FOREST PRODUCTS LABORATORY BUSINESS PLAN

Progress Through Partnerships

Working with the Forest Products Laboratory

FOREST PRODUCTS LABORATORY

U.S. Forest Service

Forest Products Laboratory

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We use science and technology to conserve and extend our Nation's forest resources.

Our mission is to promote healthy forests and forest-based economies through the efficient, sustainable use of our wood resources.

Many breakthrough technologies that influence the way we live today started at the Forest Products Laboratory.

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SCIENCE YOU CAN USE

FROM THE DIRECTOR

For close to 100 years, the Forest Products Laboratory (FPL) has worked to make forests healthier, rural economies stronger, and quality of life better for all Americans. It is a bold statement to make, but perhaps no other research laboratory in America has had a greater impact on our way of life than the FPL.

When you consider that the Nation's first prefabricated house was developed and constructed at the FPL in the 1940s, that we had a significant role in the development of such commonly used engineered wood products as glulam beams, plywood, and oriented strandboard (OSB), and that many of today's processes for producing paper and packaging were developed at least in part at the FPL, the reach of our research really begins to take shape. In addition, the FPL's development of Best Opening Face sawmilling optimization technology in the 1970s, still in use today, is estimated to save about 1 billion board feet of lumber from going to waste annually. This technology also saved a probable industry collapse at the time. The impact of our research is even more evident when you consider the countless products produced over the years using FPL-developed drying schedules and grading procedures; and the quality, safety and consistency of American forest products that our work with codes and standards has ensured.

However, recent developments caused us to take a long hard look at our programs. Some of the reasons for doing so were out of our hands. For instance, to help cover the costs of other administration priorities, the Forest Service, along with many other government agencies, was asked to take a critical look at its operations and make tough decisions on what services we could continue to provide to the public. Just like many other locations in the Forest Service, the FPL needed to make some hard choices about what programs it would continue to fund, and what programs would be scaled back or eliminated. But perhaps the bigger question that we were wrestling with was simply whether or not the FPL was still conducting research in areas that were going to have the biggest pay-off for the American taxpayer. After much thought and discussion both among ourselves and with our many partners, our leadership team decided that it was time to refocus the research direction of the FPL.

Making program changes is never easy. However, after many planning sessions with the FPL Management Team, and perhaps more importantly, our key partners and customers, we made some tough, but I believe necessary, decisions. Research Work Units were consolidated to increase our operating efficiency. Programs that were deemed to be mature were scaled back or eliminated. Some administrative support positions were eliminated to put more money back into our research program.

By streamlining our operations and refocusing our research direction, we were able to pool our remaining resources into those areas that we felt presented the greatest opportunity for growth and resurgence in the forest products industry. After all, if the FPL is to be successful in its mission of providing forest managers the tools necessary to reduce the build up of undesirable material in our Nation's forests, then we desperately need to begin rebuilding and reenergizing America's forest products sector.

It is no secret that forest fires have been increasingly burning hotter and more destructively. Part of the problem is a severe build up of fuel loads in the under story. Mill closures across the West and elsewhere have eliminated the infrastructure and markets necessary to process the amount of material that needs to come out of our forests to restore them to health. Without an economic incentive to remove and use the material, the enormous burden is left to the taxpayer. What is needed to restore the forest products industry and improve forest health is breakthrough developments in emerging areas such as biorefining, nanotechnology, and advanced composites. These sustainable technologies can also help reduce our dependence on foreign oil, increase National security, sequester carbon, reduce greenhouse gas emissions and help fight the effects of global warming.

The bottom line to all of this is that we had to make some tough choices, but I believe in the end we came out of the experience much better prepared to meet the challenges of the 21st century. I hope that in the coming decades we look back at this time as a turning point in America's history that resulted in a brighter future for America and America's forests; an America less dependent on foreign oil, emitting less greenhouse gases, while at the same time enjoying an even better quality of life due to breakthroughs in some revolutionary technologies. We realize the FPL will not accomplish this work alone. It will take many of us working together to accomplish this vision, and the Forest Products Laboratory will be a leader in this effort.

As you page through this booklet, I hope you get a sense of the optimism and possibilities posed by our research program. And if you are ever in Madison, Wisconsin, we invite you to stop by to see firsthand the visionary work our research staff and many partners are doing.

Dr. Chris Risbrudt

Chris Risbrudt

Director, U.S. Forest Service,
Forest Products Laboratory

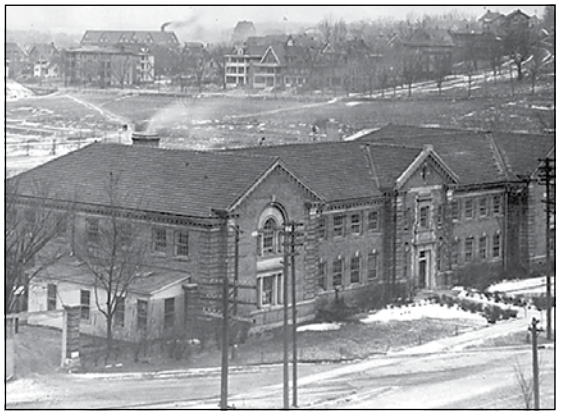
WHO WE ARE

At the turn of the 19th century, logging had proceeded across much of the eastern United States and demands for wood products were rising rapidly.

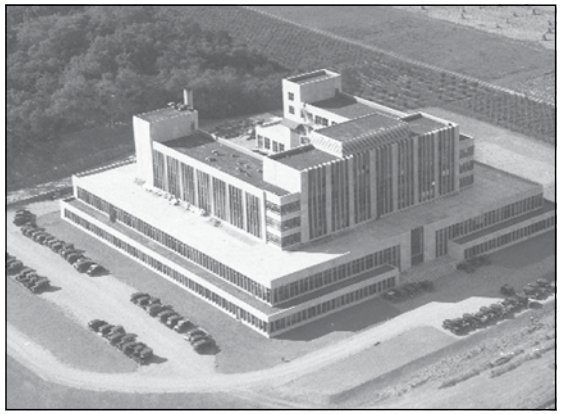
In 1910, the Forest Products Laboratory (FPL) was established in Madison, Wisconsin, to find ways to conserve scarce timber resources.

The original Forest Products Laboratory, 1910.

For almost 100 years, our mission has been to use our Nation's wood resources wisely and efficiently, while at the same time keeping our forests healthy. Our research began with preserving railroad ties, and now we are venturing into nanotechnology and finding ways that our research can contribute to mitigating the impacts of climate change.



Forest Products Laboratory, 1910–1932.



FPL moved to its current location in 1932.

FPL campus today featuring the new Centennial Research Facility.

WHO WE ARE

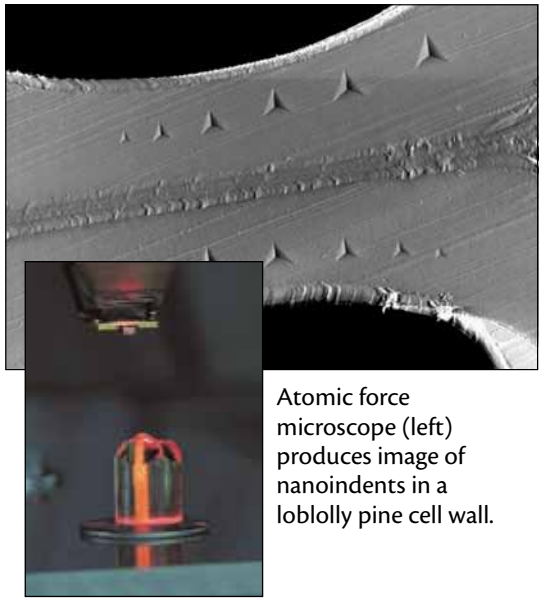
The FPL research staff has the experience and expertise needed to make us world renowned among forest products research organizations and an unbiased source of information. FPL researchers have longevity, with an average of 20 years of experience in their related fields.

The range of our wood research spans from fiber and chemical science to composites:

- Advanced wood structures
- Testing
- Economics
- Statistics
- Engineering properties of wood and wood-based materials
- Nanotechnology
- Biorefining and bioenergy
- Durability and wood protection
- Performance-enhanced biopolymers

Spaceboard—A 3D engineered fiberboard developed by FPL researchers.

FPL research proved that small-diameter timber can be used in structural applications. Small-diameter timber is very strong when left in its natural round shape.



Atomic force microscope (left) produces image of nanoindents in a loblolly pine cell wall.

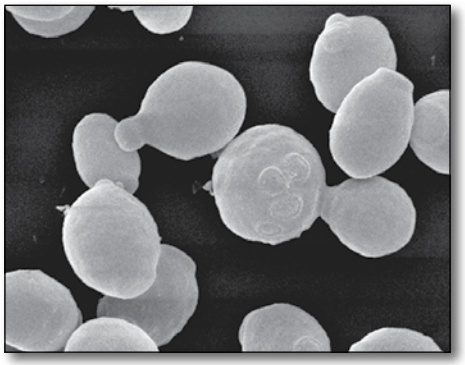
We take pride in knowing that our research touches the American public's daily life. Whether it's putting a self-adhesive, environmentally friendly stamp on an envelope or walking on a hardwood floor, FPL has in some way contributed to making those products and innovations.

Recyclable stamp using FPL-developed pressure sensitive adhesives.

Scientists work to preserve historic timber bridges and develop standards for modern, stress-laminated deck bridges.

RESEARCH EMPHASIS AREAS

- Underutilized Woody Biomass
- Nanotechnology
- Forest Biorefinery and Biomass Utilization
- Advanced Structures Research
- Advanced Composites



Underutilized Woody Biomass

Forests in the United States contain a substantial amount of small-diameter, overstocked, and underutilized material. The catastrophic wildfires we are seeing in increasing numbers in the western United States are caused in large part by overcrowded forests. Not only do these overstocked stands increase the risk of fire, they are prone to insect, disease, and drought damage. Thinning these dense, overstocked stands of trees can help reduce the risks mentioned; however, the thinning process can be very costly and may exceed the value of the material removed. Using thinned material to create valuable products is one way to improve the economics of the situation and to promote thinning operations that improve forest health.

Catastrophic wildfires seen in increasing numbers in the western United States are caused in large part by overcrowded forests.

Since 1993, the Forest Products Laboratory (FPL) has focused some of its research effort on characterizing small-diameter and thinning material, identifying potential uses, and providing technology that can help rural-based communities create successful businesses from the by-products of ecosystem management. FPL research projects are exploring the potential of the small-diameter roundwood as a structural material for uses such as bridges, boardwalks, trail structures, picnic shelters, storage sheds, and other rustic-type buildings. Other FPL research is finding other innovative ways to use underutilized woody biomass.

Lumber and Newsprint from Forest Thinnings

Our national forests are so overcrowded that the growth of many trees is suppressed. Initial research has shown that small-diameter (suppressed-growth) trees have narrower annual rings, more uniform fiber cell structure within the rings, and a higher volume of mature wood. Ironically, due to a number of economic factors, availability of pulpwood from public and private lands in the western United States is diminishing, and the pulp and paper industry has become increasingly reliant on availability of residuals from sawmill operations.

Pulping trials undertaken by FPL in an industrial pilot-scale facility showed that the characteristics of suppressed-growth trees improve pulp properties in the production of paper. Furthermore, less refining energy was required to produce pulp from forest thinnings than from conventional wood supplies. Results of this work also showed that lumber produced from forest thinnings meets or exceeds the sawmill specification.

Standing Dead Trees

Cooperative research involving FPL and industry showed that log home manufacturing provides a high-value use for logs cut from standing dead trees killed by insects and wildfires and is an excellent source of local employment.

Suppressed-Growth Forest Thinnings for Guardrail Systems and Structural Components

FPL scientists and partners analyzed small-diameter Douglas-fir and ponderosa pine round wood posts to determine possible guardrail system designs to utilize salvaged logs. Two full-scale guardrail systems were constructed and successfully crash tested, demonstrating the feasibility of these materials for strong guard rail posts. FPL has also studied mechanically graded lodgepole pine logs for use in building cable suspension bridges. Results provided two options for determining bending strength properties for design of such structures.

Suppressed-Growth Forest Thinnings for Biocomposites

Engineered wood composites are a classic high-value, large-volume use for small-diameter trees and underutilized species. FPL research has developed new engineered composite products and process technologies to manufacture them. This work has shown that suppressed-growth, small-diameter trees from overstocked fire-prone forests can be used to offset costs associated with hazardous-fuels removals.

Fuel Treatment Evaluator Web Tool

FPL led a project with other Forest Service research stations that produced FTE 3.0, a web tool using data from the Forest Service's Forest Inventory and Analysis Program to identify locations in Western states (such as around a particular community) where utilization of biomass from hazardous fuel thinnings can cover costs of treatments.

Saltcedar and Juniper as Fillers in Wood–Plastic Composites

As the environmental and ecological problems related to the incursion of invasive species into native ecosystems have become more prevalent, the economic concerns about removing the invasives have become more pressing. One method to help offset the sizable harvesting and natural-rangeland restoration costs is to develop value-added biocomposite products that use these invasive species. FPL has investigated using two especially problematic invasive species, salt cedar (*Tamarisk ramosissima*) and Utah juniper (*Juniperus osteosperma*), for use as fillers in biofiber-polymer composites.

Some invasive species can be used as fillers in biofiber-polymer composites.

Small-Diameter Ponderosa Pine

The FPL conducted a study investigating the use of small-diameter ponderosa pine lumber in glued-laminated (glulam) timber members. The objective of this work was to develop an efficient glulam combination utilizing small-diameter ponderosa pine for all laminations. The experimental results suggested that the allowable properties of the glulam combinations using two separate lamination grades were generally higher than the currently available single-grade combination in the glulam standard.

These are but some of the examples of how utilization Research and Development (R&D) has been finding cost-effective uses of the low-valued forest biomass that must be removed from the Nation's forests to restore their health and condition. FPL R&D work is focused on creating new, improved technologies to economically use fuel-reduction biomass in bioenergy, solid sawn wood, composites, and wood fiber products needed by the public. Because of the large volumes of material available, specific research projects develop the science, technology, and economic information needed for cost-effective use of small-diameter trees and forest thinnings as a raw material feedstock in the high-volume commodity uses of wood (dimensional lumber, engineered wood, composites, and pulp, paper and paperboard). In addition, research is assessing the potential of using this currently unmerchantable material to provide unique product properties and use as a feedstock in the emerging end use of forest biomass to energy (space heating, industrial process steam production, liquid transportation fuels, syngas, and chemical feedstock). In addition to hazardous fuels reduction, these R&D activities contribute to expanding markets for forest products, providing sustainable benefits to the American public, and restoring, enhancing, and sustaining the Nation's forests.

Nanotechnology

A leader in wood products research for nearly a century, the FPL is positioning itself to become the lead Federal research facility for the application of nanotechnology in forest products. With our multiple evaluation techniques (structural, chemical, and mechanical), multiple perspectives, and interdisciplinary teams of scientists (materials scientists, synthetic chemists, analytical chemists, and botanists), FPL continues to expand its nanotechnology research program.

What does nanotechnology mean and how does it apply to forests?

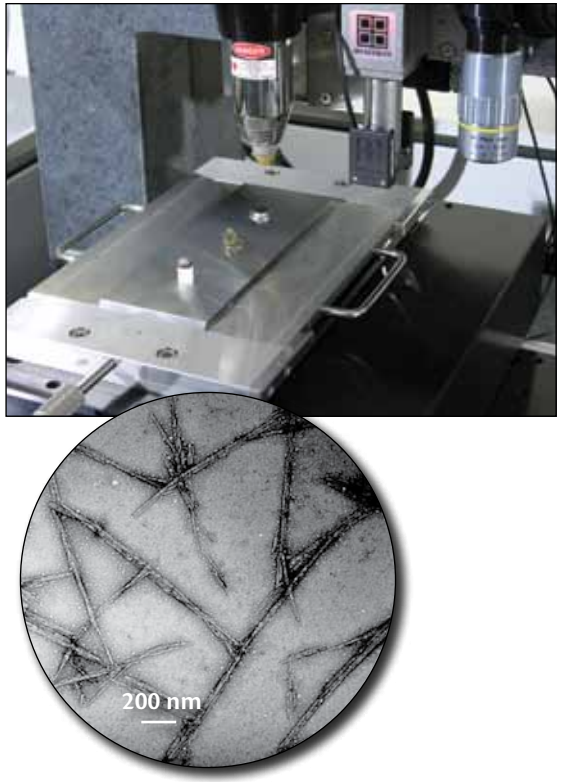
Nanotechnology is a broad multi-disciplinary field of applied science and technology whose theme is the control of matter on the atomic and molecular scale. This nanoscale is generally defined as 100 nanometers or smaller in at least one dimension, with a nanometer being a billionth of a meter, or 80,000 times thinner than a human hair. But nanotechnology is not merely the study of small things; it is the research and development of materials, devices, and systems that exhibit physical, chemical, and biological properties different from those found at larger scales. FPL scientists are conducting nanoscale research to learn about the fundamental components of matter and put them to use in beneficial ways.

These new, unique properties are what make potential nanomaterials and nanotechnology so promising to scientists and engineers. The ability to organize, characterize, and manipulate matter at the nanoscale has launched a revolution in science, engineering, and technology. Nanotechnology has the potential to drive global economic growth and development in this century. Already, nanotechnology is providing glimpses of exciting new process capabilities and the potential to controllably produce nanomaterials with unique properties.

To get some idea of how nanotechnology might relate to forest products, first consider that the world's forests and oceans are natural regulators of carbon dioxide content in the atmosphere. Trees are remarkable photochemical organisms that produce rich sources of renewable raw materials using sunlight, water, and carbon dioxide. Trees consume carbon dioxide (and store carbon) in the production of these raw materials, which makes forests a major carbon sink for this important greenhouse gas.

The forest products industry, an approximately $260 billion sector in the U.S. economy, relies on the vast renewable resource of trees to manufacture products that are indispensable to our modern society. American paper and wood products companies produce millions of tons of goods each year (including lumber, panel products, paper and paperboard, adhesives, sealants, and coatings). The industry accounts for 6% of U.S. manufacturing output, employs more than 900,000 people, includes more than 400 U.S. production facilities, and ranks in the top 10 in manufacturing in 46 of 50 states.

We can use nanotechnology to tap the enormous undeveloped potential of trees. Nanotechnology could transform the forest products industry from production of raw materials, to new applications for composite and paper products, to new generations of functional wood-based (or lignocellulosic) materials at the nanoscale. Lignocellulose is one of the most abundant biological raw materials, yet its potential as a nanomaterial and its interaction with other nanomaterials are largely unexplored.



Nanoindenter and nanoscale image of wood.

By harnessing the potential of trees, nanotechnology can provide benefits that extend into the areas of sustainable energy production, storage, and utilization; entirely new approaches for producing engineered wood- and fiber-based materials; and a wide range of new or enhanced wood-based materials and products that offer cost-effective, sustainable substitutes for nonrenewable materials used in the manufacture of metallic, plastic, or ceramic products.

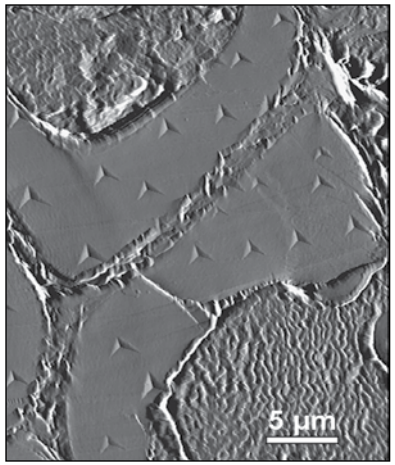
Potential uses for nanotechnology in the forest industry hint at the broad scope of possible benefits:

- Intelligent products with nanosensors for measuring forces, loads, moisture levels, and temperatures
- Building blocks for macro-scale products with substantially enhanced properties
- Coatings for improving surface qualities to make existing products more durable
- A basis for making lighter weight products using less material and less energy

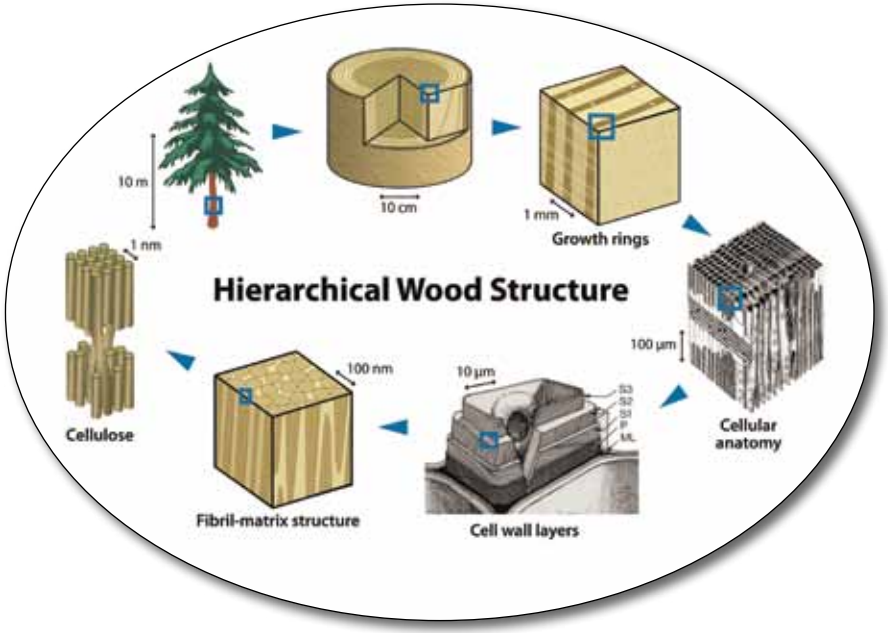
As this new discipline emerged, the National Nanotechnology Initiative (NNI) program was established in 2001 to coordinate Federal nanotechnology research and development. Under the aegis of the National Science and Technology Council, the NNI creates a framework for a comprehensive nanotechnology research and development (R&D) program by establishing shared goals, priorities, and strategies, and it provides avenues for each individual agency to leverage the resources of all participating agencies.

Subsequently, the 21st Century Nanotechnology Research and Development Act was signed into law in 2003, calling for development of a strategic plan for Federal nanotechnology R&D programs. This multi-agency R&D initiative in nanotechnology is critically important to the economical and sustainable production of these new generations of forest-based materials—materials that will meet societal needs while improving forest health and contributing to the further expansion of the biomass-based economy.

As a partner in the NNI, we are determining the highest priority research areas based on FPL's mission, the needs of the Forest Service, our capabilities, and our resources. Partnering with other Federal agencies, industry, and universities, we will continue to redefine FPL's role in nanotechnology research. With our unique capabilities and expertise, FPL will continue to bring the possibilities of nanotechnology into practical use.



Atomic force microscope image of nanoindents in tracheids walls embedded in the polypropylene of a polypropylene–wood composite.



Forest Biorefinery and Biomass Utilization

We all know the compelling reasons that the United States needs to reduce its dependence on fossil fuels. Historically, the greatest increases in energy demand have been for transportation fuels, and known fossil fuel reserves are declining. Byproducts of fossil fuel combustion are steadily increasing the concentration of carbon dioxide and other greenhouse gases in the atmosphere. Computer models predict that changes in atmospheric composition will increase global temperatures and continue to cause profound changes in weather patterns.

Along with these concerns, exciting new opportunities are emerging for meeting global energy needs and simultaneously creating high-value bio-based products. The agricultural sector has already made significant progress in developing bio-based fuels and chemicals, and ethanol is a fast-growing business throughout the Midwest. The dominant feedstock for ethanol transportation fuel presently is fermentable sugars derived from agricultural crops such as corn, rice, and sugarcane. An alternative to producing ethanol from food crops is to use the stalks and other non-food portions of agricultural crops as well as trees, grasses, and other herbaceous plants.

Trees are one of the best potential sources of biological fuel and chemicals—they grow in marginal soils that will not support agriculture; do not require fertilizer, herbicides, or pesticides; and accumulate biomass density for several years before incurring harvest costs. 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, thanks in part to researchers at the FPL, who are continually developing technologies to reduce the net cost of renewable bio-fuel.

For decades, researching opportunities to improve the economics of producing transportation fuel and chemicals from biomass has been part of the FPL program of work. Biorefinery technology uses chemical, biochemical, and thermal methods for producing chemicals and liquid fuels from biomass. Wood is hydrolyzed into sugars, with those sugars subsequently fermented to ethanol or other fermentation products. Thermochemical conversion methods involve heating biomass under controlled conditions. Fermentation research recently progressed exponentially when an FPL scientist successfully modified yeast DNA to increase the amount of ethanol produced when the yeast metabolizes certain components of wood.

At the same time that our need for alternative fuels becomes more pressing, large areas of forest lands are littered with an unnatural accumulation of stunted, overcrowded trees and woody debris. Decades of fire suppression have disrupted the natural fire cycle of U.S. forests. Fires on these overstocked stands are more intense and harder to control than forest fires in previous decades, and

they often result in catastrophic crown fires that kill large areas of forestlands. An estimated 8.4 billion dry tons of material needs to be removed from the national forests to reduce the risk of fire hazard, insect infestation, and disease. This vast source of biomass is available for production of wood products, chemicals, and energy; yet harvesting this material is expensive. Therefore, to reduce the costs of forest management, we need to find profitable uses for the removed biomass.

As national concerns about our forests and international concerns over global warming and greenhouse-gas generation rise, governmental support for biological fuels is likely to increase. For example, the 2008 Farm Bill provides loan guarantees for the development, construction, and retrofitting of commercial-scale biorefineries and grants to help pay for the development and construction costs of demonstration-scale biorefineries; it provides $75 million in FY 2009 and $245 million in FY 2010 for commercial-scale biorefinery loan guarantees and authorizes funding of $150 million per year starting in FY 2009 and continuing through FY 2012 for both demonstration- and commercial-scale biorefineries. Also, in 2008, the U.S. Department of Agriculture awarded $4.1 million in grants to help small businesses and community groups find more innovative uses of woody biomass from national forests. The grants, which are being administered by FPL, help create markets for new products and renewable energy from forest biomass.

Building on a long history of handling and treating wood and our ability to develop strong multidisciplinary teams, FPL experts in wood structure, wood chemistry, microbiology, enzyme technology, chemical engineering, and economics are working together toward processes that promote the use of sustainable, bio-based, environmentally neutral technologies to meet global demands for

building and materials end uses, chemicals, and energy. With such ongoing capabilities and the addition of highly developed microbiology and chemistry laboratories in our new Centennial Research Facility, FPL can continue to be a leader in developing profitable biorefineries.

We need to further research using lignocellulose (materials such as flakes, particles, and fiber) as a raw material for transportation fuel and chemicals.

The FPL is poised to help the Nation in several developments:

- Pretreatments that make more cellulose available for enzymatic saccharification or to derive value from lignin
- Value from resistant (recalcitrant) cellulose
- Co-production of specialty chemicals with greater value than ethanol and paper pulp
- Improved gasification with less char and a higher energy yield
- Transportation fuels and higher value chemicals from producer gas
- Ways to integrate ethanol production with pulping and composite products
- Enzyme modeling, life cycle assessment, and biomass case development
- Greenhouse gas modeling

In conclusion, FPL's work in biorefining will

(1) promote sustainable development,

(2) move toward energy independence,

(3) mitigate climate change,

(4) support local economies, and

(5) promote sustainability of natural resource production and use.

Advanced Structures Research

Can different technologies make a home more livable? Do specific technologies change a home's affordability, durability, quality, energy use, and disaster resistance?

The FPL answers these questions with a resounding yes. We know that a home is a complex system of components and that technology innovation can improve the performance of a homes individual components and integrated systems. Creating advanced technologies and alternative building methods can greatly enhance the value of wood in residential, nonresidential, and transportation structures.

The FPL has been in the forefront of wood-frame housing research since 1910 and has long been recognized as a world leader in such housing-related areas as engineered wood products and structures, moisture control, material design and performance, coatings and finishes, adhesives, wood preservation, and composites. Many of the materials and technologies currently used in wood-frame housing were developed through basic research at FPL in cooperation with industry, academia, and government.

Wood has been used as a structural material for thousands of years. Despite the development of other materials, wood continues as a primary structural material and is widely used because of its excellent performance characteristics and affordability. Additionally, wood helps to mitigate climate change. Using wood in building structures extends the carbon storage beyond the life of the tree throughout the life of the product, and later, through recycling. Life-cycle assessment studies have shown that wood frame buildings represent a significantly lower environmental burden than buildings made of materials such as steel, concrete, and bricks.

Many of the engineered wood products in use today were developed in part through research at FPL.

As we move into the future, lumber used for housing is likely to continue to come from plantation-grown trees and small-diameter secondary species (substitute woods). We need to further research and develop more efficient and durable structures that are adaptable to these sources from our changing forests.

Research at FPL evaluates technology needed for both new and existing housing and encompasses all types of residential structures in which wood or wood-based products are used as primary or secondary building components. Emphasis is on the improved use of traditional wood products, recycled and engineered wood composite materials, durability, moisture control, natural disaster resistance, and an improved living environment. The FPL's research focuses primarily on housing structure and practical technologies that can be readily adopted by homebuilders, industry, and consumers. FPL also cooperates with partners in areas involving the latest theories and ideas in resource management, including water conservation.

To move new wood technologies into use, FPL has established strong links to industry and has played an active role in technology transfer and in the development of codes and standards. Our mission as a Federal research and development facility is to share skills, knowledge, technologies, methods of manufacturing, samples of manufacturing, and facilities among industries, universities, other government agencies, and institutions to ensure that scientific and technological developments are accessible to a wide range of users. This process is known as technology transfer, and our partners can further develop the technology we research into new products, processes, applications, materials, or services.

FPL research recognizes that construction technologies are changing, and more than ever, America needs housing that is affordable, energy-efficient, durable, and safe. In the 20th century, the traditional regional prototype for single-family homes was built with a shell of forest products—dimensional lumber framing and plywood—on strip foundations with wood, plywood, plaster and drywall, and stone or brick masonry finishes. This prototype emerged at a time when land, fuel, forest products, and labor were relatively cheap and the pool of skilled workers in the building trades was relatively large.

To meet today's needs, FPL researches high-value homebuilding that can produce houses that are more livable, more responsive to universal and regional environments, and more frugal with

Improving timber bridges is part of FPL's Advanced Structures Research. More than 27,600 timber bridges are in use across the United States.

available resources than those using current practices. The current housing prototype is an amalgam of mobile homes, modular construction, and a partially evolved version of the traditional type described previously. Today's new houses incorporate more petroleum-based and other synthetic materials, more applied chemical compounds, more machine-fastened components, lighter weight materials, and greater across-the-board standardization of materials and methods. Material sources are more diverse than in the past. Because construction is a huge use of energy and creates considerable waste, FPL is researching the environmental effects and energy use of wood-based structures and the processes of updating and remodeling them.

Advanced structures research and development at FPL is focused on developing next generation residential and non-residential structures

that are aesthetic, affordable, functional, durable, low maintenance, energy efficient, and disaster resistant (earthquake, high wind, hurricane, tornado, wildfire, and flood). FPL advanced structures research will improve the performance of structures during natural disasters while providing an outlet to use building materials produced from small-diameter timber. Research results will be made available to home builders, the forest products industry, and consumers.

As an evolution of our research and partnerships, academic and industry leaders, together with the FPL, formed the Coalition for Advanced Wood Structures (CAWS). The Coalition is but one example of the ways in which FPL works with partners to bring new technology and research into the structures that we use every day.

Coalition for Advanced Wood Structures

Research is needed to develop more efficient and durable structures that are adaptable to the changing forest resource. Recognizing this need, academic and industry leaders together with the Forest Products Laboratory formed the Coalition for Advanced Wood Structures (CAWS). CAWS brings together representatives from universities, industry, and government to work in a cooperative, complementary manner to foster sustainable, efficient use of our forest resources while improving the economy and performance of wood structures. The scope of activities includes all types of wood structures, focusing in three areas:

- Housing, including single- and multi-family units using conventional in-place stick built, panelized, modular, or manufactured construction
- Non-residential building structures, focusing on low-rise structures such as schools, retail stores, manufacturing/warehouses, and office buildings
- Transportation structures, including vehicle, railroad, and pedestrian bridges; noise barriers; and marine facilities

The Coalition effectively functions as an extension of the Forest Products Laboratory and cooperatively participates in research and technology transfer to meet National and regional needs. Coalition research maximizes the unique capabilities of the respective members to develop and evaluate technology for both new and existing structures in which wood and/or wood-based products are used as primary or secondary components. It also leverages federal funding to do more with less and maximize public benefit.

Current members of the Coalition are Mississippi State University, Iowa State University, University of Idaho, APA–The Engineered Wood Association, NAHB Research Center, and the U.S. Forest Service, Forest Products Laboratory.

Advanced Composites

The FPL works to conserve and extend our Nation's forest resources. We advance healthy forests and forest-based economies through researching and promoting the efficient, sustainable use of wood.

As an integral part of the FPL mission, we improve the long-term sustainability of our Nation's forests by creating valuable composite products from biobased materials. Composites encourage the use of undervalued materials and improve the economics of forest restoration projects because they can be made from a variety of materials: fiber, particles, or flakes from small trees, especially those from invasive species and overgrown forests at risk of wildfire; post-industrial and post-consumer wood wastes; and other natural biofibers, such as wheat straw, corn straw, and even chicken feathers.

Composites research has a long history at FPL, and wood composite technologies have been used for decades to create building and home furnishing products. Composites are used for a number of structural and nonstructural applications including interior paneling, sheathing, furniture, and support structures in many different types of buildings. Wood-based composites represent more than 40% of the total materials used in residential construction in North America, making them the largest single material type used in residential construction. Wood-based composites have become so widely used because they are readily available, light, strong, easily worked, and cost-effective. Nonetheless, to expand into other markets such as non-residential and commercial construction and consumer goods, today's composites need to achieve enhanced performance, serviceability, durability, and reliability.

Composites research has a long history at FPL.

Composite shingles on FPL's Research Demonstration House.

More recently, new innovative biobased composite products based on natural fibers, such as agricultural fibers or residues, or on wood–natural fiber hybrids, have also come on the market and now compete directly with traditional wood composites. Other composites, such as wood- or natural fiber–plastic composites, have recently become popular for decking, siding, roofing, fenestration, and millwork. The use of new, innovative technologies in the macro-, micro-, and nanoscale will create still other opportunities in entirely new areas of application.

Advanced engineered biocomposites are needed to meet the diverse needs of users for high-performance and commodity products that also increase the health and sustainability of forests. This next generation of engineered biocomposites must provide materials and products that far exceed current expectations (such as lower cost, greater adaptability and reliability, lower maintenance), open new markets (such as commercial construction, automotive, aerospace), and reduce environment impacts.

FPL has the expertise and facilities to meet the challenges of the evolving biobased composites sector. With our multidisciplinary approach and various laboratories, our scientists can collaboratively expand the current level of performance of our advanced engineered composite products and explore entirely new opportunities.

Model of emergency housing structure built from three-dimensional engineered fiberboard (3DEF) composite materials.

WORKING WITH US

A partnership with the Forest Products Laboratory helps your research advance 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

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.

The following types of agreements allow FPL, universities, government, and industry to work together in developing new technologies. They do vary based on the level of contribution from each party and the expected benefits. Ultimately the purpose of technology transfer is to better coordinate research activities between the parties so the results are efficiently transferred to the public.

Cooperative Research and Development Agreement (CRADA)

The CRADA was created by the Federal Technology Transfer Act of 1986 (Public Law 99-502). The CRADA authorizes FPL scientists to work collaboratively with private firms to help commercialize technology based on collaborative research. The CRADA provides the cooperative firm with the first right to exclusive licenses on patented inventions discovered or developed under the agreement. To enter into a CRADA, the research objective must be consistent with FPL's mission. The CRADA is effective when the cooperating firm provides the know-how needed to develop and commercialize a product, process, or service. The firm may also contribute funds to cover some of the added costs to FPL for work done under the agreement; or the firm may provide personnel, equipment, or materials. In some cases a CRADA may involve no transfer of funds to FPL. As a cooperator, FPL provides research personnel, laboratory facilities, materials, equipment, supplies and other "in-kind" contributions.

Challenge Cost-Share Agreement (CCS)

The CCS is an agreement with an entity to work cooperatively with FPL to produce something of mutual interest. Costs are shared between FPL and the partner.

Cooperative Agreement (CA)

A CA is entered into when FPL provides support or stimulation to a cooperator's program of mutual interest. FPL is substantially involved in the research, and has oversight responsibility. Both parties make contributions towards the research.

Memorandum of Understanding (MOU)

The MOU is needed when there is a common purpose for the coordinated activities. No funding or value changes hands and it is not a fund-obligating document.

Research Joint Venture Agreement (RJVA)

The RJVA is used when there is a mutual benefit of the basic or applied research. The parties must share a mutual benefit in addition to a mutual interest. Mutual benefit exists when the parties benefit in the same qualitative way from the objectives of the agreement. Each party makes a minimum monetary contribution.

Research Cost-Reimbursable Agreement (RCRA)

The RCRA is used for acquiring goods and services, including personal services, for mutual benefit from a State Cooperative Institution.

Patents and Licensing

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.

Examples of patents 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
- Method for Fiber Loading a Chemical Compound

Patented wood decay test kit developed by FPL researchers.

FPL's Technology Marketing Unit: Putting Technology to Use

Similar to the extension services provided by many universities, the 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 & Private Forestry.

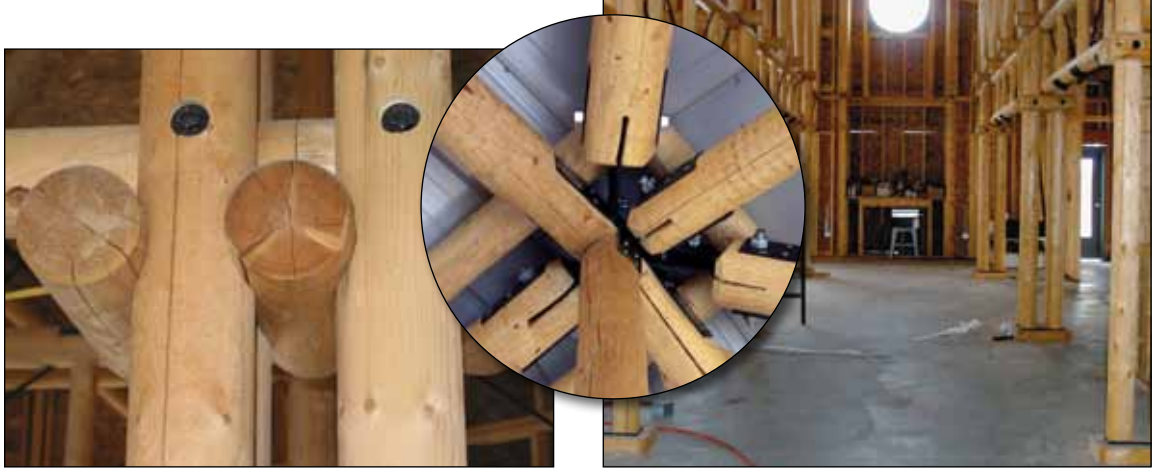
The TMU's mission is to promote the efficient, sustainable use of wood by transferring technologies developed by the FPL, other Forest Service research stations, universities, and other Federal laboratories. The TMU works in collaboration with many different partners, particularly the Forest Service's Research and Development staff, and state forestry agencies to identify opportunities for working with local governments, private landowners, rural communities, and forest industries. The TMU supports 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 their 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. The 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.

According to TMU Program Manager Sue LeVan-Green, *"The fun thing about working for the TMU is variety. No day is ever the same. We work with a wide range of customers, most of them rural small business owners or entrepreneuers, and their issues are all very different. Many times they don't know who to turn to for assistance. People who have worked with us find us to be very customer service oriented. To help promote rural, sustainable, forest based businesses, we focus on problem solving, facilitation, and networking."*

Some of our customers and partners

- National Forest System
- State foresters and other Federal agencies
- Forest-based businesses
- Rural communities
- Landowners
- Tribal nations
- Conservation groups
- Rural and urban economic development councils

BioMAX 15 generates electricity from wood.



Roundwood construction used in Darby, Montana, library.

The TMU at Work

Woody Biomass Grant Program

Over the past few years, the TMU has administered the national woody biomass utilization grant program. This program focuses on helping communities and rural businesses improve efficiencies in processing and using woody biomass 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 the by-products of forest restoration activities into marketable forest products and/or energy products.

Program goals

- Help reduce forest management costs by increasing value of biomass and other forest products generated from forest restoration activities
- Create incentives or reduce business risk for increased use of biomass from national forestlands
- Institute projects that target and help remove economic and market barriers to cost-effective hazardous fuel reduction activities

Examples of past award projects

- Produced residential and industrial pellets from hazard fuel treatment residues for a local greenhouse.
- Scragg mill and dry kiln used to produce flooring and paneling for use in homes in area.
- Purchased a track-mounted mechanized harvester, feller-buncher for cut-to-length merchandizing of hazardous fuel reduction treatments; material used for shavings, energy, and timbers.

Roll-on/roll-off containers became an instant hit with many forest managers trying to remove woody biomass. Montana Community Development Corporation received one of the 2006 Woody Biomass Utilization Grant awards to develop and implement the concept of roll-on/roll-off containers. These containers are similar to waste dumpsters, but they are located at sites where fuel reduction projects are underway. These containers facilitate the efficient transport of woody biomass logs and residues from the forest landings to the marketplace.

- Acquired truck for loading and transporting pole material collected from hazardous fuel treatments around town to post & pole operator.
- Purchased whole tree chipper for onsite hazardous fuel treatments; material used for biomass energy.
- Used hazardous fuel treatment to test co-firing of boiler with biomass and determine economics; material used for biomass energy.
- Installation of a dry kiln and resaw improved recovery and use of hazardous fuel treatment material to produce molding and paneling.
- Replaced existing boiler system in high school with a wood biomass heating system.
- Acquired horizontal grinder and band resaw to utilize material from hazardous fuel reduction treatments; material will be used for lumber.
- Installation of a new biomass boiler for producing 1.5 MW power to grid from hazardous fuel reduction treatments
- Installed a recovery system to use slabs and other material that currently goes to waste; material is derived from small-diameter forest thinning material.
- Purchased horizontal grinder; material processed is shipped to biomass power plant for energy.
- Acquired and installed shaving processor to produce high-quality animal bedding from material too small to process into logs; material removed from hazardous fuel treatments.
- Purchased a horizontal feed tub grinder to use material currently left in woods after hazardous fuel treatment; material transported to utility for biomass energy.
- To process hazardous fuel treatments and transport material to mills, a feller-buncher, tanglehead processor, and skidder were purchased.
- Constructed a 1,000-kW co-generation facility at a prison utilizing woody biomass as the primary fuel.
- Installed a pressure treatment cylinder at post-and-pole facility to add value to material.

Harvesting and removing woody biomass is an expensive job. Many of the woody biomass utilization grant recipients have requested equipment to improve the efficiency of harvesting and removing woody biomass. W.B. Contracting received a grant in 2005 to purchase a versatile whole-tree log forwarder. According to Dwayne Walker, one of the owners, "A whole-tree log forwarder allows us to harvest acres that were previously inaccessible, thus reducing the number of new or reconstructed roads and landings."

For more information on current grant programs, check out the TMU website at www.fpl.fs.fed.us/tmu/about_us.html

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National Center for Wood Transportation Structures

The objective of the National Center for Wood Transportation Structures (NCWTS) is to bring together academia, government, and industry to efficiently complete research, demonstration and education that result in durable, cost-effective wood transportation structures to improve the transportation infrastructure of America and the world.

The NCWTS is located on the campus of Iowa State University (ISU) and is part of the Bridge Engineering Center. Maintained in partnership with the Forest Products Laboratory, the Federal Highway Administration, and the National Park Service (NPS), the NCWTS integrates university and government research programs and supports a national demonstration and technology transfer program. It also serves as an international center of excellence with an emphasis on the improved use, durability, and performance of wood transportation structures on primary and secondary roads and the rural transportation infrastructure. Research may be accomplished entirely by the NCWTS partners but will more commonly be accomplished through cooperative efforts with universities, government agencies, and private industry.

FPL has been involved in wood transportation structures research for over 60 years. In 1988, the traditional program expanded significantly when Congress passed the Timber Bridge Initiative (TBI). Its objective was to establish a national program to provide effective and efficient utilization of wood as a structural material for highway bridges. Responsibility for development, implementation, and administration of the program was assigned to the U.S. Forest Service. Within the program, the Forest Service established three primary program areas: demonstration bridges, technology transfer, and research. The demonstration bridge program, administered by the Forest Service National Wood in Transportation Information Center (NWITIC) in Morgantown, West Virginia, provided matching funds on a competitive basis to local governments to demonstrate timber bridge technology through the construction of demonstration bridges. The NWITIC also maintained a technology transfer program to provide assistance and state-of-the-art information related to timber bridges.

Responsibility for the research portion of the TBI program was assigned to the Forest Products Laboratory. The primary focus of TBI research was the development of new and improved technology for timber bridge materials and systems. In 1992, the FPL research program was expanded to include wood transportation structures such as noise barriers, marine facilities, retaining walls, and sign supports. At the same time, a substantial joint research program was initiated between the Federal Highway Administration (FHWA) Turner–Fairbank Highway Research Center and FPL to implement the FHWA timber bridge research program mandated under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. In subsequent years, the FHWA also initiated a substantial covered wood bridge rehabilitation and research program under the National Historic Covered Bridge Preservation Program mandated in 1999 by the Transportation Equity Act for the 21st Century (TEA21) and in 2004 by the Safe, Accountable, Flexible, and Efficient Transportation Act—A Legacy for Users (SAFETA-LU). To assist in implementing this program, the FHWA developed partnerships with FPL and the NPS.

Funding for the NWITIC ended in FY 2004, leaving significant voids in research capability, education, and technical assistance to governmental agencies, industry, and research institutions. In response, FPL moved to establish the NCWTS at ISU based on more than 25 years of cooperative research between ISU and FPL in the area of wood bridges as well as their extensive expertise in transportation structures. This Center was established in FY 2007 as a university–government–industry partnership to provide greater program efficiency and leverage federal funding to maximize public benefit at minimal cost. Given the longstanding cooperative relationship with FHWA, and the developing partnership with the NPS, both agencies were also included as partners in the new NCWTS at ISU. This joint national program and the creation of the NCWTS are particularly timely and valuable because wood bridges represent more than 27% of the Nation's bridges and afford an opportunity to efficiently utilize naturally sustainable forest resources. Additionally, more than 25% of our Nation's bridges are structurally deficient or functionally obsolete. The problem is especially critical on rural road systems where wood bridges offer many advantages due to their ease of construction.

Proposed biorefinery pilot plant (foreground).

FPL Business Incubator

A New Direction

To expedite the discovery and application of new science, the Forest Products Laboratory must now, more than ever, expand its partnerships with industry. FPL is in the initial stages of developing a business incubator for emerging or fledgling advanced wood technology business ventures. Our newly established Partnership Liaison Specialist position will facilitate and manage a range of support services and research collaboration for new and continuing research and development partners.

Research will be conducted in partnership with FPL scientists in existing FPL laboratories, in our new Centennial Research Facility (to be completed and dedicated at our centennial celebration in 2010), and in our proposed biorefinery pilot plant. Other research and office space will be available for rent in an upgraded building located between FPL and the University of Wisconsin campus.

Several areas of current FPL research are ripe for joint research, development, and commercial application. And FPL scientists are always looking to explore emerging research needs and apply new research tools. The business incubator environment will provide an array of new opportunities for our industry partners to move research results to the marketplace to strengthen both our national and local economies.

RESEARCH FACILITIES AND EQUIPMENT

Centennial Research Facility

The Centennial Research Facility (CRF), the newest addition to the FPL campus, is currently under construction. This 90,000 square foot combined research facility consolidates research activities, allowing for maximum collaboration between scientists and with outside partners. The facility is expected to be complete by January 2010.

The CRF will house state-of-the-art equipment and laboratories in three major areas of research:

- **Engineering Mechanics**
- **Wood Preservation and Durability**
- **Composites**

Engineering Mechanics

The Engineering Mechanics and Remote Sensing Laboratory (EMRSL) is designed to conduct physical and mechanical tests on a wide range of materials, building systems and structures—from houses to transportation structures. Results obtained from tests conducted here are used in the development of building codes and, consequently, structural design. These tests follow a standard procedure to ensure that test methods are consistent.

Testing of products and structures can involve samples ranging in size from toothpicks to full structural beams (50 feet long) and made of solid wood or combinations of wood fibers, plastics, adhesives, and metal. Tests can be static (simulating snow loads or dead loads) or dynamic (simulating seismic, fatigue, and wind loads). The EMRSL has testing machines ranging from desktop-sized machines (rated from 1 to 10,000 pounds) to stand-alone machines (rated from 60,000 to 1 million pounds).

A strong floor and wall system in the EMRSL gives researchers the ability to apply loads from multiple directions; this will allow for full-scale testing of three-dimensional structures, such as wood-framed building mock-ups, up to 20 feet fall.

To conduct standardized tests, supplemental information must be collected, such as specimen weight, dimensions, moisture content, and specific conditioning. All the equipment necessary to measure these properties is available in the EMRSL, including several conditioning rooms used to reach specified material moisture contents.

Wood Preservation and Durability

Once completed, the preservation and durability laboratories and equipment in the CRF will provide the widest variety of testing capabilities available to date.

The wood preservation treatment facility will house five pilot-scale pressure treatment cylinders capable of conducting both water- and oil-based chemical treatments on a wide variety of wood dimensions. The facility will be equipped with computerized temperature controls, emulsification, pumping, and ventilation equipment required to conduct cutting-edge research on penetration and retention of new preservative formulations on both commercially available and underutilized wood species.

Wood preservation humidity room.

The new facility includes dedicated environmentally controlled chambers for research with mold and decay fungi and termites featuring separate air handling systems to avoid cross-contamination between research projects. A fungal cellar is available to conduct accelerated durability tests on treated wood across a range of simulated environmental exposure conditions. Researchers will have the capability to conduct accelerated laboratory tests of preservative releases into the environment when exposed to water submersion, simulated rainfall, and a range of weathering regimes. Chemistry, biochemistry, and bacteriology laboratories round out the features of this top-notch facility.

Custom-designed moisture testing facility.

The CRF will also house a custom-designed moisture testing facility that is unlike any other of its size in North America. The primary role of the facility is to test larger-sized wall assemblies in various combinations of rain and wind simulation. For example, researchers will be able to use the facility to simulate a wind-driven rain onto a wall assembly and determine how and where leaking occurs.

Capabilities of this unique facility include simulating up to 25-mile-per-hour wind speed with faster gusts lasting up to 5 seconds; rainfall of up to 5 inches of rain per hour; temperature settings of 30°F–110°F; and dew point temperatures of 25°F–80°F.

Composites

Composites researchers at FPL study every facet of composite materials, from raw materials to processing methods to finished products. To facilitate this research, the CRF contains laboratory and pilot-scale equipment for various technologies including both wet and dry forming of wood-based composites, three-dimensional engineered fiberboard, wood–plastic composites, and nanocomposites.

Specialized equipment is available for raw material characterization, size-reduction, fiber and flake processing, web and mat forming, pressing, wood–plastic composite processing, and composite characterization. A wide range of processing scales are possible, from small-scale fabrication of nanocomposites to pilot-scale equipment for producing panels or large wood–plastic composite profiles.

A multitude of engineered wood products developed or improved at FPL are being used in the construction of the Centennial Research Facility, including glulam beams, I-joists, plywood, and oriented strandboard.

Pilot Plant

FPL's fiber processing pilot plant is equipped to replicate industrial pulping and papermaking processes on a pilot scale. From production and sizing of chips to chemical and mechanical pulping to paper and fiberboard production, researchers can test new methods and evaluate their effectiveness on equipment similar to that used by commercial pulp and paper manufacturers.

The pilot plant contains a state-of-the-art recycling plant with processes and equipment similar to those found in mills today. The 45,000 square foot facility has the capacity to recycle five dry metric tons of paper per day. The paper recycling pilot plant includes (1) high-consistency pulping, (2) pressure screening, (3) centri-cleaning, (4) flotation, (5) washing/dewatering, (6) clarification by dissolved air flotation. The plant is configured in a closed-loop operation. Clarified process water can be recycled upstream for use in the pulping of additional batches and also as dilution water for the cleaning and screening stages. Typical yield is 70%.

For kraft pulping, the pilot plant has three 1 cubic foot digesters (~2 kg capacity) and two 13 cubic foot digesters (~35 kg capacity). Two batch bleaching towers can mix over 35 kg at 10% consistency or higher. A small drum washer is used to wash and thicken the pulp from both bleaching and the recycle system. A two-stage chemithermomechanical pulping pilot plant has been added to the facilities. A Sunds Defibrator CD-300 system, a plug screw discharge has been added between the preheater and refiner to enable filtrate extraction in biomass pretreatments for biorefinery and prehydrolysis thermomechanical pulp.

The Paper Test Laboratory is also a critical component to the success of FPL's pulp and paper research at the pilot plant. This pulp and paper testing facility focuses mainly on the testing of printing and writing grades of paper and is able to address most paper testing needs regarding strength, optical, and surface properties. Testing is conducted in a tightly controlled humidity room for optimum accuracy.

Analytical Chemistry and Microscopy Laboratory

The Analytical Chemistry and Microscopy Laboratory (ACML) provides high-quality analytical support and technical consultation to researchers with the use of specialized equipment and capabilities.

Nanoindenter

The nanoindenter uses a fine stylus to measure hardness and stiffness of materials at a submicrometer scale. The stylus can also be used to create typographical images. These measurements of mechanical properties at a microscopical scale support the development of hardened wood products, more durable adhesives, and better composites. It is also being used to explore the structure of wood cell walls, which is still not completely understood.

Atomic Force Microscope

The atomic force microscope (AFM) provides images and some mechanical measurements with resolution at the nanometer scale. This is an extraordinarily versatile tool for three-dimensional imaging at a resolution that cannot be achieved by light microscopy. Sample preparation for AFM is often easier than for electron microscopy.

Scanning Electron Microscope (SEM)

SEM provides image resolution exceeding that obtained by optical microscopy. The current microscope can image samples in low vacuum and without the application of metal coatings. It is also equipped with an energy dispersive x-ray analyzer which can be used for image-wise elemental analysis. Our SEM is also capable of imaging natural materials without extensive drying, so that they can be observed in a native state.

Inductively Coupled Plasma Atomic Emission Spectrometer

This highly sensitive method for quantitative elemental analysis is frequently used for determining the amounts of wood preservatives or leaching of preservatives from wood.

Fourier Transform Infrared Spectrometer

This instrument is mainly applied for qualitative identification of materials or to determine when and how materials have been changed by some process.

Gas Chromatography/Mass Spectrometry (GC/MS) and Liquid Chromatography/ Mass Spectrometry (LC/MS)

GC/MS is used for the separation and chemical identification of components of mixtures of volatile materials. LC/MS is similar to GC/MS, but its use is not limited to materials that can be volatized. Both are used to separate mixtures of compounds and then identify each of the components.

High Pressure Liquid Chromatography

This method is mostly used for quantitative sugar analysis. All carbohydrates (cellulose and hemicellulose) are composed of sugar molecules that are chemically linked. Through sugar analysis, the carbohydrates are decomposed into individual sugars. The mixture of sugars is separated by chromatography, and each sugar is measured quantitatively.

Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR is used for qualitative identification of organic material in solution or liquid state. It is often applied to investigate changes that occur due to chemical reactions. NMR can be used to determine the way in which atoms of a compound are connected to each other. Natural materials often have similar composition but behave differently because of different linkages.

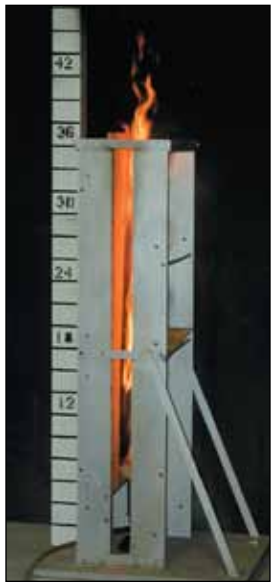
Fire Test Lab

The fire testing facility at FPL is key to developing safe, durable building products; it is equipped to perform standardized tests for flame retardancy and fire resistance.

The planned fire test lab addition will enhance our current capabilities by enabling simulation of actual fire scenarios and better validation of computer models enabling evaluation of protection options or design changes. Features of the new facility will include air pollution control devices and a large-scale adjustable hood with a capacity for testing fires up to 8 MW.

Current fire test laboratory equipment available to users of this facility includes horizontal fire endurance furnace/tension apparatus, small vertical fire penetration furnace, Cone calorimeter, full-scale room/corner test, and non-standard fire endurance wall furnace, lateral ignition flame-travel test apparatus (LIFT), critical radiant flux apparatus, National Bureau of Standards smoke chamber, fire tube apparatus, modified Schlyter-panel apparatus, two-foot tunnel apparatus, oxygen-index test apparatus, and accelerated weathering chamber.

Ignition flame-travel test (LIFT) apparatus.



Modified Schlyter-panel apparatus.

Full-scale room/corner test equipment.

Cone calorimeter.

RESEARCH WORK UNITS

- Durability and Wood Protection Research
- Engineering Properties of Wood, Wood Based Materials and Structures
- Economics and Statistics Research
- Engineered Composites Sciences
- Fiber and Chemical Sciences Research
- Institute for Microbial and Biochemical Technology
- Performance Enhanced Biopolymers

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.

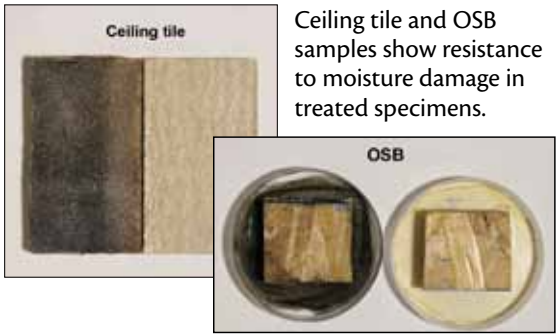
Wood is an aesthetic and versatile structural material and it represents one of our most valuable renewable resources. However, vulnerability to moisture, fire, and biodeterioration are important limitations to the expected long service life of wood and can result in significant economic and resource 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.

Wood structures need to be properly designed to minimize wetting of building components to reduce the risk of biodeterioration. Wood products specifications have often not kept pace with changes in building design, such as the use of new composite and engineered wood products as well as the introduction of non-wood building products, which have changed how building components interact in service, especially in regard to their response to moisture.

Replacement of decayed wood resulting from moisture damage to homes is responsible for an estimated 10% of the annual timber cut in the United States. Our research aims to minimize the potential for moisture damage to structures while maintaining or improving the energy efficiency of the building and the indoor air quality for the occupants.



Ceiling tile and OSB samples show resistance to moisture damage in treated specimens.

Researchers are studying the wetting and drying behavior of building components and how rainwater penetration and air leakage into a structure affect its durability. New test methods are being developed to measure the corrosion of fasteners, particularly those associated with preservative-treated building products, to improve the durability of wood-fastener connections.

The sustainability and health of America's forests depends on the efficient use of our timber resources. Research on improved building design helps conserve the wood resource by increasing the durability and service life of wood and wood products, thereby lessening the need for replacement and repair.

Improving the fire safety of forest products to ensure personal safety and forest health.

Protection of wood structures from fire is one of the most critical safety issues facing our country. Our research in this area focuses both on increasing the survival of homes and structures located in the wildland–urban interface that are threatened by forest fires, as well as studying the behavior of engineered wood products used in construction when subjected to fire.

Our research is aimed at improving our understanding of the fundamental multi-scale physical processes that govern fire behavior. Our findings will allow us to develop predictive models to

Fire research aims to improve personal safety and forest health.

estimate the in-service behavior and performance of wood products, and aid in the development of technologies to improve the survivability of wood structures subjected to wildfires. Evaluation of exterior decking, siding, and roofing materials will be useful in creating guidelines for homeowners concerning the use of these products.

The increased use of engineered wood products in construction provides many benefits, including efficient structural performance, improved wood utilization, and reduction in hazardous fuels in our Nation's forests; however not enough is currently known about their performance in severe fires. Our research outcomes will result in the creation of a database to support the establishment of performance standards for engineered wood products, such as trusses, I-joists, and composite lumber products, increasing the safety of their use.

Developing wood treatments that improve durability of wood products without adversely impacting the environment.

Almost 400 million cubic feet of preservative-treated wood is produced and consumed in the United States annually. However, more environmentally compatible preservatives are needed to replace conventional biocides currently in use.

Testing a fire-retardant treatment.

The voluntary withdrawal of chromated copper arsenate (CCA) from residential applications in 2004 was a historic change for wood preservation, and other preservative systems may soon face similar environmental scrutiny. Our researchers are developing new, environmentally preferable wood preservation technologies, including heavy-metal-free formulations. We are also studying methods for reducing the levels of preservatives needed for effectiveness and evaluating the natural durability of some species as an alternative to treated wood in appropriate applications.

Researchers are assessing the environmental impact of existing preservative treatments to ensure that treated wood can be safely disposed of and does not adversely affect water quality. Studies include investigating the leaching of preservatives from treated wood into the surrounding environment and identifying current treatment practices or exploring alternative treatment methods that reduce leaching.

Although these changes in wood preservation are needed, it is difficult for researchers to respond quickly to societal pressure for environmentally compatible preservatives because it takes many years to evaluate the long-term effectiveness of new preservatives. Our researchers are working to develop improved accelerated test methods to more rapidly assess the potential for a wood preservative to provide long-term protection, and reduce the time needed for the development and acceptance of new environmentally preferable preservatives.

Wood specimens tested for early stages of decay.

Formulating new, sharply targeted inhibitors to protect wood products in service and prevent economic and resource losses that result from biodeterioration.

Chemicals used to protect wood from deterioration by fungi and insects have generally been broad-spectrum biocides that are facing increasing environmental regulatory pressure. Our researchers are taking a new approach to wood preservation that focuses on developing selective biocides that protect against specific threats to wood. Developing targeted preservative systems offers a way to control wood-degrading organisms in an environmentally responsible manner.

With this approach, researchers study the mechanisms by which a particular fungus or insect is able to degrade wood, enabling them to develop an inhibitor based on that particular mechanism. Researchers also study how specific organisms tolerate various wood preservatives and use that knowledge to design preservative systems that neutralize, block, prevent, or counteract that tolerance.

Researchers study termites on wood samples.

Research Scientist Samuel Glass and Research Physicist (Retired) Anton TenWolde prepare for a durability test.

Project Leader

Carol Clausen
Supervisory Research Microbiologist

Primary Research Areas
- Development of low-toxicity wood protection systems
- Diagnostic methods for decay and mold fungi
- Remediation methods for treated wood waste
- Mechanism of brown-rot decay

Education
B.S., Microbiology, Western Illinois University, Macomb, IL

MS., Bacteriology, University of Wisconsin, Madison, WI

Contact Information
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Research Staff

Frederick Green III, Ph.D.
Research Microbiologist
- Mechanisms of brown-rot and white-rot decay
- Wood preservation/NHA/copper
- Termite baiting and termite damage

Robert H. White, Ph.D.
Research Wood Scientist
- Fire resistance of structural wood members and assemblies
- Fire testing of fire-retardant-treated wood products
- Fire performance of composite wood products
- Fire testing of vegetation
- ASTM Committee E-5 on Fire and Subcommittee D7.07 on Fire Performance of Wood

Samuel V. Glass, Ph.D.
Research Physical Scientist
- Moisture control in buildings
- Heat, air, and moisture transport
- Hygrothermal properties of wood products
- Interior and exterior moisture loads
- Durability of wood products

Stan T. Lebow, Ph.D.
Research Forest Products Technologist
- Evaluating and minimizing environmental impacts of preservative treated wood
- Accelerated methods for predicting performance of durable wood products
- Methods of applying preservatives to wood
- New approaches to wood protection

Mark A. Dietenberger, Ph.D.
Research General Engineer

- Fire growth research as applied to wood products
- Wildland–urban interface fire and moisture science
- Thermochemical biomass to biofuels conversion

Charles Carll
Research Forest Products Technologist

- Performance of wood-based siding
- Rainwater management for wood-frame walls
- Seasonal moisture accumulation in wood-frame walls
- Moisture conditions in attics and crawlspaces

Partnership Profile

Partnership Aiming for Faster Research Results

One major hurdle to durability research is the amount of time it takes to obtain results; studying materials in real-life, or in-service, scenarios can take years. To address this issue in one area of durability research, researchers at FPL and the University of Wisconsin are working together to develop methods that correlate in-service performance of metal fasteners and controlled corrosion experiments in wood. One step in developing this correlation is to understand how uncertainties in measurements affect the calculated corrosion rate in a controlled environment. The next step will be to compare metals immersed in a solution of preservative chemicals with corrosion of metals in contact with treated wood. The goal of this collaborative effort is to develop a qualitative test that mimics the corrosion behavior of metals in contact with treated wood without using actual wood specimens. Such a test would be of great value in rapidly evaluating the corrosiveness of new wood preservatives.

Researchers study corrosion rates of metal fasteners.

Engineering Properties of Wood, Wood Based Materials and Structures

MISSION: Improving the characterization of the 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 round wood 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.

Dehumidification dry kiln loaded with green mixed hardwood.

Research Focus Areas

Conducting foundation research aimed at developing information on the fundamental anatomical, physical/mechanical, and processing characteristics of wood.

Our researchers are constantly working to provide an extensive databank of information on wood from both foreign and domestic tree species. The three main areas of investigation are studying how wood quality affects its properties, gathering property data as input for analytical modeling of performance, and providing basic wood processing information to effectively manufacture wood products.

Examples of work in this area include gathering information on the effect of juvenile wood on the properties of softwood and hardwood species and overcoming the technical barriers to efficient drying of small-diameter trees to increase their use for solid-sawn wood products by both small community-based industries as well as traditional industrial operations.

Providing information on the engineering properties and performance characteristics of wood-based structural products.

The basic elements for wood-based buildings of tomorrow will be engineered wood products, such as I-joists, trusses, glued-laminated beams, and round timbers, and built-up components, such as stressed-skin and sandwich panels. The wood resource that will be available in the future to manufacture such products will increasingly consist of underutilized, reused, or recycled materials. However, the lack of engineering

Research General Engineer Robert Falk (right) inspects lumber tainted with lead paint from a deconstruction project.

property data is currently a barrier to using such resources, and the efficient design and safe use of these engineered wood products hinges on the ability to reliably predict their properties. Researchers are working to collect this data and develop analytical models to predict their properties in order to promote increased production and use of engineered wood products made from this nontraditional wood material.

Developing information on the performance and design of structural wood systems

A fundamental knowledge of structural building systems, including optimizing current construction and developing new systems based on either

Research General Engineer James Wacker inspects historic structures such as the WAPAMA, a wooden steam schooner, pictured here.

existing or new wood-based materials, promotes sustainability through more efficient utilization of our wood resource. In order to encourage the most efficient design and construction of buildings, researchers are studying the interaction between individual components, the connections used, and the overall system performance.

Specifically, research projects include developing analytical models of structural systems under extreme conditions such as high winds or earthquakes; studying fastener performance; developing new connection systems; providing engineering design information on adhesive systems; and developing innovative repair methods for wood structures.

Project Leader

Robert Ross, Ph.D.
Supervisory Research General Engineer

Primary Research Areas
- Nondestructive testing and evaluation of wood and wood products
- Condition assessment of structures

Education
B.S., Wood and Fiber Utilization, Michigan Technological University, Houghton, MI

M.S., Engineering Mechanics, Michigan Technological University, Houghton, MI

Ph.D., Engineering Science, Washington State University, Pullman, WA

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Research Staff

Robert Falk, Ph.D.
Research General Engineer
- Properties of reclaimed lumber and timber
- Salvage and reuse of wood products
- Wood deck construction

John Hermanson, Ph.D.
Research General Engineer
- Engineering analysis and modeling

David Kretschmann
Research General Engineer
- Engineering properties of wood products

Douglas Rammer
Research General Engineer
- Engineering design of wood structures
- Fastener and corrosion research
- Design standards

James Wacker
Research General Engineer
- Timber bridge health monitoring
- Inspection of historic structures
- Non-destructive testing of wood

Strength testing of wooden guardrail posts.

Michael Wiemann, Ph.D.
Botanist

- Effects of climate and silviculture on wood anatomy and properties
- Specific gravity/property relationships
- Reduction of discoloration in temperate and tropical woods
- Wood anatomy
- Wood identification

Xiping Wang, Ph.D.
Senior Research Associate
(Univ. of Minnesota–Duluth)

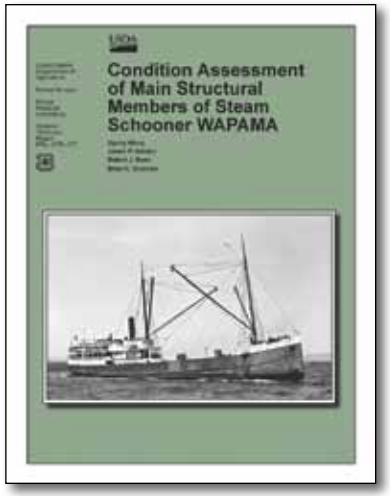
- Nondestructive evaluation
- Field assessment methods

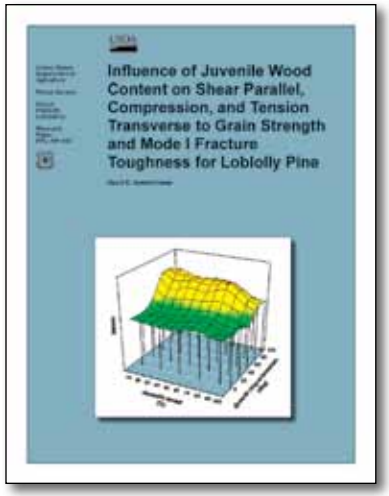
Alex Wiedenhoeft in the Center for Wood Anatomy Research at FPL.

Hardwood forest with black cherry.

Decayed black cherry tree.

Acoustic tomography testing to detect decay.





Samples of Engineering Properties of Wood, Wood Based Materials and Structures publications available online at www.fpl.fs.fed.us/.

Partnership Profile

Sound waves reveal wood quality in logs and standing trees

Researchers at the Forest Products Laboratory have extensively studied techniques using sound waves for assessing the mechanical and physical properties of wood and wood-based materials. Called non-destructive evaluation, or NDE, the techniques involve measuring the speed at which sound waves travel through logs or standing trees to determine the quality of the wood before it is sawn.

Director HM200.

FPL researchers, working cooperatively with Fibregen, a New Zealand company, developed several tools on the market today that use acoustic, laser, and ultrasound technologies to evaluate the strength and soundness of the wood in logs and standing trees.

The Director HM200TM uses a pulse-echo measurement to assess logs and gives landowners and loggers a new way to grade and market logs by sorting and matching them to manufacturer and customer demands for stiffness and strength of products. The technology is beneficial when integrated into log supply and processing decision-making.

The Director ST300 utilizes several technologies (ultrasound, lasers, and impact-induced stress waves) to assess standing timber and allows forest managers to determine the quality of wood without cutting down the tree. The technology can be easily integrated with pre-harvest and earlier stand assessments, which aids in assessing mature stands for marketing, harvest planning and scheduling, assisting in planning silvicultural operations in immature stands, and in tree breeding operations.

Economics and Statistics Research

MISSION: Providing economic information, analysis, and projections and to enhance the efficiency of the Forest Products Laboratory's research through development, evaluation, and application of modern statistical research.

Economics and statistics is a critical component to the success of research at FPL. Economists provide information indicating how and why the markets and technologies for wood products change over time, implications for natural resources management, and selected broad environmental and social impacts, and statisticians apply modern statistical methods to enhance the integrity an deficiency 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 values for wood or conserve wood.

Research Focus Areas

Applying statistical methods to enhance the quality of FPL's wood utilization and economics research.

FPL research is enhanced by the ability of scientists to get professional assistance with designing experiments, analyzing data, mathematical modeling, and summarizing experimental results in tables and graphical displays. Statisticians are integral parts of the research teams, as they help identify research objectives, decide on the best research approach, and design experiments that effectively and efficiently allow testing of research hypotheses. Support of technology transfer is also provided in the form of user-friendly computer programs that provide new capabilities for scientists.

Economists and statisticians evaluate all aspects of the forest products industry.

Improving statistical modeling of wood, fiber, and composite properties, processing, and performance.

A better understanding of existing statistical tools and the development of new tools are critical to the innovative research conducted by FPL scientists. For example, the development of new methods of engineering design that will conserve wood will require development and application of refined statistical methods. Researchers are working to develop models that predict performance when materials are under a combination of stresses and models that predict how processing affects performance.

Monitoring and modeling market equilibria, production trends, and technology changes of the U.S. forest products industry.

Researchers are focusing on the long-range economic modeling of the U.S. forest products sector in the context of structural changes, policy shifts, and global trade. This includes long-range modeling of supply, demand, production and capacity trends by U.S. region, as well as other model development research, such as modeling market impacts of expanded fuel treatment programs in the western United States.

Improving understanding about the effect of production trends and technology changes in solid wood, composites, and end-use industries on product and wood needs.

To support this focus area, researchers maintain detailed capacity and production statistics for softwood lumber and panel mills in the United States and Canada and assess how drivers of wood supply and product demand are causing the observed trends in production and technology. In addition, the prospects for new markets are assessed for individual new products by identifying possible use markets and the size of those markets. Researchers collaborate with industry associations and others to conduct detailed surveys of wood use and prepare reports that display use rates and analyze how the use of different products is changing.

Providing readily available, consistent information on timber, wood products, and paper products industries for forestry and forest industry strategic planning.

Developing Forest Service and industry strategic plans requires basic national-level information about forest products and the timber they use. Researchers provide readily available, consistent information and statistics on timber, wood, and fiber products production, trade, consumption, and prices. The data serve as a uniform source for analysts in government, industry, and universities.

Providing knowledge on the economic viability of new technologies for converting wood and fiber into new or improved paper and wood products or biofuels.

FPL researchers develop new technologies for converting timber into new or improved wood products that can extend timber supplies, reduce processing costs, and provide consumers with better products. However, the wood products industry will not make use of a new technology without adequate assessment of its commercial viability. Our scientists can help make the adoption of new technologies more desirable by providing economic feasibility analysis and identify pathways for adoption, including assessing needs for communities seeking business development and analysis of competitive products.

Project Leader

Kenneth Skog, Ph.D.
Supervisory Research Forester

Primary Research Areas

- Estimate wood biomass supply for bioenergy and biofuels
- Evaluate carbon storage in wood products
- Provide socioeconomic indicators of forest sustainability
- Evaluate status and trends in markets for fuelwood, bioenergy, and biofuels

Education

B.S., Mathematics, Michigan State University, East Lansing, MI

M.S., Forestry, Michigan State University, East Lansing, MI

Ph.D., Forest Economics, Michigan State University, East Lansing, MI

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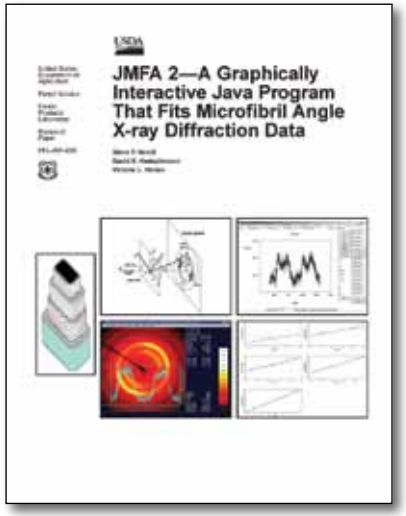


Samples of Economics and Statistics Research publications available online at www.fpl.fs.fed.us/.

Research Staff

Rick Bergman
Research Forest Products Technologist

- Life-cycle inventories that identify environmental impacts (energy, emissions, waste) to make wood products
- Life-cycle assessments comparing the environmental impacts from making buildings using alternate mixes of wood, steel, and concrete
- Life-cycle inventories for using wood biomass to make (a) liquid biofuels, (b)electric power, (c) combined heat and power, and (d) wood pellets for combustion

E.M. (Ted) Bilek, Ph.D.
Economist

- Analysis of the performance of woody biomass grants. The Forest Service is continuing to fund a grants program to improve the health of the Nation's forests through the removal of woody biomass. The objective of this work is to evaluate the success (or otherwise) of the program.
- Financial analysis of capital equipment in the wood-based industries. The focus of this objective is to develop models and methods to analyze the economics of capital equipment investments. These methods incorporate after-tax break-even costing and risk analysis.

James Evans, Ph.D.
Mathematical Statistician

- Establishment of new and more accurate sampling procedures; cheaper, more efficient testing procedures for evaluating the mechanical properties of structural lumber; and new databases of lumber property information
- Evaluation and modeling of the effects of environmental factors on lumber properties
- Development of new statistical analysis procedures
- Research on the Weibull distribution
- Research on how to monitor for changes in lumber properties over time
- Research on uses of small-diameter material
- Collaborative research with other scientists at FPL as a part of a research team

James L. Howard
Economist

- Providing consistent information on timber, wood products, and paper products industries for forestry and forest industry strategic planning

Peter J. Ince, Ph.D.
Research Forester

- Modeling long range economic trends in the forest product sector for the RPA Assessment
- Assessing the economic outlook for wood-based biofuels in the United States
- Monitoring market conditions in the paper and allied products sector
- Evaluating and modeling forest biorefinery business concepts

Patricia Lebow, Ph.D.
Research Mathematical Statistician

- Statistical consultation/collaboration in various areas of wood utilization research, statistical/mathematical modeling, design of experiments, exploratory data analysis

David B. McKeever
Research Forester

- Wood products consumption in major end use markets
- Changing use of wood in residential and nonresidential construction
- Types and amounts of solid waste wood generated
- Potential recovery of solid waste wood for reuse and recycling

Henry Spelter
Economist

- Sawmill and panel mill economics including trends in:
  1. Capacity and production
  2. Employment and productivity
  3. Manufacturing costs
  4. Wood yields and recoveries
  5. Prices and profit margins

Steve Verrill, Ph.D.
Mathematical Statistician

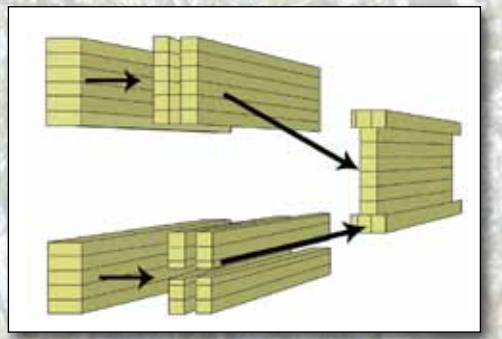
- X-ray determination of microfibril angle
- Predictor-sort sampling
- Coefficient of variation estimation and testing
- Modeling air-drying of logs
- Repetitive member reliability calculations

Samples of Economics and Statistics Research publication available online at www.fpl.fs.fed.us/.

Partnership Profile

Promoting Success Through Economic Analysis

Collaborative work between outside partners and FPL's Economics and Statistics Research group generally occurs through other research work units at the Forest Products Laboratory. For example, researchers in Engineered Composites Sciences and their commercial partner, Wyoming Sawmills, turned to FPL economists to help boost the success of a newly developed product.



Laminated lumber is a valuable product made from undesirable material.

FPL and Wyoming Sawmills worked together to develop value-added laminated lumber products that helped improve forest health by creating a valuable use for undesirable timbers and also proved to be successful building materials. Upon researching the market for such a product, Wyoming Sawmills realized the demand was potentially much larger than they could supply, and decided it would be advantageous to put together an economic model of the process. Such a model would assist other business in picking up on the technology as well, thereby expanding the market, increasing the success of the product, and ultimately promoting Wyoming Sawmills.

FPL economists developed a tool for evaluating the financial feasibility of laminated lumber plants. This spreadsheet-based computer program, called LamLum, analyzes the economics of laminated lumber manufacturing facilities by helping organize information (such as wood supply, loan interest rates, financing, product prices, and materials and labor costs) and then determining how important each of these factors are in the profitability of the facility. The program is now available to anyone interested in a business venture of this nature and can provide critical information to help get them started.

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.

Today's composites incorporate a variety of woody-based raw materials that have traditionally been tailored to meet specific requirements for use in specific products. In the future, raw materials will come from a variety of wood species, other biomass forms, and even materials from recycling and recovery operations. The diversity of such material can have a significant impact on the processing and performance of alternative composites, so researchers are working to develop correlations between raw materials and the final product.

Research goals include developing a database of raw material characteristics that correlate material properties to process options to performance characteristics; studying alternative materials suitable for composites; developing test methods and standards for composite materials that reflect performance in actual use conditions; and understanding how composite performance can be maximized with a minimum cost to performance ratio.

Improving the performance, durability, and value of existing composites and defining the next generation of hybrid composites made from natural fibers and alternative materials.

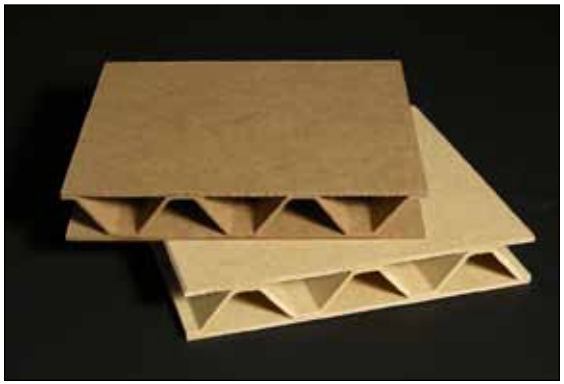
Researchers are working to develop, define, and characterize various raw materials and processing options to improve traditional composites and develop composites of the future. Heat, pressure, chemical and temperature parameters in processing and use will be investigated as they relate to the mechanical and physical properties of various products.

Researchers develop bio-based composites that promote sustainability and recycling while providing improved products.

Current work is also focusing on developing an understanding of how non-wood materials, such as adhesives, fire retardants, and preservatives, interface and combine with woody materials; studying treatment methods to improve the fire-, decay-, insect-, and moisture-resistance of composites; investigating the feasibility of innovative binder systems; developing standards for alternative wood and wood/non-wood composites; and identifying new applications and markets for bio-based composites.

Developing tools to address resource sustainability, enhance recyclability, and minimize the environmental impacts of composite processing.

Composite products offer many varied opportunities to promote sustainability of our natural resources. Development of new technologies provides tools for foresters that add value to underutilized timber and thereby add sustainability-promoting management options. Researchers are also working to develop tools that offer post-industrial and post-consumer waste-stream managers options to enhance waste-stream value and promote recyclability. We are also working to provide industry with technologies that minimize the environmental impacts of processing these products, including "in-the-woods" technologies for the conversion of woody biomass into consumer products.



Examples of engineered composite products.

Project Leader

Currently vacant, contact unit staff at (608) 231–9397.

Research Staff

Zhiyong Cai, Ph.D.
Materials Research Engineer

- Bio-based composites
- Processing
- Warping
- Performance
- OSB, plywood, MDF properties
- Engineered composite properties
- Engineered composite creep
- Stabilized playground or recreational trail surfaces

Craig Clemons, Ph.D.
Materials Research Engineer

- Wood–polymer composites
- Cellulose nanocomposites
- Morphology
- Processing
- Durability

John Hunt
Research General Engineer

- Pulp molding
- 3D engineered fiberboard
- Bio-based composites
- Wet-formed hardboard
- Recycle fibers
- Agro-fibers
- FT-NIR spectroscopy
- Poisson's ratio of hardboard
- Microwave heating wood
- Laminated structures

Nicole Stark, Ph.D.
Research Chemical Engineer

- Wood–plastic composites
- Durability
- Weathering
- Mechanical properties
- Processing

Phil T. Archuletta, CEO, P&M Signs, Inc., produces wood–plastic composite products from western juniper and pinyon pine in Mountainair, New Mexico.

Dense western juniper and pinyon pine in a very dry climate is used for making wood–plastic composite products in Mountainair, New Mexico.

Partnership Profile

Product Promotes Healthy Ecosystems and Rural Economy

Western juniper and pinyon pine have spread over millions of acres of rangeland in the west, lowering the water table and increasing erosion and pollution of streams and lakes. Researchers in Engineered Composites Sciences developed a composite panel made from juniper and recycled high-density polyethylene plastic as a means to better utilize and add value to this resource while helping to alleviate some of these ecological tensions. With the help of FPL's Technology Marketing Unit, P&M Signs, Inc., of Mountainair, New Mexico, now produces Altree™ based on this research. Altree™ is a high-value wood-plastic composite that is non-corrosive, insect and mold resistant, nontoxic, and stable in all weather conditions. It can be used in many applications, including signage, decking, fencing, picnic tables, park benches, tool handles and landscape timbers. Altree™ has been a success for the company and the community; major customers include the U.S. Forest Service, New Mexico Highway Department, New Mexico State Parks, New Mexico Game and Fish, and National Parks.

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; the 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

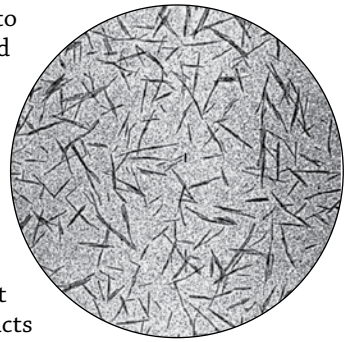
Advancing forest biorefinery for production of transportation fuels, such as ethanol, and valuable chemicals.

New technologies are needed to derive transportation fuels and valuable chemicals from wood. Researchers are studying various chemical and biological conversion methods such as acid hydrolysis, enzyme saccharification and fermentation, as well as thermochemical methods such as gasification and pyrolosis for the production of fuels and chemicals. The primary goal in each case is to overcome barriers to increase yield.

Conducting research on nano-materials derived from wood.

Nano-particles are of interest in many industries because of the unusual material properties they can possess. These properties include significant benefits as reinforcing materials, supporting catalysts, improving the performance of barrier films, acting as carriers for wood preservatives, and sensing or reporting wood moisture and decay. National research in nanotechnology has focused on the use of carbon nano-tubes and metallic nano-wires. These are both very expensive to produce. Cellulose nanocrystals derived from wood are a much lower cost high-performance alternative.

Research in this area includes efforts to understand wood as a nanoscale structure, methods to produce nanomaterials from cellulose, and support for other units at the Forest Products Laboratory working to incorporate nanotechnology into their research. An additional area of interest is an improved understanding of the organization of the woody cell wall, as that knowledge is critical to technical advances in nanotechnology.



Cellulose nanocrystals.

Forest Products Laboratory Pilot Plant.

Continuing advances in traditional wood pulp applications.

Research in this area includes investigating the use of invasive species and small-diameter trees from thinning operations for wood pulp and paper products and developing environmentally preferable pulping and bleaching processes.

Material from forest thinning operations can be used effectively in pulp and paper products; however, industry needs more information on the fundamental chemical and physical properties

of these materials. Researchers are gathering this information and evaluating conventional papermaking processes as an outlet for the wood that needs to be removed from our Nation's forests to reduce fire risk. Evaluation of suppressed-growth trees can help to dispel the notion that these materials are inferior to normal pulpwood trees and increase their valuation in the market. Researchers are also investigating novel pulping and bleaching processes to increase yield and decrease the environmental impact of producing pulp.

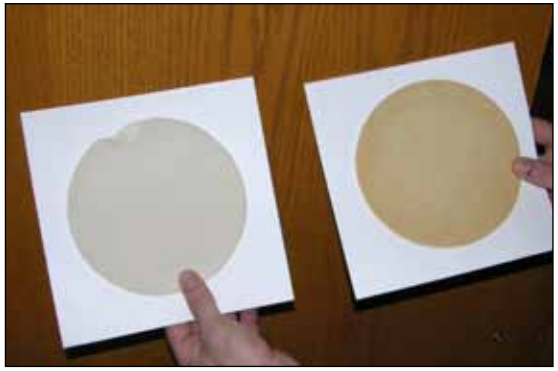
Improving paper and paperboard recycling.

Using recycled wood fiber in paper products is an effective way to reduce societal demands for wood. Wastepaper recovery in the United States is at historically high levels, but much of the recovered paper is exported and not recycled for use in the United States. The high costs and reduced quality of the recycled fibers combine to make U.S. paper companies prefer virgin wood pulp. Yield and fiber quality improvement are keys to increasing paper recycling in the United States.

Research on improving paper recycling is focused on gaining a fundamental understanding of the physical behavior and removal of contaminants relative to fiber loss in the recycling process. Scientists are looking at treating recycled fibers to improve their performance and exploring methods to tailor fibers for specific products. For example, recycled fibers tend to have high stiffness, which can be used to improve paper products requiring stiffness or bulk.

Understanding the fundamentals of paper structure and applications for pulp-fiber-based products.

Researchers are investigating the mechanics of paper and paperboard failure, including developing improved methods to test and predict product performance. One goal in this arena is to characterize paper and other pulp-fiber-based products as engineering materials in order to improve current uses and develop new applications.



FPL's Pilot Plant simulates processes used in the papermaking industry.

Project Leader

Alan Rudie, Ph.D.
Supervisory Research Chemist

Primary Research Areas
- Wood conversion to chemicals
- Prehydrolysis for biomass conversion
- The bonding and behavior of alkali earth and transition metals in wood pulps
- Trace metal accumulation and scale formation in pulping and bleaching
- Kraft pulping

Education
Ph.D., Inorganic Chemistry, Massachusetts Institute of Technology, Cambridge, MA

B.A., Chemistry and Mathematics, Wartburg College, Waverly, IA

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Research Staff

Umesh Agarwal, Ph.D.
Research Chemist
- Raman spectroscopy
- Lignin
- Cellulose crystallinity

John Considine
Research Materials Engineer
- Paper physics
- Paper laminates
- Paper failure
- Pressure-sensitive adhesive

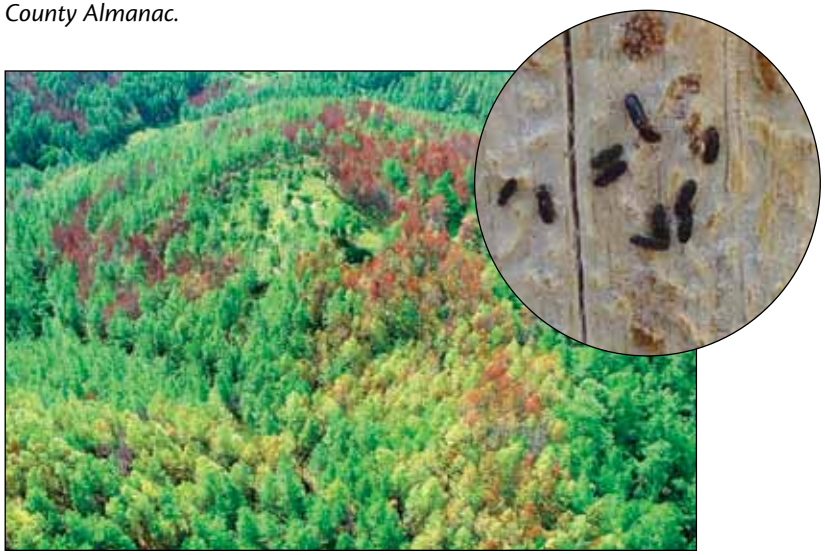
Carl Houtman, Ph.D.
Chemical Engineer
- Pilot plant
- Separations
- Wood hydrolysis
- Paper recycle
- Pulp processing

Thomas Urbanik
Research General Engineer
- Container failure
- Corrugated box design
- Corrugated box testing

David Vahey, Ph.D.
Materials Research Engineer
- Paper physics
- Paper stability
- Paper formation
- Paper structure

Junyong Zhu, Ph.D.
Research General Engineer
- Paper recycling
- De-inking
- Wood and paper fiber
- Biomass pretreatment

FPL researchers assisted in the production of pulp made from pine trees planted by conservationist Aldo Leopold. The pulp became paper for the printing of a special edition of Leopold's *A Sand County Almanac.*



Bark beetles on pine wood and their infestation in a pine forest. Researchers are evaluating bark-beetle-killed pines for use in pulping and paper products.

Partnership Profile

Forest Thinnings Produce Thermomechanical Pulp and Quality Lumber

A research collaboration among FPL, University of Idaho (Moscow), Pacific Northwest Research Station, Colville National Forest, Ponderay Newsprint Company (PNC), and Ponderay Valley Fiber (PVF) has addressed two forestry-related issues, one of environmental and one of economic concern: overcrowding of forests in the western United States and a diminishing supply of pulpwood from public and private lands in the same region.

Preliminary FPL research showed that small-diameter, thinned trees, once thought to be inferior, are in fact suitable for lumber and pulp production. Furthermore, less refining energy was required to produce pulp from forest thinnings than from conventional wood supplies. To convince the pulp and paper industry that thinnings are a good alternative source of wood fiber, researchers demonstrated their findings at Ponderay Newsprint company and Ponderay Valley Fiber. Results of this study show that lumber produced from forest thinnings meets or exceeds the saw mill specification. Chips generated from forest thinnings as either whole logs or sawmill residuals produced commercial-quality thermomechanical pulp for newsprint.

This collaboration with the Pacific Northwest Research Station and Colville National Forest continues, now evaluating bark-beetle-killed pines for use in pulping and paper 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

Develop technologies for the efficient and economical bioconversion of underutilized woody biomass, such as forest thinnings, unmerchantable timber, and mixed species, into a full array of wood-based materials, from fiber to chemicals.

Underutilized wood from overstocked forest stands could be made into fuels, chemicals, and polymers through appropriate pretreatment and bioconversion. Our research is working to develop fundamental knowledge to enable novel technologies for the economic bioconversion of wood to such useful products.

Researchers are studying pretreatment, saccharification, and fermentation technologies, which can be integrated into traditional fiber processing to generate a mixture of fuels, chemicals, and biomaterials. In one example of this research, scientists are working to understand, modify, and adapt xylose-fermenting yeasts for the production of fuels and chemicals. Xylose is the major component of hardwood hemicelluloses, and its utilization is essential to the economics of the saccharification/fermentation process for bioconversion of wood waste. If the technology for fermenting xylose and other hemicellulosic sugars is practicable, wood-derived ethanol could provide a significant fraction of our Nation's transportation fuel needs from renewable resources in an environmentally sound manner.

Gasification is also being studied as a method of bioconversion, and is an attractive option because it could potentially be used to convert low-grade biomass into fuels and chemicals on-site, eliminating the expense of handling and transporting the bulky woody materials. However, the economic feasibility of gasification needs to be further studied.

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.

Researchers are studying how selected white rot, brown rot, and soft rot fungi degrade wood. Understanding the biodegradative systems of forest fungi is important in regards to the durability of wood-based products, biomass cycling in forests, and the bioconversion of wood to value-added products.

Increasing knowledge of how organisms attack wood will help researchers predict with confidence the performance of wood and wood-based materials in particular environments and find new environmentally benign ways to protect wood in use.

Examples of well maintained forests following thinning necessary to improve their health.

This knowledge can also be useful where wood decay has a positive impact: on the forest floor. The degradation of woody biomass by fungi in forests is an essential component of global carbon cycling and is required for nutrient retention in forest soils. Researchers are working to increase our understanding of the factors that control the rate of decay, as knowledge in this area will lead to improved forest productivity and faster ways to recycle logging slash, thereby mitigating fire hazards.

Because of their unique capabilities, wood-decay fungi and the chemicals they produce also show promise as versatile, environmentally benign bioprocessing agents. Almost nine billion board feet of preservative-treated wood is used in this country each year, and management of the treated wood taken out of service is a growing problem. Using decay fungi for mycoremediation and degradation of this waste wood are alternatives to incineration and landfilling, and our research in this arena has led to seven patents for remediating and recycling wood treated with chromated copper arsenate (CCA), creosote, pentachlorophenol, or ammoniacal copper quaternary (ACQ).

Develop basic information and operation conditions for efficient and effective enzymatic and microbial processing of wood and wood fiber.

The use of enzymes is important to meet the public's demands for environmentally benign technologies. Enzymes catalyze reactions under conditions that are environmentally less severe than similar chemical processes. Researchers study the enzymatic and microbial modification of wood and fiber surfaces that provide great potential in developing new products. Specific removal or modification of components of wood may be useful in producing new products; such as chemicals or fuels, heavy metal or nutrient adsorbants, or replacements of stringent chemicals in industrial processes.

Researchers focus on discovery and use of microorganisms, enzymes and biomimics to treat virgin fibers, recycled fibers, and wood residues. Enzymes or processes possessing the capacity to release lignin and chromophores from pulps are sought, along with enzymes that might increase the strength of paper made from lower grade residuals and pulp. The pulp and paper industry already uses enzymes for pulp bleaching and removing inks and contaminants from recycled fibers. Further research is being conducted using proteins that may be useful in restoring flexibility or bonding properties to recycled fibers, which could expand the use of recycled fibers and conserve timber while providing the public with material goods. Enzyme pretreatment of biomass will be indispensable for the new forest biorefinery initiatives and hold promise for the value prior to pulping process (VPP). An important consideration in this research, is ensuring that the use of enzymes can fit in with existing industry technologies to increase their acceptance and use.

Increasing understanding of the functional genomics of lignocellulose-degrading fungi to optimize their use in the bioprocessing and bioconversion of wood.

White rot fungi possess the unique ability to efficiently degrade lignin from plant biomass into carbon dioxide in order to gain access to the carbohydrate polymers of plant cell walls for use as carbon and energy sources. Wood-decay fungi are among the most prevalent and diverse degradative organisms in forests, yet their genetic systems for cellulose, hemicellulose, and lignin degradation have barely been examined.

Woody biomass gathered and bundled for future use in a full array of wood-based materials, from fiber to chemicals.

White rot fungi are of considerable interest for many industrial applications, including biological pulping of paper, fiber bleaching, and remediation of pesticides, certain textile dyes, and hydrocarbons associated with wood preservation. Our researchers are working to identify and characterize these key genetic systems, as the poor understanding of the molecular genetics of these fungi have been a critical barrier to their commercial use.

Project Leader

Barbara Illman, Ph.D.
Supervisory Research Plant Pathologist

Primary Research Areas

- Characterization of fungal mechanisms of wood decay at the micro- and nanoscale levels with solid state physics methods available only at large x-ray/IR/UV generating synchrotrons.
- Isolate and identify natural pesticides in wood inhibiting fermentation of biomass conversion to fuel ethanol and other chemicals, especially during value prior to pulping processes (VPP)
- Isolate and characterize natural pesticides involved in chemical ecology of wood, insects and fungi.
- Mycoremediation of waste wood treated with toxic chemicals, especially chromium copper arsenate (CCA) and pentachlorophenol (PCP)
- Prevent introduction of invasive species by developing methods to kill invasives in wood and providing scientific support to quarantine agencies for international phytosanitary standards for wood during international trade.

Education

B.S. and M.S., Biology and Biochemistry, Tennessee Technological University, Cookeville, TN

Ph.D., Plant Pathology and Biochemistry, The Pennsylvania State University, University Park, PA

Contact Information

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Research Staff

Casey Crooks, Ph.D.
Microbiologist

- Molecular cloning and characterization of pyranose 2-oxidase gene from the brown rot fungus *Gloeophyllum trabeum*
- Forward genetic identification of elements influencing ethanol production in *Pichia stipitis* for use in strain improvement.
- Improved transformation technologies for manipulation of white and brown rot fungi using biolistic bombardment.
- Identification of novel factors involved in wood decay process.

Daniel Cullen, Ph.D.
Microbiologist

- Genomics of wood decay fungi
- Development of improved enzymatic systems for woody biomass conversions through integrated genomic, ultrastructural, and chemical approaches

Kenneth Hammel, Ph.D.
Chemist

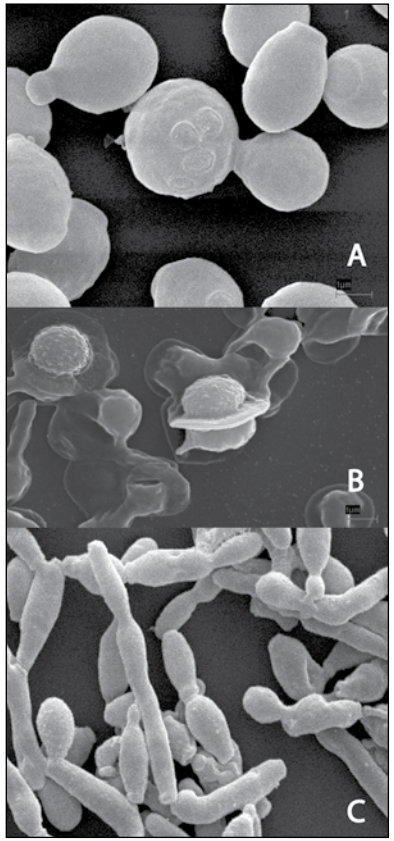
- New solution-state NMR approach for elucidation of fungal and enzyme/mediator delignification systems
- Mechanism and physiological role of peroxygenases from litter-decomposing fungi
- Metabolomic analysis of lignocellulose colonized by white rot fungi
- Heterologous expression and functional analysis of lignocellulose-degrading enzymes from wood decay fungi.

Thomas Jeffries, Ph.D.
Microbiologist

- Global expression analysis of the xylose fermenting yeast, *Pichia stipitis*
- Analysis of functional gene clusters in *Pichia stipitis*
- Development of pretreatment conditions for hemicellulose and cellulose saccharification.
- Development of *Pichia stipitis* for the fermentation of xylose to ethanol
- Development of *Pichia stipitis* for the fermentation of cellulose
- Assessment of *Pichia stipitis* for the fermentation of pretreated agricultural residues
- Hybridization of *Pichia stipitis* to create improved fermentative strains
- Assessment of *Pichia stipitis* for the fermentation of xylanase and cellulase pretreated and saccharified agricultural residues
- Physiological studies on the anaerobic growth of *Pichia stipitis*
- Metabolic engineering for improved fermentation of xylose and cellulose by *Pichia stipitis*
- Development of ethanol and acetic acid resistant strains of *Pichia stipitis*
- Metabolic engineering of *Saccharomyces cerevisiae* for xylose and cellulose fermentation

Philip Kersten, Ph.D.
Microbiologist

- Biochemistry of wood sugar metabolism by fungi
- Synthesis of novel products from sugars using a combination of enzyme and chemical catalysts
- Nanocatalysis for conversion of wood to value-added products
- Natural product isolation and identification



The xylose-fermenting yeast, *Pichia stipitis* (A) during vegetative growth, (B) forming spores, and (C) under carbon limitation.

Partnership Profile

Making Ethanol from Biomass to Meet Energy Demands

Forest Products Laboratory (FPL) researchers have had proven and continuing success working with commercial partners to improve methods of converting biomass to alternative fuels such as ethanol. One important goal of these collaborations is to promote biomass as a way to meet increasing worldwide energy demands.

Xethanol Corporation, an ethanol producer with facilities in Iowa, acquired licensing rights to a patented process developed by FPL and the University of Wisconsin and signed a cooperative research and development agreement to solidify the partnership. The patented process aids in the conversion of xylose, a sugar found in waste biomass and corn fiber, to ethanol and xylitol, a sweetener used in food processing.

The conversion takes place through a fermentation process in which specialized yeast strains break down the xylose. The process reduces the time and labor involved in the critical task of isolating and screening yeast strains for effective fermentation agents and can be used for conversion of both agricultural waste and woody biomass.

Collaborative research in this area is continuing with a new partnership recently formed between FPL and EdeniQ, a company that focuses on turning abundant, non-food biomass into fuels. Researchers are developing yeasts used to ferment xylose and glucose from biomass for commercial ethanol production.

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 nano-materials. 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 woo-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 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.

Recent advances in chemistry, biology, and physics facilitate modification of wood-based materials to meet specific needs. Our basic research will answer questions such as the effect of nanoscale modification of the cell wall on water and water vapor transmission through materials, or the inhibition of degradation through polymer modification. Components such as caulks and sealants, adhesives, structural insulated panels, and new composite materials will also be evaluated for their suitability in various structures and conditions such as high-moisture areas.

Goals in this area include continued development of a database on the mechanisms or weathering of wood, modified wood, and treated wood; refining and improving service life prediction models for the outdoor performance of wood; determining the effect of wood moisture content on materials used in conjunction with wood; and evaluating the surface properties of wood for resistance to sunlight and moisture degradation.

This research strives to address one of the biggest challenges in modern construction: creating and maintaining a water-proof building envelope. We need to develop better designs for structures that take into consideration the properties of both wood and non-wood components and the interaction between the two, and gain an understanding of how climate, weather, natural disasters, and structure use affect these interactions.

Understanding wood surface chemistry, how materials bond to wood, and the processing of components during manufacture to improve wood-based composites.

There is a continuing need for low-weight, high-performance composites for the transportation, construction, and aerospace industries, as well as for consumer goods. Our research focuses on five components to help meet this need:

Chemical modifications and surface treatments will be investigated as a way to enhance

Painted wood specimens being evaluated for outdoor durability.

properties such as water repellency, dimensional stability, wet strength and stiffness, hardness, toughness, weathering, resistance to ultraviolet radiation, fire, decay, and insects, and the ability to resist damage during processing.

Researchers will study the basic principles of adhesion theory to improve bonding. Examples of work in this area include studying the interaction of adhesives with wood surfaces; examining adhesive penetration into the cell wall; determining how wood surfaces changes, such as aging, drying, and chemical treatments, affect adhesive performance; and determining how different wood species influence the effectiveness of various adhesives.

The properties and performance of wood adhesive systems need to be improved. Our research will lead to a better understanding of the limitations of existing systems, which can then be applied to develop new or modified adhesive systems with improved properties, performance, and

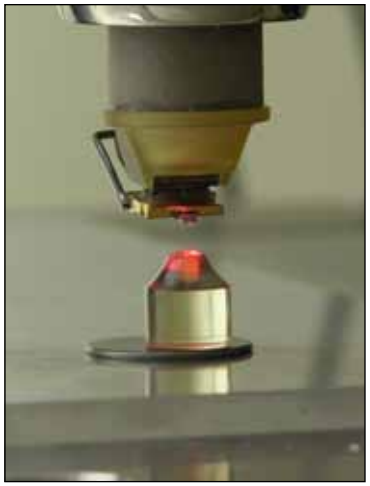
economics. Researchers are looking to develop adhesives with desirable and beneficial properties, such as not containing formaldehyde, being more earth-friendly and addressing the rising cost of petroleum and natural gas, lower cost, faster curing rate or curing at lower temperatures, more efficient and able to be used at lower levels, and tolerable of high moisture content in wood.

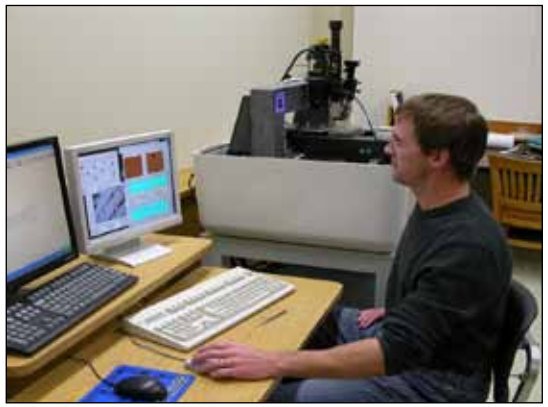
Researchers are examining using the byproducts of biorefining and bioenergy processes as a cost-effective source of material for advanced composites.

The development of new adhesive systems must include improving dimensional stability and the product's resistance to fire and decay. Basic research will be conducted to understand the limitations to treating wood with preservatives and fire retardants, and their reactions with wood adhesives.

Understanding wood properties at the molecular, nano, and cell wall dimensions to solve performance problems.

By expanding our understanding and control at nanoscale, new avenues of basic and applied research and product development can be achieved. The aim of this research is to use nanotechnology to facilitate the creation of novel materials or improve the properties of existing materials, devices, and systems. Researchers are working to gain fundamental knowledge of nanoscale phenomena, understand how changes at the nanoscale modify physical, chemical, and biological properties, develop new instruments to measure materials properties at the nanoscale, develop methods for structure evaluation and materials and systems design, and develop standards for testing, manufacture, and characterization of nano-materials.





Nanotechnology research being conducted by Research Materials Engineer Robert Moon at the Forest Products Laboratory.

Project Leader

R. Sam Williams, Ph.D.
Supervisory Research Chemist

Primary Research Areas

- Computerized data collection during outdoor materials testing and analysis of data
- Reliability-based service life prediction of wood and other materials used with wood
- Mechanism of photodegradation of wood and other organic materials

Education

B.S., Chemistry, Westminster College, New Wilmington, PA
Ph.D., Eng. Science, Washington State University, Pullman, WA

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Research Staff

George Chen, Ph.D.
Research Chemist

- Chemically modified wood for dimensional stability, decay, fire and UV protection
- Wood preservatives
- Chemical conversion of monosaccharides to gasoline and liquid fuel
- Nano-characterization of chemically modified wood

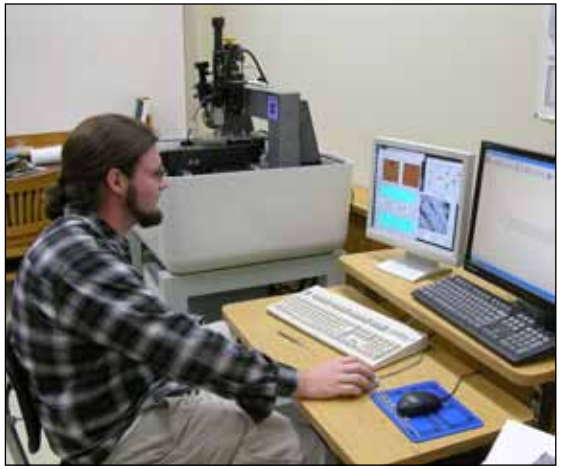
Example of adhesive study.

Charles Frihart, Ph.D.
Research Chemist

- Wood adhesive chemistry
- Wood adhesive bond durability
- Mechanisms of adhesive bonding
- Analysis of wood bonds
- Bio-based adhesives
- Analytical chemistry of wood adhesives
- Performance of wood adhesives

Christopher Hunt, Ph.D.
Research Chemist

- Mechanisms of fungal wood decay
- Wood adhesives, paint and finish performance
- Interactions of wood and water
- Fluorescent probes to localize ROS species in fungal/wood systems



Performance Enhanced Biopolymers employee Joseph Jakes works with the nanoindenter.

Rebecca Ibach, Ph.D.
Research Chemist

- Woodfiber–plastic composites durability: laboratory and field evaluations
- Chemical modification for improvement of wood properties
- Integrated approach to wood protection
- Solid wood polymer composites

Robert Moon, Ph.D.
Research Materials Engineer

- Wood hierarchical structural effects on properties
- Characterization and applications of cellulose nanocrystals for advanced materials
- Sensor technology development for wood science
- Cell wall characterization techniques

Mandla Tshabalala, Ph.D.
Research Chemist

- Surface chemistry of wood polymers and related lignocellulosic materials
- Isolation, characterization and material properties of hemicelluloses
- Performance properties of hybrid inorganic-organic thin films on wood substrates
- Chemical and physical modification of wood
- Wood products performance enhancement
- FTIR, LC/MS, GC/MS characterization of modified wood constituents

Performance Enhanced Biopolymers employee Peter Sotos applies an exterior finish.

Partnership Profile

Ongoing Collaboration Leads to Success for Adhesives Research

Producing a composite panel using soy-based adhesive.

Adhesives are only a small part of wood composites by weight but are a substantial part of the cost. Increasing petroleum prices have stimulated commercial interest in using soybean flour for bonding wood products instead of the traditionally used petroleum-based phenol-formaldehyde. Based on this interest, a partnership was formed between the Forest Products Laboratory and Heartland Resource Technologies in 2004, and a technology was jointly developed that uses up to 75% soybean flour in the adhesive.

The research was initially aimed at replacing part of the existing adhesive for oriented strandboard. However, the success of the laboratory work, including the issuance of several patents, has led to the pursuit of additional applications, including plywood and molded wood products. Research moved from mainly laboratory work to a mixture of laboratory studies and plant trials.

The success of this work is further illustrated by the creation of a new research and development venture in 2007 called H2H Innovations, which is the result of Heartland Resource Technologies joining forces with Hercules Incorporated. H2H Innovations plans to leverage existing soy-based adhesive technologies from both companies to accelerate the development of new adhesive products for the wood products industry.

FPL FAST FACTS

Want to know more?

Technical tours are available by appointment for organizations interested in partnering with us. The general public is always welcome to visit our lobby to pick up informational handouts, read displays, and watch a video about our research. Visit our website for more information or send us an email to sign up for our free quarterly newsletter.

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Forest Products Laboratory

- 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
- Research partnerships located in virtually every state in the Nation

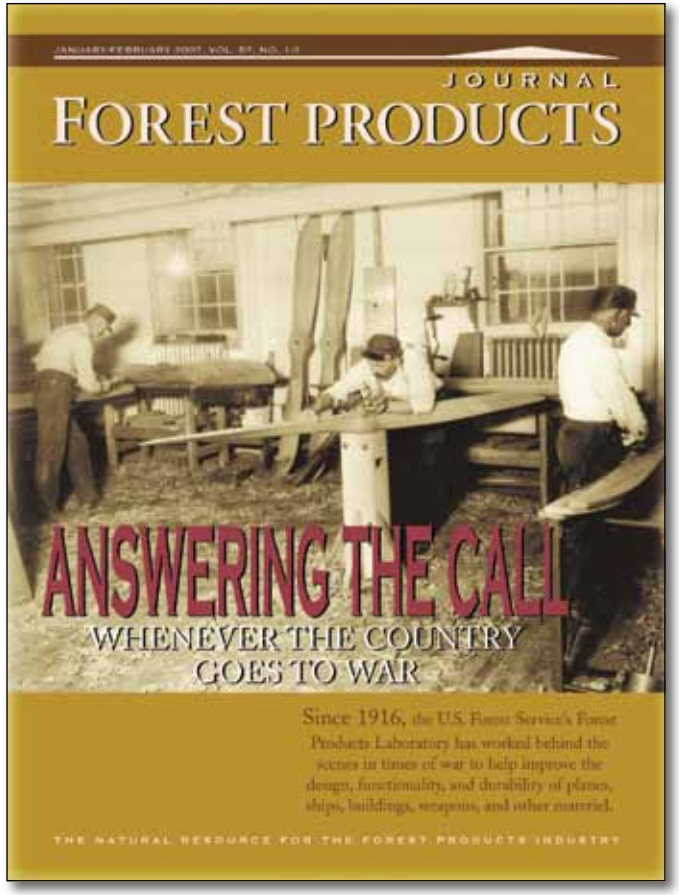
Early research highlights

- Reduced timber demand for railroad ties by 75% through preservatives research
- Increased average lumber yield per log from 25% to 60%
- Wood frame technology used in over 90% of our Nation's homes
- Designed and constructed Nation's first prefabricated home

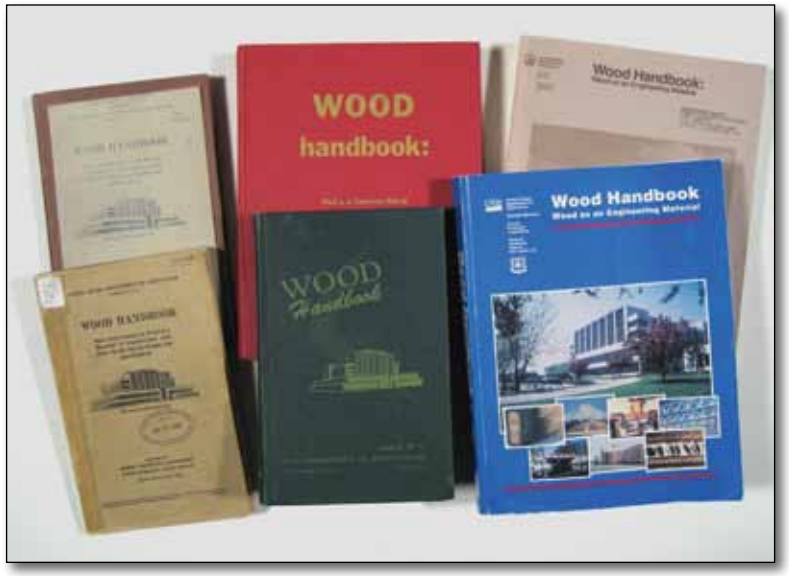
Current research initiatives

- Nanotechnology
- Forest Biorefinery and Biomass Utilization
- Advanced Composites
- Advanced Wood Structures
- Underutilized Woody Biomass

SCIENCE THAT MADE A DIFFERENCE



Since 1910, the FPL has contributed significantly to the conservation of forest resources, enhanced forest management, and the economy of the Nation.



The content of the *Wood Handbook* is based on decades of general research on wood along with engineering and studies of wood products.

One of our most popular publications is the *Wood Handbook,* first issued in 1935. This publication has been revised several times, with the centennial edition expected by 2010. The content of the *Wood Handbook* is based on decades of general research on wood along with engineering and studies of wood products.

The internet has positively affected the distribution of this information as the Handbook is now on our website and can be downloaded by chapters (www.fpl.fs.fed.us).

Along with the *Wood Handbook,* our website has assisted many customers in finding answers to their wood related questions. We now have 4,000 publications available, and more are being added daily.

Improving wood preservatives was one of FPL's first goals; this research continues today.

1910–1940

Extend forest resources

Improved use of preservatives to extend the service life of railroad ties and utility poles thus requiring fewer trees.

Low-cost housing

Developed the first low-cost, plywood panel prefabricated house, helping to pioneer the factory-built house.

Use renewable materials

Developed new adhesives and timber connectors, thus allowing the manufacture of laminated wood arches for use in arenas, churches, and other large structures rather than using nonrenewable materials.

Use new species

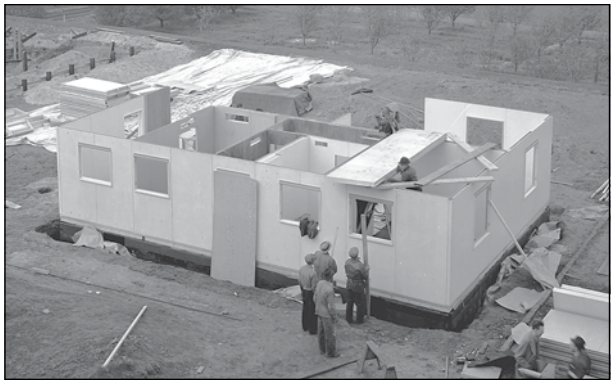
Determined the fundamental properties of various wood species, thus allowing the substitution of many species for those few that were favored and being overcut.

Reduce defects

Developed the fundamental wood–moisture relationships, which led to the design of the internal-fan dry kiln for drying wood and proper drying schedules. Applying this technology greatly reduced lumber defects, thus reducing waste and conserving timber.

Producing a composite panel using a soy-based adhesive.

Engineered wood composites.



The first prefabricated house was developed by FPL in 1937.

FPL studied reducing weight and maintaining durability of packing crates during air transport in World War II.

Engineered wood-fiber surface for playgrounds.

Engineered wood products have made a huge impact on both building and forest management practices.

Recycled fibers

Based on fundamental research on recycled fibers, papermaking, and container design, it is technically possible to make usable corrugated containers out of 100% recycled fiber, thus greatly extending our forest resource.

Saving the resource

FPL Spaceboard is a totally new type of fiberboard with unique strength properties. It can be made from recycled fibers or high yield pulps thus conserving the forest resource.

The development of Spaceboard created a high-value use for recycled fibers.

2000–Present

Making ethanol from biomass to meet energy demands

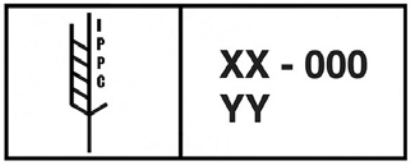
In 2005, FPL researchers patented a process of converting xylose to ethanol and xylitol. The conversion is through a fermentation process in which specialized yeast strains break down the xylose. This research will promote biomass as a way to meet increasing worldwide energy demands.

Producing three-dimensional structural biocomposites from small-diameter, underutilized, and hazardous-fuel trees and recycled fiber

This novel sandwich panel, called three-dimensional engineered fiberboard (3DEF), is wet formed and the water used in the process can be recycled. It is strong and stiff but much lighter in weight than many commercial wood composites.

International standard slows the spread of invasive species

Heat treatment protocols were developed to kill pests in packaging materials before they are shipped around the world. These protocols became the scientific basis to support new international shipping standards for wood packaging materials.



Mark developed for international shipping standards.

An environmentally sound soy adhesive is developed

Using soybean flour as the main component in an adhesive proved to be successful for FPL researchers and a cooperator. This research is looking into replacing part of the existing adhesive for oriented strandboard, plywood, and molded wood products.

Improving accessibility for Americans with disabilities by using engineered wood fiber surfaces for playgrounds

Stabilized engineered wood fiber (SEWF) is a thin top layer of loose mulch-like mixture of hardwood chips bonded together with stabilizing binders. This forms a resilient, uniform surface that allows for easy navigation of wheelchairs and walkers, while the hardwood chips under the SEWF remain loose and provide cushioning for falls from the playground equipment.

Enhance forest management

Developed the semichemical pulping process that significantly increased the yield of pulp from a given amount of wood, thus extending the wood supply. It also increased the variety of woods that could be used in pulp, thus enhancing forest management.

Chemicals from wood

Enhanced the understanding of the complex chemistry of wood, providing the basis for information on naval stores, chemical intermediates, extractives, explosives, rayon, flavorings, alcohol, fuel and many other chemical derivatives.

First structural glue-laminated building without metal pins, circa 1935.

1940–1970

Higher yields

Significantly increased lumber yield through wood processing by developing new saw blade technology. This resulted in better utilization of each log.

Increased service life

Pioneered research and development of plywood for exterior use.

Benefiting the war effort

Using fundamental information on wood properties, fasteners, and engineering design, developed packaging standards to assist the country in winning World Wars I and II.

Protecting wood surfaces

Developed "FPL Natural Finish" to protect wood siding without the problems of other surface finishes.

Using the residues

Improved panel products such as hardboard, particleboard, flakeboard, and insulation boards by applying process knowledge developed at the FPL.

1970–2000

Forensics

Using the world's largest collection of wood specimens, experts at FPL aid in criminal and other investigations.

Mycology

FPL is the home of the world's largest forest fungi collection. Utilizing specific organisms from the collection allows breakthrough research, such as biological pulping, which reduces pulping energy requirements by 30%.

Laetiporus sulphureus.

Saving large trees

Truss-frame construction is one of the major accomplishments that greatly affects forest management. Truss-framing allows for the use of small lumber rather than large lumber, thus taking some of the pressure off the use of large old-growth timber.

Truss-frame construction allowed for the use of small lumber, taking pressure off the harvesting of larger trees.