USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

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Wood Innovations for a Sustainable Future

In a future sustainable society, everyday products and necessities—food, clothing, medicine, energy, cars, electronic devices, high-rise buildings, and more—can be made from wood or wood-based polymers and chemicals. Recognizing the potential of wood and wood polymers, U.S. Department of Agriculture (USDA) Forest Service scientists are developing innovative technologies to use these renewable materials in products that are essential to our daily living.

By discovering the unique properties of wood, Forest Service research will be the driver for opening nonconventional markets, thereby increasing the demand for wood and wood-derived products. Wood innovations can incentivize forest restoration and fuel reduction operations, provide an economic boost for landowners, create manufacturing jobs in the forest products supply chains, stimulate economic development in rural communities, and provide solutions to climate change.

Cellulose Nanomaterials From the Forest

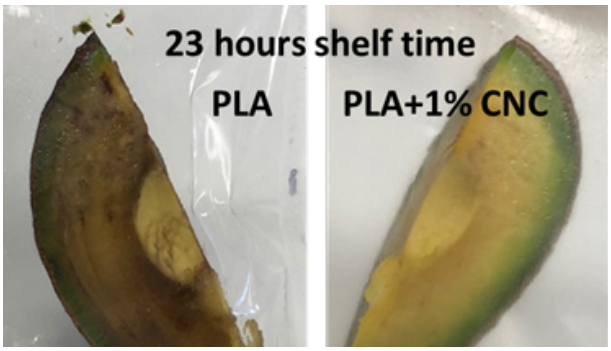
Cellulose nanocrystals (CNC) are nano-scale (one-billionth of a meter) materials produced from wood. For context, a sheet of paper is 100,000 nanometers thick. Forest Service scientists have discovered that cellulose nanomaterials can enable unique properties in other materials. From 2016 to 2020, the Forest Service invested $22.7 million in nanotechnology research and technology transfer, including:

- Investigating CNC's role in light-weight fiberglass composites to improve the fuel efficiency of cars. Laboratory results show that fiberglass composites with 1 percent CNC can reduce the amount of glass fiber from 25 to 35 percent, making the fiberglass lighter while maintaining the material's strength.

- Adding CNC to concrete to improve its strength and lower carbon emissions associated with concrete production. Forest Service scientists and program staff worked with several public and private partners to install CNC-enhanced concrete beams in the Moffett Creek bridge in Siskiyou County, CA to demonstrate its application in bridges. The team is also looking at replacing bridges destroyed in California forest fires with CNC-enhanced concrete.

CNC's are used to improve the strength and lifespan of concrete, a valuable addition for sustainable infrastructure. USDA Forest Service photo.

- Using CNC to develop packaging material with improved barrier properties. Laboratory results show that adding 1 percent of CNC to polylactic acid (PLA), a biodegradable packaging material, can extend the storage life of packaged produce.



Using a small amount of wood-based nanomaterials in packaging can extend the storage life of produce—because no one likes brown avocados! USDA Forest Service photo.

Renewable Carbon Materials From Wood

Forest Service scientists are developing renewable carbon-based materials, either directly from underused forest biomass or from lignin. Lignin, a structural component in trees, is produced as a byproduct from pulping and biorefineries. Lignin's chemical structure and higher carbon content make it an attractive renewable resource. Working with academic and industry partners, Forest Service scientists:

- Are developing activated carbon fiber from lignin that provides better ventilation and improved comfort for clothes. Forest Service scientists are also investigating the potential of using activated carbon fiber from lignin as a superconductor for flexible electronics and batteries.

- Created a carbon foam from lignin. This stiff, porous material is lightweight, nonflammable, capable of absorbing sound and radiation, and able to maintain its performance at high temperatures. Potential uses for the carbon foam include military aircraft and ship insulation, wall panels, and stealth technology.

- Engineered a device, called "CharBoss," that continuously produces biochar from forest biomass. Biochar helps store carbon, improves water holding capacity and soil structure, and reduces nutrient leaching in soil. Adding biochar to soils can enhance the success of silviculture treatments and forest restoration projects and can be used to reduce environmental contaminants when remediating mine sites.

Biomedical and High-Value Chemicals From the Forest

Forest Service scientists and academic partners are developing ways to produce high-value chemicals from wood. These chemicals provide green alternatives to conventional chemicals or those that are difficult to produce from crude oil. The diverse markets for these high-value chemicals open new opportunities for wood, and as a result, offer landowners broader and more balanced market opportunities. Working with academic partners, agency scientists:

- Are creating a process to produce 3-hydroxybutyrolactone (3-HBL) from wood. 3-HBL is a bioactive molecule that has application in cholesterol-lowering drugs such as Crestor® and Lipitor®. The process also produces glycolic acid, which is used in skin-care products, food, and textiles.

- Developed methods to produce methyl levulinate from bamboo and poplar. Methyl levulinate can be used in food flavoring, fuel additives, medicine, and other chemical products.

Technology Transfer

Forest Service scientists often partner with industry experts in the early stages of research to accelerate technology transfer of our discoveries. Whenever possible, agency scientists pursue patent opportunities from their research, and the Forest Service filed at least six U.S. patents in the last 3 years. To remove barriers to commercialization, Forest Service experts are leveraging resources to explore regulatory frameworks for taking new technologies to market and facilitated the creation of innovation ecosystems. In addition, Forest Service has:

- Invested in the "Forestry and Related Resources" topic in the USDA Small Business Innovation Research (SBIR) grant program. Administered by the USDA National Institute of Food and Agriculture (NIFA), from 2018 to 2020 the program funded 16 Phase I projects totaling $1.6 million and 10 Phase II projects totaling $6.1 million.

- Led or actively participated in the development of international standards for cellulose nanomaterials in the International Organization for Standardization (ISO), the CSA Group (formerly the Canadian Standards Association), and the Technical Association of the Pulp and Paper Industry (TAPPI). Five international standards for cellulose nanomaterials have been developed from Forest Service leadership or participation.

- Participated in the development of standards for building codes, the American Society for Testing and Materials (known as ASTM International), and other standards development organizations (SDOs).

About Forest Service Research and Development: The Research and Development (R&D) arm of the Forest Service works at the forefront of science to improve the health and use of our Nation's forests and grasslands. Research has been part of the Forest Service mission since the agency's inception in 1905. The organization consists of 7 research stations and 81 experimental forests and ranges. Forest Service R&D partners with other Federal agencies, States, Tribes, nongovernmental organizations, universities, and the private sector. Today, more than 400 Forest Service scientists work in a range of biological, physical, and social science fields to promote sustainable management of the Nation's diverse forests and rangelands.