Forest Products Laboratory

Restoring America's Forests Through the Wise Use of Wood

The long-term health of our Nation's forests depends on sound conservation practices, including utilization. Founded in 1910, the Forest Products Laboratory in Madison, Wisconsin, uses science and technology to conserve and extend our Nation's forest resources. FPL is recognized around the world as a source of unbiased information about wood science and use.

www.fpl.fs.fed.us

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Fast Facts and Key Points

Research at the Forest Products Laboratory promotes healthy forests and forest-based economies by developing efficient, sustainable uses for our wood resources.

Forest Products Laboratory (FPL)

- Located in Madison, Wisconsin, since 1910
- Nation's only federally funded wood utilization research laboratory
- Currently employs 60 scientists
- Primarily or partly responsible for many of today's wood-based technologies, including wood preservatives, glulam beams, oriented strandboard, and fiber-based packaging, recycling and building deconstruction, green building technologies, and new uses for forest biomass from restoration activities
- Research partnerships located in virtually every state in the Nation
- Current research initiatives
  - Underutilized woody biomass
  - Nanotechnology
  - Biobased energy and biorefining
  - Advanced composites
  - Advanced wood structures and green building technologies
- Research outcomes
  - Reduce wildfire intensity and suppression costs through economic use of forest biomass
  - Create economically viable uses for beetle-killed trees
  - Mitigate the effects of climate change on forests through carbon sequestration

Wood Use

- More sustainable to use than alternative construction materials
- Requires much less energy to process than other materials
- Energy requirement to build wood-framed houses 15% to 20% less than for steel- or concrete-framed houses
- Produces less air pollution, solid wastes, and greenhouse gases than steel and concrete

Forest Products Industry

- Employs about 1 million workers
- Accounts for approximately 6% of the total U.S. manufacturing GDP
- Ranks among the top 10 manufacturing sector employers in 48 states
- Generates over $200 billion a year in sales and about $54 billion in annual payroll
- In 2011, recovered 66.8% of paper consumed and is the leading generator and user of renewable energy

Forest Management

- Rough average of 10 ft^3 of wood per harvested tree
- 9.9 billion trees per year (1.1 million trees per hour) harvested worldwide—equivalent to 1.7 trees per person per year
- 1.5 billion trees per year (170,000 trees per hour) harvested in the United States—equivalent to 6.3 trees per person per year, nearly 4 times the global rate
- Harvested trees replaced by planting and natural regeneration at a rate of more than 3 to 1 in the United States
- Volume of growing trees increasing in the United States despite rate of harvest
- U.S. consumption of wood products in 2005 at 28% of global total
- U.S. consumption of wood products (roundwood equivalent, excluding fuelwood) increasing, from 16.3 to 18.8 billion ft^3 between 1990 and 2006
- U.S. harvest (excluding fuelwood) decreasing, from high of 15.7 billion ft^3 in 1989 to 14.9 billion ft^3 in 2006, as consumption from imports increasing
- Nearly 215,000 trees per hour are consumed in the United States, and the Nation is a net importer of wood and paper products that require an average of 45,000 trees per hour

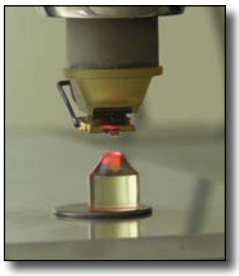
Mission and Science Themes

FPL Mission

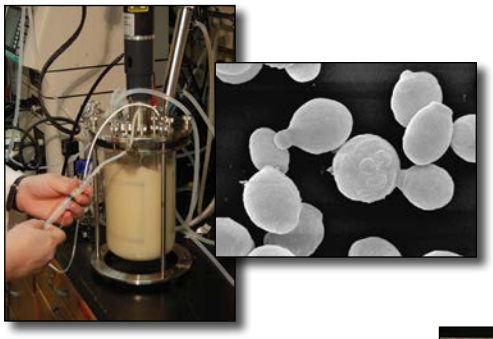
To identify and conduct innovative wood and fiber utilization research that contributes to conservation and productivity of the forest resource, thereby sustaining forests, the economy, and quality of life.

Science Themes

Underutilized woody biomass—Developing uses for small-diameter softwoods, underutilized hardwoods, and urban woody biomass will improve forest health, decrease fire risks, boost local economies, and provide renewable products.



Nanotechnology—Using nanotechnology tools and nanoscale materials to enhance the utility or performance of wood- and fiber-based products, understand wood properties at their most fundamental level and how they differ, and develop totally new products enable the U.S. forest products industry to compete successfully in the increasingly competitive global marketplace.



Biorefinery/bioenergy—Processing forest feedstocks, such as waste from wood processing plants, tree tops and limbs, and urban waste wood, can produce higher value products, such as ethanol, specialty chemicals, and pharmaceuticals.

Advanced composites—Developing engineered biocomposites can simultaneously meet the Nation's diverse needs for high-performance building and commodity products while maximizing the sustainability of forest resources.

Advanced wood structures—Creating advanced technologies and alternative building methods can greatly enhance the value of wood in residential, nonresidential, and transportation structures.

Durability and Wood Protection Research

Mission: *Improving durability and wood protection through improved building design, advances in low-toxicity wood preservatives, and improvements in fire safety*

Wood is an aesthetic and versatile structural material, and it represents one of our most valuable renewable resources. However, vulnerability to moisture, fire, and biodeterioration are important limitations to the expected long service life of wood and can result in significant economic and resource loss. One of the surest ways to extend the available timber supply and increase the resources to meet present and future demands is by improving the durability of wood in use.

Research Focus Areas

- Extending the service life of residential and non-residential buildings through proper design and operation of the structures
- Improving the fire safety of forest products to ensure personal safety and forest health
- Developing wood treatments that improve durability of wood products without adversely affecting the environment
- Formulating new, sharply targeted inhibitors to protect wood products in service and prevent economic and resource losses that result from biodeterioration

Engineered Composites Sciences

Mission: *Understanding relationships between materials, process, and performance to engineer biocomposites that benefit users while promoting sustainability of both virgin and recycled forest resources*

The engineered wood and other bio-based composites developed through our research provide improved value, service life, and utility to consumers, while also promoting sustainability and recycling. Biocomposite technologies can be manufactured into highly engineered building products using low-value natural resources, helping to offset the costs of thinning operations needed to improve forest health. Composites also present an opportunity to promote jobs in rural communities that depend on forest resources for their economic health.

Our research will focus on enhancing traditional composites while simultaneously developing the next generation of biocomposites, which will provide construction and building products that far exceed current expectations while opening new markets and reducing effects on the environment.

Research Focus Areas

- Understanding the fundamental relationships between wood, natural fiber, and alternative materials to optimize composite processing and performance
- Improving the performance, durability, and value of existing composites and defining the next generation of hybrid composites made from natural fibers and alternative materials
- Developing tools to address resource sustainability, enhance recyclability, and minimize the environmental impacts of composite processing

Engineering Properties of Wood, Wood-Based Materials and Structures

Mission: *Improving the characterization of mechanical and physical properties of wood and wood-based products that are important in engineering design and fostering their efficient use in wood building systems*

The United States is the world's largest producer and consumer of wood products. Annual harvest of roundwood is approximately 350 million tons, and more than half that harvest is used in some form of solid wood product (lumber, wood-based composites, and roundwood products, such as posts, poles, and pilings).

Because construction accounts for most of the consumption of solid wood products, trends in demand for these products are largely determined by trends in construction. It is projected that over the next 50 years there will be a two-thirds increase in the number of new households; therefore, our research is focusing on increasing the efficiency of wood-products use to support both the conservation and productivity of our Nation's forests.

Research Focus Areas

- Conducting fundamental research aimed at developing information on the fundamental anatomical, physical/mechanical, and processing characteristics of wood
- Providing information on the engineering properties and performance characteristics of wood-based structural products
- Developing information on the performance and design of structural wood systems

Economics and Statistics Research

Mission: *Providing economic information, analysis, and projections and enhancing the efficiency of FPL's research through development, evaluation, and application of modern statistical research*

Economics and statistics are critical components of the success of research at FPL. Economists provide information indicating how and why markets and technologies for wood products change over time, implications for natural resources management, and selected broad environmental and social impacts. Statisticians apply modern statistical methods to enhance the integrity and efficiency of utilization research.

This unit supports other research projects by providing statistical methods that help develop innovations that expand the competitive use of wood to meet needs and conserve resources; evaluating the role of market trends and innovations on competitiveness of U.S. firms with foreign firms; and evaluating the impact on forests of possible forest industry or forest management policies and initiatives that provide new value for wood or conserve wood.

Research Focus Areas

- Applying statistical methods to enhance the quality of FPL's wood utilization and economics research
- Improving statistical modeling of wood, fiber, and composite properties, processing, and performance
- Monitoring and modeling market equilibria, production trends, and technology changes of the U.S. forest products industry
- Improving understanding of the effect of production trends and technology changes in solid wood, composites, and end-use industries on product and wood needs
- Providing readily available, consistent information on timber, wood products, and paper products industries for forestry and forest industry strategic planning
- Providing knowledge of the economic viability of new technologies for converting wood and fiber into new or improved paper and wood products or biofuels

Fiber and Chemical Sciences Research

Mission: *Formulating efficient processes for converting wood to chemicals and fibers, developing economically viable uses for underutilized wood resources, and improving methods for recovering and reusing forest products such as waste paper and construction debris*

The need to reduce fire risk has led to a significant change in the utilization needs of the Forest Service; available material has shifted from traditional timber to small trees, woody shrubs, and forest floor debris. Fortunately, there are national efforts to use such materials as fuels, chemicals, and nanoscale materials. Our research is helping to develop commercial uses for this new wood supply and Forest Service need. The unit also continues research on improving pulping technologies, paper performance, and the performance of recycled paper.

Research Focus Areas

- Advancing forest biorefinery for production of transportation fuels, such as ethanol, and valuable chemicals
- Conducting research on nano-materials derived from wood
- Continuing advances in traditional wood pulp applications
- Improving paper and paperboard recycling
- Understanding the fundamentals of paper structure and applications for pulp-fiber-based products

Institute for Microbial and Biochemical Technology

Mission: *Developing biotechnology and nanotechnology for wood and fiber conversion through research that contributes to efficient wood utilization and improved forest health*

Research conducted in the Institute for Microbial and Biochemical Technology (IMBT) at FPL extends basic discoveries in microbiology, genetics, biochemistry, biophysics, nanotechnology, and bioprocessing into technologies that improve wood utilization and forest management practices.

Our research improves knowledge of the chemical properties of wood, particularly as they relate to mechanisms and processes for bioconversion and decay prevention. This enhanced knowledge will increase product yield from traditional wood supplies and will lead to new and improved technologies to convert low-value, underutilized forest resources into renewable fuels, chemicals, pulp, paper, and paperboard.

Research Focus Areas

- Developing technologies for the efficient and economical bioconversion of underutilized woody biomass, such as forest thinnings, unmerchantable timber, and mixed species, into a array of wood-based materials, from fiber to chemicals
- Identifying and understanding the mechanisms of wood decay fungi to increase their efficacy in bioconversion technologies, devise new environmentally sound wood preservatives, and accelerate decomposition of forest litter
- Developing basic information and operation conditions for efficient and effective enzymatic and microbial processing of wood and wood fiber
- Increasing understanding of the functional genomics of lignocellulose-degrading fungi to optimize their use in bioprocessing and bioconversion of wood

Performance Enhanced Biopolymers

Mission: *Understanding the basic properties of wood and other materials used in conjunction with wood to improve their properties, enhance their service life, and develop new uses*

Research in performance-enhanced biopolymers focuses on three problem areas: advanced structures, advanced composites, and nanomaterials. There is considerable interdependence among these three areas (i.e., improvements in structures will depend on advances in composite materials), and improving the performance of wood and wood-based structures will require basic and applied research in each of these three areas. Our research will help ensure that newly developed materials and structure components are robust, durable, cost effective, compatible with other materials, and easily disposed of or recycled at the end of their useful service lives.

Research Focus Areas

- Understanding why wood-based materials fail under end-use conditions, developing new and improved methods for predicting service life, and incorporating new designs, materials, and methods to make structures last longer
- Understanding wood surface chemistry, how materials bond to wood, and the processing of components during manufacture to improve wood-based composites
- Understanding wood properties at the molecular, nano, and cell wall dimensions to solve performance problems

Budget

Allocations	*FY11*	*FY12*	*FY13**
Research Base	$18,643,000	$18,451,000	$18,266,000
National Fire Plan	$703,000	$597,000	$591,000

*President's Budget

Build Green: Wood Can Last for Centuries

Since we are on the cusp of a "green revolution", there is no better time than now to promote wood in construction as a means to mitigate climate change and to highlight the environmental benefits of choosing wood for residential and non-residential construction. FPL researchers published a report to dispel the myth that wood construction will not last as long or be as "green" as steel or concrete. They aim to educate the public on home maintenance and empower them with proper information to make an informed choice for their next construction project. With user-friendly information, home-owners can address many home maintenance issues prior to costly repairs. This report illustrates many common moisture-related problems that can lead to decay if ignored and points out that with proper attention to detail, wood that is protected from moisture can last indefinitely.

Residuals to Aviation Fuel

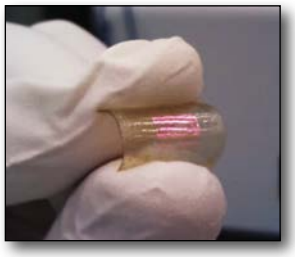
In September 2011, the U.S. Department of Agriculture announced that Washington State University was to receive a five-year, $40 million grant to help develop alternatives to petroleum-based fuels and chemicals. Called the Northwest Advanced Renewables Alliance (NARA for short), FPL received a $1.1 million subcontract to pretreat woody biomass for conversion to aviation fuel. FPL's participation is to demonstrate the SPORL (Sulfite Pretreatment to Overcome Recalcitrance of Lignocellulose) process for efficient sugar production from Douglas-fir forest residue. In the first year of the project, FPL scientists developed a fractionation technique to reduce the bark content of forest residues. The goal is to leave the bark in the forest for soil conditioning and nutrients. Improved bark removal also reduces the deadload in transportation and biorefinery processing. Preliminary laboratory evaluation has confirmed the high performance of the SPORL process for pretreatment of the Douglas-fir, providing efficient enzyme conversion to sugars and high biofuel yield.

Going to Bat for Major League Baseball

Breakage of bats during play has become a safety concern for Major League Baseball (MLB), and FPL researchers, along with university and private sector partners, are on board to help improve the situation. Researchers have been giving technical advice to MLB officials on the mechanical properties of various species of wood commonly used to make baseball bats, and a contract between FPL and MLB was signed to continue the partnership. The committee compiled relevant information for each broken bat, including manufacturer, model, dimensions, game situation when it broke, area in which the bat fragments landed, and video footage of each incident. FPL began working with a private certification and testing agency to help assess and categorize the bat failures, as a first step toward reducing future catastrophic incidents. Recommendations were then made on steps that could be taken to reduce the number of bats broken during play, and implementing those recommendations resulted in a 50% reduction in the number of catastrophic bat failures.

Flexible Electronics Using Cellulose Nanofiber Composite Substrates

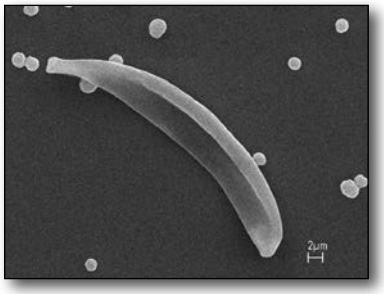
Flexible electronics have many potential applications including malleable displays, solar cells, smart cards, radio frequency tags, medical implants, and wearable computers. Transparent films made from cellulose nanofibers, a renewable nanomaterial, have the potential to serve as a foundation for flexible electronics. Researchers from FPL and the University of Wisconsin–Madison have demonstrated the first example of using cellulose nanofiber composite substrates for flexible electronics. Although some challenges remain, the cellulose nanofiber composite showed good chemical and thermal resistance necessary for electronic fabrication and the use of cellulose nanofibers as a sustainable component for high-speed flexible electronics is extremely promising.



Protecting Wooden Bridges

Wooden bridges, whether historic covered bridges or current highway timber bridges, can be vulnerable to damage from biodegradation or fire. Only about 800 of more than 10,000 covered bridges built in the United States are still standing, and many of those are suffering from biodeterioration. The remaining covered bridges are also vulnerable to damage by intentional or accidental fires. Modern timber bridges, which represent an important component of the transportation resource, can also be vulnerable to fire and decay. With funding provided by the Federal Highway Administration, Forest Service and university researchers collaborated to evaluate methods of protecting wooden bridges from fire and biodegradation. This research and the resulting recommendations were consolidated into a guide that provides detailed information on factors that contribute to vulnerability, best practices for minimizing vulnerability, selecting and applying supplemental preservative treatments, use of fire retardants, and fire protection technology. This is the first document of its kind to provide such detailed information and instructions. It will be used by historic preservationists and transportation maintenance personnel in their efforts to extend the life of both historic and modern wooden bridges.

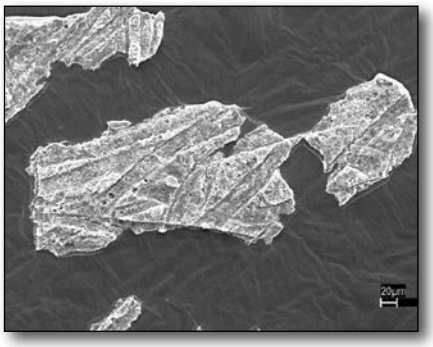
Highly Unusual Yeast Makes Biofuel Production Faster and Less Expensive



A yeast isolated from the gut of wood-boring passalid beetles can ferment xylose to ethanol three times faster than it ferments glucose, whereas normal yeasts do not ferment xylose at all or at a much slower rate than glucose. It can also ferment different sugars simultaneously when presented with a mixture, and can ferment xylose to ethanol under anaerobic conditions on minimal medium. All these features are conducive to faster, cheaper biofuels production, and the findings are being developed for possible commercial use.

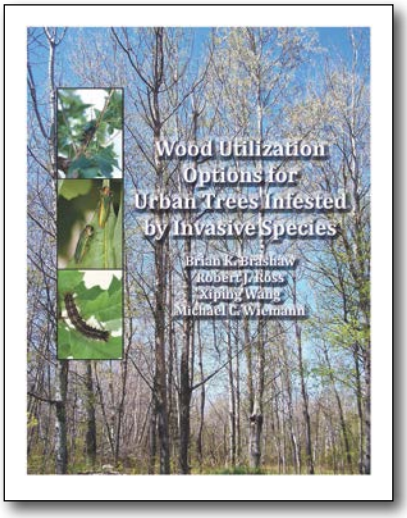
Making Recyclable, Compostable Stamps that Last "Forever"

The US Postal Service has sponsored cooperative research projects at FPL for more than 20 years. Initial research developed stamp adhesives that do not cause problems during paper recycling. Researchers are now developing improved performance and accelerated aging tests to assure that Forever Stamps are indeed useful—if not forever—at least close enough to qualify for the name. Also, in an effort to reduce the environmental impact of stamp materials, researchers are developing new adhesives that are produced from renewable materials and degrade in landfills. Beyond developing adhesives that may be used on future stamps and other commercial products, researchers are developing experimental methods for determining the biodegradation rate of new materials.



Making the Most of Beetle-Killed Trees

FPL researchers and their partners have developed a user-friendly guide that focuses on how best to use wood obtained from trees that were infected by invasive species. *Wood Utilization Options for Urban Trees Infected by Invasive Species* is a comprehensive manual that can be used by professionals when assessing use options for this material. The publication includes a summary of the technical viability of using these materials for value-added products in a variety of applications, and will be useful to urban foresters, municipalities, and local industries looking for ways to use beetle-killed trees. The publication places a major emphasis on trees killed by the emerald ash borer.



Projecting the Future of the U.S. Forest Products Industry

FPL researchers developed a detailed model that provides projections of future timber demands and timber prices under alternative scenarios regarding global economic growth and wood energy consumption. The model provides insights on how U.S. competition and trade in forest products could be impacted by expanded global use of wood for energy in future decades. The model provides a range of new and expanded capabilities, including modeling regional U.S. forest product production and trade, stumpage markets for hardwood and softwood timber, regional timber harvest and wood residue disposition calibrated to Forest Service timber data, and the relationship between housing construction and wood product demands. Using global economic scenarios, the FPL model showed that scenarios with large expansion in global use of wood for energy would likely result in large increases in real timber stumpage prices in U.S. regions, but U.S. producers of forest products could nevertheless gain competitive advantages if global roundwood prices increase more in foreign countries than in the United States as a result of expanded global wood energy consumption.

Effect of Heat Treatment on Black Locust

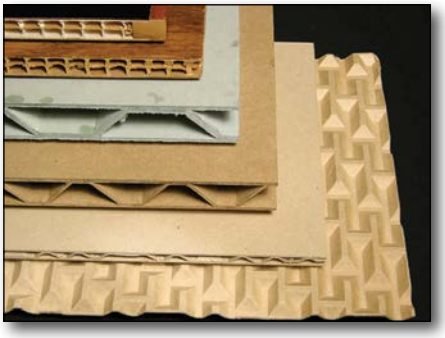
Black locust is a fast growing wood species with superior mechanical properties. It is often used in making furniture but discoloration during drying often limits its application. Heat treatment variables have been shown to affect color changes in wood. Color change is largely due to chemical structures within the wood. A better understanding of heat treatment variables during the drying of wood allows for enhancement of color in black locust wood. Heat treatment creates the potential for black locust wood to resemble exotic hardwoods thus increasing the use of this fast growing wood species and potentially decreasing demand for exotic foreign species.

Effective Fire Retardants for Wood–Plastic Composites (WPC)

Wood composites made with highly flammable plastics are increasingly being used in a wide range of applications. Such applications include decking boards and other exterior products around homes in the wildland–urban interface. Tests have shown that fire retardant treatments can reduce the potential contribution of the WPC to a fire. Studies have also shown that increasing the wood fiber content in the WPC significantly improved the fire performance over that of the plastic alone.

Public–Private Partnership Moves Research Results to Marketplace

Researchers at FPL have developed technology whereby cellulose fibers can be formed into structural and three-dimensional engineered fiberboard panels. Noble Environmental Technologies Inc. (NET), San Diego, Calif., has signed an exclusive license agreement with the USDA to use jointly patent-pending technology and structures for office furniture and packaging applications. These naturally bonded boards can use fibers produced from a variety of renewable sources including forest thinnings and recycled paper fibers. A number of global industries and markets will have access to products and processes that are design-versatile, non-toxic, 100% recycled content, 100% bio-based. Such license agreements exemplify the value of public-private partnerships in moving basic research to valuable market-driven applications. The collaboration between FPL and NET is an excellent example of government and industry collaboration aiming to meet market demands. By combining the unique capabilities of NET and FPL, research results have transferred into tangible products bringing improved, sustainable options to consumers.



The Cellulose Nano-Materials Pilot Plant

FPL opened a new Forest Service-funded $1.7 million nanocellulose pilot plant in 2012. The pilot plant is now producing about 30 kg of cellulose nano-crystals (CNC), or 5 kg of cellulose nano-fibrils (CNF) per week. These materials are being supplied to three government agencies and six partner universities to accelerate the development of advanced cellulose-reinforced composites, and printed, flexible electronic circuits and products.

Cellulose nano-crystals are rod-like particles of pure cellulose, about 5 nm in diameter and 150–200 nm long. With the strength of steel at 1/6th the weight, they have applications in high-performance composites, replacing Kevlar and carbon fibers in these materials. Cellulose nano-fibrils are string-like particles, 20 nm in diameter and up to 2 microns long. They form high-strength clear films that can be used in high-performance epoxy layup processes, barrier coatings, or because of the very low coefficient of thermal expansion—the backing for printed circuits. The new pilot plant enables Forest Service R&D to continue to supply these materials to our partners, and make the materials available to dozens of new partner companies. Product applications as diverse as flexible solar panels, printed electronic circuits, auto body parts, military drones, light weight armor and ballistic glass are all under investigation by our partners.

Biomass and Bioenergy

Vision

America's forest resources significantly contribute to energy security and independence while reducing greenhouse gases.

Through sustainable forest management and cost-effective harvesting and collection, America's forests are a strategic asset in meeting U.S. energy security, environmental quality, and economic development needs and effectively contribute to displacing 30% of U.S. petroleum consumption by 2030.

Sustainable forest management on public and private lands generates excess woody material that can be used to help meet the Nation's renewable energy needs. Biomass management also supports efforts to provide economic opportunities, improve ecosystem health, decrease catastrophic wildfires, enhance wildlife habitat, and protect watersheds. Sustainable woody biomass management also mitigates, in part, the impacts of climate change and provides an alternative fuel and chemical source.

In coordination with other federal and state agencies, academia, businesses, environmental interests, and nongovernmental organizations, we will continue to improve and deploy technologies and underlying science for biofuels production while applying and supporting sustainable forest management practices on the Nation's forests.

Capabilities

Following are some attributes of Forest Service Research and Development:

- An integrated platform of innovative field and laboratory research that provides a unique opportunity for advancing biofuels feedstock production and conversion technology
- A cadre of wood scientists, biologists, chemists, and engineers who have already developed partnerships with universities and industrial partners in cooperative biofuels R&D ventures
- Extensive experience with business case analysis for biorefineries with expanding work relevant to today's questions about net energy and net greenhouse gas emissions for wood-based biofuels and chemicals
- A track record of providing leading-edge science and technology that has formed the basis for new products and improved efficiency from woody materials in a manner that is consistent with sustainable forest management
- A full spectrum of data and models to help reduce financial risk

Deliverables

Following are some advances in forest biomass to energy science and technology that we will accomplish and deploy with an expanded emphasis in biofuels in the Research and Development mission area:

- **Sustainable forest bioenergy production systems and new wood energy crops**
  - Best management practices for forestry with expanded biomass removal, while providing important wildlife habitat, water quality, fuels reduction, and nutrient management.
  - New varieties of perennial woody crops that are resistant to disease, fast growing, nutrient and water efficient, and optimized for bioenergy
  - Strategies to integrate woody plants with agricultural production of biofuels, so that environmental performance and synergistic outcomes are improved

- Experimental deployment and evaluation of woody bioenergy feedstock that will provide improved understanding of plantation silvicultural practices, soil nutrient management, and economics

- **Competitive biofuels conversion technologies that reduce fossil fuel use greenhouse gas emissions**
  - New chemical and biochemical technologies for extracting, modifying, and fermenting carbohydrates and lignin from woody biomass feedstocks
  - New cost-effective thermoconversion (pyrolysis and gasification)
  - Demonstration and evaluation of various forest feedstock used with emerging technology such as small-scale gasification, pilot biochemical conversion, and thermochemical conversion technologies
  - Feedstock selection, sorting, and preprocessing technology optimized to meet quality standards for various biofuels and biochemical conversion technology platforms
  - Improved microbes for extracting and converting woody biomass to fermentable materials

- **Efficient and environmentally friendly woody biomass harvesting systems**
  - Improved harvesting and transportation systems for forest biomass, cost and equipment information, and options for field processing to improve efficiency and mitigate impacts

- **Life-cycle and sustainability analysis for wood bioenergy systems**

Benefits

An expanded science program in forest-based biofuels will provide benefits to a wide range of constituents:

- Increasing national energy security and independence as a result of a technically, financially, and ecologically sound biofuels systems replacing some fossil fuel usage
- Improving forest health and reduction of fire risk as excess forest biomass is used for biofuels production.
- Reducing greenhouse gas emissions and increased financial benefits to non-industrial private forest landowners as they receive credit for carbon sequestration, emission offsets, and biofuels production
- Economic development of $120 billion from a new forest biomass to biofuels industry
- Reducing or eliminating the need for federal biomass to bioenergy subsidies

Nanotechnology

Wood-based nanotechnology offers a revolutionary way to restore the health of our Nation's forests, while creating new jobs and strengthening America's forest-based economy through industrial development and expansion.

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique material properties enable novel, high performance applications. (For frame of reference, a sheet of paper is about 100,000 nanometers thick.) Wood, or cellulose, at the nano-scale is a high-value material that enables products to be lighter and stronger, have less embodied energy, and come from a renewable resource.

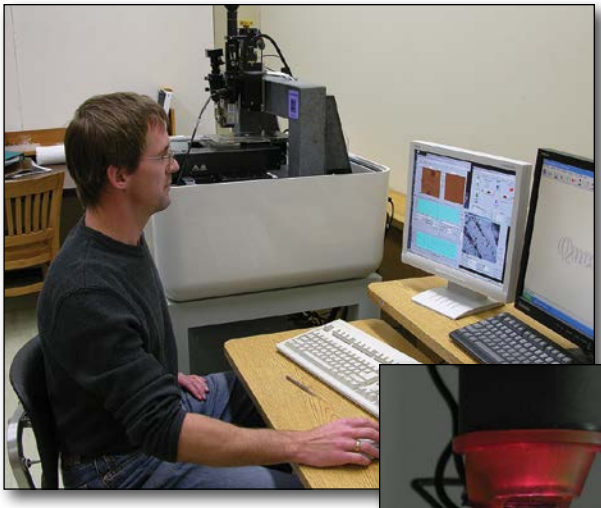
Nanotechnology will allow for the creation of new multifunctional materials and devices with a vast range of applications in many realms, including medicine, electronics, transportation, biomaterials, and energy production and use. It holds the potential for a dramatic impact on the national economy—estimated to be as much as $250 billion worldwide by 2020.

As for forest health, today we grow about twice as many trees as we use. Our forests are becoming overcrowded with hazardous fuels that cause catastrophic fires. The devastating impacts of these fires are seen time and again, with lives lost, homes destroyed, and millions of acres blackened. The cost of fighting these catastrophic wildfires is enormous, sometimes as much as $1 million per hour.

Wood-based nanotechnology offers a solution to this wide-spread loss. Currently, there are at least 300 million acres of forests in America needing some type of restorative action. Wood-based nanotechnology will create a cost-effective way to enable enough hazardous fuels to be removed so wildfires can remain smaller and become a tool for improved forest health. It is estimated that a strong, established program in wood-based nanotechnology that creates high-value markets from low-value wood (hazardous fuels) could help restore 20 million forested acres annually and reduce future fire suppression costs by at least 15 to 20 percent—up to $300 to $400 million annually.

Potential Markets for Cellulosic Nanomaterials

Cellulosic nanomaterials are expected to find applications within many industrial sectors, many of which are not currently employing wood-based materials. Being a light-weight, high-performance, renewable and recyclable material makes nanocellulose very compatible with the growing trend of greening products and markets in order to meet the pressing need to supply sustainable materials for the 21st Century.



Applications include:

- Structural composite panels for construction
- Flexible electronic displays
- Printed electronics
- Abrasion resistant/self-repairing architectural finishes
- Lightweight armor
- Ballistic glass
- Medical devices
- Aerospace and automotive panels and parts
- Industrial tools
- Consumer products
- Super insulating and sound proofing materials for buildings, appliances, devices, construction, and industrial processing
- Sensors for food packaging
- Sensors for structural load applications
- Actuators and switches
- Batteries and energy storage devices
- Photoactive structures for construction materials and consumer products
- Smart labels and packaging
- Packaging barrier coatings
- Printing paper coatings
- Potential component building block in additive manufacture (3-D printing)

Within these industrial sectors several companies have begun to explore uses of nanocellulose, including: Lockheed Martin, PepsiCo, IBM, Hyundai-Kia Motor Company, Georgia Pacific, Ecolab, 3M, Ford Motor Company, General Motors, DuPont, Hewlett Packard, Procter & Gamble and Kimberly Clark.

Collaboration

Recognizing the importance of nanotechnology and wood-derived cellulosic nanomaterials, the U.S. forest products industry and the USDA Forest Service have established a common vision and agenda for the commercialization of cellulosic nanomaterials. Public–private partnerships that combine the unique abilities of industry, government, and academic entities provide the best way to successfully commercialize innovative new technology platforms, develop new products, and create new jobs. Successful partnering will help to reinvent the U.S. forest products industry, improve forest health, make sustainable and efficient use of America's abundant forest resources, revitalize rural economies, and position the United States as a world leader in the commercialization of cellulosic nanomaterials.

The United States and other nations will see numerous benefits from the commercialization of wood-derived cellulosic nanomaterials. Development and commercialization of new lightweight, high-performance wood-derived products can help reduce fossil fuel consumption and greenhouse gas emissions while improving forest health and increasing the potential for rural manufacturing opportunities, including the creation of many new high-paying jobs.

FPL's new facility aids in the commercialization of these materials by providing researchers and early adopters of the technology with working quantities of forest-based nanomaterials.

The Cellulose Nano-Materials Pilot Plant

The Forest Products Laboratory recently opened a $1.7 million production facility for renewable, forest-based nanomaterials. This facility is the first of its kind in the United States and one that positions the laboratory as the country's leading producer of these materials, also called nanocellulose.

Climate Change Adaptation and Mitigation

Climate change refers to changes in long-term weather patterns and in the environment caused by increasing levels of carbon dioxide and other greenhouse gases released into the atmosphere. These gases come from natural events such as forest fires and from burning wood, peat, and fossil fuels for various uses.

Forest Service researchers have studied the effects of climate change and air pollutants on forests and grasslands for over 30 years. This research already identifies trends and subsequent effects to ecosystems across the United States. The U.S. Forest Service is developing a national framework for guiding and directing land management activities in light of expected changes. FPL research is contributing significantly to this effort.

For instance, FPL has been researching fundamental genetics and physiology of white-rot fungi for decades. White-rot fungi are the only microbes known to efficiently break down lignin, a complex chemical compound most commonly derived from wood and one of the most abundant materials on Earth. Collectively, the wood- and litter-degrading brown- and white-rot fungi play a pivotal role in the carbon cycle and significantly influence forest health.

Researchers at FPL are combining wood fiber with thermoplastic resin to create various composites. Composite research has a long history at FPL, and wood composite technologies have been used for decades to create building and home furnishing products. Composites can use undervalued materials and improve the economics of costly forest restoration because they can be made from fiber, particles, or flakes from small trees, especially those from invasive species and overgrown forests at risk of wildfire. By using low-value and problematic timber (which store great amounts of carbon) and clearing this material from our forests, new vigorous timber will grow (sequestering additional carbon). This in turn mitigates the uncontrollable release of carbon into the environment by forest fires.

Because transportation accounts for about a third of total U.S. emissions of carbon dioxide (an abundant greenhouse gas), cleaner transportation fuels can play an important role in addressing climate change. FPL economists are evaluating business cases for making biofuels using selected biochemical and thermochemical technologies. Trees are one of the best potential sources of biological fuel. Although a more challenging process than creating biofuel from agricultural matter, converting wood resources into liquid fuels and chemical feedstock is becoming more cost competitive, and FPL is a leader in innovative research on forest biomass to energy production.

Contributing to the U.S. report under the UN Framework Convention on Climate Change, FPL researchers have collaboratively estimated carbon emission offsets caused by additions to carbon stored in wood and paper products. The Environmental Protection Agency will use these data in their annual greenhouse gas emissions and sinks report.

The Consortium for Research on Renewable Industrial Materials (CORRIM) is a not-for-profit consortium of 15 research institutions working with the effects of producing and using renewable materials. FPL has collaborated with CORRIM to conduct life cycle assessments of carbon offsets caused by forest treatments, fire emission reduction, wood product storage, and wood energy offset of fossil fuels emissions. We have also collaborated with CORRIM to increase wood use in structures, which will offset carbon emissions of materials that emit more carbon in production and use.

FPL scientists have cooperated with the National Council for Air and Stream Improvement (NCASI) to estimate the carbon emissions/carbon emissions offset footprint of the U.S. forest products industry.

Using Unified Standard Format Markers (USFM) and the Global Forest Products Model (GFPM), FPL scientists have been evaluating the effect of increased use of woody biomass for energy on forest products markets. Our scientists have been using these models to contribute to the 2010 Resources Planning Act (RPA) Assessment. In addition to extending the treatment of climate effects, resource analyses will continue to be linked by common assumptions about population growth, economic growth, and land use change.

FPL researchers were instrumental in estimating county-level forest biomass supplies (including costs) for a revision of the joint study conducted by the Departments of Energy and Agriculture, the USDA/DOE Billion Ton Biomass Supply Study.

The Forest Service Biomass Utilization Grants program is intended to help improve forest restoration activities by using and creating markets for small-diameter material and low-valued trees removed from forest restoration activities, such as reducing hazardous fuels, handling insect and diseased conditions, or treating forestlands impacted by catastrophic weather events. These funds are targeted to help communities, entrepreneurs, and others turn residues from forest restoration activities into marketable forest products and energy products. FPL researchers are continually evaluating the economic effectiveness of projects funded under the grants program.

Patents Program

A partnership with FPL helps advance research by tapping into the expertise of our research personnel, providing access to our extensive laboratory facilities and equipment, and creating opportunities for patent and licensing agreements.

Our researchers have a history of successful partnerships, and they welcome the opportunity to collaborate with industry, academia, trade associations, tribes, nongovernment organizations, and federal, state, and local government agencies to convert research into usable information and technology.

Technology transfer agreements were developed to improve cooperation with commercial firms to convert research to usable information and technology. This cooperation increases the benefits to the public and commercial firms.

Various types of agreements, such as Cooperative Research and Development Agreements, Memorandums of Understanding, and Research Joint Venture Agreements, allow the government and industry to work together in developing new technologies.

Agreements vary based on the level of contribution from each party and the expected benefits, but the ultimate purpose of all technology transfer agreements is to better coordinate research activities between the parties so the results are efficiently transferred to the public.

A patent is an instrument by which the United States grants an inventor the right to exclude others from making, using, or selling an invention for a term of years. To qualify for a patent, the invention must be new, useful and a non-obvious process or product.

Patenting enables FPL to grant patent licenses, which provide an important avenue for technology transfer. The exclusive nature of patent licenses promotes the transfer of technologies to the private sector for commercial markets, The following patents are available for licensing at FPL: bolted wood connections, concentric finger jointed timber, break-in resistant wood panel door, hardened and fire retardant wood products, method and apparatus for molding three-dimensional objects, and method for fiber loading a chemical compound.

Technology Marketing Unit

Similar to the extension services provided by many universities, FPL's Technology Marketing Unit (TMU) provides a broad scope of expertise in wood products utilization and marketing, technology transfer, and technical assistance. The TMU is part of the U.S. Forest Service's State and Private Forestry, Cooperative Forestry Branch.

TMU's mission is to promote the efficient, sustainable use of wood by transferring technologies developed by FPL, other Forest Service research stations, universities, and other federal laboratories. The TMU works in collaboration with many different partners, particularly the Forest Service's Research and Development staff, to identify opportunities for working with local governments, private landowners, rural communities, and forest industries. They support the National and international mission of the Forest Service in forest products utilization by ensuring ready adoption of forest-based material technologies to many small, rural forest product businesses.

The breadth of TMU's work includes forest products conservation, processing, manufacturing efficiency, marketing, recycling, and bioenergy. The technical assistance they provide includes publications, technical assistance visits, conferences, workshops, meetings, and just simply meeting with customers face to face or via phone.

TMU also manages and awards over $5 million each year in grants dedicated to helping improve the utilization of woody biomass removed from forest restoration projects. The Woody Biomass Utilization Grant Program is intended to help improve forest restoration activities by using and creating markets for small-diameter material and low-valued trees removed from forest restoration activities, such as reducing hazardous fuels, handling insect and diseased conditions, or treating forestlands impacted by catastrophic weather events. These funds are targeted to help communities, entrepreneurs, and others turn residues from forest restoration activities into marketable forest products and/or energy products.

U.S. FOREST SERVICE

Forest Products Laboratory

Organization Chart

Forest Products Laboratory
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State & Private Forestry Technology Marketing Unit (TMU)
Program Manager
Vacant

Office of Communications
Director
Doug Clawson

Administration
Assistant Director
Lon Yeary

Financial Resources Management
Administrative Officer
Vacant

Analytical Chemistry & Microscopy Laboratory
Supervisory Chemist
Vacant

Research Facilities Engineering
Supervisory General Engineer
Michael J. Kaspszak

Paper Test Laboratory
Supervisory General Engineer
Nancy Ross Sutherland

National Forest Service Library
Supervisory Librarian
Julie Blankenburg

Engineering Mechanics & Remote Sensing Laboratory
Supervisory General Engineer
Steve Kalinosky

Wood Products Research
Assistant Director
Michael A. Ritter

RWU 4851
Economics & Statistics Research
Supervisory Research Forester
Kenneth E. Skog

RWU 4714
Engineering Properties of Wood, Wood Based Materials & Structures
Supervisory Research General Engineer
Robert J. Ross

RWU 4723
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Supervisory Research Microbiologist
Carol A. Clausen

Wood, Fiber, and Composites Research
Assistant Director
Theodore H. Wegner

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