

The Future of Forest and Biomass-derived Products: Challenges and Opportunities

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 **UNIVERSITY OF CALIFORNIA**
Agriculture and Natural Resources

About

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**One of the biggest challenges for California:
Wildfires**



What is Woody Biomass?



Material obtained from trees which **do not have a viable, existing market**. This includes non-timber trees (e.g., dead or small-diameter trees), forest management by-products (e.g., barks, limbs, tops, branches, leaves), manufacturing and processing residues, and urban consumer waste.

The closed loop of FOREST CARBON in the ATMOSPHERE

Carbon Cycle

Fossil fuel use is an **OPEN SYSTEM** where CO_2 remains in the atmosphere.

Wood products can store carbon and can **substitute** for emission-intensive products such as concrete & steel.



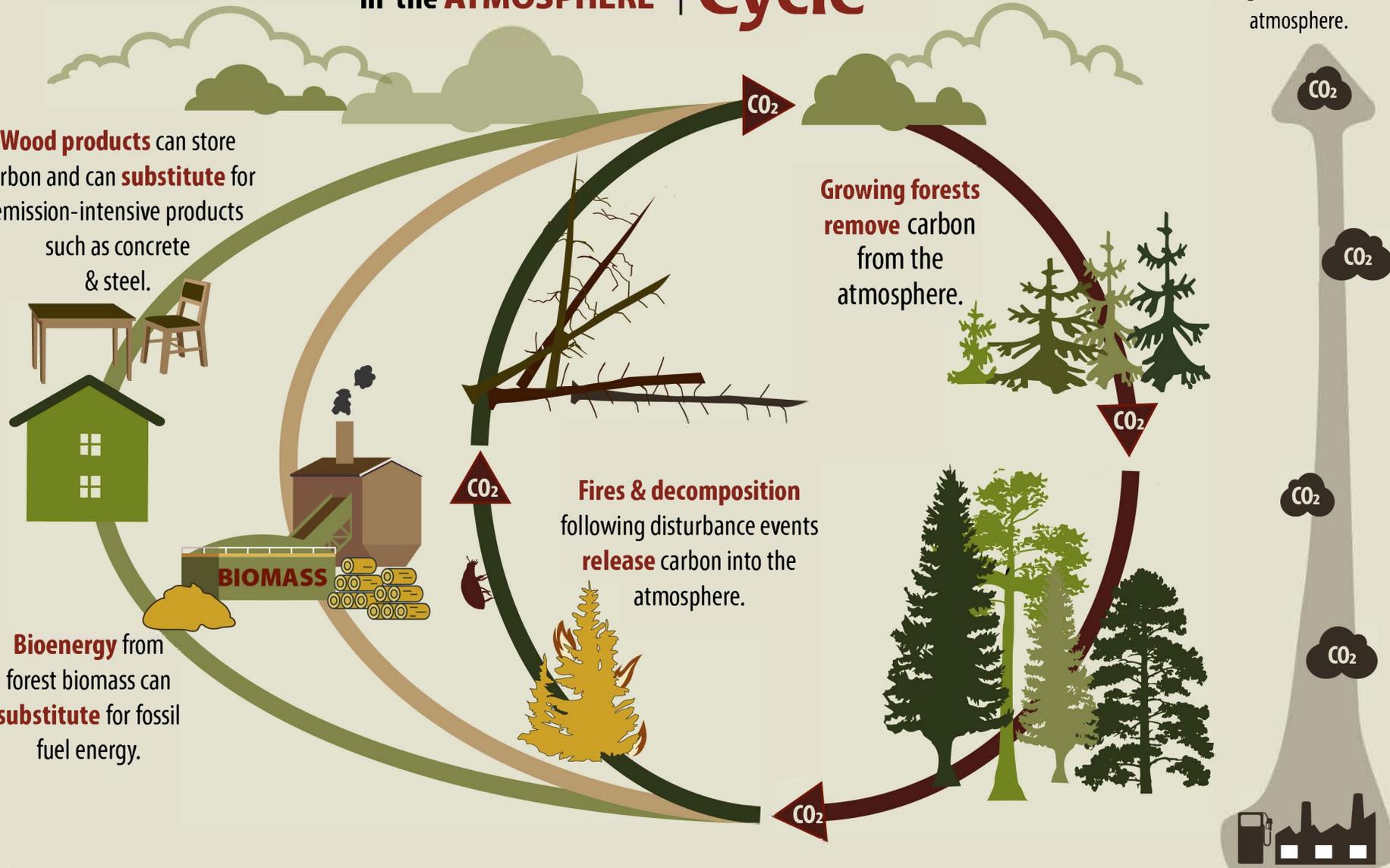
Bioenergy from forest biomass can **substitute** for fossil fuel energy.



Growing forests remove carbon from the atmosphere.

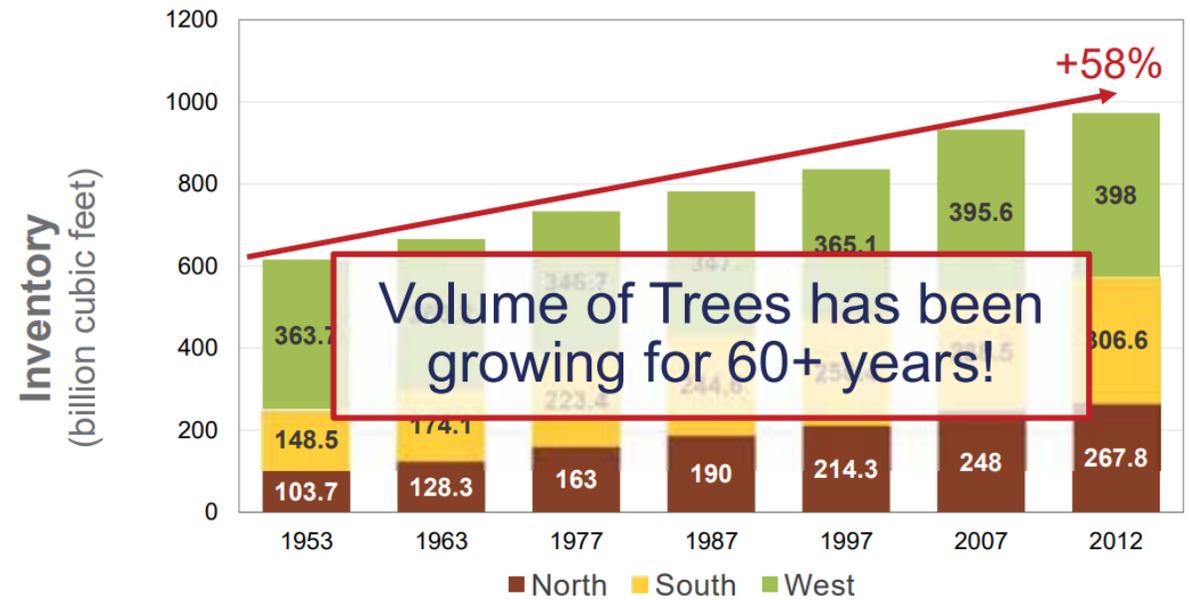
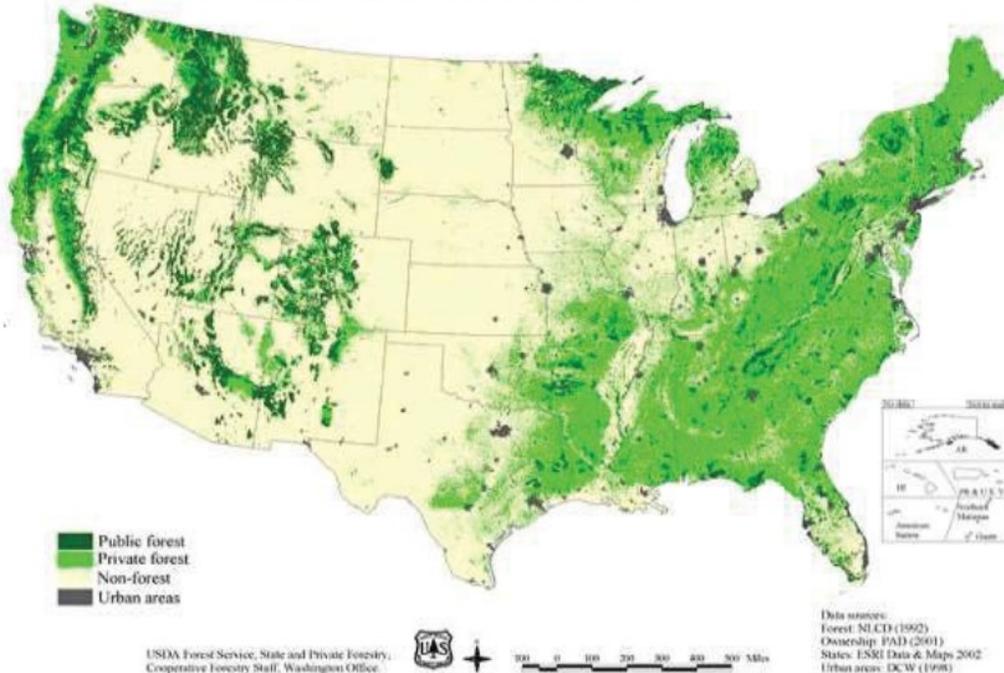


Fires & decomposition following disturbance events **release** carbon into the atmosphere.



- Forest land in the U.S. has been stable for over 100 years.
- We have more forests than lumber factories.
- Sustainable forest management is the key.

This map displays the basic vegetation (forest vs. non-forest) of the conterminous United States as well as ownership (private vs. public). The lands displayed as "public" include Federal and State lands but do not generally include lands owned by local governments and municipalities.



Source: USDA-Forest Service, US Forest Resource Facts and Historical Trends FS-1035. (2014).

- In the U.S., 44% public owned and 56% privately owned.
- 40% of California's forestland is owned by families, Native American tribes, or companies. Industrial timber companies own 5 million acres (14%). Federal agencies owns 57% and 3% is owned by state agencies.
- Economic values of forest products is an important motivation for private landowners to keep their lands.

Common Products

Biomass Products



Advanced Wood Products



Woody Biomass Utilization

Lowest Value
Least Processing



Highest Value
Most Processing

- Soil additives and amendments (mulch, compost, etc.)
- Firewood and fuelwood
- Fuel for biomass power plants
- Solid wood products (lumber and roundwood)
- Densified fuels such as wood pellets and fire logs
- Non-structural composite products including wood/plastic lumber and wood/cement products
- Composite products such as particleboard and medium density fiberboard (MDF)
- Engineered wood products such as laminated veneer lumber (LVL) and oriented-strand board (OSB)
- Pulp chips for paper products
- Organic chemicals including alcohol (ethanol, methanol), cellulose-based compounds, turpentine, tannins, pharmaceuticals, fragrances, and the basic building blocks for many plastics

Forest-derived products options for California

- Recent report identified several products that are most promising in California:

- Mass timber and other engineered wood products

- Cross-laminated timber, glue-laminated timber, Dowe-laminated timber, etc.

- Liquid and gaseous transportation fuels

- Ethanol, renewable hydrogen, etc.

- Chemically and thermally treated wood

- Thermally modified wood, chemical extractives

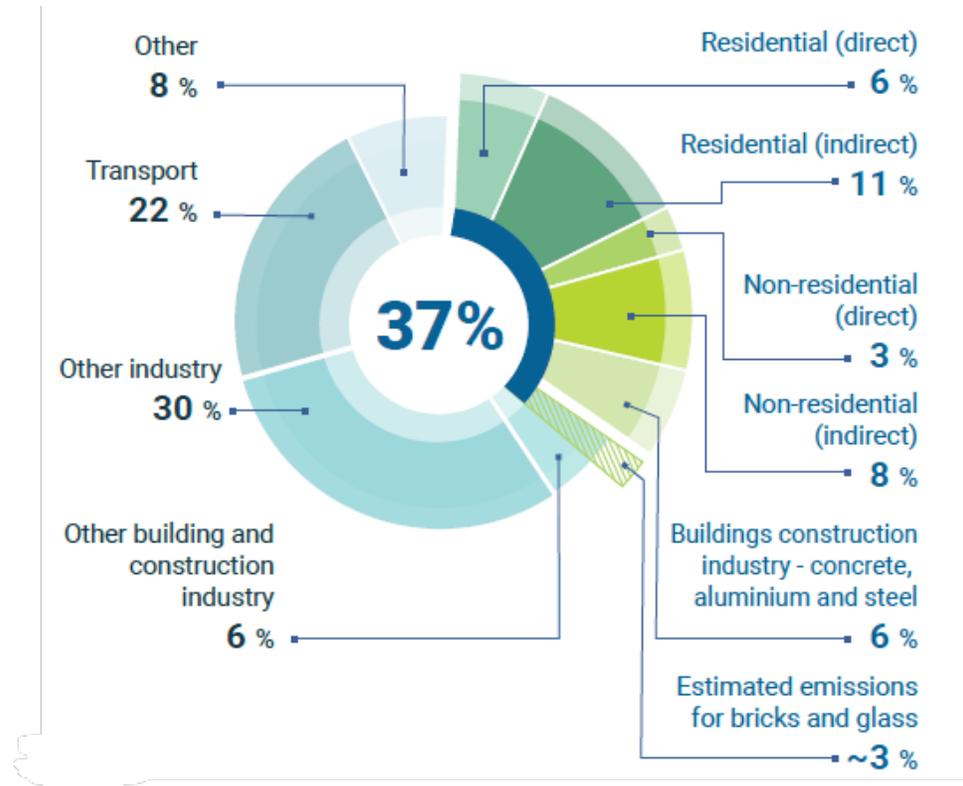
Wood as a Construction Material



Carbon12 building in Portland, OR
Photo: Andrew Pogue

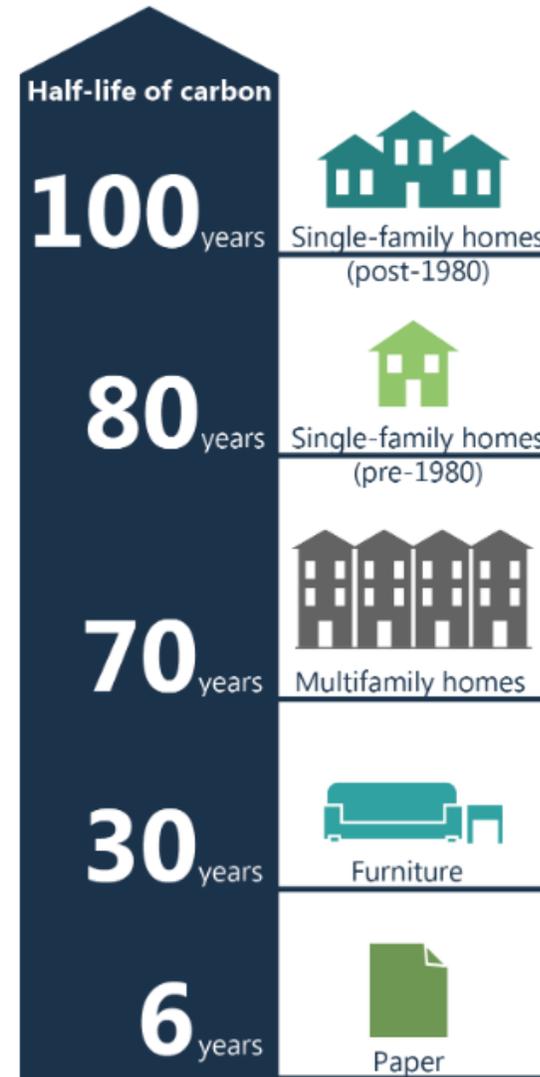


Wood in Construction



Notes: Buildings construction industry and other building construction industry refers to concrete, steel and aluminum for buildings and infrastructure construction respectively

Share of the building sector in global CO2 emissions in 2021



Common Mass Timber Products

- CA is the largest consumer of engineered wood products west of Mississippi River.
- Viable **alternative building material** to concrete and steel.
- **Fast construction time** and less construction traffic compared to concrete buildings.
- Building code change, allowing mass timber **tall buildings**.
- Strong and **high fire-resistance** rating (i.e., charring)
- Multiple **end-of-life options**



Cross-laminated timber (CLT)



Glued-laminated timber (glulam)



Nail-laminated timber (NLT)

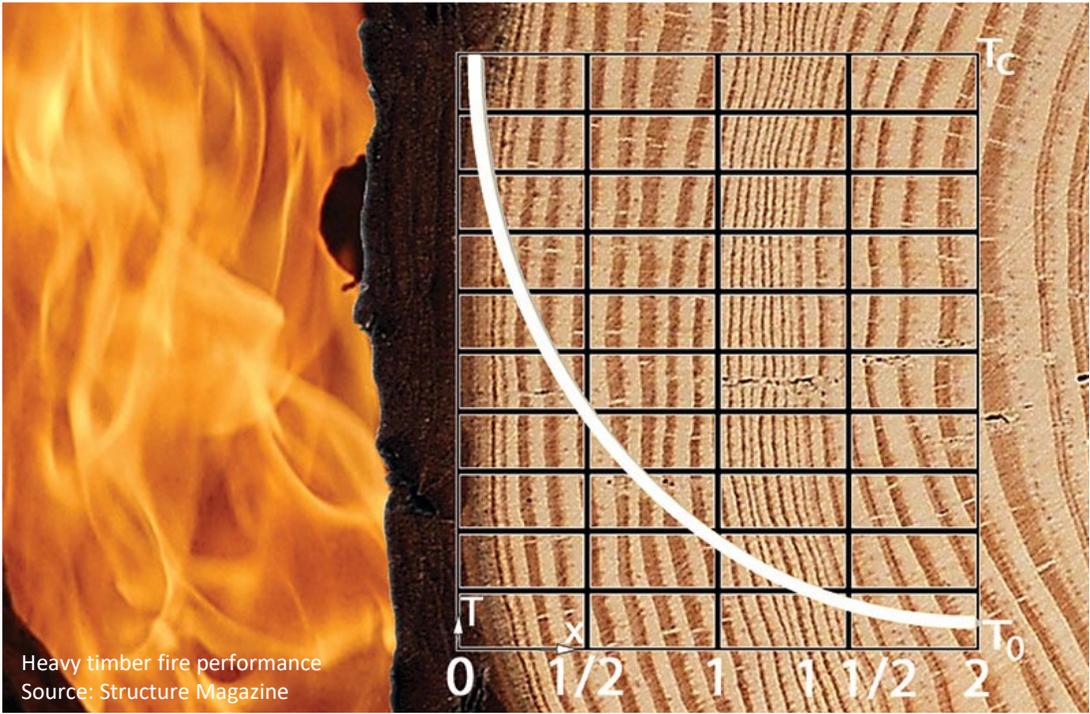


Dowel-laminated timber (DLT)

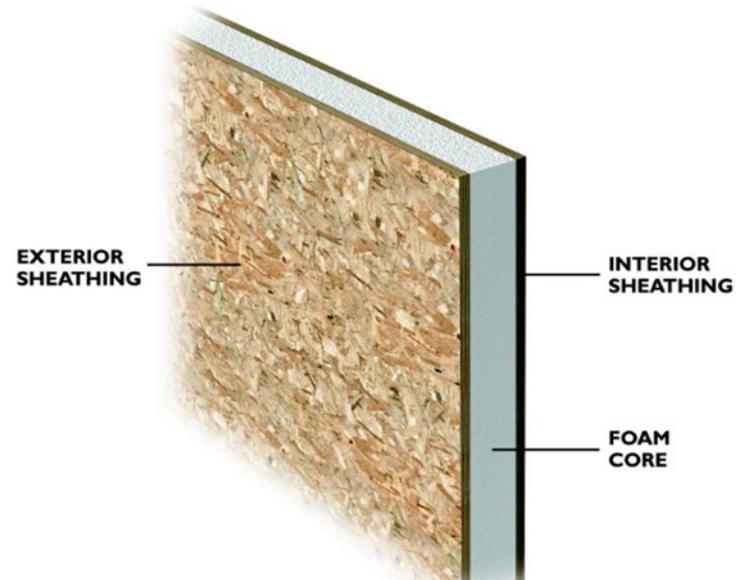


Structural composite lumber (SCL)

Can wood be fire-resistant?

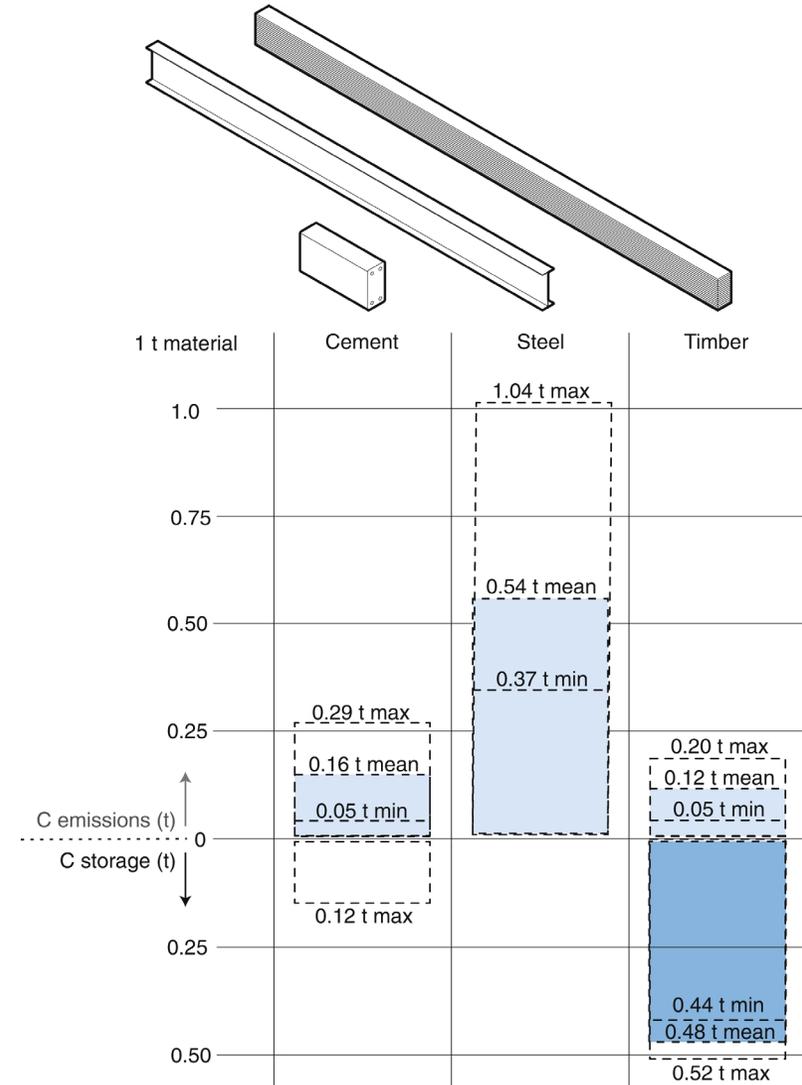


Other engineered Wood Products



Engineered Wood Products

- California is the largest consumer of engineered wood products west of Mississippi River.
- Engineered wood products have long service life.
- A “turning point” of carbon emission will be reached with longer building service life.
- Case studies in the U.S. suggested at least 20% carbon reduction in mass timber hybrid buildings compared to concrete buildings.



Churkina, G., Organschi, A., Reyer, C.P.O. et al. Buildings as a global carbon sink. *Nat Sustain* 3, 269–276 (2020).

Bio-based Homes



Source: Advanced Structures & Composites Center, University of Maine
<https://composites.umaine.edu/biohome3d/>



Post-fire Rebuild - Greenville, CA

Sierra Institute worked with atelierjones, LLC to develop CLT housing in Plumas County amid housing lost during the Dixie Fire. Sierra Institute is currently working with community members who want to rebuild with CLT construction.



Three housing prototypes (one-, two-, and three-bedrooms) were pre-approved by the county and built in Greenville, CA. These houses consisted of fire-prevention features such as defensible space and fire-resistant materials.

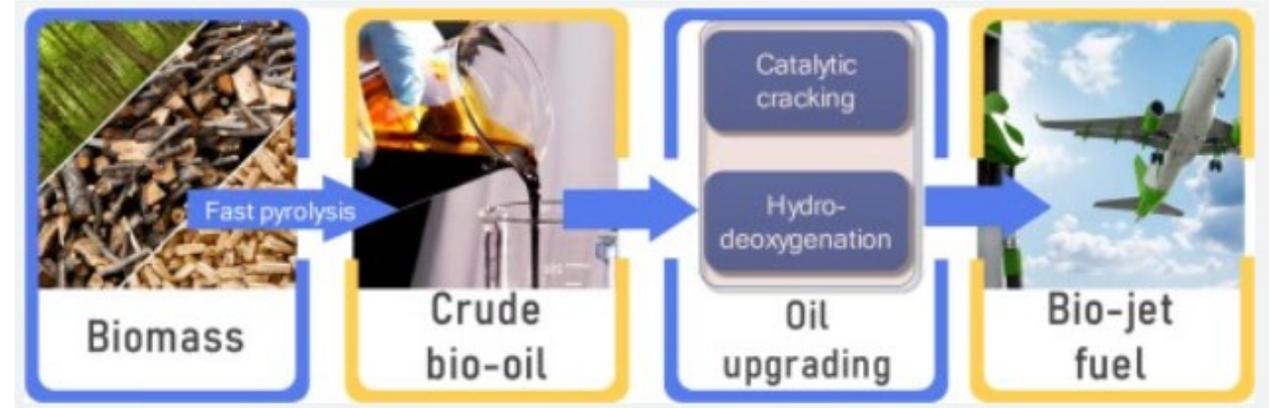
Mass timber construction in real time



What can innovative wood products bring?

- Benefits:
 - Alternatives to concrete and steel
 - Regional economic development through manufacturing jobs and investments
 - Forest fuel reduction and value-added products
 - California-made sustainable materials
- Challenges:
 - Lack of facilities
 - Regulations hindering development of new infrastructure
 - Cost to build
 - Lack of skilled-labor

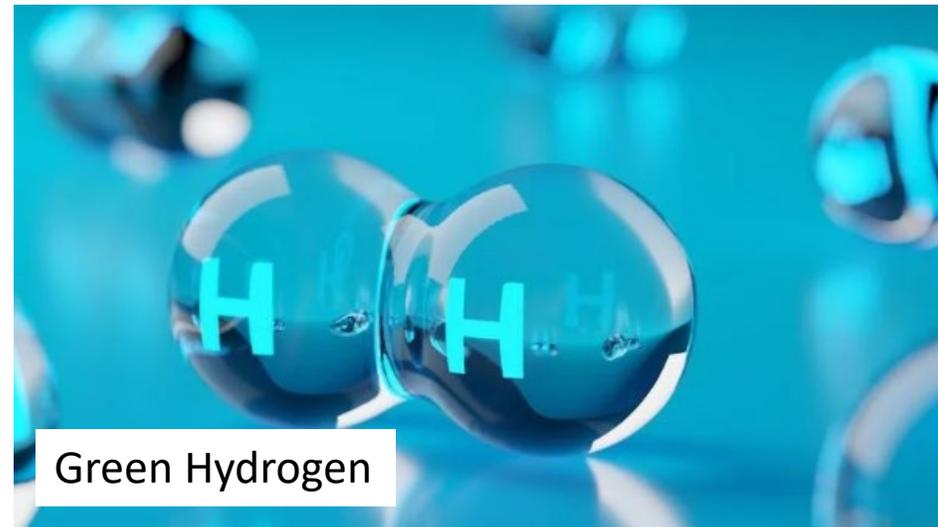
Energy, Biofuel, and More



Renewable energy share in California by source, 2021



Biochar



Green Hydrogen

Bioenergy and Biofuel

- **Heat Energy** – Through the exothermic combustion process, wood or woody biomass, is converted into the primary products of carbon dioxide, water, inorganic ash, and various gaseous and particulate emissions while giving off about 8,000 BTU's of heat for every pound of dry wood burned.
- **Electrical Energy** – Coupling the combustion process with a steam boiler and using the produced steam to drive an electrical turbine is a well proven method of producing electricity from woody biomass.
- **Biofuels** – Common types:
 - **Solid or milled Wood** – wood in any size or shape can be directly combusted to produce heat and as such is a biofuel
 - **Densified wood** – wood particles are compressed into a smaller volume of a specific size and shape (pellets, logs, bricks, etc.) to increase the fuel density (Btu's per unit volume)
 - **Charcoal** – Produced by subjecting wood to a slow pyrolysis process (heating at 700 - 900°F in the absence of oxygen for many hours)
 - **Bio-diesel** – catalytic conditioning of syngas that was derived from the gasification of woody biomass can be directed towards the production of synthetic bio-diesel

Woody biomass for biochar



USDA Forest Service photo by Jessica Brewen



Benefits of Biochar and Compost



Improve rain absorption and soil moisture retention

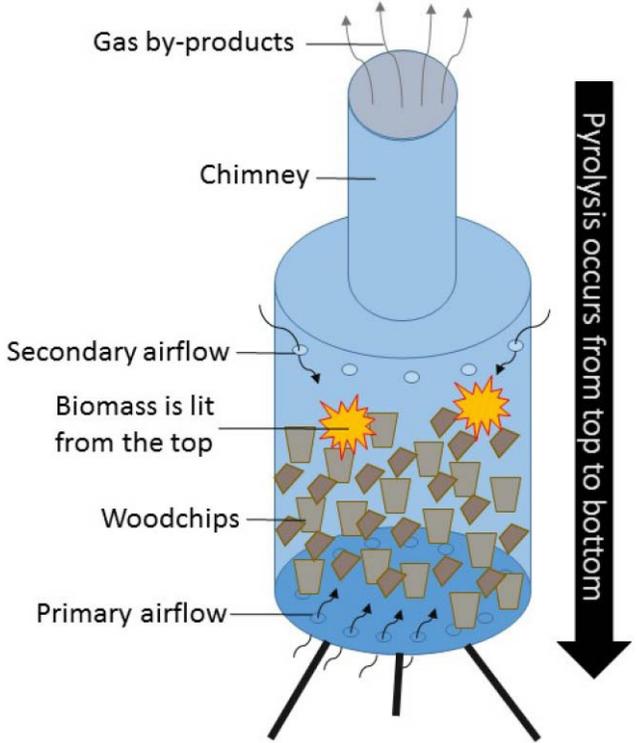


Increase crop yield and reduce the need for synthetic fertilizers

Reduce greenhouse gas emissions



Improve soil health and water quality



The design of the TLUD produces high quality char with efficient conversion rates <https://nfs.unl.edu/publications/small-scale-biochar>

REGIONAL CLEAN HYDROGEN HUBS



Potential Biofuel and hydrogen market for California:

- Transportation Fuels
- Cleaner fertilizer industry
- Benefits: Air pollution reduction; self-reliance

California is the largest consumer of both motor gasoline and jet fuel in the U.S. In 2020, California consumed over 11 billion gallons of gasoline and 5 billion gasoline gallon equivalent (GGE) of jet fuel.

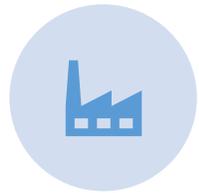
Sanchez, D. & Gilani, H. 2021. *Advancing Collaborative Action on Forest Biofuels in California*.



What can green hydrogen bring?

- Benefits:
 - Workforce development and job creation
 - Healthier environment and forests
 - Regional economic development
- Challenges:
 - Transportation and space requirement
 - Development of centralized treatment facilities
 - Reliable long-term feedstock

Policy Support and Assistance



CA's plan to become the nation's largest clean hydrogen hub



California Building Code (CBC) allows mass timber buildings of up to 18 stories



Organizations: UC ANR, California Resource Conservation District (RCD), NRCS, etc.



Grant funding opportunities from USDA, USFA, CalFire, DOE, and others



Various policies that promote carbon storage, energy efficiency, wildfire prevention

Status

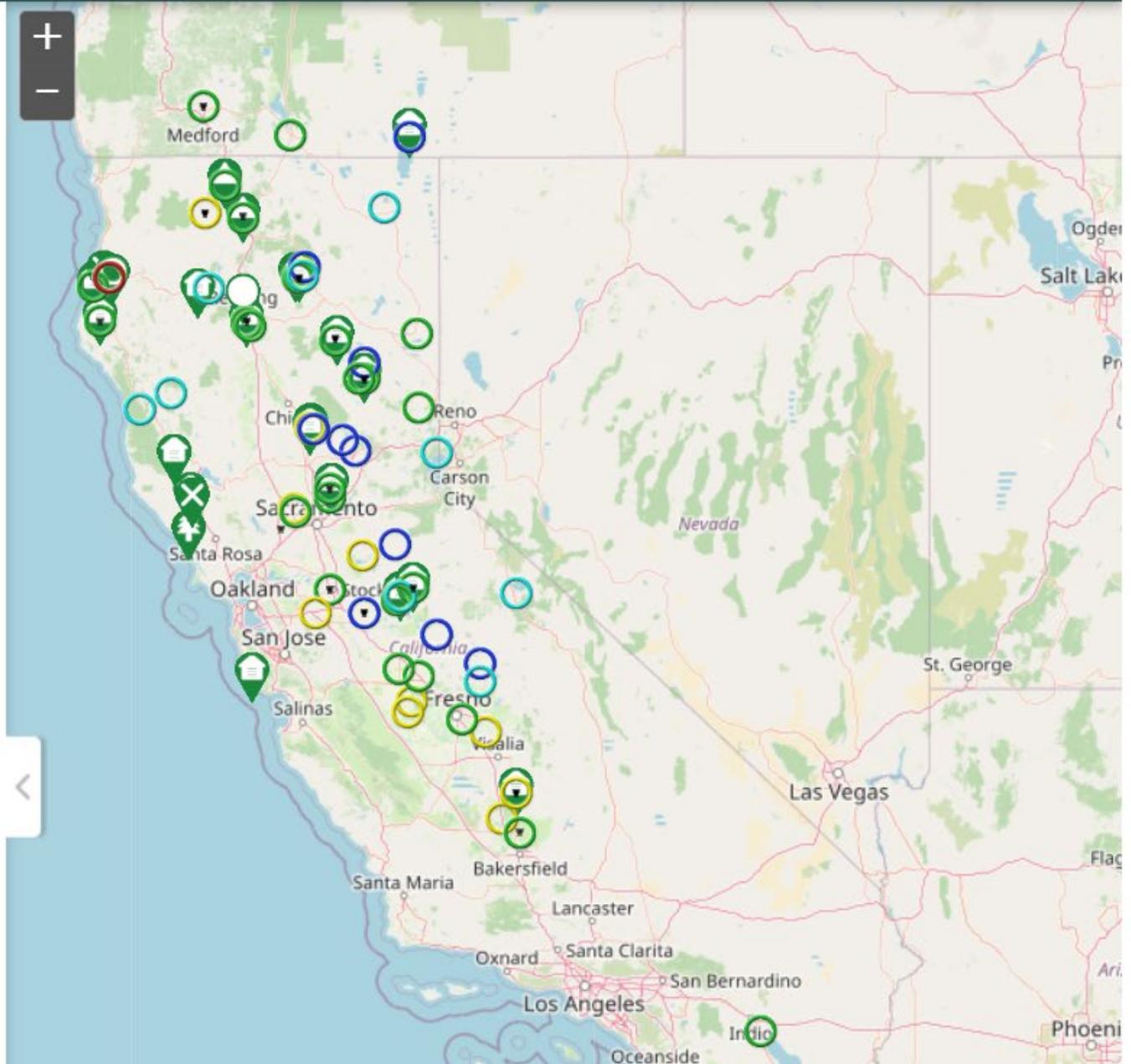
- Operational
- In Development
- Idle
- Proposal
- Closed

Facility Type

- Biomass Generator (Standalone)
- Biomass Cogeneration
- Large and Small Log Mill
- Large Log Mill
- Small Log Mill
- Fence Board Mill
- Peeler Mill
- Specialty/ Small Production Mill
- Post/Pole Mill
- Cedar Mill

Timber Production by County

Explore county-based timber production volume by clicking the graph icon on the bottom left of the map and following the prompts. [Detailed instructions here](#)



What's next?

Institutional and stakeholders collaboration in innovation and exploring market opportunities

Work with landowners to improve forest management strategies

Workforce development in forestry, manufacturing, energy and utilities, etc.

Develop regional facilities/hubs to receive raw materials from rural communities

Demonstration projects to promote clean energy and renewable materials

Find better options for byproducts

Woody Forest Products Manufacturing

This diagram conceptualizes the transformation of wood from the forest ecosystem into "end market products," or products one might interact with on a regular basis. Forest provide many benefits from recreational opportunities, to clean air and water. Woody biomass is but a small part of these services, but one that is deeply embedded in our everyday lives. Wood can build homes, print newspapers, and even power cellphones. This diagram will explain the complex pathways necessary to facilitate these everyday interactions with wood. Wood products generally follow these main steps:

- Step 1: Source**
Wood is grown and managed for in the forest ecosystem
- Step 2: Raw Extract**
Raw materials are extracted from the forest ecosystem
- Step 3: Processing**
Extracted material is reformed into an intermediate product for further processing or a final product.
- Step 4: Intermediate**
Products with limited consumer level use on its own is further manufactured into a final market product
- Step 5: End Product**
Final product is produced and made available for consumer use. See below for specific type definition

This is a product of the UC Berkeley Wood Resources Group (WRG), provided with funding support from the USFS, US State and Private Forestry and from donors like you. Last updated: 10/14/15, RPJ

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Agriculture and Natural Resources

Start Here!

Forest Ecosystem
Natural forest ecosystem producing mechanical wood for conversion to a valuable end product. Primary woody forests are broadly categorized as wetland, riparian, and upland. Riparian and wetland forests are located in riparian corridors and wetlands. Upland forests are located on upland sites.

Firewood
Wood of variable size and quality, cut into lengths of 16" and 24" and stacked in piles for use as fuel for heating and cooking.

Soil Amendment & Mulch
Chipped bark or woody material designed for increased water retention and soil enrichment. Used in landscaping, agriculture, and as a physical barrier to reduce soil erosion.

Post & Pole
Used in construction, agriculture, and landscaping. Includes utility poles, fence posts, and other structural applications.

Sawdust
Fine particulate byproduct of logging, grinding, or cutting operations. Pure wood material without non-wood contaminants (plastic, bark).

End products are grouped into the following color coded categories based on functional use.

Composite
Blend of wood particulates with non-woody materials including waxes, cement, adhesives, and plastics. Usually formed into specific shapes on the basis of engineering strength and end use requirements.

Energy
Wood products that are specifically manufactured for the purpose of generating heat to produce electrical power.

Landscaping
Materials used in outdoor applications ranging from aesthetic design, soil reinforcement, and even weed control.

Lumber
Sawn lumber commonly used for building or construction uses. Typically directly sawn from forest output and only undergoes a single processing step.

Mass Timber
Engineered product with high strength and stability that can replace steel and concrete building materials. Mass timber can create wood shapes and sizes not found in traditional timber products.

Panel
Sheet based wood product. All have design specifications that vary strength and hydrophobicity. Can be used for aesthetic, design, or structural purposes.

Paper
Wood fiber based products typically produced in the form of rolls but may be shaped into a variety of products.

Reinforced
Finished product built from taking an end market product and reprocessing it into another form.

Sawmill
Processes logs directly sourced from the forest into a range of solid wood products (plank, custom and dimensional lumber, rail ties, planks, beams, etc.). Products can be planed, kiln dried, resurfaced, and glued into decorative products.

Molding & Scrollwork
Wood shaped into decorative or functional forms. Includes moldings, scrollwork, and other decorative elements.

Peeler Log
Straight, high grade log banded or softwood log clear of knots, trunks, and other defects. Log lengths vary depending on end product. Loggers peeled or skid along the circumference to form veneer sheets.

Veneer Peeler/Slicer
Produces veneer sheets by slicing length or peeling logs with a rotary blade. Veneer end use determines product thickness from 3mm decorative high grade to 1mm low grade stock. Veneer sheets may be further processed with heat and other panels products to form solid panels.

Veneer Sheet
Sheet peeled along the circumference of a clear log. Veneer length or thickness depends on structural (thick) or decorative (thin) application and material type. Quality hardwoods are usually used for decorative purposes.

Structural Composite Lumber
Composite lumber is made from the same species of wood as the lumber it is made from. It is made from wood chips, sawdust, and other wood waste. It is a strong, durable material that can be used in a variety of applications.

Plywood
Panel of veneer sheets bonded together at alternating grain directions. May be mixed with other materials like fiberglass for enhanced strength. Used in construction, furniture, and other applications.

I-Joist
"I" shaped beam created from engineered panels. A structural self-centering panel with a tapered top and bottom flanges made from a variety of engineered wood products. Used in construction for floor joists.

Electricity
Electricity generated through internal combustion process. Wood chips may be used as a fuel source for power generation. Wood chips are a renewable energy source that can be used to generate electricity.

Smallwood Log
Roundwood residue of sawlogs and other logs, with structural qualities suitable for manufacturing into larger post or dimensional products. Higher value use for input materials (logs) may be achieved through conversion into particulates.

Strander/Flaker
Mechanically processed roundwood into small diameter, uniform, clean material with long fiber strands. Strands retain tension strength of wood fibers and can be oriented and temporarily panel products with green strength (then similarly shaped solid panel).

Wood Strands/Flakes
Small, flat wood particles of uniform dimensions and fiber distribution. The shape of the fiber similar to a laminated strand board. Used in manufacturing of OSB, particleboard, and other wood products.

Producer Gas
Natural gas alternative derived from biochar. Producer gas is a mixture of hydrogen, carbon monoxide, and methane. It can be used for heating or as a fuel source for power generation.

Oriented Strand Board
Particle panel formed by drying and orienting wood strands. Used in construction for floor sheathing, wall sheathing, and other applications.

Wood Pellets
High-density, compressed fuel particles. Manufactured from wood chips, sawdust, and other wood waste. Used for heating and power generation.

Direct Heat
Heat power generated directly or as a byproduct of power generation. Wood chips are a renewable energy source that can be used to generate direct heat.

Management Residual
Material left over from wood processing. Suitable for direct conversion to fuel product but suitable for processing into intermediate products (chips, mulch, etc.).

Chipper
Produces small, uniform diameter pieces from the lowest value woody material (cultural treatment residue, harvest residue, mill residue, etc.). Wood may be used as a fuel source, but with bark on a rotating disk, or processed with rotating hammers.

Shavings
Flaked material (1/8" to 1/2") suitable for energy production. Used in power generation and other applications.

Bio-Oil
Liquid fuel product of fast pyrolysis or gasification of wood chips. Used as a fuel source for power generation and other applications.

Wood Fiber Composite
Wood fibers bonded with other plastic or resin to create a composite material. Used in construction for floor sheathing, wall sheathing, and other applications.

Charcoal/Biochar
Wood carbonized by partial combustion. Used for heating, power generation, and as a soil amendment.

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Firewood
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Post & Pole
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Sawdust
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Wood Fiber
Pure wood fibers from mechanically and/or chemically deconstructed logs, chips, or manufacturing residue. Product retains cellulose fibers to enhance composite strength and durability. Used in a variety of applications (textiles, paper, etc.).

Cellulosic Ethanol
Ethanol biochemically produced via fermentation of wood chips. Used as a biofuel and other applications.

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Find out where wood comes from!

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Cellulosic Ethanol
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Injection Molded Composite
Wood particles (microfibrillated cellulose, fibers, plastic, and other materials) mixed with resin and injected into a mold. Used in construction for floor sheathing, wall sheathing, and other applications.

Furniture
Interior and exterior furniture produced from wood. Includes tables, chairs, and other household items.

Lumber
Sawn lumber commonly used for building or construction uses. Typically directly sawn from forest output and only undergoes a single processing step.

Glued Laminated Timber
Engineered beam manufactured from dimensional lumber. Used in construction for floor joists, wall sheathing, and other applications.

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For more information, please visit us at ucanr.edu/woodybiomass

A photograph of a large stack of cut logs in a forest. The logs are stacked in a way that their circular ends are visible, showing the wood grain. The background consists of tall, thin trees with green foliage, and bright sunlight is streaming through the canopy from the top center, creating a lens flare effect. The overall scene is bright and natural.

Thank you!