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[1.]Imre KISS, [2.]Eleonora DESNICA, [3.] József SÁROSI

MODERN ENGINEERED WOOD PRODUCTS: AN OVERVIEW ON THEIR TIPOLOGY AND BENEFITS FOR THE CONSTRUCTION SECTOR

[1.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Department of Engineering & Management, Hunedoara, ROMANIA
[2.]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA
[3.]University of Szeged, Faculty of Engineering, Szeged, HUNGARY

Abstract: Timber is a fundamental construction material with a rich history and significant modern importance due to its unique structural, environmental, and economic benefits. Timber is valued for its high strength relative to weight, allowing it to support heavy loads in structural elements like beams, columns, and trusses. It is also easy to cut and shape, making it versatile for use in furniture, roofing, door/window frames, and scaffolding. Modern timber construction integrates sustainability and prefabrication, emphasizing carbon storage and building efficiency. Timber remains a vital construction material due to its structural capabilities, versatility, environmental benefits, and longstanding cultural role in building history—from ancient civilizations to cutting–edge modern architecture. Modern engineered wood products encompass a variety of types designed for specific structural and functional applications in construction, offering enhanced strength, stability, and versatility compared to traditional solid wood.
Keywords: timber, modern Engineered Wood Products (EWPs), Structural Composite Lumber (SCL), Wood–Based Panels, Mass Timber Products

INTRODUCTORY NOTES

WOOD, as a natural, sustainable, and renewable bio–composite material, has a long history of serving humanity as construction materials. With the advance in technologies, many modern ENGINEERED WOOD PRODUCTS (EWPs) have been invented, produced, and used in construction, such as laminated veneer lumber, oriented strand board, and cross laminated timber.[1] There is an increasing demand for using wood, as a green building material, to construct large and tall residential, commercial, and industrial buildings. [2–4]

Figure 1: Lumber from the log

In order to address the foregoing challenges of sourcing raw wood materials and catering to the market demands, an ever–growing number of value–added wood–based commodities and building materials have been created through the advances of technology. Contemporarily, modern engineered wood products (EWPs) have been widely used in construction. [2–4]

TIMBER use dates back to ancient times, such as in Ancient Rome, Egypt, and China, where it was used for homes and temples. During the Middle Ages, timber framing dominated European building construction, prized for its strength and flexibility. The Industrial Revolution mechanized timber processing with steam–powered sawmills, increasing production scale and leading to innovations like laminated timber.[2–4] In the 20th century, steel and concrete largely replaced timber in large–scale construction, but engineered timber products like glue–laminated timber (glulam) and cross–laminated timber (CLT) have revived its use, enabling multi–storey buildings and skyscrapers again. Modern timber construction integrates sustainability and prefabrication, emphasizing carbon storage and building efficiency. Timber remain a fundamental construction material with a rich history and significant modern importance due to its unique structural, environmental, and economic benefits. [2–4]

TIMBER remains a vital construction material due to its structural capabilities, versatility, environmental benefits, and longstanding cultural role in building history—from ancient civilizations to cutting–edge modern architecture. Timber is rapidly gaining prominence as a sustainable, efficient, and versatile construction material, driven by increasing environmental concerns and regulatory pressures to reduce the carbon footprint of the building sector. Modern advanced timber materials such as cross–laminated timber (CLT), glue–laminated timber (glulam), nail–laminated timber (NLT), dowel–laminated timber (DLT), laminated veneer lumber (LVL), and structural composite lumber (SCL) represent a transformative shift from conventional wood construction to highly engineered, factory–fabricated components offering superior strength, durability, and precision. [5–10]

Modern engineered wood products (EWPs) used in the construction sector primarily include glued laminated timber (glulam), finger–jointed structural timber, and especially cross–laminated timber (CLT). These products are manufactured through bonding smaller wood pieces into larger, structurally strong components for prefabricated building elements. [5–10] The use of EWPs is expanding due to their favourable properties like high strength–to–weight ratio, fire resistance, sustainability, and cost effectiveness compared to traditional concrete and steel in multi–storey buildings. Prefabrication of these products allows fast and standardized assembly on–site, reducing construction time significantly. CLT, in particular, has seen rapid growth and adoption in Europe for mid–rise and high–rise timber construction. [5–10] These products support the shift toward sustainable construction as they store carbon, use smaller and less valuable wood species, and enable efficient modular building approaches.

ABOUT ENGINEERED WOOD PRODUCTS

Many EWPs are created by bonding wood veneers or flakes with adhesives. The choice depends on whether a natural wood grain appearance (veneer) or a cost–effective, composite structure (flakes) is desired. Veneers are thin sheets of wood, while flakes are small, rectangular pieces.[11–13] VENEER consists of thin, decorative wood sheets glued to a substrate for a natural wood look, while FLAKES are smaller, irregular–shaped wood particles used in composite products like particleboard for structural or insulating purposes, rather than aesthetics. In fact, veneers are flat, thin sheets, while flakes are smaller, irregular particles. The veneer provides a natural wood grain pattern, offering an appearance identical to solid wood, whereas flakes provide a more uniform, composite look. These products maximize the use of wood resources by utilizing smaller, fast–growing trees or less desirable parts of a log, which leads to less waste and a more efficient use of natural resources. [11–13]

VENEER–BASED ENGINEERED WOOD PRODUCTS are made from thin layers of wood called veneers. These are bonded together with adhesives to create strong, stable, and versatile building materials used in various construction applications. Thin slices (leaves) are cut from logs, dried, and then glued onto a core material like particleboard, fibreboard or plywood. [11–13]

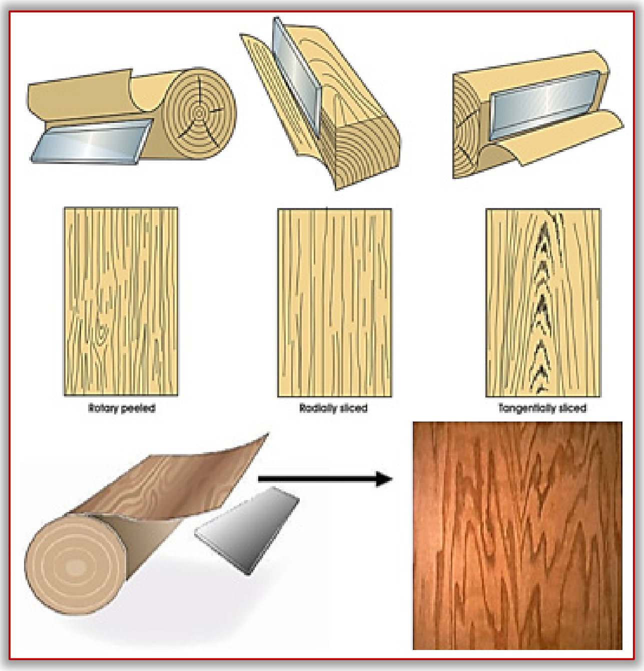

Figure 2: Veneer producing

PLYWOOD is made by gluing thin layers of wood veneer, with the grain of adjacent layers alternating to create a strong, stable panel. LAMINATED VENEER LUMBER (LVL) is produced by bonding thin wood veneers together with the grain of all veneers running in the same direction and it is used for beams, headers, and rafters. ORIENTED STRAND BOARD (OSB) is formed from compressed, rectangular–shaped strands or flakes of wood bonded with adhesives. OSB is a popular alternative to plywood. PARALLEL STRAND LUMBER (PSL) & LAMINATED STRAND LUMBER (LSL) are made from long veneer strands or flakes that are bonded together to form beams and headers.

FLAKE–BASED ENGINEERED WOOD PRODUCTS are made from small, rectangular pieces of wood, often called strands or wafers that are mixed with adhesives and then pressed into panels. This process efficiently uses smaller trees and wood residues, making it a sustainable alternative to traditional solid lumber.

Figure 3: Wood particles used in the particleboard production

FLAKES creates a rough, mottled, or less defined texture, lacking the natural grain of veneer. The smaller pieces of wood are produced by slicing or milling, then bonded together with resin. Are used in products like PARTICLEBOARD/LOW–DENSITY FIBREBOARD (LDF) and ORIENTED STRAND BOARD (OSB), where strength and cost are more important than appearance, and also in some wood fibre insulation. Similar to OSB, PARALLEL STRAND LUMBER (PSL) & LAMINATED STRAND LUMBER (LSL) are made from long, narrow strands of wood. However, these strands are all aligned in a parallel direction, which gives the product its strength. [11–13] To create OSB, wood strands are arranged in cross–oriented layers. The outer layers are aligned in the long direction of the panel, and the inner layers are perpendicular. This orientation gives the final product its strength and stiffness, making it ideal for structural applications.

Modern engineered wood products (EWPs) are not only made from veneer or flakes, but also from other sources, including WOOD FIBRES and DIMENSIONAL LUMBER. Beyond veneers and flakes, EWPs are also manufactured using other materials, which allow for a broader range of applications and properties. [11–13]

WOOD FIBRE–BASED ENGINEERED WOOD PRODUCTS are created by breaking down wood into its most basic components—fibres—and then reconstituting them into dense, stable panels. Unlike products made from veneers or flakes, these EWPs have a uniform composition and a very smooth surface, making them ideal for a wide range of non–structural and some structural applications. Products like MEDIUM–DENSITY FIBREBOARD (MDF) and HIGH–DENSITY FIBREBOARD (HDF) are made by breaking down wood into fine FIBRES, mixing them with wax and resin, and then pressing them into panels. They are typically used for non–structural applications like furniture and cabinetry.

DIMENSIONAL LUMBER–BASED ENGINEERED WOOD PRODUCTS are a category of structural materials created by bonding standard sawn boards or "dimensional lumber" with adhesives. This process allows manufacturers to create larger, stronger, and more stable components than can be produced from a single piece of wood. The DIMENSIONAL LUMBER includes standard sawn lumber, which can be further processed and bonded to create larger, stronger structural components. In this sense the GLUED LAMINATED TIMBER (Glulam or GLT) is produced by bonding layers of stress–rated dimensional lumber with durable, moisture–resistant adhesives. It's often used for large beams, arches, and other structural members where high strength and custom shapes are needed. Also, CROSS–LAMINATED TIMBER (CLT) is made by gluing layers of solid dimensional lumber at right angles to each other. This creates extremely strong and rigid panels used for walls, floors, and roofs in mid– to high–rise buildings. FINGER–JOINTED LUMBER is created by joining smaller, shorter pieces of dimensional lumber end–to–end using interlocking "fingers" and a strong adhesive. This process allows for the removal of defects like knots from the lumber, resulting in a stronger, more uniform, and longer piece of wood. [11–13]

Figure 4: Dimensional lumber for engineered wood products

These products are often referred to as "mass timber" and are at the forefront of modern, sustainable construction. They offer an alternative to steel and concrete in many applications, especially for mid– to high–rise buildings.

Sawdust, chips, and trimmings are by–products of woodworking and are a primary source material for reconstituted wood products. These are created by breaking down wood into small particles or fibres, which are then bonded with adhesives under heat and pressure to form large panels. This process is a highly efficient way to utilize wood waste that would otherwise be discarded, making these products a sustainable and cost–effective alternative to solid lumber. PARTICLEBOARD/LOW–DENSITY FIBREBOARD (LDF) is a low–density material made from a mix of wood chips, sawmill shavings, and sawdust. These particles are bonded with a synthetic resin, resulting in a product with a uniform, grainy texture. Particleboard is often used for non–structural applications. Also, the fine fibres allow MEDIUM–DENSITY FIBREBOARD (MDF) and HIGH–DENSITY FIBREBOARD (HDF) to be pressed into a very dense and smooth panel.

ENGINEERED WOOD PRODUCTS: TIPOLOGY

An ENGINEERED WOOD PRODUCT (EWP) is a product fabricated with wood materials and adhesives and/or fasteners (such as nails) targeted mainly for structural applications. An EWP has gone through an engineering design, which is often inspired by nature, and innovative technology. [11–24] With the great efforts made by scientists and engineers in the last century, EWPs have grown into an extended family.

EWPs (usually excluding fibre–based ones) can be classified into parallel and cross–laminated groups. The parallel–laminated EWPs include LSL, OSL, LVL, PSL, GLT, NLT, and DLT; meanwhile, cross–laminated EWPs contain OSB, plywood, and CLT. [21–24] The parallel–laminated EWPs are usually used for load–carrying members such as beams and headers, while the cross–laminated EWPs are used for floor plates and sheathing sheets. The way of lamination inspires a philosophy of designing EWPs

Another way of grouping EWPs is rooted in the wood elements that make them, which include fibre, strand, veneer, and lumber–based EWPs. MASS TIMBER PRODUCTS (MTPs) basically include lumber–based EWPs, i.e., CLT, GLT, NLT, and DLT. SCL basically includes LVL, LSL, OSL, and PSL. STRUCTURAL COMPOSITE LUMBER (SCL) refers to those products that combine dried strands, veneer, or other small wood elements bonded with an exterior structural adhesive(s) to form thick–panel–like or beam–like EWPs.

Modern ENGINEERED WOOD PRODUCTS (EWPs) can be categorized into three main groups based on how they're manufactured and used: STRUCTURAL LUMBER, WOOD–BASED PANELS, and WOOD–BASED COMPOSITES. Each category includes specific subcategories with unique properties and applications. [11–24]

- **STRUCTURAL COMPOSITE LUMBER (SCL)**: This category includes products made by bonding together wood veneers, strands, or flakes to form large, strong members that act as a substitute for traditional lumber in load–bearing applications. The grain of the wood elements (each layer of veneer or flakes) is generally aligned in the same direction to maximize strength. The resulting products out–perform conventional lumber when either face– or edge–loaded. SCL is a solid, highly predictable and uniform engineered wood product that is sawn to consistent sizes, is virtually free from warping and splitting and exhibits highly predictable physical and mechanical properties.

STRUCTURAL COMPOSITE LUMBER (SCL) is a family of engineered wood products created by layering dried and graded wood veneers or strands with moisture–resistant adhesive into blocks of material known as billets, which are subsequently re–sawn to specified sizes. Is a family of engineered wood products manufactured by bonding together dried and graded wood veneers, flakes, or strands with waterproof adhesives. The grain of the wood elements is aligned primarily in the same direction, creating a large, solid block (or billet) that is then cut into the desired dimensions. Veneer–based EWPs differ by wood species, adhesive type, as well as by layup structure.

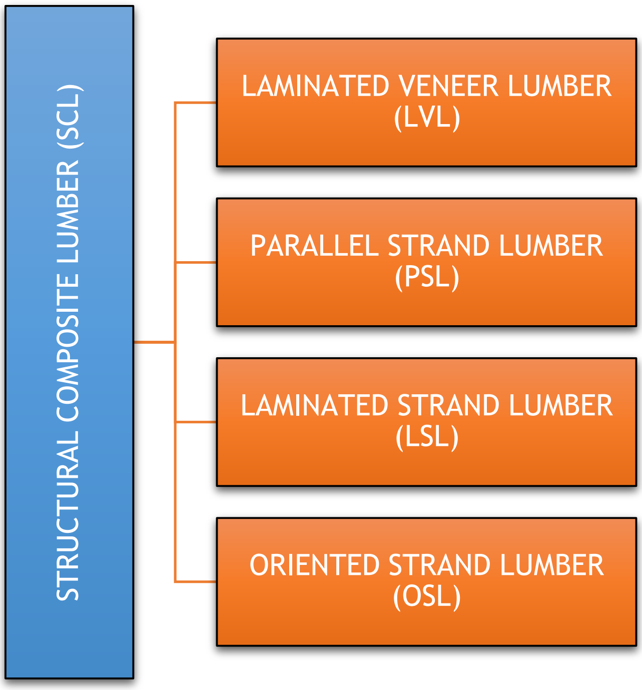

Figure 5: Structural Composite Lumber (SCL)

A category including LAMINATED VENEER LUMBER (LVL), PARALLEL STRAND LUMBER (PSL), LAMINATED STRAND LUMBER (LSL), and

ORIENTED STRAND LUMBER (OSL), designed for high strength and specialty structural uses.

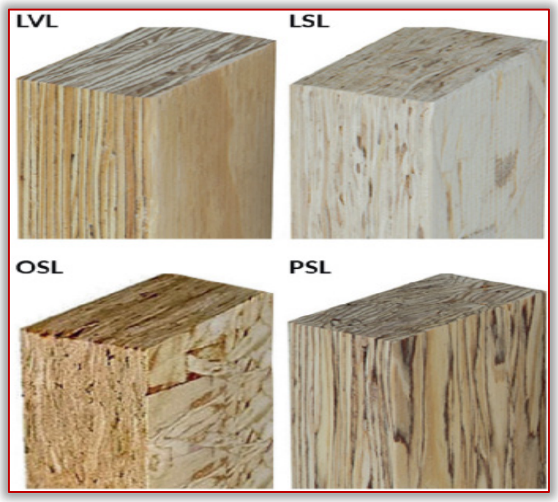

Figure 6: Structural composite lumber (SCL) family

Therefore, SCL products used in construction applications include:

— LAMINATED VENEER LUMBER (LVL): Is a high–strength engineered wood product, being the most widely used type of SCL. It's manufactured by taking multiple thin layers of wood veneer, bonding them together with adhesives, and then pressing them under heat and pressure to form a large, solid block called a "billet." Is made by bonding thin wood veneers so the grain of all veneers is parallel to the long direction. Composed of multiple thin layers of wood veneer with all grain running parallel.

LVL is significantly stronger and more stable than solid lumber. The wood grain of each veneer layer is oriented in the same direction, which gives the material superior strength for load–bearing applications. Produced by bonding thin wood veneers with grains parallel, offering high strength and dimensional stability for beams, headers, and structural supports. The manufacturing process removes or disperses natural defects like knots, which makes the final product more consistent in strength and quality than traditional lumber. LVL is considered a sustainable and cost–effective alternative to steel, concrete, and traditional lumber, as it efficiently uses smaller trees and fast–growing species. LVL is exceptionally strong and is commonly used for beams, headers, and rafters in residential and commercial construction. It is used for beams, headers, and rafters because of its high bending strength.

— PARALLEL STRAND LUMBER (PSL): It's part of a family of products known as Structural Composite Lumber (SCL). Is manufactured from veneers clipped into long strands and oriented primarily along the strong axis.

Parallel Strand Lumber (PSL) is a type of engineered wood product made from long, thin strands of wood that are laid in a parallel formation and bonded (glued) together with a waterproof structural adhesive under heat and pressure. This results in a product with superior strength and is commonly used for posts and columns. The long, continuous strands give PSL a high bending strength, making it ideal for heavily loaded columns, beams, and headers where high strength is critical.

— LAMINATED STRAND LUMBER (LSL): LSL is manufactured from flaked wood strands or flakes that are shorter and wider than those used for PSL. These flakes are oriented and formed into a large mat, which is then pressed into a billet.

LSL has good dimensional stability and fastener–holding strength, making it a versatile material for headers, studs, and rim boards.

— ORIENTED STRAND LUMBER (OSL): Similar to LSL, OSL is also made from flaked wood strands with a smaller length–to–thickness ratio than LSL. However, the strands are even shorter than those in LSL. In fact, it is similar to LSL but uses shorter, flatter strands. It provides consistency and is used for structural framing members.

The strands are oriented and pressed into a solid billet, resulting in a product that resembles oriented strand board (OSB) in appearance but has superior structural properties due to the parallel alignment of the strands. OSL is used for applications like tall wall studs, headers, and rim boards. This is what makes it so good for structural applications.

- **WOOD–BASED PANELS**: This category consists of engineered wood products that are manufactured into flat sheets or panels. Wood–based panels are a diverse group of engineered wood products manufactured from wood in various forms—from thin veneers to small particles and fibres. By breaking down and reassembling wood, manufacturers can create a wide range of sheet materials with properties tailored for specific applications.

These panels are a sustainable and cost–effective alternative to solid lumber, as they make efficient use of wood resources, including sawmill by–products and fast–growing trees. They utilize wood waste and smaller, fast–growing trees, reducing pressure on old–growth forests. They're primarily used for sheathing, subflooring, and as a material for furniture and cabinetry.

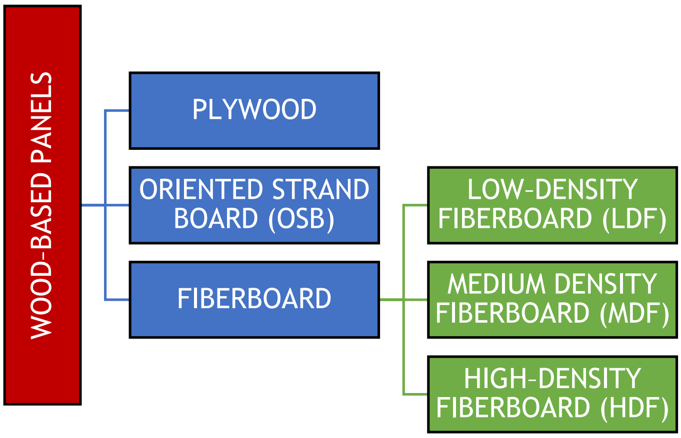

Figure 7: Wood–based panels

Wood–based panels are generally categorized by the size and form of the wood elements used in their production:

— PLYWOOD: Is the original engineered wood panel and is one of the oldest veneer–based EWPs. Plywood has a more classic, wood–grain aesthetic on its surface, which can make it a preferred choice for applications where the material is visible, like cabinetry or furniture.

Plywood is a laminated engineered wood product made from thin layers of wood veneer, or "plies", so the plywood can be deemed as a wood sandwich. These plies are peeled from logs in a continuous ribbon, similar to unrolling a paper towel. Each layer (plies) are then stacked with the grain of each layer rotated 90 degrees to the adjacent one. Made by gluing thin layers of wood veneer with grains at right angles. It is strong, flexible, and moisture–resistant, used for sheathing, cabinetry, and industrial packaging. It is made by gluing together multiple thin layers of wood veneer with the grain of each layer oriented perpendicularly to the next. The alternating grain direction makes plywood highly resistant to shrinking, swelling, or warping due to changes in moisture and temperature. The cross–lamination distributes strength in both directions, making it strong along both the length and width of the panel. This cross–lamination provides excellent dimensional stability and strength. Plywood is a glued wood panel consisting of several thin layers of veneer with wood fibres in adjacent layers at right angles in most cases. Usually, a plywood sheet consists of an odd number of veneer layers.

The universal hardwood plywood has five layers, resulting in a thickness of 4 mm or so, which can be used for multiple outdoor and indoor applications. Multiple layer plywood with more than seven layers can be classified as thick plywood, which is widely used for structural purposes, requiring acceptable strength and durability under the loading condition.

Figure 8: Universal hardwood plywood and thick plywood (multiple layer plywood)

— ORIENTED STRAND BOARD (OSB): OSB is a cost–effective alternative to plywood and is widely used for roof sheathing and walls. OSB is an engineered wood product made from compressed layers of large, thin wood strands or flakes. It is made from rectangular strands of wood that are oriented in layers and bonded with adhesive.

Figure 9: Oriented Strand Board (OSB)

The strands are mixed with a wax and a waterproof resin adhesive, then layered in a specific orientation: the strands in the outer layers are aligned in the long direction of the panel, while the strands in the core layers are randomly or cross–aligned. This is where the "oriented" in its name comes from. Because it's made from small strands, OSB has fewer voids and soft spots compared to some grades of plywood, making its performance more consistent across the entire panel. Composed of compressed wood strands bonded with waterproof adhesives. It is an affordable alternative to plywood used for wall and roof sheathing and subflooring. The oriented strands provide excellent shear strength, which is the ability to resist forces that cause internal layers to slide against each other.

— FIBREBOARD: When we talk about "FIBREBOARD," we're often referring to a family of engineered wood products made from wood fibres, but the term itself can be a source of confusion because it is used interchangeably with different products. The main types are categorized by their density and manufacturing process. The main difference between these three types of fibreboard—or more accurately, the three grades of fibreboard—is their density, which is a measure of mass per unit volume. Therefore, the most common way to classify fibreboard is by its density. This single characteristic directly impacts their strength, durability, weight, and best applications.

Figure 10: Fibreboard

All three are types of fibreboard, which is an engineered wood product made by breaking down wood residuals (like sawdust and wood chips) into very fine fibres, mixing them with a wax and a resin binder, and then forming them into panels by applying heat and pressure. The variations come from how much pressure is applied during this final step. [11–24]

≡ LOW–DENSITY FIBREBOARD (LDF): LDF, also sometimes called PARTICLEBOARD or CHIPBOARD, is the lightest and least dense of the three (typically ranges from 160 to 450 kg/m³). It is manufactured using less pressure, which results in a softer and more porous board. It's often made from larger wood particles (sawdust, shavings, and chips) rather than fine fibres, and resin.

PARTICLEBOARD is manufactured from wood chips, sawdust, and other waste wood particles bonded together with resin. It is lightweight, easy to cut and shape, and more porous and this makes it less durable and weaker. LDF is inexpensive but has the lowest strength and durability. It's often used for cheap furniture, temporary shelving, and underlayment. It's less dense and strong than MDF but is an affordable option for low–cost furniture and shelving.

≡ MEDIUM DENSITY FIBREBOARD (MDF): MDF is the most common and widely recognized type of fibreboard. Made from wood fibres and resin compressed under heat, is produced by breaking down wood into fine fibres, mixing them with wax and a resin binder, and pressing them into dense panels.

MDF represents a balance between density, strength, and workability, making it the go–to choice for a wide range of applications. It has a smooth surface ideal for painted furniture, decorative moldings, and millwork. MDF is significantly denser than LDF (typically falls between 600 and 800 kg/m³), providing a smooth, consistent surface free of knots and grain.[11–24] It holds screws better than LDF and is more dimensionally stable than solid wood, meaning it is less prone to warping or cracking. Its uniform density makes it excellent for cutting, routing, and painting. MDF is stronger and more durable than LDF. MDF has a smooth surface that's ideal for painting and is commonly used in furniture and millwork.

≡ HIGH–DENSITY FIBREBOARD (HDF): also sometimes called HARDBOARD, is the densest, strongest, and most durable type of fibreboard (ranges from 800 to over 1000 kg/m³, making it denser than plywood and often even solid wood). It is created by applying the highest amount of pressure during manufacturing.

HDF has a very hard, smooth surface and is extremely resistant to impact and moisture (though not waterproof). Its high density can make it more challenging to cut and route than MDF, but it offers superior durability. It is often produced in thinner sheets compared to MDF. HDF is made from compressed wood fibres, just like MDF, but with a greater amount of pressure applied during manufacturing. [11–24] This makes it significantly denser, stronger, and more moisture–resistant than MDF. This is the densest and strongest type of fibreboard, created with the highest pressure during manufacturing. HDF is incredibly durable and resistant to impact and moisture. Its high density makes it ideal for demanding applications like laminate flooring cores, door skins, and heavy–duty furniture backs.

▦ **MASS TIMBER & OTHER PRODUCTS**: This is a growing category of engineered wood products, often used in large–scale construction projects as a sustainable alternative to steel and concrete.

These wood products provide superior strength, stability, and versatility compared to traditional lumber and are increasingly favoured in modern construction for sustainability and performance. [11–24] Mass timber is a category of engineered wood products made by bonding smaller wood elements such as dimension lumber, veneers, or strands with adhesives or mechanical fasteners to create large structural components. These products are known for their strength, durability, versatility, and sustainability, and they are used for building elements like beams, columns, floor, roof, and wall panels.

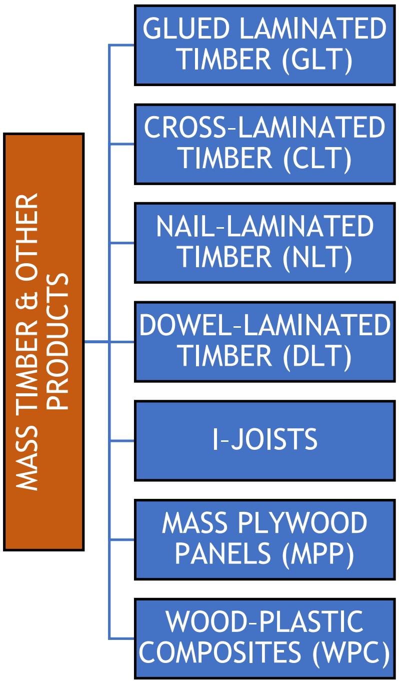

Figure 11: Mass Timber Products

— GLUED LAMINATED TIMBER (Glulam or GLT): Made by gluing together layers of dimensional lumber, with the grain running parallel. Glulam can be made in large, custom shapes and is often used for long–span beams, columns and arches.

Glulam has a high strength–to–weight ratio, which allows it to support heavy loads and span long distances. It is often used as an alternative to steel and concrete for large structural applications. Due to its manufacturing process, glulam can be fabricated into straight beams, elegant arches, and complex curved shapes. This provides architects and engineers with tremendous design flexibility to create unique and visually appealing structures.

— CROSS–LAMINATED TIMBER (CLT): The most well–known mass timber product, CLT is made from layers of solid lumber that are stacked perpendicular to each other and bonded with structural adhesives.

Consists of layers of solid lumber panels stacked and glued together at alternating 90–degree angles. This provides exceptional strength in two directions, making it a key component for walls and floor systems in multi–story buildings. This cross–laminated design gives the panel excellent strength and stability in two directions, making it ideal for walls, floors, and roofs.

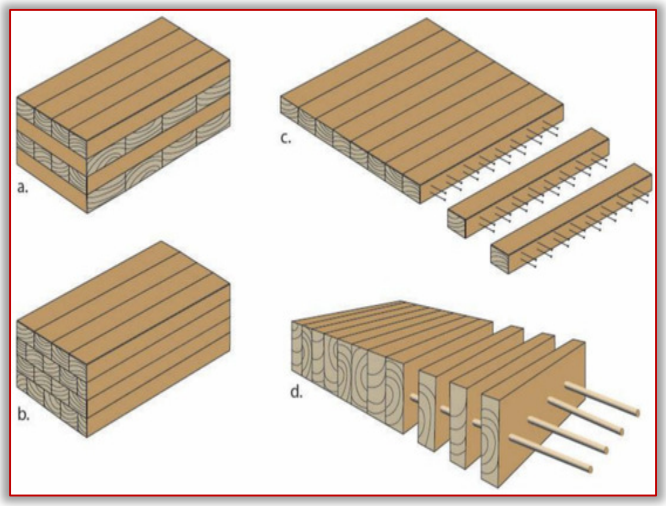

Figure 12: Laminated Timber types: (a) Cross–Laminated Timber (CLT); (b) Glued Laminated Timber (GLT); (c) Nail–Laminated Timber (NLT); (d) Dowel–Laminated Timber (DLT)

— NAIL–LAMINATED TIMBER (NLT): Is the more traditional of the two, with a history spanning over a century. It's a simple and effective method of creating large structural panels.

NLT is relatively easy to manufacture with basic tools and readily available lumber, which can make it a cost–effective option. Individual pieces of dimensional lumber (e.g., 2x4s, 2x6s, etc.) are placed on edge and fastened together with nails driven in a specific pattern. The panels can be prefabricated in a factory or assembled on–site. Since it can be made on–site, NLT offers a high degree of flexibility for custom shapes and sizes. The exposed underside of an NLT panel has a distinct, rustic aesthetic with visible nail heads and the seams between boards.

— DOWEL–LAMINATED TIMBER (DLT): Is a newer, all–wood alternative to NLT. It eliminates the use of metal fasteners and adhesives.

DLT is the only mass timber product that is 100% wood, containing no nails, screws, or structural adhesives. This makes it a very sustainable choice and easier to process at the end of its life. Graded lumber boards are joined together with oversized, threaded hardwood dowels. The dowels are friction–fit into pre–drilled holes. The difference in moisture content between the softwood boards and the hardwood dowels causes the boards to swell and the dowels to shrink slightly over time, creating a powerful friction fit that holds the panel together. Because there are no metal fasteners, DLT panels can be easily milled and routed by Computer Numerical Control (CNC) machinery for precision cuts, complex shapes, or integrating mechanical and electrical systems. The all–wood surface can be easily profiled during manufacturing to create a variety of aesthetic finishes and integrate acoustic dampening features.

— MASS PLYWOOD PANELS (MPP): Are a relatively new and innovative engineered wood product that belongs to the mass timber category. MPP distinguishes itself from other mass timber products like Cross–Laminated Timber (CLT) by using structural–grade plywood veneer as its primary building block, rather than solid dimensional lumber. Because MPP uses veneers, which have fewer natural defects like knots compared to solid lumber, the resulting panel has a more uniform and predictable strength. This allows MPP to be engineered to be as strong as or stronger than a CLT of a similar thickness, while potentially being lighter and requiring less wood. MPP is often used for walls and floors in large buildings.

Figure 13: Mass Plywood Panels (MPP)

— I–JOISTS: These are pre–fabricated beams shaped like the letter "I" and are used for floor and roof joists. They consist of a web (the vertical piece, typically OSB or plywood) and flanges (the top and bottom pieces, typically solid lumber or LVL). Its cross–section has the shape of a capital letter "I," which gives it a high strength–to–weight ratio. This design makes I–joists an efficient alternative to traditional solid sawn lumber. Their lightweight nature makes them easier to handle and install, and they can be manufactured in longer lengths, allowing for greater design flexibility and the creation of open floor plans. I–joists are typically made of two main parts:

≡ Flanges: The top and bottom horizontal sections of the "I" shape. They are designed to resist bending forces, or tension and compression, when a load is applied. Flanges are made from high–strength timber, such as laminated veneer lumber (LVL) or solid sawn lumber.

≡ Web: The vertical section in the middle that connects the two flanges. It provides shear resistance, which is the force that acts parallel to the cross–section. The web is commonly made from a thinner engineered wood product like oriented strand board (OSB) or plywood.

Figure 14: I–Joists

— WOOD–PLASTIC COMPOSITES (WPC): A hybrid material made from a mix of wood fibres and recycled plastic. WPC is highly durable, moisture–resistant, and is primarily used for outdoor applications like decking and fencing.

Wood composite panels, particularly WOOD–PLASTIC COMPOSITES (WPC), generally outperform traditional wood in durability. WPC materials exhibit greater density and strength, which translates into superior resistance to bending, cracking, and mechanical wear compared to natural wood. [11–24] They maintain structural integrity better over time because they resist common issues that affect wood, such as warping, splitting, and decay from moisture exposure.

WPC panels also require significantly less maintenance than wood, avoiding routine sealing, painting, or staining. Their lifespan can exceed 30 years with minimal upkeep, whereas wood tends to degrade faster without continual care. In fact, wood composite panels offer greater durability, longevity, and reduced maintenance demands compared to traditional wood, making them advantageous for both indoor and outdoor applications with prolonged exposure to harsh environmental conditions.

COMPARISON BETWEEN MODERN ENGINEERED WOOD PRODUCTS

Engineered wood products (EWPs) are a diverse group of materials that are manufactured by binding wood fibres, particles, veneers, or sawn lumber together with adhesives. A general comparison reveals their varying properties, applications, and sustainability. [11–24]

The primary difference between EWPs lies in their raw materials and how they're processed / manufactured. This directly impacts their final properties.

— Veneer–based: Products like Plywood and Laminated Veneer Lumber (LVL) are made from thin layers of wood veneer. Plywood uses a cross–lamination pattern for stability, while LVL aligns all veneers in the same direction for high bending strength, making it ideal for beams.
— Flake/strand–based: Oriented Strand Board (OSB) is made from compressed, cross–oriented flakes. This gives it structural strength similar to plywood at a lower cost, making it a common choice for sheathing.
— Wood fibre–based: Medium–Density Fibreboard (MDF) and High–Density Fibreboard (HDF) are made from wood fibres, creating a very smooth, uniform panel. They are excellent for furniture and cabinetry where a quality finish is needed, but they are not typically used for structural applications.
— Dimensional lumber–based: Glued Laminated Timber (Glulam) and Cross–Laminated Timber (CLT) are created by bonding sawn boards. Glulam is used for long, heavy–duty beams, while CLT forms large panels for walls, floors, and roofs in modern mass timber construction

Different EWPs are designed for specific uses based on their mechanical properties.

— Structural strength: LVL, Glulam, and CLT are known for their high strength and dimensional stability, making them suitable for load–bearing structures like beams, headers, and walls in both residential and commercial buildings.
— Dimensional stability: The cross–lamination in Plywood and CLT makes them highly resistant to warping and shrinking. This is crucial for panels used in sheathing and flooring where a flat, stable surface is required.
— Aesthetic and finishing: MDF and HDF are valued for their smooth, grain–free surface. They are easy to machine and paint, making them the preferred choice for cabinetry, mouldings, and furniture. Particleboard is a lower–cost alternative for similar uses.
— Cost and efficiency: OSB is often a more cost–effective alternative to plywood for non–exposed sheathing applications. Mass timber products like CLT can significantly reduce construction time due to their prefabrication, which lowers labour costs and on–site waste.

EWPs are generally considered a more sustainable choice than many conventional building materials.

— Resource utilization: EWPs use a wider range of wood resources, including fast–growing trees, offcuts, and sawmill by–products (sawdust, chips), reducing waste and the reliance on old–growth forests.
— Carbon sequestration: Wood naturally stores carbon. By using EWPs in buildings, this carbon remains sequestered for the lifespan of the structure.
— Lower embodied energy: The manufacturing process for wood–based products uses significantly less energy than the production of steel or concrete, which have a much higher carbon footprint.

BENEFITS OF MODERN ENGINEERED WOOD PRODUCTS

Modern engineered wood products (EWPs) offer a wide range of benefits that are transforming the construction industry. They are a compelling alternative to traditional building materials like solid lumber, steel, and concrete, offering advantages in performance, sustainability, and cost–effectiveness.

Unlike solid wood, which can warp, shrink, and split as it gains or loses moisture, EWPs are dimensionally stable. The manufacturing process distributes or eliminates natural defects, resulting in a product that maintains its shape and integrity over time.

— The first type of veneer–based EWPs invented is PLYWOOD. Later, modifications applied to the veneer layups resulted in LVL, and afterward, the long veneer strands were used to make PSL. The veneer–based EWPs have been widely used in construction nowadays. Plywood is usually used as the sheathing material for walls, floors, and roofs, and the web stock for I–joists. LVL is commonly used as beams, columns, and the flange stock of I–joists. PSL is mainly used as columns and beams.
— PLYWOOD and other structural panels have changed the way of constructing light wood–frame houses and buildings. Plywood can be made from various types of wood. Softwoods are commonly used to make veneer for plywood. These wood species can be divided into various categories based on their strength and use within the plywood structure. Of hardwoods are most popular for veneer production. These species are characterized by uniform density and structure, making them easy to be peeled to

produce thin and durable veneer. Hardwood can be peeled or sliced for the production of decorative veneer for making furniture, cabinets, and interior decoration. Slicing results in more loss in raw materials and more intensiveness in labor.

— WOOD–BASED PANELS are often more affordable than solid lumber, making them a popular choice for a wide range of construction and furniture applications. The different types of panels can be tailored to meet specific performance requirements, from structural strength to a smooth, decorative finish. It is important that the manufacturing process eliminates natural defects like knots and grain variations, resulting in a consistent, stable product that resists warping and splitting.

— STRUCTURAL COMPOSITE LUMBER (SCL) is a family of engineered wood products made by layering and bonding veneers, strands, or flakes of wood with adhesives. This process creates a large billet that is then sawn into specific dimensions. Because of its manufacturing process, SCL overcomes the natural defects found in solid sawn lumber, such as knots and irregular grain patterns, resulting in a product with consistent strength and stability. SCL is increasingly important in construction due to its superior performance characteristics and sustainability benefits. Because SCL is manufactured from dried and graded wood, it has a low moisture content and is highly resistant to changes in size or shape. This dimensional stability ensures that structures remain straight and true over time, reducing the risk of structural issues. Its use in residential and commercial buildings provides reliable, high–strength structural components. SCL can be manufactured in a wide range of sizes, shapes, and lengths. This flexibility allows it to be used for a variety of structural applications, including beams, headers, rafters, joists, and columns. Single SCL members can also be joined together to create larger, built–up beams for heavier loads. Also, SCL makes efficient use of wood resources by utilizing smaller, fast–growing trees and sawmill by–products. This reduces the demand for old–growth timber and minimizes waste, making it an environmentally friendly choice for construction projects.

— MASS TIMBER is an increasingly important family of engineered wood products for construction, primarily due to its combination of structural strength, sustainability, and construction efficiency. It is made by laminating and bonding layers of sawn lumber, veneers, or strands to create large, prefabricated structural components. Mass timber has emerged as a viable alternative to steel and concrete, especially for mid– to high–rise buildings. Its importance is driven by several key factors:

≡ Mass timber is a renewable resource that sequesters carbon from the atmosphere as trees grow. When used in construction, it keeps that carbon stored for the life of the building. This makes it a building material with a lower carbon footprint compared to the energy–intensive production of steel and concrete.

≡ Mass timber products like Cross–Laminated Timber (CLT) and Glued Laminated Timber (Glulam) are often prefabricated off–site. This means components arrive on the construction site ready for assembly, significantly reducing construction time, labour needs, and on–site waste. Buildings can be erected much faster.

≡ Despite being made of wood, mass timber products are incredibly strong and have a high strength–to–weight ratio. They are also fire–resistant; in a fire, the outer layer of the timber chars, creating an insulating layer that protects the inner core and maintains the structural integrity of the building for a predictable amount of time. Mass timber buildings also perform well in seismic events due to their lighter weight and ability to flex.

— GLUED LAMINATED TIMBER, or Glulam, is an engineered wood product made by bonding layers of stress–graded dimensional lumber with durable, moisture–resistant structural adhesives. All the wood grain runs parallel to the length of the final product, resulting in a single, large structural member. The fabrication of Glulam is a precise industrial process that ensures a high–quality finished product. The laminated boards are stacked, then pressed together under high pressure. This pressure is maintained until the adhesive cures, bonding the layers into a single, solid piece. A durable, waterproof adhesive is applied to the surface of the laminations. Glulam is a highly versatile and important material for a wide range of construction projects.

— DOWEL–LAMINATED TIMBER (DLT) and NAIL–LAMINATED TIMBER (NLT) are both categories of mass timber. They are solid timber panels created by stacking dimensional lumber on edge and fastening them together to form a larger structural element. DOWEL–LAMINATED TIMBER (DLT) and NAIL–LAMINATED TIMBER (NLT) are two prominent types of mass timber panels used for floors, roofs, and walls in modern construction. While both are made from dimension lumber stacked on edge, their primary difference lies in the fastening method, which dictates their unique characteristics and applications.

— CROSS–LAMINATED TIMBER (CLT) is a modern mass timber product made by gluing layers of solid sawn lumber together. What distinguishes it is that each layer is oriented at a 90–degree angle to the one below it. This cross–lamination results in a panel with exceptional strength and dimensional stability in both directions, making it a viable alternative to concrete and steel for a wide variety of construction applications. The fabrication of CLT is a precise, multi–step process that takes place in a controlled factory environment. The stacked layers are pressed together under high pressure until the adhesive cures and forms a rigid, solid panel. The cross–laminated layers give CLT panels' excellent structural rigidity and stability. They can withstand heavy loads and have a high strength–to–weight ratio, which allows for the construction of tall, multi–story buildings. They also perform well in seismic events due to their lightweight and durable composition. Because CLT panels are prefabricated off–site, they arrive at the construction site ready for assembly. This can significantly reduce construction time and on–site labour requirements, leading to faster project completion and lower costs. The "dry" construction method also means less noise and waste on–site.

— I–JOIST is a cutting–edge engineered wood product revolutionizing the construction industry, being the epitome of strength and durability, yet they are surprisingly lightweight, making them easy to handle and install. Their unique design, featuring structural LVL flanges and a robust plywood web, provides unparalleled stability and load–bearing capacity. The combination of strength, lightweight design, and environmental sustainability sets these joists apart in the market. The use of high–grade LVL and plywood ensures superior load–bearing capacity and resistance to warping or twisting, common issues in traditional lumber. This makes them an ideal choice for both residential and commercial construction projects. I–Joists advanced design reduces waste and enhances energy efficiency, making them a popular choice among forward–thinking builders and architects.

— While mass timber is gaining prominence, other engineered wood products (EWPs) are also crucial to modern construction. These products include:

≡ Plywood and Oriented Strand Board (OSB): These are panel products used primarily for wall and roof sheathing, as well as subflooring. They provide structural rigidity to buildings and are essential for creating the building envelope.

≡ Laminated Veneer Lumber (LVL) and Laminated Strand Lumber (LSL): These are types of Structural Composite Lumber (SCL) used for beams, headers, and rafters where a high strength–to–weight ratio is needed. They are a reliable alternative to solid sawn lumber for long–span applications.

≡ Particleboard and Fibreboard (MDF/HDF): While not typically used for primary structural purposes, these products are vital for interior applications such as cabinetry, furniture, and decorative panelling. Their smooth, uniform surface is ideal for finishing and takes paint and veneers exceptionally well.

— MASS PLYWOOD PANELS (MPP) is gaining traction in the construction industry as a strong, efficient, and sustainable material. As with other mass timber products, MPP is prefabricated off–site, which leads to a faster and more efficient construction process. This "dry construction" method reduces on–site labour, waste, and overall project timelines. The use of veneers and a highly controlled manufacturing process results in a product with low moisture content and excellent dimensional stability. This reduces the risk of warping, shrinking, or splitting over time.

Other benefits include:

— Fire resistance: Mass timber products like CLT and Glulam are surprisingly fire–resistant. When exposed to fire, the outer layer chars, forming an insulating barrier that protects the core and maintains the structural integrity of the building for a predictable amount of time.

— Aesthetics: The natural look and feel of engineered wood, from the smooth surface of MDF to the exposed layers of CLT and Glulam, offer a warm and inviting aesthetic that is highly valued in modern architectural design.

- Thermal and acoustic insulation: Wood naturally has excellent insulating properties. When used as a structural material in walls and floors, it can help reduce energy consumption for heating and cooling and also provide superior acoustic performance by absorbing sound.

These advantages together support stronger, more sustainable, efficient, and innovative construction practices transforming modern building approaches. Available in various shapes, sizes, and customizable designs, EWPs provide architects and engineers with flexible options for beams, columns, floors, roofs, and panels, allowing for innovative and complex structures. They are suitable for structural and non–structural applications alike.

CONCLUSIONS

These engineered products are widely appreciated for their optimized material use, enhanced mechanical properties, and capacity for innovative architectural designs. ENGINEERED WOOD has notable environmental impacts, both positive and negative, that influence its sustainability profile:

Positive Environmental Impacts:

- Carbon storage: Engineered wood stores carbon sequestered by trees during growth, locking it within buildings and reducing overall greenhouse gas emissions. This helps climate change mitigation by keeping carbon out of the atmosphere for many years.
- Renewable resource: Wood is a renewable resource, unlike steel and concrete. EWPs are often made from smaller, fast–growing trees from sustainably managed forests, which helps to preserve old–growth forests and promote healthy forest management.
- Waste reduction: EWPs efficiently use wood that would otherwise be considered waste, such as sawdust and trimmings, turning them into valuable building materials.
- Lower energy use: Its manufacturing generally consumes less energy and produces fewer emissions than steel or concrete production, resulting in a smaller carbon footprint.
- Material efficiency: Engineered wood products use smaller pieces of wood or wood fibres efficiently to create strong structural components, reducing timber demand and waste compared to solid wood. EWPs utilize a wider range of wood resources, including offcuts, chips, and sawdust, which minimizes waste from the milling process. The precise, factory–based cutting also results in less material waste on the construction site.
- Life Cycle Benefits: Engineered wood can be reused, recycled, or biodegraded at end of life, extending carbon storage and reducing landfill impacts. Prefabricated components also reduce construction phase emissions through easier transport and assembly.

Negative Environmental Impacts:

- Emissions from Adhesives: Many engineered wood products rely on adhesives and resins containing formaldehyde or volatile organic compounds (VOCs) that can contribute to indoor and outdoor air pollution during manufacturing and use.
- Air Pollutants from Manufacturing: Production facilities emit hazardous air pollutants (HAPs), VOCs, and particulate matter, necessitating strict pollution controls to protect workers and the environment.
- Resource and Supply Chain Considerations: The environmental benefit depends heavily on sourcing wood from sustainably managed forests. Unsustainable logging or long transportation distances increase the carbon footprint and ecological impact.

While the initial material cost of some EWPs can be higher than traditional lumber, the overall project cost can be lower. This is due to reduced labour costs, less on–site waste, and faster construction times. Many modern EWPs, particularly mass timber products like Cross–Laminated Timber (CLT), are prefabricated off–site. This allows for rapid, "dry" assembly on–site, significantly reducing project timelines and the need for large on–site crews.

Public perception plays a significant role in the growth of the engineered wood market. In Europe, the perception of wood construction is generally positive, especially where wood has been promoted for environmental, aesthetic, and comfort benefits. This positive image encourages demand for engineered wood products (EWPs) as sustainable, renewable construction materials. However, concerns persist around long–term durability, fire resistance, and sustainable forest management. Addressing these concerns through clear communication, certification, and traceability improves confidence among consumers and decision–makers, which is essential for market growth.

In conclusion, engineered wood is generally recognized as an environmentally preferable construction material when produced and sourced responsibly, as it contributes to carbon sequestration and demands less energy than conventional materials. However, attention to emissions from adhesives and sustainable forestry practices is critical to minimizing negative effects.

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