HPL: Opportunities for post-consumer recycling and refurbishing

Preface

High-pressure laminate (HPL) manufactured in accordance with EN 438 has been used in the construction and furniture sector for decades. The European standard EN 438 defines the material, requirements and properties of HPL.

HPL is a resin and paper-based (cellulose) thermosetting composite material and features a unique, extremely robust, resistant, modern decorative surface. HPL is found in all aspects of our day-to-day lives and can be self-supporting or used bonded to a substrate. The application and usage areas of HPL are extremely diverse and are constantly evolving. This requires regularly updated information about different applications and processing techniques. ICDLI technical bulletins are a valuable source for this knowledge.

This technical bulletin is the first to deals with the question of how HPL can be recycled and processed. The ICDLI would like to thank the two authors Dr Arne Schirp and Dr Steven Eschig, Fraunhofer-Institute for Wood Research (WKI), Braunschweig, Germany for the scientific preparation.

For more than 50 years the ICDLI has been the international representative of the interests of European laminate manufacturers. Further information about the ICDLI and the data sheets published up to now can be found at www.icdli.com.

This application was compiled by the International Committee of the Decorative Laminates Industry. It considers the conditions of application technology in the European countries. If you have further questions, please contact us:

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1. Objective

Environmental sustainability is one of the top issues of our time, and this also applies to HPL which are predominantly used in the furniture, building and construction sectors. High-pressure laminates are differentiated into compact HPL which contain approximately 70% cellulose (kraft papers) and 30% resin (phenolic, melamine), and HPL elements which consist of a substrate (for example, particleboard or fibreboard) plus HPL top layers.

The main advantages of HPL are their extreme durability and long service life. Products in service last for 30-50 years, depending on the application (indoor vs. outdoor, compact HPL vs. HPL elements, etc). This means that the carbon content in the material is stored for a relatively long time, compared to many other products in the furniture and building sectors. Often, HPL are disposed of only due to their appearance; for example, if the colour is not liked any more, while technical requirements are still met.

An environmental product declaration (EPD) has been published for HPL for the first time in 2012 by the European association of HPL producers, the International Committee of the Decorative Laminates Industry (ICDLI). The EPD contains important information about the environmental product features of HPL complying with EN 438 parts 3 (thin laminate, thickness < 2 mm) and part 4 (compact laminate, thickness ≥ 2 mm) with a density of at least 1350 kg/m³. This is especially useful for the end-users of HPL such as architects and construction engineers.

The resins used in HPL production are thermosets. For some composites made with thermosets, chemical recycling methods exist in which the polymers are depolymerized and can be re-used. However, to the best of our knowledge, this approach cannot be applied to HPL, since the currently used resins are permanently cross-linked.

At present, HPL residues are used for energy production („thermal recycling") in approved industrial incineration units. In some European countries, landfilling still occurs which is the least environmentally friendly option as the material will not decompose under such conditions.

In the case of post-consumer HPL elements, these can be recycled into particleboards, and this option is already practiced. The advantage is that there is no need to separate substrate (e.g., particleboard) and HPL top layer. The complete HPL elements can be ground to a suitable particle size for re-use in the processing of particleboards.

There are in fact some promising end-of-life-recycling options for HPL, as shown in the following Figure 1. As mentioned, at the end of service life, HPL has usually been in use for 30 years or more. If the material is then ground and re-used in, for example, cement-bonded particleboard, plasterboard or thermoplastic polymer composites, a total lifetime of up to 100 years can theoretically be expected.

In some cases, grinding of post-consumer HPL may not even be the best choice if the material is still functional. Re-furbishing, i.e., adding a new film or laminate on top, could be the better option.

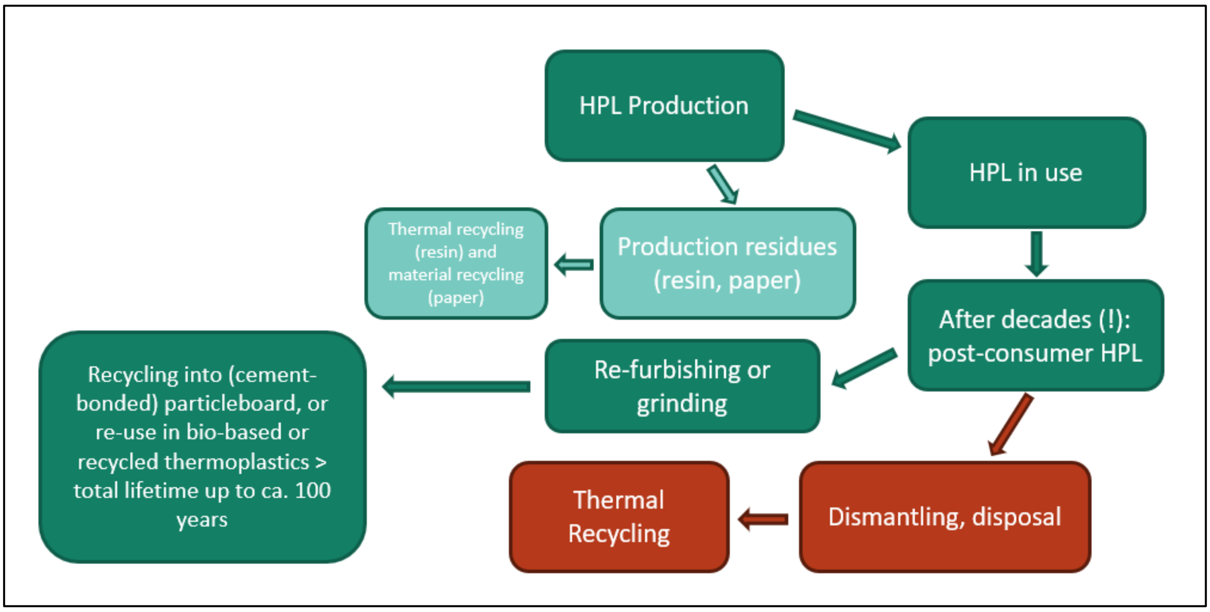

Figure 1: Post-consumer recycling of HPL: status quo and outlook.

2. Recycling

In detail, we foresee the following options for post-consumer recycling opportunities:

a. HPL–Compact in interior applications

HPL–Compact in interior applications (e.g., wall materials, furniture components, separating walls in bathrooms, locker rooms):

- Evaluation of options and technical feasibility for grinding of HPL into small fragments (high amount of energy required)
- Re-use of HPL particles in particleboards, thermoplastic composites or floorings (for houses, roads, etc)
- Determination of maximum possible amount of thermoset component in novel applications
- Cement-bonded particleboards, consisting of approximately 70% portland cement and 23% of wood particles, are of particular interest since they may tolerate a higher proportion of HPL recyclate compared to regular particleboard
- Addition of fresh thermoset adhesive (particleboard) or fresh thermoplastic polymer (e.g., polypropylene, polyethylene) components to fulfil requirements
- In the case of thermoplastics, consider the use of bio-based or recycled plastics to increase the bio-based content, or to create a product based on 100% recyclate.

b. HPL–Compact in exterior applications

HPL–Compact in exterior applications (e.g., facades):

- Since facade panels made of HPL are typically of large dimensions, they could be dismounted from their substructure if mechanical fasteners are used, cleaned, brushed and covered with new laminates or foils
- If parts of the facade panels are damaged, smaller fragments could be cut and re-used in new applications
- This end-of-life option would be re-furbishing: HPL would receive a „second life" after re-furbishment
- If re-furbishing is not possible, grinding of dismantled HPL facades could be done; the milled residues could be re-used in (cement-bonded) particleboards, plaster board or thermoplastic profiles.

c. HPL elements

HPL elements (mostly used in interior applications; e.g., furniture):

- As with HPL compact, grinding of the complete elements without separation of HPL and wood substrate can be done, and this option is already used in the industry to produce new particleboards
- Increased added value may be gained by separation of particleboard, fibreboard or plywood substrates and HPL
- This could be accomplished by subjecting the HPL elements to hot water or impregnation solutions, as has been demonstrated earlier for the recycling of particleboards and MDF bonded with urea-formaldehyde resins [1]
- Such a process is feasible if HPL are glued to the wood-based substrates using urea-formaldehyde or PVAc resins which can be easily hydrolyzed in such processes
- Following separation of wood particles / fibres and HPL, the wood residues could potentially be re-used in wood-based panels or thermoplastic profiles
- Alternatively, they could be used in a bio-refinery approach to generate bio-based platform chemicals as shown in Figure 2.

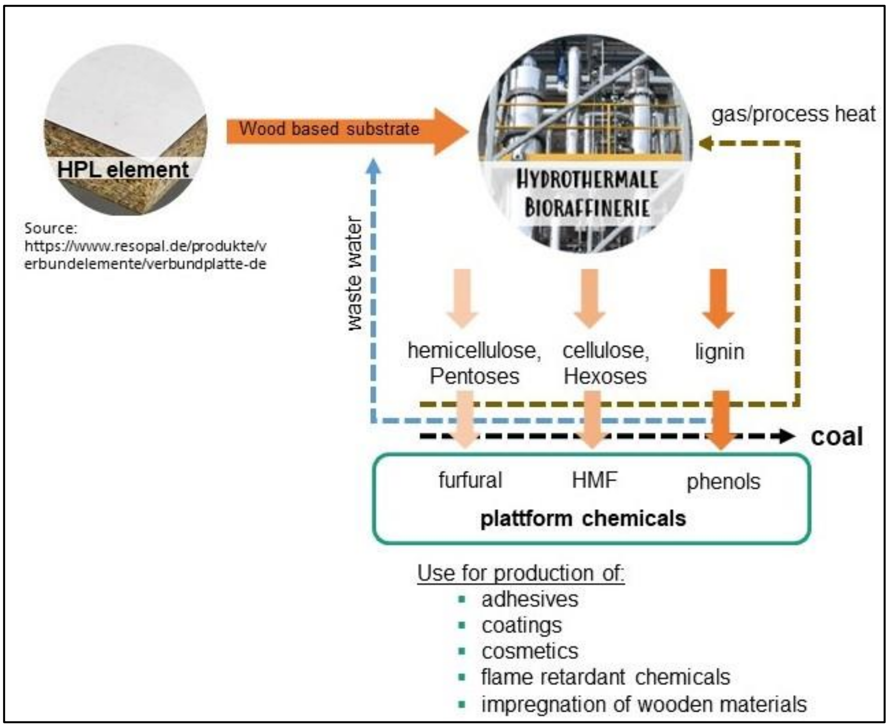

Figure 2: Biorefinery approach for the recycling of wood-based substrates in HPL elements: Using platform chemicals from wood (furfural, hydroxymethyl furfural, lignin) to synthesize, for example, formaldehyde-free adhesives for the wood-based panels industry.

Extending the life span of HPL by re-using the material in new products such as cement-bonded particleboards or plaster boards which are also highly durable will result in environmental benefits that can be quantified as part of a life cycle analysis (LCA).

Furthermore, the carbon footprint of HPL can be improved if the used resins are replaced by bio-based substitutes with components such as lignin, furfural and tannin [2]. Lignin-, humin- and hydroxymethylfurfural-based condensation resins have been developed in a current project at Fraunhofer WKI for wood-based panels [3]. A major advantage is that these adhesives are formaldehyde-free.

In addition, by using renewable carbon, carbon dioxide emissions can be reduced. In 2019, emissions rose to a record 55 Gt CO_2e, compared to 50 Gt CO_2e in 2018 [4]. Yet to limit the temperature rise to 1.5°C in 2030, these emissions must be reduced to a maximum of 24 Gt CO_2e per year [4]. Globally, a third of oil reserves, half of gas reserves and over 80% of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2°C [5]. The only way to phase-out fossil carbon sources is to switch to renewable carbon from CO_2, biomass or recycling streams.

Adhesives can also be designed to facilitate recycling. This approach has been applied in the case of cement-bonded wood-based panels for timber-panel construction [6]. Here, polyurethane adhesives were developed whose adhesive effect can be switched on and off in a temperature-controlled manner.

Below 60 °C, the adhesive is cross-linked while above 120 °C, chemical functional bonds dissolve and the adhesive melts. This process can be repeated several times („bonding and de-bonding on demand“).

One important pre-requisite for efficient end-of-life-recycling of HPL is that the materials are collected, identified and sorted. It is expected that most of the waste HPL is collected in the form of bulky waste. In Germany, more than two million tons of bulky waste are generated annually [7]. Depending on the regional disposal concept, up to 50 percent thereof consists of wood, predominantly old furniture, probably including a significant portion of HPL. Because HPL consists of a high proportion of cellulose, in Germany, it can be classified as waste wood category A-II which encompasses glued, painted, varnished or otherwise treated waste wood without halogen-organic compounds in the coating, e.g., PVC, and without wood preservatives [8, 9].

If waste HPL is considered as a valuable resource, then efforts will be placed on extracting this material from the waste streams currently going into incineration plants. Obviously, HPL produced by different manufacturers and during different decades vary in their composition. For example, colours, UV protection agents and fire-retardants can be added. Halogen-containing chemicals or other environmentally dangerous substances should not be expected in HPL.

While it would be technically feasible to analyze the composition of end-of-life HPL, the effort to analyze each panel would be too high. Trained employees in waste-management companies can easily recognize wood-containing parts from pre-crushed bulky waste, but they are not infallible. Until now, commercially available sensor-based sorting processes on the basis of conventional color-camera technology have been less able to reliably detect wood-containing components from chunky waste mixtures. Prior shredding of the entire bulky waste is laborious and the sorting results remain inadequate. Modern imaging methods generate additional information which a sorting employee does not have. By means of an “intelligent” system, bulky waste can be sorted accurately and fatigue-free - even without prior shredding [7]. If bulky waste can be transformed into including HPL, can be increasingly utilized in the production of high-performance materials, for example in polymer composites or as an aggregate in concrete (gravel substitute). a valuable raw material, consumers could theoretically also profit from a direct financial benefit. It is expected that waste wood,

3. Summary and Outlook

In Table 1, end-of-life recycling options for HPL were summarized. The next step will be to evaluate if these recycling options are technically and economically feasible, and if they can improve the carbon footprint of HPL.

Table 1: Summary of recycling options for compact HPL and HPL elements.

Type of product	Particleboard	Cement-bonded particleboard, plaster board	Re-furbishing[1]	Thermoplastic composites[2]	Floor finishes (indoor, outdoor); filler for asphalt
HPL element	+	+		+	
HPL–Compact	+	+	+		+

[1] Means, for example, glueing film or new laminate on top of old HPL (if still undamaged).[2] Can be biopolymers or recycled polymers; intermediate product is compound; final products can be injection-moulded or extruded into profiles or sheets.

In addition to material recycling efforts, focus should be placed on increasing the bio-based content of HPL by using sustainably sourced raw material options for resins. Switchable resins which are designed for easier recycling can also be developed and included. LCA should be performed in parallel to evaluate the ecological and economic advantages of material recycling options. By pursuing these objectives, it will be possible to keep HPL at the forefront of choices for high-quality, long-lasting and sustainable materials for the furniture, building and construction sectors.

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