

## What Next for Wood Construction/Demolition Debris?

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Residents in localities throughout the world voluntarily participate in the routine recycling of household wastes, such as paper, metals, and plastics containers. But when a house in their neighborhood gets built or torn down, most of the debris – including wood waste – gets landfilled. Such a waste of material suggests that there are opportunities to add value to these under-utilized resources. The great variability, as well as contamination, pose major challenges. It is recommended that reclaimed wood be primarily used in the manufacture of durable goods, and then whatever is left over be used for energy (or heat) generation.

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### The Challenge to Reclaim Value from Used Wood

Huge amounts of wastes are loaded into dumpsters around the world in the course of typical building construction or demolition projects. It has been estimated that 38 million tons of wood debris from such sources are disposed of per year in the US alone (Sandler 2003). The proportion of wood in such mixtures can be about 40% in a typical case (Carpenter *et al.* 2012). Most of this debris is placed in landfills (Mercante *et al.* 2012). One would think that there must be a higher-value, more environmentally responsible usage of such wood rather than just burying it. To make matters worse, degradation of mixed wastes under uncontrolled conditions is likely to generate methane (Lou and Nair 2009), a gas having approximately 25 times greater global-warming potential in comparison to carbon dioxide (IPCC 2007).

Life-cycle studies of wood construction and demolition debris have projected great environmental benefits if the wood component can be reused or somehow recycled in the form of durable secondary products (Werner *et al.* 2010; Carpenter *et al.* 2012; Sandin *et al.* 2014). Options that come to mind include reuse with minimal modification, oriented strandboard, particleboard, papermaking, and various kinds of composites. Another possibility is to burn the material to generate electricity. This could be done either directly in a steam generator, or one could convert the wood debris into wood pellets (Stelte *et al.* 2012) or liquid biofuels such as ethanol (Jafari *et al.* 2011).

So why isn't everyone doing this already? The short answer may be "variability and contamination." Not only is the wood component of construction and demolition debris mixed with gypsum, aggregate, roofing material, and plastic, among other things, but it is also highly variable from batch to batch and from day to day. Also, the mixture is likely to be partly bound together by nails, screws, various adhesives, and laminations. The wood may sometimes contain toxic preservatives, and it even may be coated with lead paint in some cases.

### Strategy “One” – Find Uses that Tolerate Variability and Contamination

Suppose that your aim is to produce oriented strandboard (OSB). Should you regard reclaimed wood to be a promising source material? Among the potential problems that come to mind, perhaps the most severe is the great difficulty in preparing a consistent dimension of strands from a mixture that can contain hardwood and softwood species, along with a broad range of sizes, orientations, and states of contamination of the wood pieces. Nails in the reclaimed wood can be expected to increase downtime, as well as maintenance costs of the equipment. Differences in porosity among strands from different wood sources might make it nearly impossible to optimize the amount of adhesive used. Whereas OSB is frequently used in applications requiring high strength characteristics, the use of strands from multiple sources would naturally yield a wide range of performance, depending on the batch of material. Thus, one could only guarantee performance corresponding to the lower-performing strands.

How about particleboard? According to Werner *et al.* (2010), particleboard, which is sometimes called “chipboard,” is the only wood product that is widely prepared from reclaimed wood. Strength specifications of particleboard are not as demanding as those of OSB, and they can be controlled to some extent by varying the amounts of phenolic resins employed. Better yet, one does not need to cut veneer pieces. Particleboard can be employed in such functions as floor underlayment and in cabinets, where it is often covered on at least one side with a laminate.

Occasionally one might walk into a fancy restaurant and find the place decorated with old wood from barns, having a weathered look. Or sometimes wood with nail holes or even with old paint is used to achieve a certain nostalgic effect. But such uses are not typical. Only small amounts of wood are ever used in such applications. And most building and construction debris are not exactly what you want to be looking at while eating a fine meal.

Now let's suppose now that you decide to convert the recovered wood to energy. In principle, you could burn the wood in a generator, you could make pellets so that it could be more efficiently transported and sold to customers having suitable boilers or furnaces, and you could use it as a feedstock for a biorefinery operation to make ethanol (using a so-called “biochemical route”) or various gaseous, bio-oil, and tar-like fractions (using a so-called “thermal” route). Of these options, the biochemical route could be expected to be most severely disadvantaged by the great variability within wood from building sites. In effect, one would be forced to over-dose the system with cellulases and white-rot enzymes, *etc.*, based on the recalcitrance of the least-digestible wood species having a chance to be dominant in a given batch. Jafari *et al.* (2011) showed that a high yield of bioethanol would be obtained from reclaimed wood by treatment successively with concentrated phosphoric acid, N-methylmorpholine-N-oxide solvent, cellulases, and yeast. Though such studies show what is possible, it seems likely that the cost of obtaining ethanol from waste wood will remain cost-prohibitive in the foreseeable future.

### Strategy “Two” – More Intensively Sort the Debris Components

Given the multiple problems posed by variability and contamination, perhaps the most promising scenario for future use of reclaimed wood will involve improved sorting facilities (Mercante *et al.* 2012). Already in Hong Kong, efforts have been made to sort construction waste at construction sites (Yuan *et al.* 2013). This is not unlike what many consumers do at home when they sort their recyclable glass, newspaper, office waste, and

plastics. Alternatively, one can expect there to be innovations in centralized sorting of mixed wood-containing debris, analogous to the facilities that currently handle commingled residential recycled materials.

Automated equipment has been developed having the ability to sense and separate different grades of recycled paper, even separating the wood-containing paper (e.g. newspapers and many magazines) from wood-free papers (most office papers) (Ramasubramanian *et al.* 2012). In principle, a near-infra-red (NIR) approach could be used to rapidly and remotely distinguish between hardwood and softwood pieces – based on the different compositions of lignin (Yang *et al.* 2012). By separating the mixed wood into hardwood and softwood streams, the resulting product, whether it be particleboard or pulp for papermaking, would be more predictable in quality.

Pre-sorting of wood wastes by type, e.g. by separating it into hardwood and softwood batches, can be expected to benefit various options for adding value to the material. Suppose, for instance, that one's interest is in thermochemical conversion (Mohan *et al.* 2006). A better-defined and more uniform wood supply to such a process can allow better optimization of processing conditions, hopefully giving rise to more predictable ratios of gaseous, bio-oil, and bio-char components. It is important to note that separation of the resulting bio-oil into fractions can be regarded as an essential part of any such operation. Thus, even if there is a high variability in the initial pyrolysis products, in principle one still can separate the bio-oil into useful components, though in different proportions. All of these considerations suggest that reclaimed wood is likely to be considered as an optional feed for future wood-to-monomer thermochemical conversion installations, if and when that type of technology reaches the point of commercial implementation.

Wood pellet production is another important type of energy-related product that would stand to benefit from more intensive sorting of wood wastes. Since pellets are likely to be utilized in a broad range of facilities – either for heating or for energy generation – one can expect there to be stiff requirements regarding the possible inclusion of toxic substances, such as lead from lead paint. A system of being able to detect and exclude painted wood on a conveyor system could add value in such cases.

Papermaking is worth mentioning, if only because it consumes huge amounts of wood. Though reclaimed wood could be used to make pulp, it seems doubtful that the market would accept the high variability. Fortunately, there's a great alternative, using a low-cost and widely available resource: One can collect and recycle used paper.

### **Integrated Strategies**

It has been said that the best time to plant a tree is 30 years ago. The second best time is now. Since both trees and demolition of buildings have relatively long cycles, it will be important to develop long-term strategies and then stick to them faithfully. A general approach that seems to make sense, both for the environment and for economic viability, involves a “cascade” of end-of-life utilization scenarios for recovered wood (Werner *et al.* 2010). According to a cascade system, one uses as much of the recovered wood as practical to make durable products, and then the rest is converted into energy – most probably by the generation of steam. Though the energy generation does not sequester CO<sub>2</sub>, it can displace the use of fossil fuels. Putting wood into durable products not only can act as a carbon sink, but it also may displace more energy-intensive construction materials such as metals (Werner *et al.* 2010).

Though the emphasis in this essay has been on construction and demolition debris, one ought not to lose sight of the forest. According to Werner *et al.* (2010), the greatest environmental benefits – in terms of either CO<sub>2</sub> sequestration in highly durable structures or in displacement of fossil fuels – can be achieved by continual utilization of wood at a rate that matches the growth/replacement rate of the forest, *i.e.* by matching the “sustainable increment” of forest growth. Although a slower rate of utilization might temporarily increase the amount of “standing carbon” in a forest, in a longer term the elderly trees will decay, and the carbon stored in the forest may decline (Werner *et al.* 2009). Forests are also vulnerable to fire, severe storms, and insect blights. Wooden structures are vulnerable too, but perhaps less so in comparison to forests.

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