>

* Moisture content (MC) varies according to supplier, with material specifications currently ranging from 8% - 12% MC. The extrusion process runs most efficiently with wood MC below 8%. Therefore any materials introduced into the process above that MC require extra processing to remove the excess moisture. Vannplastic has expressed a wish for the rMDF to be supplied at or below this 8% MC threshold.

** Fibre size can vary according to the end use application. It is not an exact science in terms of Vannplastic’s operations. At present a typical feedstock, as used for the decking application, would have a particle size range between 200microns and 500microns. rMDF would offer longer fibres which it is hoped will offer a greater strength to weight ratio for products in service. rMDF will provide manufacturing flexibility for Vannplastic.
7.3 Trials using rMDF

Three WPC trials were carried out. In all of the trials reference samples were made and then the rMDF was added as a total replacement for wood flour in the ratio of 65% rMDF to 35% HDPE. Allowing for moisture content and flow additives (lubricants), the final proportion of rMDF embedded within the manufactured product was approximately 60% by volume.

Production problems were experienced during trial 1 because of the low bulk density of the rMDF when supplied in its loosest, ‘fluffiest’ form (43g/l). This caused some feeding problems in the first trial resulting in poor mixing with the plastic and therefore sub-optimal dispersion within the body of the final extruded product. It was clear that to overcome the feeding and dispersion issues, some additional processing would be required to optimise the form of the rMDF when presented to the extrusion line.

The method chosen for trial 2 was pelletisation of the rMDF. The bulk density of the material produced for trial 2 was approximately 120g/l. The results from trial 2 were encouraging with significant visual and process management improvements noted. There was better dispersion of the rMDF within the profile of the board i.e. fewer clumps and less penetration of the surface of the board by clumps which resulted in a smoother looking finish to the products. The process improvements included slightly faster line speeds, easier feed due to pellets and better materials handling as there was less loose fibre in the vicinity.

Dispersion issues, however, remained and a second rMDF product was produced in two passes whereby boards produced on the first pass were re-ground and the granulate was re-introduced into the extruder prior to the second pass.

An alternative fibre processing method was employed for trial three. It was anticipated that the use of a milling technique, in this case hammer milling, would provide an appropriate balance between bulk density and maintenance of fibre length (Figure 7.2). The properties of the rMDF offer a potential improvement over the wood flour extruded products in that WPCs with high wood content (≥ 60%) could be produced which would open up the possibility of their use in structural applications.

\[\text{Figure 7.2} \quad \text{Hammer milled fibres as used in the third trial at Vannplastic} \]

In trial 3 a total of 18kg of rMDF was fed into the extrusion process in order to produce a run of WPC decking boards. The total weight of the raw material mix for the WPC process was approximately 45kg. Vannplastic’s standard decking board weighs 3.85kg per metre, thus a little over 11.5metres of board were produced. These boards utilised the same profile (die) as for trials one and two so that direct visual comparison could be made to the original reference boards.
The product mix was altered for this trial on the advice of Vannplastic. All efforts were made to attempt to overcome some of the dispersion and extrusion issues previously experienced. In addition to the rMDF being introduced in a hammer milled form, a different grade of HDPE was utilised.

It was felt that by using a higher melt flow polymer the dispersion of the fibres would improve. For this reason an HDPE polymer used for milk bottle production was incorporated into the mix. This polymer has a much higher MFI (melt flow index) than the other grades used by Vannplastic and has a different physical form (a thin flake). As a flake it has a much higher surface area to mass ratio resulting in faster melting. This gave the best possible chance for good dispersion bearing in mind machine / equipment limitations.

The extruder was operated with the feed and mixing zones at 220°C to drive off the moisture and improve the melt homogeneity, and a standard, reducing temperature profile was used along the barrel to ensure adequate back pressure at the metering zone exit point.

### 7.4 Results

#### 7.4.1 Manufacturing

The manufacturing problems experienced with trials 1 and 2 are detailed in the previous section of this report and form part of the argument for making production changes for the third and final trial.

Slow production speeds and feed problems hampered the manufacture, although Vannplastic plans to remedy this when it relocates. With the correct up-stream equipment (crammer, fibre heater and agglomerator) there is no foreseeable reason why line speeds for products based upon rMDF feedstock should not be comparable to those with standard wood flour.

In the final trial the speed of the production line (~1 m per min) was maintained during the change of feedstock (wood flour to rMDF). In a similar fashion to that of trial two, the initial section of rMDF decking board demonstrated good visual characteristics. However, the surface of the extruded board once again began to ‘break up’ after a few minutes. This was thought to be related to lubricant dosing level and possibly processing characteristics. It is quite normal for Vannplastic to experience the same issues day to day in normal production and as such the company felt confident that with more material and more processing time, they would be able to overcome these issues quite easily.

To ensure maximum production from the small amount of material to hand, it was decided to reduce the line speed to a much more manageable 0.5m per min which then allowed the board to form correctly in the die.

During the trial it was not possible to maintain a vacuum. This was due to the rMDF feedstock’s physical characteristics. The vacuum chamber removes the air from the fibre / plastic feedstock as it is mixed and before introduction to the die. Due to the bulk density of the rMDF being lower than that of wood flour the ‘draw’ of the vacuum was too great and fibre was being pulled through the chamber. A ‘seal’ was thus difficult to obtain.

The product produced after the loss of the vacuum was consistent but of a poorer visual quality than that experienced at the beginning of the trial. Visually, it also appeared to be of lower quality than that produced during trial 2.

A decision was made, therefore, to re-grind the boards and re-introduce the granulate into the extruder. The extruded material was sawn and processed through an on-site plastics granulator. This does not represent the ideal methodology for manufacture for the reasons previously outlined in the report from trial 2. However, it did offer a greater chance of producing a high quality product during this particular trial.

The process line was slowed to approximately 0.3m per min during the second pass, roughly one third of the normal operating speed. A distinct improvement in the aesthetic properties of the boards was noted whilst running the plant at slower speeds.
The output of boards from the three trials is illustrated in Figure 7.3.

Figure 7.3 comparison of WPC decking boards from the three Vannplastic trials

The figure shows the output of the 3 trials as detailed below.

- **Top board (unlabelled)**: Trial 1 with the straight addition of fibre into the production process.
- **T2A**: Trial 2 using rMDF pellets
- **T2B**: Trial 2 using rMDF pellets plus a re-grind into the production process
- **T3**: Trial 3 using hammer milled fibre and regrinding to improve the fibre distribution

7.4.2 Product performance

Samples were taken for laboratory assessment from all three trials.

Vannplastic’s decking performance criteria are very much customer led as they produce a variety of different products specifically for each customer, with acceptable quality varying between customers. A subjective assessment of quality is carried out by monitoring the feedstock and production parameters and making a visual check on the product as it is manufactured.

However, the raw materials (being recycled and natural) can contribute to some variations in quality which can be compensated for to a certain extent by adjusting processing parameters.

Strength tends not to be an issue as the decking is over engineered and its density doesn’t vary much.
This made it difficult to select appropriate tests to enable valid comparisons between the wood flour and rMDF products because, as yet, there are no actual standard test methods for WPC.

To enable an objective comparison, a series of appropriate product tests were selected based on European standards and FIRA test methods developed internally as industrial standards.

The tests carried out were as follows:

- Modulus of elasticity (MOE) based on procedures in BS EN 310
- Bending strength (MOR) based on procedures in BS EN 310
- Thickness swelling 7day cold water immersion FIRA test method
- Screw holding retention FIRA test method

Table 7.1 summarises the average test results for the three different trials and compares these with the reference board (control sample) that was manufactured using wood flour at the start of trial 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Thickness swelling %</th>
<th>Water absorption %</th>
<th>MOE N/mm²</th>
<th>MOR N/mm²</th>
<th>Screw holding N</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>0.5</td>
<td>1.46</td>
<td>2362</td>
<td>23.7</td>
<td>4263</td>
</tr>
<tr>
<td>T2A</td>
<td>1.22</td>
<td>3.93</td>
<td>1169</td>
<td>14.52</td>
<td>2750</td>
</tr>
<tr>
<td>T2B</td>
<td>0.73</td>
<td>2.86</td>
<td>1307</td>
<td>13.14</td>
<td>2679</td>
</tr>
<tr>
<td>T3</td>
<td>0.38</td>
<td>1.57</td>
<td>1711</td>
<td>16.31</td>
<td>3708</td>
</tr>
<tr>
<td>Control</td>
<td>0.53</td>
<td>1.08</td>
<td>3122</td>
<td>43.5</td>
<td>5725</td>
</tr>
</tbody>
</table>

The samples from trial 1 (T1) exhibited the closest properties to those of the control samples, with slightly reduced swelling characteristics. However, strength properties were about 25% to 50% lower for this board than for the control.

The trial 2 boards exhibited a greater degree of swelling and water absorption and strength properties were generally 50% to 70% lower than for the control boards, although the sample that contained reground product (T2B) performed slightly better in thickness swelling, water absorption and MOE than the other trial 2 sample (T2A). The reground product was, however, slightly weaker in terms of MOR and screw holding.

The trial 3 samples (T3) represented a significant improvement over the trial 2 samples yet their performance characteristics failed to meet those of the samples taken for trial 1 or the control samples. These samples did, however, exhibit the lowest thickness swelling of all samples tested.

High magnification electron micrographs confirm this potential source of weakness and clearly show the different surface appearances of a sample containing rMDF fibre bundles. Figure 7.4 illustrates clumps of fibres whereas, on the same sample, there are areas where single fibres have separated out (Figure 7.5). Whilst this shows that there are potential manufacturing problems to overcome, it also demonstrates that it should be possible to produce a much more homogenous, and potentially stronger, product.
Some of the reductions in strength properties can be accounted for because the densities of the rMDF decking samples were 7 - 8% lower than the control. However, the results clearly demonstrate that the use of rMDF appears to have an adverse effect on the quality of production from the specific WPC process under investigation and additional “tweaking” of the processing parameters will be required to improve the performance of the rMDF product.
### 7.4.3 End use

It was not possible to undertake end user trials because much of the time was spent trying to develop the production line to accommodate rMDF. However, after trial 1, control (wood flour) and rMDF samples were subjected to abrasion testing.

Three sub-samples measuring 100mm x 100mm were cut from each specimen in such a manner as to ensure that the juxtaposition of grooves relative to each sub-sample was consistent in each. Each sub-sample was pre-conditioned for approximately two weeks in an environment of 20°C @ 65% relative humidity (rh) prior to testing.

Abrasion testing was performed with a rotary (Taber) abrader fitted with pre-conditioned, self-adhesive sandpaper strips (Taber category S-42) calibrated against a standard aluminium test plate (Taber category S-34) under a weight of 1kg with a vacuum extractor operating at maximum capacity.

The weight of each sub-sample was recorded immediately before being subjected to a total of 2000 abrasion cycles. After every 500 cycles weight loss was recorded in order to monitor linearity and the old sandpaper strips discarded and replaced with new ones. Weight loss charts were produced for each individual sub-sample and amalgamated to provide an indication of average weight loss for an rMDF product and a control product (wood flour) (Figure 7.6).

**Figure 7.6** Abrasion testing of WPC decking showing mean weight loss of samples

Once again the performance of the rMDF product was significantly worse than the wood flour product although there is no industry standard to put these results into context.

### 7.5 Conclusions

Although a commercial quality decking board was not produced in these trials, the achievements have been sufficient enough to convince Vannplastic that further experimentation and testing is warranted. They are confident of making the manufacturing and product quality improvements necessary once they have moved site and integrated new equipment to resolve the feeding issue. This would enable commercial quality decking to be made with rMDF in one pass.
8.0 Case study Excel Industries - Insulation fibres and oil spill absorbers

8.1 The process

Excel manufactures a range of fibre products which utilise waste newsprint in their manufacture, diverting it from other waste disposal routes. The competition in the market for recycled fibres means it is sensible to ensure that a diverse range of suitable sources is investigated and available.

Two potential applications for the use of rMDF were initially examined (thermal insulation products and oil absorbents) and, whilst positive results were obtained for both applications, the most obvious and immediate opportunity for rMDF would appear to be within the thermal insulation market (Section 8.4).

The process under consideration for the production of the thermal insulation product (Warmcel) is described below and illustrated in Figure 8.1. Warmcel is a 'loose fill' thermal insulating material produced using sustainable sources of recycled paper and inorganic flame retardants. The product is used in lofts and timber frame wall, roof and floor panels.

Figure 8.1 Excel process for production of Warmcel

Import of raw materials

The raw materials required in Warmcel production are imported into the production facility. Waste newsprint comprises upwards of 90% by weight of the end product. This material may be diverted from closed loop recycling but also from landfill or incineration. Additional raw materials imported are boric acid, magnesium sulphate and aluminium hydroxide.

Newsprint shredding and sorting

The newsprint is initially shredded to aid in the removal of contaminants, such as metal, in the form of staples.

Milling process

After shredding the paper is further shredded first by coarse milling and then fine milling to reduce the particle size. Chemical additives assist in the breakdown of the paper to fibrous material.

rMDF addition

The rMDF, in the assessments which contain a proportion of recycled MDF fibre, was added to the Warmcel product prior to packaging. As the process described in Figure 8.1 is designed to break paper down to fibrous material, recycled fibre is a viable replacement for a proportion of Warmcel while retaining the properties required for its application as an insulator.

Initial trials were carried out using rMDF and recycled paper in a 50:50 ratio. This mix was selected as previous in-house trials conducted by Excel have revealed that rMDF has too high a density and thermal conductivity to be...
considered as a viable insulation product on its own. Also, the paper fibre is more hydrophilic than rMDF, so this lends itself to better applicability for the damp spray application technique.

**Packaging and distribution**
The product is then packaged (mixed with rMDF) and delivered to the customer.

### 8.2 Trials using rMDF

A series of trials and analyses were undertaken with a view to establishing the potential for utilising rMDF as either a complementary or replacement raw material within a selection of industrial application markets that Excel currently services with its recycled paper fibre.

Thermal insulation products and oil absorbents offer potential for the use of rMDF, although, subsequent to the initial trials, there was more focus on the thermal insulation product as it offered greater opportunity for industrial exploitation. This is because rMDF has limited use in ‘oil in water’ spillages, as it tends to be too hydrophilic, even with the presence of resins.

Plant trials were performed, which comprised the following actions:

- Installation of an ‘in-line’ mixer in order to sufficiently mix the rMDF fibre with the paper fibres.
- Blending recovered rMDF fibres
- Testing the material

The introduction / mixing of rMDF fibres takes place at the end of Excel’s fibre manufacturing process. The main challenge was to ensure that a good mix of the rMDF and recycled paper fibres was achieved. A ‘good mix’ is one which has no detrimental effect on the performance and application properties of Warmcel (e.g. thermal conductivity, settlement, density and the ability to use the damp spray application technique). Another important parameter is dust levels in application.

To do this an in-line mixer was hired from JR Boone Engineering (Figure 8.2). This mixer had a 200l batch capacity with a maximum r.m.p. of 101Hz.

**Figure 8.2 In-line fibre mixer**

rMDF fibre was mixed with paper fibre, in a 50:50 blend, at a rate of 101Hz, for 1 minute. Mixing speeds in-excess of 2000kg/hour would be achievable using the development scale mixer.
The paper feed stock used was Excel’s grade XL 10,000

8.3 Results

8.3.1 Manufacturing

The addition of rMDF at the end of the fibre production process means that, in effect, there are few manufacturing challenges. The main aim was to achieve a uniform, homogenous mix of the paper fibres and the longer, less free flowing rMDF fibres. This was achieved on an experimental level using the hired in-line mixer. For continuous production, it will be necessary to incorporate effective mixing technology within the existing Excel plant.

8.3.2 Product performance - Insulation

**Thermal Conductivity**

This is the key parameter for insulation products. The thermal conductivity, expressed in Watts per metre Kelvin (W/mK), gives the rate of heat flow through a material. The lower the thermal conductivity value, the better the result. Samples of material were dried at 70°C to a constant mass and then placed into a sample holder and measured using a heat flow meter.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Thermal Conductivity (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmcel® Insulation from fibreised newsprint</td>
<td>0.0378</td>
</tr>
<tr>
<td></td>
<td>0.0382</td>
</tr>
<tr>
<td></td>
<td>0.0376</td>
</tr>
<tr>
<td></td>
<td>Average = 0.0379</td>
</tr>
<tr>
<td>50:50, Warmcel Insulation / MDF Fibre mix</td>
<td>0.0393</td>
</tr>
<tr>
<td></td>
<td>0.0401</td>
</tr>
<tr>
<td></td>
<td>0.0396</td>
</tr>
<tr>
<td></td>
<td>Average = 0.0397</td>
</tr>
</tbody>
</table>

The introduction of the rMDF fibres into the Warmcel gives rise to a slight increase in thermal conductivity (Table 8.1) which represents a drop in performance compared to the standard product. It may be possible to improve the performance of the mixed product by using a broader range of particle sizes.

**Insulation Settlement**

Loose fill cellulose fibre insulation (Warmcel) can settle over a period of time when exposed to load or shock/vibration. For this test a sample of the trialled Warmcel/rMDF fibre mixture was blown into a cage. The cage was then subjected to a series of mechanical shocks. The depth of the blown fibre is measured before and after shock treatment. This test was performed on a standard Warmcel® product (made from re-cycled paper) and also on a 50:50, Warmcel: rMDF fibre blend.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Settlement Under 200g (mm displacement from 330mm)</th>
<th>Settlement Under Mechanical Shock (mm)</th>
<th>% Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmcel Insulation from fibreised newsprint</td>
<td>320</td>
<td>60</td>
<td>23.10</td>
</tr>
<tr>
<td>50:50, Warmcel Insulation / rMDF Fibre mix</td>
<td>315</td>
<td>50</td>
<td>18.88</td>
</tr>
</tbody>
</table>

Table 8.2 illustrates that there is greater resistance to settlement under load and mechanical shock for the Warmcel / rMDF mix. This is considered to represent a significant improvement in performance over the standard product and offers economic benefits both to the manufacturer and the customer (see section on economic benefits).
The reduced (improved) settlement is possibly due to the fact that the rMDF fibre is able to bind and hold firm the paper fibre, reducing its ability to move freely. This imparts greater stability to the fibre mass, giving resistance to compaction. This has the effect of reducing the density, and increasing the resistance to compaction imparted by mechanical shock.

In order that a true working representation of the rMDF/paper fibre mixes can be evaluated, a long term settlement experiment is currently ongoing at Excel’s research facility. Numerous settlement trials are being conducted over a long term period (12months) to deduce true settlement over time. This will give an accurate working representation of how the rMDF / paper fibre composite behaves when exposed to climatic humidity over a time period.

**Shock performance of structural insulated panels (SIPs)**

The improvement in the settlement under shock performance (Table 8.1) for an insulation material is a very important attribute. This is particularly important when factory finishing structural insulated panels (SIPs) which are increasingly used in Modern Methods of Construction (MMC). In the MMC process the timber wall, roof and floor panels are insulated in the factory. The insulated panels are then taken to the construction site and erected. During this process the panels are subjected to large amounts of shock and attrition, which in turn, potentially leads to settlement of the insulation occurring in the panel. This settlement can result in a loss of performance that will have an effect on the buildings energy rating.

Given the potential to reduce settlement under mechanical shock a series of experiments were designed to measure the resistance to shock of a mixture of rMDF and paper for MMC applications.

In order to estimate the potential for settlement in a factory insulation filled panel the insulated panels were tested in a special shock rig. The test rig for this analysis was developed by TRADA Technology Ltd and is used to measure full scale panels. The rig is one of a kind in the UK and was designed specifically for evaluation of SIP products.

The insulated panels were mounted onto the rig that then vibrated at a set frequency for a period of time to simulate the effects of transport to site during the MMC process (e.g. on the back of a lorry or winching into position on site), see Figure 8.3.

During the test the panel was subjected to a series of ten shock treatments. After each set of ten shock treatments the panel was assessed for any settlement. This was repeated for 200 shocks or until a settlement of >5mm occurred.

A standard Warmcel panel was compared with one containing 25% MDF fibre and 75% Warmcel

**Figure 8.3 Insulated SIP on the shock test rig**

Similar settlement results were obtained from both formulations and a slight improvement in the 25% MDF fibre was observed. In terms of absolute results (i.e. number of drops before settlement occurs) it is anticipated that both formulations would be able to withstand any shock during the overall MMC process (i.e. transport from the factory to site and the construction process) and thus both are appropriate for factory filled panels.
Insulation products with improved settlement performance could therefore be developed by blending rMDF with the paper fibres. Following this work the company will also undertake a test with a construction company to further trial the idea in a timber frame application using MMC.

Open blown density
The applied density for loose fill insulation is important when considering installation cost. If the density is too high then more material is required per square meter of the loft. In this test, bales of material were added into the hopper of a fibre blowing machine. The product was blown into a box, with dimensions 1m x 1m x 100mm high. The product was ‘levelled off’ and then weighed. The blown insulation was then weighed and the density calculated and expressed in the units kg/m³.

Table 8.3 Open blown density test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Open blown density (Krendl 250 Blower at 100mm thickness) kg/ m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmcel Insulation from fiberised newsprint</td>
<td>25.8, 24.6, 25.2</td>
</tr>
<tr>
<td></td>
<td>Average = 25.2</td>
</tr>
<tr>
<td>50:50, Warmcel® Insulation / MDF Fibre mix</td>
<td>29.3, 28.6, 29.5</td>
</tr>
<tr>
<td></td>
<td>Average = 29.1</td>
</tr>
</tbody>
</table>

Table 8.3 illustrates that the addition of the rMDF fibre to the Warmcel gives rise to a significant increase in open blown density. However, the density achieved from the 50:50 Warmcel/rMDF fibre mixture just about falls within the competitive range. The higher density is probably due to the relatively high degree of fibre coarseness.

8.3.3 Product performance – Oil spill absorber
The following tests were carried out to assess product performance:

Oil absorption
A weighed amount of fibre was added to a wire mesh cage and then immersed in oil. The cage was removed and the oil was allowed to seep through the mesh until all of the excess oil had exited the cage (no more oil drips occur). The fibre was then weighed in order to calculate the amount of oil absorbed by the fibre.

Table 8.4 Oil absorption test results

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Oil absorption (litres/ kg fibre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper Fibre</td>
<td>16.6</td>
</tr>
<tr>
<td>rMDF Fibre</td>
<td>23.5</td>
</tr>
<tr>
<td>50:50 Paper Fibre : rMDF Fibre</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Table 8.4 shows that the rMDF fibre has the best oil absorption properties. The mixing of paper fibre with the rMDF fibre does not improve the oil absorbency compared with that seen from paper fibre alone. It might have been expected that the 50:50 mix would show absorption properties between those of the paper only and rMDF only samples. However, the mix demonstrated the lowest absorption properties and the reasons for this, at this stage, are unknown.

rMDF fibre has a greater surface area than milled paper fibre, therefore it is able to bind and hold the fibre mass to a greater degree than milled paper. The increased surface area of the fibre mass also imparts greater absorption capabilities to the fibre mass, since there are more active sites available to the absorption of oil into the fibre surface. This explains the enhanced oil absorption properties of the rMDF fibre, compared to those of the paper fibre.
**Water absorption**

A weighed amount of fibre was added to a wire mesh cage and then immersed in water. The cage was removed and the water was allowed to seep through the mesh until all of the excess water exited the cage (no more water drips occur). The fibre was then weighed in order to calculate the amount of water absorbed by the fibre.

<table>
<thead>
<tr>
<th>Table 8.5 Water absorption test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Paper Fibre</td>
</tr>
<tr>
<td>rMDF Fibre</td>
</tr>
<tr>
<td>50:50 Paper Fibre</td>
</tr>
</tbody>
</table>

The best results were obtained from the paper fibre (Table 8.5). Given that the rMDF fibre is coated with resinous material this result is not surprising. Again, it must be noted however that in all cases high levels of water absorbency were observed compared to those observed with many commercially available spillage absorbent materials. As for oil absorbency it might have been expected that the 50:50 mix would show water absorption properties between those of the paper only and rMDF only samples. However, once again the mix demonstrated the lowest water absorption properties and the reasons for this, at this stage, are unknown.

### 8.4 Conclusions

The trials conclude that a commercially acceptable insulation product could potentially be produced using rMDF combined with paper fibre. The key issues are as follows:

- The product containing rMDF exhibited a 5% increase in thermal conductivity. This has implications in the construction industry as target elemental U-values could then only be achieved by using 5% thicker wall or floor elements.
- Cost is also a potential issue. Recycled paper has a cyclic cost. Clean sorted newsprint currently varies between £75-120/tonne. Continuous use of rMDF will necessitate a competitive fibre cost.
- User acceptance is also important. Questions that still need to be answered include the adhesion of the fibres when using the damp spray and potential dust levels when using the product in loft spaces.

The use of rMDF fibres (either on their own or mixed with paper fibres) for cleaning up oil spillages had some positive attributes. Whilst the ability to absorb oil is greater than that of recycled paper the rMDF products also have a tendency to absorb much more water than existing products on the market which is considered to be disadvantageous.

### 9.0 Economic benefits of using recycled MDF fibre

#### 9.1 Introduction

The following guidelines were used for the cost benefit analyses

Current manufacture

- Costs of manufacture using existing techniques
- Production volumes
- Cost trends (predicted for raw materials)
- Cost of waste disposal and or incineration
- Selling price
The cost implications and potential benefits of using rMDF

- Costs of manufacture using rMDF (full or partial substitution for existing raw materials)
- Cost of making / buying rMDF fibre
- Cost of new equipment
- Installation costs of new equipment (including training of staff, downtime and loss of production)
- Reduction in equipment and associated cost savings (maintenance, less staff)
- Effects on volume of production
- Effects on other processing parameters (e.g. less binder needed)
- Power consumption considerations associated with equipment changes
- Selling price of rMDF product (higher or lower?)

The price of rMDF fibre will be a function of manufacturing costs and the financial considerations of the rMDF supplier. The cost benefit analyses within the report incorporate a range of potential rMDF fibre prices (from £80 to £160 per tonne) and these provide an easy reference tool for the assessment of the potential economic viability of using rMDF in each of the processes considered.

The energy and material costs used for these assessments were applicable at the time of the study (Winter 2007) and will vary depending upon factors such as economic conditions and location of the plant. This needs to be taken into consideration in any future cost benefit analysis (CBA).

Full details of the proceeding cost benefit analyses, including the assessment parameters and supporting data, are in Appendix 1 of this report.

The cost benefit analysis carried out for this report was based on the best available data at the time of writing. However these calculations may need to be revisited to take into account the current uncertainty in the economic situation.

9.2 Glunz – Sonae Indústria

The following analyses focus on the raw materials and energy costs of manufacturing MDF with and without rMDF content. Personnel and other overheads have been considered to be constant irrespective of the fibre content and do not form part of the assessment.

At this stage it is difficult to envisage that there will be a price premium for boards with recycled MDF content as no significant performance improvements have been identified. There will probably be more to be gained by tweaking the processing parameters (e.g. resin content) to optimise production costs and continue to produce a board demonstrating acceptable performance criteria.

For the purpose of the following analyses the functional unit selected for comparison between different scenarios is m³ of MDF production. To convert these figures to a "per tonne" basis it is necessary to multiply by 1.33. (this assumes a density of 750kg/m³).

9.2.1 Influence of % rMDF content and fibre costs on cost of production

The final cost for rMDF production has yet to be fully established. For this reason an assessment of production costs for a range of rMDF dry fibre costs was carried out (Figure 9.1).

As expected, the general principle is that the greater the % of rMDF added, and the lower the price, the more significant the savings on board production. However, at the higher rMDF prices the cost of production never falls below that for virgin fibres only.

It is important to note that at rMDF fibre costs of €150+ per tonne then production costs are higher when only a small percentage of recycled fibre is added and significant savings only begin to accrue once rMDF contents are above 30%, which is a substitution level that has not been assessed on a commercial scale.
These figures have implications for Microrelease Ltd in the selection of the most cost effective processing options for the recycling of waste MDF. However, at 20% rMDF content, cost savings can still be made even if the price of the recycled fibre exceeds €125 per tonne.

Figure 9.1 The influence of percentage and cost of rMDF on the manufacturing cost per m$^3$ of production of MDF (excluding staff and overheads)

A number of factors come into play here. Primarily savings are made for three reasons:

- Raw material costs are lower (for the lower end of the rMDF prices assessed)
- Savings in energy converting raw materials to fibre
- Reduction in resin content (as the percentage of rMDF increases the overall resin content falls).

Trials have only been undertaken at 10% and 20% rMDF content and it is probable that resin content would have to be increased to accommodate recycled fibre percentages above this level. However, by substituting 20% rMDF, it is clear that, if rMDF prices are lower than €100 per tonne, then savings of up to €8 per cubic metre of production are possible. On an annual basis this could account for savings of nearly €900,000. At rMDF prices of €125 per tonne the situation is less favourable (€3 per cubic metre), but annual savings of €330,000 are still achievable.

It is important to note that these savings do not take account of any capital investment and plant alteration costs that would be required to accommodate recycled fibres. For example, Glunz considers that one practical solution would be to incorporate a dry blender into the production process to deal with the rMDF. This could have a total cost of instalment of about €750k. However, payback periods for this investment would be short if the above savings on production costs could be achieved.
9.2.2 Effect of raw material costs on production

Figure 9.2 considers a scenario where the cost of raw wood (thinnings, chips etc) for the manufacture of virgin fibre increases. This scenario is highly probable as there are increasing demands for wood as a raw material, not only from competing board manufacturers around the globe but also because of the significant interest in biofuels.

Using a €125 per tonne rMDF cost (for comparative purposes) it can be seen that as raw wood costs increase then the potential savings using rMDF become even greater (Table 9.1).

Table 9.1 Effect of increase in raw wood prices on manufacturing costs (excluding staff and overheads) using a rMDF fibre production price of €125

<table>
<thead>
<tr>
<th>% rMDF</th>
<th>Current wood costs</th>
<th>10% rise in wood costs</th>
<th>20% rise in wood costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>138.69</td>
<td>144.38</td>
<td>150.08</td>
</tr>
<tr>
<td>10</td>
<td>138.55</td>
<td>143.67</td>
<td>148.8</td>
</tr>
<tr>
<td>20</td>
<td>135.65</td>
<td>140.2</td>
<td>144.76</td>
</tr>
</tbody>
</table>

For a 20% increase in wood prices, with no recycled fibres the cost of production would rise by €11.39 per m³.

For the same rise in wood costs, by adding 20% rMDF to the batch, the increase in board production costs would only be €9.11 per m³.

The use of rMDF thus provides an element of protection against inflated raw wood costs. The same could also be argued for resin costs, but to a lesser degree.

A rise in fuel (electricity and gas) will have an overall effect on board production costs. Whilst the addition of rMDF lowers fuel costs and thus board production costs it must be remembered that the production of dry recycled fibres itself requires energy. As such any rise in fuel prices would also initiate a rise in the price of rMDF.

Figure 9.2 Manufacturing costs per m³ of production (excluding staff and overheads) against % recycled fibre at an rMDF fibre production price of €125. Effect of increase in raw wood costs
9.2.3 The effect of reducing resin content on board production costs

Some of the preliminary laboratory work on the microrelease process suggested that it might be possible to produce boards of comparable performance but using less resin in boards with rMDF. The science has yet to be proven at production scale. However, Figure 9.3 illustrates what the potential effect of reducing resin content might be.

For example a 1% reduction in resin content (down to 11% of virgin fibre) would result in savings of €2.63 per m³ when using 10% rMDF and €5.25 per m³ when adding 20% rMDF. It is anticipated that further reductions in resin content would have too much of an adverse effect on board quality. However, should the incorporation of rMDF permit even a small reduction in resin content then this would further support the case for its use in the manufacture of MDF.

Figure 9.3 Manufacturing costs per m³ of production (excluding staff and overheads) against resin added as a % of virgin fibre and assuming an rMDF fibre production price of €125

![Graph showing manufacturing costs per m³ of production against resin content.](image)

9.3 Vannplastic Ltd

The cost benefit analyses have been carried out using data that probably reflects a more pessimistic view of materials and production costs.

As for the other products the CBA has been restricted to the effect of the rMDF on the processing and raw material elements of manufacture with other costs such as labour, capital cost depreciation, transportation costs and maintenance being excluded as these parameters are deemed to be constant irrespective of the relative amounts of wood flour and MDF used.

Three different scenarios were compared.

**Reference board**
35% Thermoplastic material (recycled HDPE)
65% Wood flour

**Trial board - no process alterations**
35% Thermoplastic material (recycled HDPE)
65% rMDF fibre

**Trial board - with process alterations**
35% Thermoplastic material (recycled HDPE)
65% rMDF fibre
The process alterations were made to improve the feed rate of the fibre into the process and to improve the dispersion of the fibre into the WPC. These comprised the pelletisation of the wood fibre to increase its bulk density and the re-grinding of the panel and re-feeding it into the process after its initial pass through.

The values assigned for the cost of rMDF range between £80 and £160 per tonne. In addition the cost of the thermoplastic resin varies over a wide range. Taking these and other production criteria into consideration it is possible to assign a low to high cost of production range for each of the three panel types (Table 9.2).

<table>
<thead>
<tr>
<th>Table 9.2 Vannplastic economic assessment of production of WPC panels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference case</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>WPC -100% recycled fibre (no process alterations)</td>
</tr>
<tr>
<td>WPC – 100% recycled fibre (process alterations)</td>
</tr>
</tbody>
</table>

The table illustrates that the use of rMDF will increase manufacturing costs. These are slightly increased when no process alterations are made (up by £6 to £34 per tonne) but increase significantly when process alterations are incorporated (up by £49 to £77 per tonne).

The process alterations during the trials were essential in order that a quality product could be made. In effect, most of the increases in cost are attributable to the additional energy required for the regrinding and re-extrusion stages. However, it is likely that the process energy costs could be reduced significantly with improvements to the production process. For example, the introduction of an ‘agglomerator’ (which is an extra extruder that sits in line with the main extruder and pre-heats/blends/melts the wood/plastic mix before it enters the main extruder) would effectively pre-compound the material mix and allow Vannplastic to improve its production rates and fibre dispersion. This will make it a lot easier to process rMDF and manufacturing costs will drop as the regrinding and extrusion processes should no longer be needed.

Initial test results have indicated that the addition of rMDF also has a detrimental effect on the performance of the WPC boards. This could be combated by changes to production techniques. If these technical difficulties can be reconciled it is possible that the mechanical properties and performance of the panels containing rMDF will enable lighter weight products to be produced which will reduce the per unit costs.

Also, it is anticipated that higher performance panels could be produced and these are likely to command a higher selling price in the market.

It is impossible, at this stage to assign a value to these products as further product and market research will be required. However, Vannplastic is keen to continue to investigate the use of rMDF especially in the light of a proposed move of their production facility and planned investments in refinements to their plant.

9.4 Excel

Product trials and performance evaluations indicated that the use of rMDF for enhancing thermal insulation has greater potential than for oil absorbing materials. For this reason the CBA focuses on Excel’s Warmcel product.

The cost benefit analysis looks at three scenarios:

- 100% Warmcel
- 75% Warmcel : 25% rMDF
- 50% Warmcel : 50% rMDF

The energy requirements and prices plus raw material costs for this analysis have been provided by Excel. As for the other products the CBA has been restricted to the effect of the rMDF on the processing and raw material elements of manufacture with other costs such as labour, capital cost depreciation, transportation costs and maintenance being excluded as these parameters are deemed to be constant irrespective of the relative amounts of wood flour and rMDF used.
Excel has requested that actual costs are not revealed so a “normalised value” approach has been taken in which the cost of the primary constituent of Warmcel, recycled newsprint, is normalised to unity, i.e. N.V. = 1. All product costs are then relative to this.

The energy use of the process only is included in this economic assessment, without additional energy use for infrastructure maintenance. As such the energy costs are minimal as production of 1 tonne of Warmcel requires relatively little energy.

The results of the CBA suggest that the cost of Warmcel production is between N.V. 1.4 and 2.0 per tonne taking into account only raw material and process energy costs, there is variation due to the flux of the price of the raw materials and so N.V. 1.4 is the cost where all the raw materials are at the lowest cost and N.V. 2.0 where the raw materials are at high cost (Table 9.3).

Table 9.3 Excel economic assessment of production of WPC panels

<table>
<thead>
<tr>
<th></th>
<th>100% Warmcel</th>
<th>75% Warmcel: 25% rMDF</th>
<th>50:50 position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy costs</td>
<td>£ 0.04</td>
<td>£ 0.04</td>
<td>£ 0.04</td>
</tr>
<tr>
<td>Warmcel raw</td>
<td>N.V. 1.40 to 2.00</td>
<td>N.V. 1.15 to 1.63</td>
<td>N.V. 0.90 to 1.25</td>
</tr>
<tr>
<td>material costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rMDF costs</td>
<td>0</td>
<td>N.V. 0.20 to 0.40</td>
<td>N.V. 0.40 to 0.80</td>
</tr>
<tr>
<td>Total cost</td>
<td>N.V. 1.40 to 2.00</td>
<td>N.V. 1.35 to 2.03</td>
<td>N.V. 1.30 to 2.05</td>
</tr>
</tbody>
</table>

The energy costs of the product remain the same, irrespective of the proportion of rMDF fibre added.

Raw material costs are clearly critical (Figure 9.4).

The cost benefit analysis indicates that the normal cost of Warmcel production is approximately N.V. 1.4 to 2.0 per tonne taking into account only raw material and process energy costs for 100% Warmcel.

On introduction of the recycled fibres into the product, producing a 75% Warmcel to 25% rMDF the product will cost between N.V. 1.35 and 2.03 per tonne, taking into account the range used for the recycled fibre costs (Table 9.3). The slight increase in costs as the percentage of rMDF increases is attributable to the fact that the highest rMDF price selected is greater than the highest price selected for recycled paper.

On increase of the rMDF fraction from 25% to 50% the lowest costs decrease further, being between N.V. 1.3 and 2.05 per tonne of product. Once again this is governed by the raw material costs with the lowest price of rMDF selected for the analysis being less than that selected for recycled paper.
Demonstration of end uses for recovered MDF fibre

In addition to the potential cost savings for using rMDF (when rMDF costs are lower than recycled paper costs) there are also reported improvements in product performance. Preliminary laboratory tests have indicated that the addition of rMDF improves settlement performance under fixed load and shock. The financial implications of this are that:

- Less product may be required to provide the same level of insulation
- The consumer will, therefore, need to buy less product
- Excel could also benefit by charging slightly more for their product due to its improved performance
- In effect the pricing of the product could be set at a level that offers both financial savings for the consumer and a price per tonne sold gain for Excel
- This win/win scenario for manufacturer and consumer will improve Excel’s competitiveness and has the potential of generating more sales by taking market share from other products

It should be noted that the inclusion of rMDF has a tendency to reduce the thermal performance of the insulation. Economic viability may depend upon slight improvements to the products containing rMDF to ensure that they exhibit the thermal performance characteristics required by the market.

10.0 Conclusions

The use of recycled MDF fibres produced by the Microrelease process has been proven to have varying degrees of merit in all of the end use trials that were carried out.

The price of rMDF fibre will be a function of manufacturing costs and the financial considerations of the rMDF supplier. The cost benefit analyses within the report incorporate a range of potential rMDF fibre prices (from £80 to £160 per tonne) and these provide an easy reference tool for the assessment of the potential economic viability of using rMDF in each of the processes considered.

Glunz (Sonae) - MDF manufacture

- It has been shown that up to 10% rMDF can be used in the manufacture of MDF with little significant effect on board properties.
- Using 20% rMDF tends to reduce the strength properties of the boards slightly, although not below the requirements of the British / European standard.
It appears to be possible to use less resin content when using rMDF.

Costs of production decrease as greater percentages of recycled fibres are used.

Fibre costs of less than £80 per tonne (just under €100) should generate production costs savings compared to the use of virgin fibres.

Incorporation of rMDF into MDF manufacture will require investment in plant either through the addition of a dry blending system or by feeding into the production line from an on-site Microrelease plant.

**Vannplastic Ltd. - WPC decking boards**

- Replacement of paper fibres with rMDF adversely affects the manufacturing process as in these trials it was difficult to incorporate an even mix of fibres into the WPC mix.
- The performance of the rMDF decking board was poorer in these trials than that of its wood flour counterpart.
- The cost of manufacture (with no change to the process) is generally slightly more when rMDF was used compared with standard manufacture.
- This situation is exacerbated because the only way to ensure that a viable rMDF product is produced is to re-grind the boards and re-introduce the granulate into the extruder.
- Despite these results the manufacturers consider that the use of rMDF still has potential in the manufacture of WPCs. Vannplastic plans to reengineer the front end of its production facility when it moves location. With the correct up-stream equipment (crammer, fibre heater and agglomorator) they anticipate that mixing problems will be negated and that line speeds should be similar to those for wood flour based decking.

**Excel - Warmcel insulation**

- Using rMDF as a partial substitute for recycled paper fibres generates some significant product performance improvements.
- In particular, the settlement under mechanical load and shock is improved by the addition of rMDF with the overall potential for using less insulating material.
- In addition, the cost of rMDF compares favourably with that for recycled paper fibres. Under these circumstances the overall cost reduction to the manufacturer, combined with potential benefits passed on to the consumer, make for a positive cost benefit analysis.
- Some technical issues still need to be addressed including ways of counteracting the recorded drop in thermal performance of the rMDF product.

**Excel - oil absorption**

- The use of rMDF fibres (either on their own or mixed with paper fibres) for cleaning up oil spillages is also considered. Whilst the ability to absorb oil is greater than that of recycled paper the rMDF products also have a tendency to absorb much more water than existing products on the market which is considered to be disadvantageous. For this reason this product was not investigated to any degree during this study.

One of the most significant outputs of this study is that the results of the manufacturing trials, performance tests, economic analyses and environmental assessments have encouraged all three organisations involved in the case studies to continue with further trials to confirm the viability of using rMDF in their processes.
Appendix 1 Cost benefit analysis

Executive summary

The report examines the financial implications of introducing recycled MDF fibres (rMDF) into the manufacture of the following products:

- Medium density fibreboard (MDF) manufactured by Glunz (Sonae Indústria)
- Wood plastic extruded components manufactured by Vannplastic Ltd.
- Insulation fibres manufactured by Excel Industries

Cost benefit analyses (CBAs) are shown for each of the manufacturing and raw material elements of the different processes and the impact of using rMDF is demonstrated.

A detailed analysis of industrial trials done at Glunz’s manufacturing plant shows that the introduction of rMDF at levels of 10 and 20% of the fibre content of the final product has proved to be technically feasible and could offer annual savings of about €400,000 for one of their production lines. Introduction of 40% rMDF (yet to be trialled) could offer annual savings of around €1 million. However, these savings will vary depending on the cost of rMDF fibres. Additional gains could also be made through the use of less resin. The use of recycled material may also act as an “inflation proofer” against large increases in raw wood costs.

The replacement of wood flour with rMDF for the wood plastic composites (WPC) is accompanied by potential increases in production costs. There are opportunities to minimise these through process improvements and, in addition, the recycled fibre product offers the potential for producing a stronger, higher quality product which could attract a price premium in the market.

With the fibre insulation products, unlike the boards and WPCs, the main influence on the CBA is the cost of the raw materials, with energy consumption being the same irrespective of the rMDF content. The addition of up to 50% of rMDF instead of recycled paper offers the potential for significant reductions in cost. The rMDF also improves the settlement performance of the product which has potential financial benefits for the manufacturer, Excel Industries.
Contents

1.0 Introduction ........................................................................................................................................... 47
2.0 Glunz - Sonae Indústria .......................................................................................................................... 47
   2.1 Product description .......................................................................................................................... 47
   2.1.1 Key data for 16mm MDF manufactured on Topan 1 ................................................................. 47
   2.2 Cost benefit analyses for 16 mm MDF ............................................................................................ 47
       2.2.1 Influence of % rMDF resin content on cost of production .................................................... 47
       2.2.2 Influence on the cost of rMDF against production costs ....................................................... 47
       2.2.3 Effect of raw material costs on production ............................................................................ 47
       2.2.4 The effect of reducing resin content on board production costs .......................................... 47
3.0 Vannplastic Ltd ..................................................................................................................................... 47
   3.1 Product description .......................................................................................................................... 47
       3.1.1 Processes and manufacturing parameters ............................................................................. 47
       3.1.2 Raw data ................................................................................................................................. 47
   3.2 Cost benefit analysis ........................................................................................................................ 47
4.0 Excel ....................................................................................................................................................... 47
   4.1 Product description .......................................................................................................................... 47
       4.1.1 Processes and manufacturing parameters ............................................................................. 47
       4.1.2 Raw data ................................................................................................................................. 47
   4.2 Cost benefit analysis ........................................................................................................................ 47
11.0 Introduction

Industrial trials have been carried out with the following three end users to appraise the technical feasibility of incorporating recycled MDF (rMDF) into their products. Technical and environmental (Life Cycle Analysis) feasibility studies have been carried out for the different products and are detailed in other technical reports associated with this study. However, none of these applications is likely to be progressed by the industrial partners unless they are supported by compelling financial evidence.

The aim of this report is to present cost benefit analyses for each of the below organisations’ products and processes that incorporated rMDF. These analyses focus solely on production and materials parameters and the effect of change on these parameters.

- Glunz (Sonae Indústria) – MDF board manufacturers
- Vannplastic Ltd – Wood plastic extruded components
- Excel Industries – Use of cellulosic fibres for applications such as insulation, horticulture and cement fillers

Glunz, being a large manufacturer, has detailed production and cost information to hand. It has readily made this data available and, as a consequence, a detailed cost benefit analysis has been possible.

Vannplastic Ltd is a small SME and the products are relatively simple with few variable processing parameters. However, it has been possible to extract good data from the figures supplied by the organisation.

Excel considers much of its manufacturing costs as confidential and for this reason the effect on the use of rMDF is reported in comparative terms (see later).

The following guidelines for the cost benefit analyses were used:

Current manufacture
- Costs of manufacture using existing techniques
- Production volumes
- Cost trends (predicted) for each raw material
- Selling price

The cost implications and potential benefits of using rMDF
- Costs of manufacture using rMDF (full or partial substitution for existing raw materials)
- Cost of new equipment
- Installation costs of new equipment (including training of staff, downtime and loss of production)
- Reduction in equipment and associated cost savings (maintenance, less staff)
- Effects on volume of production
- Effects on other processing parameters (e.g. less binder needed)
- Power consumption considerations associated with equipment changes
- Selling price of rMDF product (higher or lower?)
- Cost of rMDF fibre now and in the future

The energy and material costs used for these assessments were applicable at the time of the study (Winter 2007) and will vary depending upon factors such as economic conditions and location of the plant. This needs to be taken into consideration in any future CBAs.
12.0 Glunz - Sonae Indústria

12.1 Product description
Glunz manufactures a range of fibre boards at a number of plants throughout Europe. Full industrial trials using rMDF were carried out at its factory in Meppen, Germany where two lines are in operation (called Topan 1 and Topan 2).

The trials were carried out using Topan 1’s continuous press facility.

For the purposes of this Cost Benefit Analysis (CBA) the process parameters pertaining to Topan 1 were used. All trials were carried out on a production run of 16mm thick MDF of a target density of 750kg/m³. Again, for ease and relevance of assessment, the CBA has been applied to this product.

12.1.1 Key data for 16mm MDF manufactured on Topan 1

The following raw data has been used to undertake the CBA. The initial assessments have focussed on the costs associated with the production process excluding production staff, other staff and overheads.

These elements were excluded from the assessment because they were considered to be constants, irrespective of the use (or not) of rMDF.

The figures include general data for annual production and, for the ease of analysis, values on a "per metre cubed of final product" basis.

**MATERIALS DATA - Annual production**

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDF avg. density</td>
<td>kg/m³</td>
<td>750.00</td>
</tr>
<tr>
<td>Topan 1 production (if running 16mm board all year)</td>
<td>m³/year</td>
<td>111000.00</td>
</tr>
<tr>
<td>Dry wood consumption</td>
<td>tonnes/year</td>
<td>85000.00</td>
</tr>
<tr>
<td>Assume avg. density dry wood</td>
<td>kg/m³</td>
<td>400.00</td>
</tr>
<tr>
<td>Volume dry wood used</td>
<td>m³/year</td>
<td>212500.00</td>
</tr>
<tr>
<td>Recycled MDF in boiler</td>
<td>tonnes/year</td>
<td>8450.00</td>
</tr>
<tr>
<td>Assume avg. density of waste mdf</td>
<td>kg/m³</td>
<td>750.00</td>
</tr>
<tr>
<td>Volume of recycled MDF in the boiler</td>
<td>m³/year</td>
<td>11266.67</td>
</tr>
</tbody>
</table>

**MATERIALS DATA - per m³ mdf produced**

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry wood (dw)</td>
<td>tonnes/m³</td>
<td>0.77</td>
</tr>
</tbody>
</table>

This figure is based on the annual dry wood consumption and annual production figures supplied by Sonae where dry wood equates to wood at 0% moisture content.

Comprising:

- Softwood thinnings (15% of virgin fibre)
- Poplar thinnings (25% of virgin fibre)
- Chips with bark (49% of virgin fibre)
- Chips without bark (10% of virgin fibre)
- Recycled mdf (largely dust) (1%) of virgin fibre

At this stage the option exists to replace some of the virgin fibre with rMDF. This is one of the variables that has been assessed at different percentages of the total dry wood mix.

By replacing virgin fibre with rMDF the respective percentages of each of the above virgin fibre constituents will also change and this has been accounted for in the model.
Additives

Under normal production conditions 11% of Urea Formaldehyde (UF) resin is added to the mix. With the rMDF, 12% of resin was added to the virgin fibre element but no resin was added to the rMDF. The reason for using a higher percentage for the rMDF boards was to allow for the fact that a proportion of the fibre contained rMDF with no additional resin added during the manufacturing process.

This amount of resin remained constant irrespective of the % of rMDF added. As a result, there are potential savings to be had as proportionately less resin is used in for example a board containing 20% rMDF than in a board containing 10% rMDF

UF resin (normal) % solids dry wood 11.00
UF Resin rMDF (12% added to virgin fibre) % solids dry wood 12.00

The amount of paraffin added remained constant irrespective of board type

Paraffin emulsion % solids dry wood 0.75

Recycled MDF from the plant

A significant proportion of MDF waste generated at the plant is burned to produce energy. This has a material cost of zero for the plant. However, there is a cost associated with its use such as maintenance and loading of the boiler.

Recycled MDF in boiler tonnes/m³ 0.08
Cost for maintenance and loading €/tonne 6.50

COSTS - Calculations based on 1m³ of mdf production

Having established the raw material components the next stage is to assign costs to these raw materials and to the energy required to produce the boards.

Energy

For energy purposes the process has been split into two parts (see Figure 1).

Fibre preparation – Debarking, chipping, screening, washing, pre-steam, heating / softening, defibrating, drying.

Board formation – Mat forming, pre-compression, continuous pressing, sawing, storage, sanding, cut to size.
In effect fibre preparation takes place prior to the addition of any rMDF.

Energy consumption will be constant for board formation irrespective of the percentage of rMDF. However, the energy for fibre preparation is associated with the production of virgin fibre from wood. These costs will fall in proportion to the amount of rMDF used.

Unit costs for power have been assumed to be as follows

<table>
<thead>
<tr>
<th></th>
<th>Cost (€/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>0.0669</td>
</tr>
<tr>
<td>Gas</td>
<td>0.0263</td>
</tr>
<tr>
<td>Wood (cost for boiler load and maintain)</td>
<td>0.0024</td>
</tr>
</tbody>
</table>

**Fibre preparation**

Typical consumption values for a non-rMDF board are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Consumption (kWh/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>290</td>
</tr>
<tr>
<td>Gas</td>
<td>580</td>
</tr>
<tr>
<td>Wood</td>
<td>350</td>
</tr>
</tbody>
</table>

**Board formation**

<table>
<thead>
<tr>
<th></th>
<th>Consumption (kWh/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>80</td>
</tr>
<tr>
<td>Gas</td>
<td>200</td>
</tr>
<tr>
<td>Wood</td>
<td>0</td>
</tr>
</tbody>
</table>
Raw materials - wood

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Price (€/tonne dry wood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwood thinnings</td>
<td>110.00</td>
</tr>
<tr>
<td>Poplar thinnings</td>
<td>80.00</td>
</tr>
<tr>
<td>Chips with bark</td>
<td>60.00</td>
</tr>
<tr>
<td>Chips without bark</td>
<td>85.00</td>
</tr>
<tr>
<td>Recycled solid (sawdust) mdf</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The unit price for rMDF is another of the variables that has been applied to the analysis. Cost benefit calculations have been carried out using potential values ranging from €80 to €160 per tonne.

Raw materials - resin and paraffin

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Price (€/tonne solids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UF resin</td>
<td>360</td>
</tr>
<tr>
<td>Paraffin emulsion</td>
<td>980.00</td>
</tr>
</tbody>
</table>

12.2 Cost benefit analyses for 16 mm MDF

As discussed previously the following analyses focus on the raw materials and energy costs of manufacturing MDF with and without rMDF content. Personnel and other overheads have been considered to be constant.

At this stage it is difficult to envisage that there will be a price premium for boards with recycled MDF content. There will probably be more to be gained by tweaking the processing parameters (e.g. resin content) to optimise production costs and produce a board demonstrating acceptable performance criteria.

For the purpose of the following analyses the functional unit selected for comparison between different scenarios is m³ of MDF production. This assumes a density of 750kg/m³. To convert these figures to a “per tonne” basis it is necessary to multiply by 1.33.

12.2.1 Influence of % rMDF resin content on cost of production

For the purposes of this initial comparison a rMDF production cost (dry fibre) of €125 per tonne has been assumed. The actual production costs have yet to be fully established and the effect of changes in fibre costs are discussed later in this report.

Figure 2 shows that production costs decrease significantly with an increase in rMDF content. A number of factors come into play here. Primarily savings are made for three reasons:

- Raw material costs are lower
- Savings in energy converting raw materials to fibre
- Reduction in resin content (calculations are based on 12% resin added to the virgin fibre mix only thus as the percentage of rMDF increases the overall resin content falls.

Trials have only been undertaken at 10% and 20% rMDF content and it is probable that resin content would have to be increased to accommodate recycled fibre percentages above this level. However, it is clear that at the higher rMDF content levels there are potential savings of up to €9 per cubic metre of production. On an annual basis (see Figure 3) this could account for savings of around €1million.
It is important to note that these savings do not take account of any capital investment and plant alteration costs that would be required to accommodate recycled fibres. For example, Glunz considers that one practical solution would be to incorporate a secondary blender into the production process to deal with the rMDF. This could have a total cost of instalment of about €750k. However, payback periods for this investment would be short if the above savings on production costs could be achieved.
12.2.2 Influence on the cost of rMDF against production costs

As discussed previously, the final cost for rMDF production has yet to be fully established. For this reason an assessment of production costs for a range of rMDF dry fibre costs was carried out (Figure 4). As expected, the general principle is that the greater the % of rMDF added, and the lower the price, then the savings on board production costs become more and more significant.

However, it is important to note that at rMDF fibre costs of €125+ per tonne then costs are higher when only a small percentage of recycled fibre is added and significant savings only begin to accrue once rMDF contents are at about 15 to 20%. At rMDF fibre costs in excess of €175 per tonne the costs are higher than production with virgin fibre even in a scenario where 40% recycled fibre might be used. This has implications for Microrelease Ltd in the selection of the most cost effective processing options for the recycling of waste MDF.
12.2.3 Effect of raw material costs on production

Figure 5 considers a scenario where the cost of raw wood (thinnings, chips etc) for the manufacture of virgin fibre increases. This scenario is highly probable as there are increasing demands for wood as a raw material, not only from competing board manufacturers around the globe but also because of the massive interest in bio fuels.

Using a €125 per tonne rMDF cost (for comparative purposes) it can be seen that as raw wood costs increase then the potential savings using rMDF become even greater (Table 1).

<table>
<thead>
<tr>
<th>% rMDF</th>
<th>Current wood costs €/m3</th>
<th>10% rise in wood costs €/m3</th>
<th>20% rise in wood costs €/m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>138.69</td>
<td>144.38</td>
<td>150.08</td>
</tr>
<tr>
<td>10</td>
<td>138.55</td>
<td>143.67</td>
<td>148.80</td>
</tr>
<tr>
<td>20</td>
<td>135.65</td>
<td>140.20</td>
<td>144.76</td>
</tr>
<tr>
<td>30</td>
<td>132.75</td>
<td>136.74</td>
<td>140.72</td>
</tr>
<tr>
<td>40</td>
<td>129.85</td>
<td>133.27</td>
<td>136.69</td>
</tr>
</tbody>
</table>
For a 20% increase in wood prices, with no recycled fibres the cost of production would rise by €11.39 per m³.

For the same rise in wood costs, by adding 20% rMDF to the batch, the increase in board production costs would only be €9.11 per m³.

The use of rMDF thus provides an element of protection against inflated raw wood costs. The same could also be argued for resin costs, but to a lesser degree.

A rise in fuel (electricity and gas) will have an overall effect on board production costs. Whilst the addition of rMDF lowers fuel costs and thus board production costs it must be remembered that the production of dry recycled fibres itself requires energy. As such any rise in fuel prices would also initiate a rise in the price of rMDF.

**Figure 5** Manufacturing costs per m³ of production (excluding staff and overheads) against % recycled fibre at a rMDF fibre production price of €125. Effect of increase in raw wood costs

### 12.2.4 The effect of reducing resin content on board production costs

Some of the preliminary laboratory work on the microrelease process suggested that it might be possible to produce boards of comparable performance but using less resin in boards with rMDF. The science has yet to be proven at production scale. However, Figure 6 illustrates what the potential effect of reducing resin content might be.

For example a 1% reduction in resin content (down to 11% of virgin fibre) would result in savings of €2.63 per m³ when using 10% rMDF and €5.25 per m³ when adding 20% rMDF. It is anticipated that further reductions in resin content would have too much of an adverse effect on board quality. However, should the incorporation of rMDF permit even a small reduction in resin content then this would further support the case for its use in the manufacture of MDF.
13.0 Vannplastic Ltd

13.1 Product description

Vannplastic Ltd. produces wood polymer composites (WPCs) which have use in a number of applications. The trials using recycled wood fibre were on panels, such as those used for decking.

The manufacturing process is relatively simple. Each constituent raw material (wood, plastic and additives) is contained within a separate silo. These materials are ‘dosed’ in known quantities into a mixing bin and from there into a heated mixing screw. The mixed feedstock is then fed into a twin screw extruder that heats, mixes and melts the material. Half way through this mixing process, all volatiles (water mostly) are removed from the mix by means of a vacuum in the process. The fully dispersed/homogenous mix is then pumped/extruded through a die into the shape required. Water is used to cool the product after the extrusion to maintain a regular temperature and minimise distortion of the products.

Figure 6 Manufacturing costs per m$^3$ of production (excluding staff and overheads) against resin added as a % of virgin fibre and assuming a rMDF fibre production price of €125.

Figure 7 Schematic of WPC production
These products are normally manufactured using wood flour but in the trials rMDF was used to replace 100% of this material. Three cases were examined:

- reference board
- straight replacement of the wood flour with recycled wood fibre with no process alterations required
- replacement of the wood flour making process alterations to improve product quality

Each of these cases will be considered side by side as the product quality without process alterations was lower.

13.1.1 Processes and manufacturing parameters

The polymer and wood flour are fed into the dry blend mixer along with the additive package. Additives include pigment, which is typically oxide based in an LDPE carrier, and UV inhibitors, which include a Hindered Amine Light Stabiliser (HALS) system.

The mixed components are then dropped into the extruder hopper for feeding into the next stage in the process.

**Extrusion**

Once the components have been dry mixed they are fed into the extruder for mixing at high temperatures followed by extrusion into boards or panels. A number of components in the extruder are heated at about 200°C to ensure full melt of the polymer component and allow thorough mixing. This also serves to allow moisture to be driven off the wood fibres, which is extracted with a vacuum pump.

**Cooling**

The panels are fed from the extruder into a cooling trough, which is water cooled to about 14°C. On removal the panels are allowed to dry without external heat. The water used to cool the panels is removed periodically for replacement and the used water disposed of to the local drainage system.

**Sawing and finishing**

Once cooled the panels are sawn to the required dimensions and finished prior to packing and distribution. The packing and distribution are not considered in this analysis.

**Regrinding**

On use of reclaimed fibres additional process steps need to be added to take into account the changes made to accommodate the fibres into the material with the same success as the wood flour.

In the raw material supply stage additional impacts need to be considered including the pelletisation of the wood fibre to increase the bulk density and feed rate requirements of the feedstock and to aid the mixing and dispersion of the fibre in a similar free-flowing form as the wood flour currently used.

An additional process step must also be introduced to represent the regrinding of the boards after cooling and sawing for re-extrusion to achieve satisfactory dispersion of the fibre. The granulated material, having dimensions of approximately 8mm x 8mm, would be re-fed into the process line (without the need for additional mixing) and extruded a second time. This was done to maximise the potential of achieving a satisfactory dispersion within the final product.

**Reference board**

35% Thermoplastic material (recycled HDPE)
65% Wood flour

Wood flour bulk density of between 120g/l and 200g/l

Line speed – 1.0 to 2.0m per min
**Trial board - no process alterations**

35% Thermoplastic material (recycled HDPE)  
65% rMDF fibre  

Fibre bulk density 40 to 45g/l  

Line speed – 1.0m per min  

**Trial board - with process alterations**

65% Thermoplastic material (recycled HDPE)  
35% rMDF fibre  

Fibre bulk density increased by pre-process hammer milling  

Line speed – 0.3 to 0.5m per min  

Regrinding, cooling and re-feeding into the extruder

13.1.2 Raw data

### Table 2 Volumes and costs of raw materials and energy

<table>
<thead>
<tr>
<th></th>
<th>Wood flour – Reference case</th>
<th>Fibre – no process alterations</th>
<th>Fibre – process alterations required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use (kWh)</td>
<td>491.88</td>
<td>491.88</td>
<td>1072.39</td>
</tr>
<tr>
<td>Process energy costs</td>
<td>£36.89</td>
<td>£36.89</td>
<td>£80.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Amount used</th>
<th>Cost (per tonne)</th>
<th>Total cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled HDPE</td>
<td>630kg</td>
<td>£350 to £700</td>
<td>£220 to £441</td>
</tr>
<tr>
<td>Wood flour</td>
<td>360kg</td>
<td>£65</td>
<td>£23.40</td>
</tr>
<tr>
<td>Process water</td>
<td>0.196m³</td>
<td>£1.25/m³</td>
<td>£0.25</td>
</tr>
<tr>
<td>Reclaimed wood fibre</td>
<td>360kg</td>
<td>£80 to £160</td>
<td>£29 to £58</td>
</tr>
</tbody>
</table>

It should be noted that care is required with these cost estimates as there are several opportunities to improve process efficiency, particularly in mixing and blending, and also energy efficiency in scaling the process. Similarly, explicit account should be taken of the logistics costs and of the enhanced nature of the final products through light-weighting and enhanced mechanical properties which could reduce the total materials use in the final product.

13.2 Cost benefit analysis

As stated above, the cost benefit analyses have been carried out using data that probably reflects a more pessimistic view of materials and production costs.

Equally the third scenario (process alterations made) assumes that greater efficiencies could not be employed by using different process techniques. However, using the data in Table 2 it has been possible to evaluate the effects of changes to process parameters on the cost of manufacture of WPCs (see Table 3).
Table 3 Vannplastic economic assessment of production of WPC panels

<table>
<thead>
<tr>
<th></th>
<th>Lowest price (£ per tonne)</th>
<th>Highest price (£ per tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference case</td>
<td>280.54</td>
<td>501.54</td>
</tr>
<tr>
<td>WPC -100% recycled fibre (no process alterations)</td>
<td>286.14</td>
<td>535.14</td>
</tr>
<tr>
<td>WPC – 100% recycled fibre (process alterations)</td>
<td>329.68</td>
<td>578.69</td>
</tr>
</tbody>
</table>

The table illustrates that the use of rMDF will increase manufacturing costs. These are slightly increased when no process alterations are made (up by £6 to £34 per tonne) but increase significantly when process alterations are incorporated (up by £49 to £77 per tonne).

The process alterations during the trials were essential in order that a quality product could be made. In effect, most of the increases in cost are attributable to the additional energy required for the regrinding and re-extrusion stages.

However, it is likely that the process energy costs could be reduced significantly with improvements to the production process. For example, the introduction of an ‘agglomorater’ (which is an extra extruder that sits in line with the main extruder and pre-heats/blends/melts the wood/plastic mix before it enters the main extruder) will effectively pre-compound the material mix and allow Vannplastic to improve its production rates and fibre dispersion. This will make it a lot easier to process rMDF and manufacturing costs will drop as the regrinding and extrusion processes should no longer be needed.

The initial test results indicated that the addition of rMDF can have a detrimental effect on the performance of the WPC boards. This could be combated by changes to production techniques. If these technical difficulties can be reconciled it is possible that the mechanical properties and performance of the panels containing rMDF will enable lighter weight products to be produced which will reduce the per unit costs.

Also, it is anticipated that higher performance panels could be produced and these are likely to command a higher selling price in the market.

It is impossible, at this stage to assign a value to these products as further product and market research will be required. However, Vannplastic is keen to continue to investigate the use of rMDF especially in the light of a proposed move of their production facility and planned investments in refinements to their plant.

14.0 Excel

14.1 Product description

Excel manufactures Warmcel cellulose fibre insulation and a range of cellulose fibre products, including Viscocel bitumen modifier in loose fibre and pellet format for the manufacture of Stone Mastic Asphalt (SMA) and other asphalt products, as well as a range of fibre products for industrial applications, including foundry tundish linings, concrete manufacture and repair, mastics and adhesives, and cement, plastics and paint manufacturing10.

This product utilises waste newsprint in its manufacture, diverting it from other waste disposal routes.

The object of this study is to examine a case study for utilising rMDF in the production of Warmcel.

Three cases have been studied in this assessment. The first is a reference case evaluating the production of 100% Warmcel. The second and third cases consider the replacement of a portion of Warmcel fibres with recycled wood fibre to produce a Warmcel: MDF product with fibre ratios of 75:25 and 50:50 by weight respectively.

---

14.1.1 Processes and manufacturing parameters

The Warmcel process is summarised in Figure 8 and can be split into a number of stages.

Import of raw materials
The raw materials required in Warmcel production are imported into the production facility. Waste news print comprises upwards of 90% by weight of the end product. This material may be diverted from closed loop recycling but also from landfill or incineration. Additional raw materials imported are boric acid, magnesium sulphate and aluminium hydroxide.

Newsprint shredding and sorting
The newsprint is initially shredded to aid in the removal of contaminants, such as metal, in the form of staples.

Milling process
After shredding the paper is further shredded first by course milling and then fine milling to reduce the particle size. Chemical additives assist in the breakdown of the paper to fibrous material.

rMDF addition
The rMDF, in the assessments which contain a proportion of recycled wood fibre, will be added to the Warmcel product prior to packaging. As the process described in Figure 8 is designed to break paper down to fibrous material, recycled fibre is a viable replacement for a proportion of Warmcel while retaining the properties required for its application as an insulator.

Packaging and distribution
This will not be included in the system boundary for this study nor will the transportation to the customer be included as this is unaltered by the use of rMDF

Figure 8 Excel process for production of Warmcel

14.1.2 Raw data

The energy requirements and prices and raw material costs for this analysis have been provided by Excel. As for the other products the CBA has been restricted to the effect of the rMDF of the processing and raw material elements of manufacture with other costs such as labour, capital cost depreciation, transportation costs and maintenance being excluded.

Excel has requested that actual costs are not revealed so a “normalised value” approach has been taken in which the cost of the primary constituent of Warmcel, recycled newsprint, is normalised to unity, i.e. N.V. = 1. All product costs are then relative to this.
The energy use of the process only is included in this economic assessment, without additional energy use for infrastructure maintenance. As such the energy costs are minimal as production of 1 tonne of Warmcel requires relatively little energy.

The potential cost for the rMDF fibres is the same as that used for the Vanplastic Ltd study in section 3.0 of this report.

The details used in the calculations of the costs of production are detailed in Table 4 along with the actual costs of production of 100% Warmcel, 75% Warmcell:25% rMDF and the 50:50 position.

<table>
<thead>
<tr>
<th>Table 4 Volumes and costs of raw materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost of raw materials for production of 1 tonne of Warmcel:</strong></td>
</tr>
<tr>
<td>Raw material:</td>
</tr>
<tr>
<td>Waste newsprint</td>
</tr>
<tr>
<td>Recycled fibres (rMDF)</td>
</tr>
<tr>
<td>Total for chemical additives</td>
</tr>
<tr>
<td><strong>Cost of energy use for production of 1 tonne of Warmcel:</strong></td>
</tr>
<tr>
<td>Energy costs for electricity (p/kWh):</td>
</tr>
<tr>
<td>Energy use for Warmcel production</td>
</tr>
<tr>
<td>Energy costs</td>
</tr>
</tbody>
</table>

### 14.2 Cost benefit analysis

The results of the CBA suggest that the cost of Warmcel production is between N.V. 1.4 and 2.0 per tonne taking into account only raw material and process energy costs, there is variation due to the flux of the price of the raw materials and so N.V. 1.4 is the cost where all the raw materials are at the lowest cost and N.V. 2.0 where the raw materials are at high cost (Table 5).

<table>
<thead>
<tr>
<th>Table 5 Excel economic assessment of production of WPC panels</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Table 5" /></td>
</tr>
</tbody>
</table>

The energy costs of the product remain the same, irrespective of the proportion of rMDF fibre added.

Raw material costs are clearly critical (Figure 9).

The cost benefit analysis indicates that the normal cost of Warmcel production is approximately N.V. 1.4 to 2.0 per tonne taking into account only raw material and process energy costs for 100% Warmcel.

On introduction of the recycled fibres into the product, producing a 75% Warmcel to 25% rMDF the product will cost between N.V. 1.35 and 2.03 per tonne, taking into account the range used for the recycled fibre costs (Table 5). The slight increase in costs as the percentage of rMDF increases is attributable to the fact that the highest rMDF price selected is greater than the highest price selected for recycled paper.

On increase of the rMDF fraction from 25 to 50% the lowest costs decrease further, being between N.V. 1.3 and 2.05 per tonne of product. Once again this is governed by the raw material costs with the lowest price of rMDF selected for the analysis being less than that selected for recycled paper.
In addition to the potential cost savings for using rMDF there are also reported improvements in product performance. Preliminary laboratory tests have indicated that the addition of rMDF improves settlement performance under fixed load and shock. The financial implications of this are that:

- Less product may be required to provide the same level of insulation
- The consumer will, therefore, need to buy less product
- Excel could also benefit by charging slightly more for their product due to its improved performance
- In effect the pricing of the product could be set at a level that offers both financial savings for the consumer and a price per tonne sold gain for Excel
- This win / win scenario for manufacturer and consumer will improve Excel’s competitiveness and has the potential of generating more sales by taking market share from other products