

INTELLIGENT RECYCLING OF SOLID WOOD

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Abstract

This is a discussion paper that presents the CaReWood process for recycling solid wood. The main aim of CaReWood is to develop and assess the viability of a method of reprocessing post-consumer wood that has a minimal impact on the cross-sectional area of the pieces. In other words, making glued and/or laminated wood products from recovered wood. Although a simple concept, its implementation is complex and so this paper provides a context and discussion of the factors that will influence putting the CaReWood process into practice.

Key words: recovered wood; CaReWood process; yield; sorting.

INTRODUCTION

Most wood scientists are aware of the "3 Rs" for minimising environmental impact, which are: Reduce, Re-use and Recycle. CaReWood is a project that falls in between re-use and recycle as its aim is to assess the viability of a method of reprocessing post-consumer wood that has a minimal impact on the cross-sectional area of the pieces. This is a step change in the thinking on how to reprocess recovered wood because, currently, it is broken down into particles. Chipping improves transport and storage efficiency, however, it does limit what can be done with recycled wood once it is in particle form.

Recycled wood particles can be used for panel manufacture, burning with energy recovery, animal beddings and mulches. The two most important markets for the particles are particleboard manufacture and energy production, which of the two is more important varies from country to country. For example, in Germany most recovered wood is used for energy recovery whereas in France and the UK it is panel manufacture. Except for panel manufacture, in all the other end-uses the recycled wood is burnt or degraded rapidly thus releasing its stored carbon to the atmosphere, so there is not an opportunity for a third life cycle. Using recovered wood for particleboard manufacture does provide the possibility of a third life cycle for some of the recovered wood if the particleboard is recycled into another panel product, but what about a fourth or fifth? Clearly the percentage that is actually recycled falls with each cycle.

The premise behind the CaReWood process is to maintain the dimensions of recovered wood as large as possible and then use a combination of finger-jointing and, if necessary, laminating to make large dimension, solid-wood products. The advantages of this approach are:

1. Large wood pieces have the potential to be recycled many times over, thus delaying the release of the carbon stored in the wood
2. Large dimension products have a greater value
3. Larger pieces are more versatile as they can be reshaped and sawn into new dimensions

Of course, making new, clean solid-wood products from waste wood will require substantial effort and generate a large amount of waste itself. This waste will be in the form of sawdust, shavings

and offcuts; all of which can be passed to the current recycling streams, i.e. chipping. The resultant solid wood products will have much higher value than the particles produced in recycling processes today. Therefore, it is possible that such an approach is economically viable.

The CaReWood project will therefore develop the most promising process for making solid wood products from recovered wood and evaluate its environmental impact. This paper describes the current ideas on what the CaReWood process might look like.

THE CAREWOOD PROCESS

The Wood Resource

Timber is sold in a wide range of thicknesses and widths. There are standard sizes in the sense that a market has a preference for the combination of certain thicknesses with certain widths and these preferences vary slightly from country to country. Consequently, there is not an infinite range of wood cross-sectional areas, but, there are very many. All wood products will eventually become waste and be available for recycling and this wide range of cross-sectional areas and shapes will have an impact on the CaReWood process.

Sorting recovered wood by dimensions, at least thickness and width, is indispensable because it makes little sense joining a small cross-sectional piece to a large one. In an ideal World it would be possible to sort each piece into a bin that corresponds to a standard size required by the market. This would require a very large number of bins and some of which would fill up very slowly. It is more realistic to select a sub-set of sizes that correspond with the most common and therefore desired dimensions.

A quick glance at a typical pile of recovered wood (Fig. 1) reveals that there are both individual pieces of wood and jointed products, e.g. pallets. Dismantling would probably be too time consuming to be profitable. Cutting and/or coarse crushing to release individual wood pieces might be an option. The concept map shown in Fig. 2A shows the main steps for preparing individual straight pieces of wood. The rest of this discussion paper covers how individual pieces of wood might pass through the CaReWood process.



Fig. 1.

A typical stockpile of recovered wood waiting to be processed.

Sorting criteria

Recovered wood is made up of a range of different wood species. Packaging tends to be predominantly softwood, whereas furniture is a mixture of both hard and softwoods. So another question is should recovered wood be sorted by species or not? Or is a separation of hardwood and softwood enough? Different wood species have different densities that gives them different mechanical and physical properties, so perhaps the wood should also be sorted by density.

In addition, some recovered wood is relatively dry and some is wet because, for example, it has been stored outside for some time. Ideally, the wood should be dry before it is made into a new product and to minimise energy consumption it makes sense to sort on the basis of moisture content.

Fig. 2A, B and C show how recovered wood might be processed to the point where it has been converted to clean, straight, smooth surfaced pieces of random lengths. These could be finger-

jointed to make continuous long lengths of timber. It is better to discuss the details of the process before discussing the final stages of end jointing the timbers.

Fig. 2B highlights the fact that not all recovered wood timbers will have a rectangular or square cross-section as some will be moulded, e.g. a window frame or skirting board. These will have to be sawn to the nearest standard dimensions. The wood removed will be chipped and used in existing markets.

The main advantage of sorting on the basis of cross-sectional area is that it will be easier to maximise the yield from each piece. The concept of yield is introduced because the faces must be cleaned so that they could be used to make a laminated product. In addition, the faces of recovered wood are often painted or coated in some way and all surfaces are soiled to a certain degree and, therefore, they are contaminated, so it is best if the outer faces are removed to reveal the clean wood underneath. Certainly, this step will improve the aesthetics of the final product. It is proposed that at least 2mm is removed from each surface by sawing and a further 1mm off each face by planing to give a smooth face (see Fig. 2C).

So the advantage of this approach is that the yield of saleable wood will be maximised. An example will be given later in the paper. The disadvantages are, however, numerous, including:

1. The process will need a lot of bins at the sorting stage. For example, if it is decided to sort on the basis of 4 thicknesses (say 19, 32, 38, and 50mm) and 6 widths (say 50, 75, 100, 150, 175 and 200mm) then 24 bins are required. If, in addition, another sort characteristic, say density, is added then the number of bins required is multiplied again by the number of categories. If three density classes are included (low, medium and high) then the total number of bins required is now 72.
2. After some consideration it was decided that the most pragmatic approach is to process the contents of a bin once it is full and thus minimise the number of times that the settings of the saws and planers are changed. They will still require, however, frequent changes each day and so machines that can set themselves seem to be essential.
3. After machining, the wood recycler will now have a large range of products to sell. This might be an advantage, but, it could also be a disadvantage as it will increase the stock levels of finished products.

The dimensions of the pieces generated by step shown in Fig. 2C will match those of the nearest popular standard size. Therefore the yield is not simply:

$$y = \frac{(w - 6) * (t - 6)}{w * t} \quad (\text{Eq. 1})$$

where: y = yield, w = width, t = thickness of the original piece¹. This is because $w-6$ and $t-6$ might not result in a saleable dimension. Rather it is:

$$y = \frac{n * w_l * t_l}{w * t} \quad (\text{Eq. 2})$$

where: w_l = width, t_l = thickness of the resultant lamella that is of a standard dimension and n = the number of lamellae cut from the cross-section. For the moment, however, the yields presented in this paper have been calculated using Eq. 1.

¹ In the CaReWood project the thickness is defined as the smallest of the cross-section dimensions. In addition, no attempt has been made to account for losses due to converting complex cross-sections into four-sided sections.

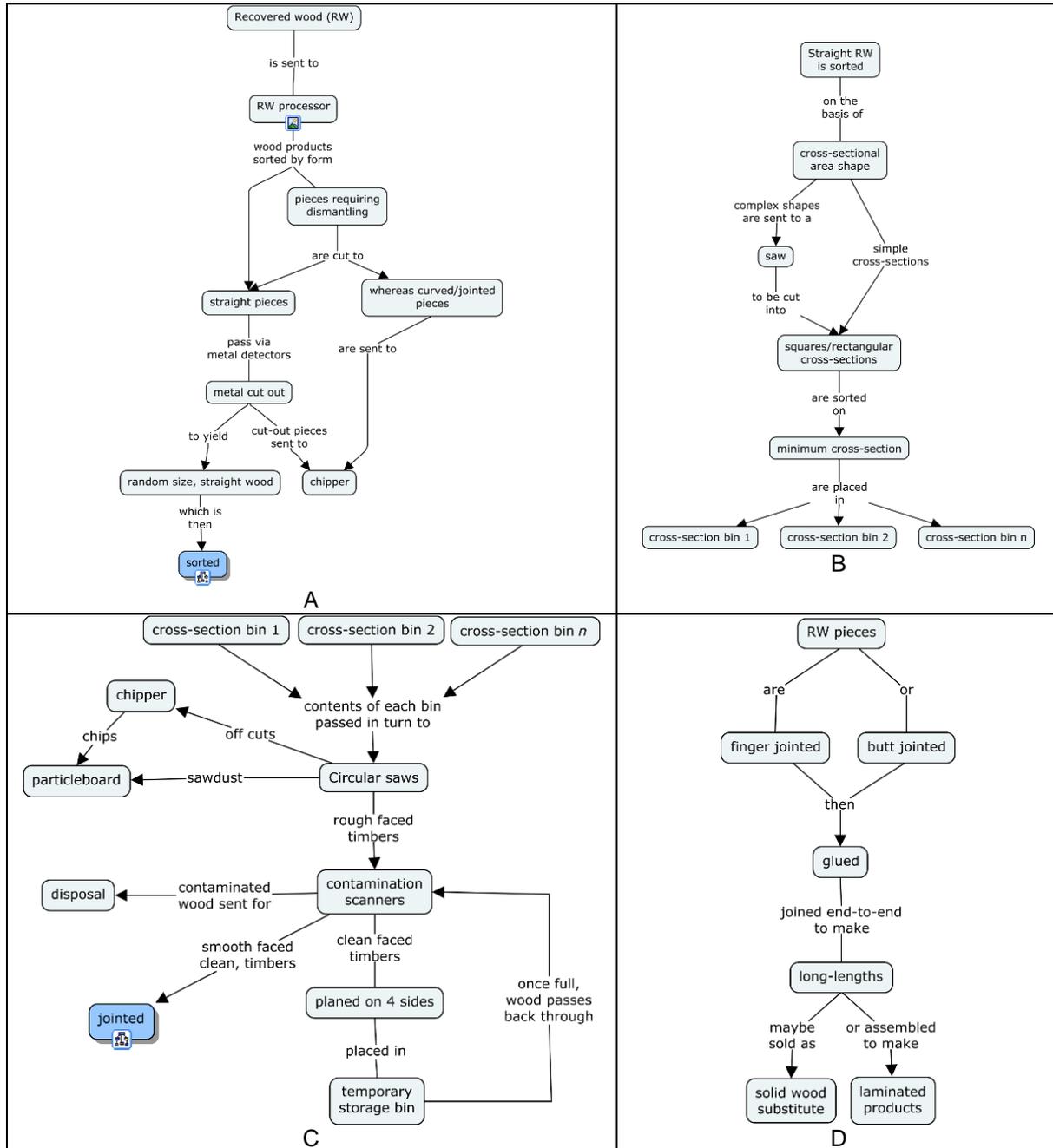


Fig. 2.

Detail of the CaReWood process: A. generation of straight pieces of RW; B. Size sorting of straight pieces; C. contamination elimination; D. Jointing/laminating of clean RW pieces

Modelling the CaReWood Process

Three visits have been made to three different wood recycling companies. As a result, 65 samples of individual pieces of recovered wood have been measured and identified as being hard or softwood. These data are unlikely to be representative because they are so few and only three sites have been visited during two seasons of the year (autumn and spring). More data will be added in the future, which might influence the conclusions on the best CaReWood processing route to develop.

Fig. 3 attempts to show the distribution of the 65 pieces if they were sorted on the basis of their cross-sectional areas, for different numbers of size classes. For example the top graph in Fig. 3A shows their distribution across 20 size classes. It would seem that the range of cross-sections is large for both hardwoods (solid circles) and softwoods (open circles). Although the volume found in each bin in Fig. 3C are not so different, the actual number of pieces in each bin is very different as 83% of 65 samples fall into the first bin.

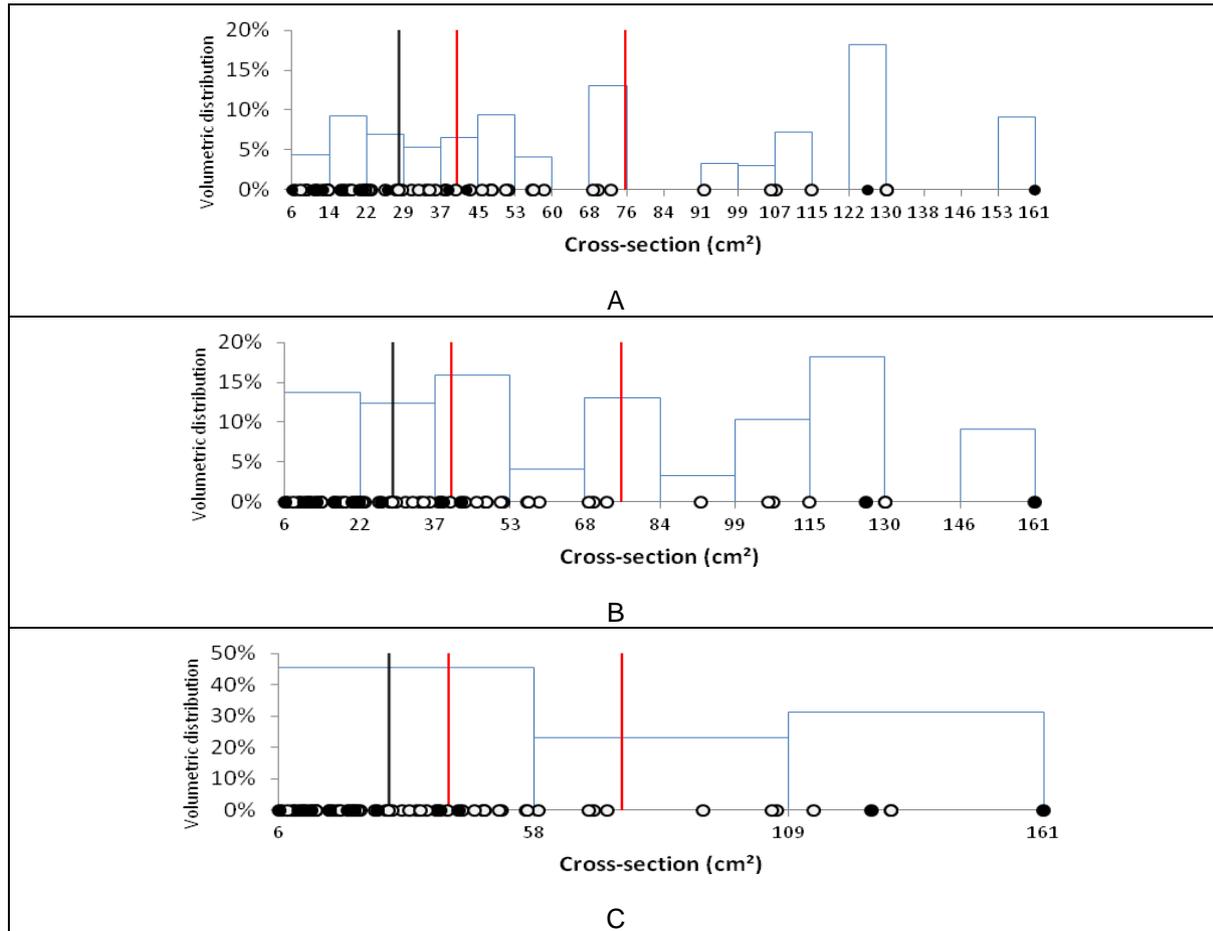


Fig. 3.

The distribution of the 65 samples if they were sorted by cross-sectional area into 20 bins (A), 10 bins (B) or 3 bins (C). Note: Open circles show softwood pieces and filled circles hardwood pieces; from the left, the first vertical line is the median of all samples, the second is the mean and the third is the mean+standard deviation of sample cross-sectional area

An Alternative CaReWood Process

Given sorting problems described above an alternative approach has also been considered. The alternative is to cut every recovered wood piece into lamellae as shown in Fig. 4. The lamellae would then be laminated and finger-jointed together to make large dimension timbers. The dimensions of the lamellae will obviously have an effect on yield; large dimensioned lamellae would reduce sawdust volumes but increase offcut volumes. So there is a need to model the effect of lamellae dimensions on yield.

A yield model was built using the calculation, logic and lookup functions in Excel. The model assumes a 2mm decontamination by sawing, a saw kerf of 3mm (for cuts between lamellae) and a final planing of 1mm. Consequently, at least 3mm is removed from each of the four sides. When the model was applied to the cross-sections of the 65 samples collected from wood recycling plants, it was found that a lamella of 30 x 15mm provided the highest yield of 39% of lamellae, 22% sawdust from sawing operations, 8% shavings from planing and 31% of offcuts. Cutting larger lamellae, reduces the yield, sawdust and shaving volumes but significantly increases the offcut volumes. Likewise, machining smaller lamellae significantly increases the sawdust volumes and does not give a benefit in yield of useful wood. In addition, small lamellae make it necessary to glue lamellae together in order to obtain useful widths and thicknesses. Plus, in the case where lamellae are glued together in two dimensions, some of them must be offset in order to minimise the coincidence of glue lines (see Fig. 5). This complicates the manufacturing process and also reduces yield of final product because the laminated block must be squared off after it is made. Even so, the window frame in Fig. 5, which was made from reprocessing old window frames, clearly demonstrates that the CaReWood process has potential.

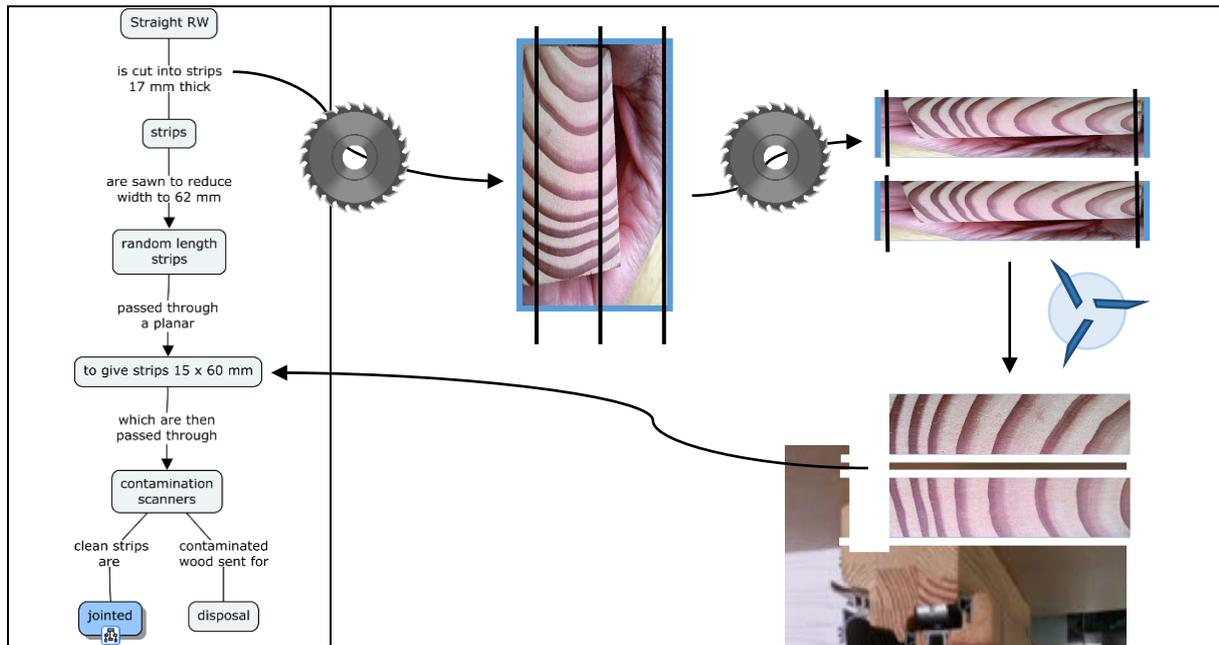


Fig. 4.

One potential production flow for the CaReWood process is shown in Fig. 4. The strips, depending on their size, are cut to lamellae of the same size.

Another variation would be to sort the pieces on cross-section into lamellae that have the optimum dimensions for that class. The samples into 3 classes (Fig. 3C) and then using optimum lamellae would provide an overall yield of 47%. The optimum lamellae dimensions would be 15 x 60 mm and this would make it difficult to combine them into new products. To ensure that at least one of the lamellae dimensions are the same, it would facilitate the subsequent lamination step.



Fig. 5.

A section of a window frame made by MSORA (an SME partner in CaReWood) using lamellae cut from old window frames.

CONCLUSIONS

If the original objective of the CaReWood project is strictly followed, then the CaReWood process should limit the removal of wood to the cleaning of the wood surfaces. This would result in a wide range of non-standard cross-sections that would be difficult to place on the market. The alternative, is to cut to the nearest standard size. Whilst technically possible, this is much more complex to realise industrially than processing all wood into lamellae of a fixed dimension. A compromise is to fix one dimension of the lamellae to, say 60mm, and then varying the thickness in relation to the typical cross-sectional areas being processed as it would be easier to combine the lamellae in the lamination step.

Although complex, none of the sorting and machining steps are beyond current technology and so it would seem that a version of the CaReWood process can be realised and that the resultant products would be useful and have a high economic value.

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