Durability and Wood Protection Research

at the

Forest Products Laboratory

USDA Forest Service
Forest Products Laboratory

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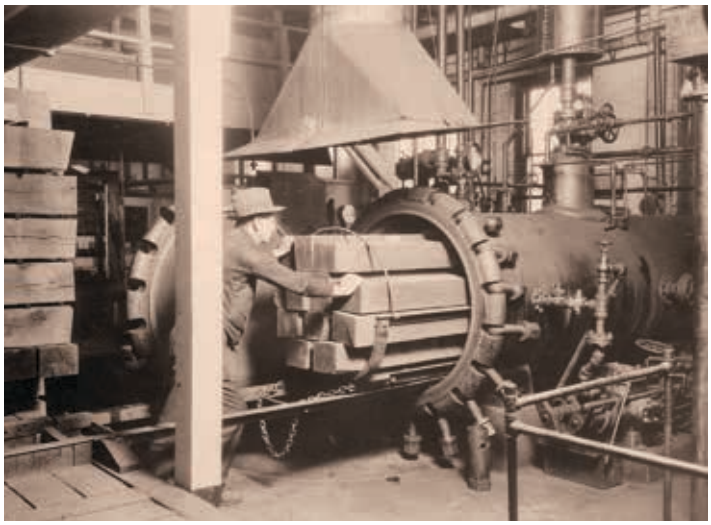

Research on protecting wood from biological degradation was part of the earliest work at the Forest Products Laboratory.

Current Research Emphasis Areas

- Achieving enhanced performance and durability of building materials and structures
- Enhancing the value of wood as a green building material for residential, nonresidential, and transportation structures
- Developing innovative nanomaterials for improved durability of wood products
- Reducing catastrophic wildfires through efficient utilization of woody biomass

Partnerships

A large portion of our research is conducted in formal or informal partnerships within the Forest Service and with other government agencies, universities, industry associations, and individual companies.

Project researchers are active in several professional societies:

- ASTM International (formerly American Society for Testing and Materials)
- American Forest and Paper Association (AF&PA)
- American Wood Protection Association (AWPA)
- Association of Structural Pest Control Regulatory Officials (ASPCRO)
- Entomological Society of America (ESA)
- Forest Products Society (FPS)
- International Research Group on Wood Protection (IRG)

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Biodeterioration

An important limitation to the usefulness of wood, and a prime cause of user dissatisfaction, is its vulnerability to biodeteriorating fungi and insects under certain conditions of storage and use.

Brown-rot decay can cause catastrophic failure of wood.

Efforts to protect wood from biological degradation are among the earliest research at the Forest Products Laboratory. This research has successfully reduced the need to repeatedly replace existing wood products.

Targeted wood protection systems are now needed to replace the broad spectrum biocides traditionally used to inhibit decay fungi. The most logical approach to develop targeted biocides is to take advantage of unique physiological attributes of decay fungi to design specific, targeted inhibitors to control decay and circumvent preservative tolerances.

Significant advances in molecular analysis have provided the capability to map intricate molecular changes in a field stake during the decay process. Information gained through molecular analysis will be used to create a database of decay fungi to address critical issues, including incidence of preservative-tolerant fungi, ecosystem changes stemming from preservative prevalence at a test site, and microbial progression during product failure. Using molecular analysis to diagnose product failure is considered a critical national issue for the preservation industry. Fundamental metagenomics research compliments manual field performance and diagnostic evaluations and may provide a tool for rapid and accurate performance assessment for preservatives.

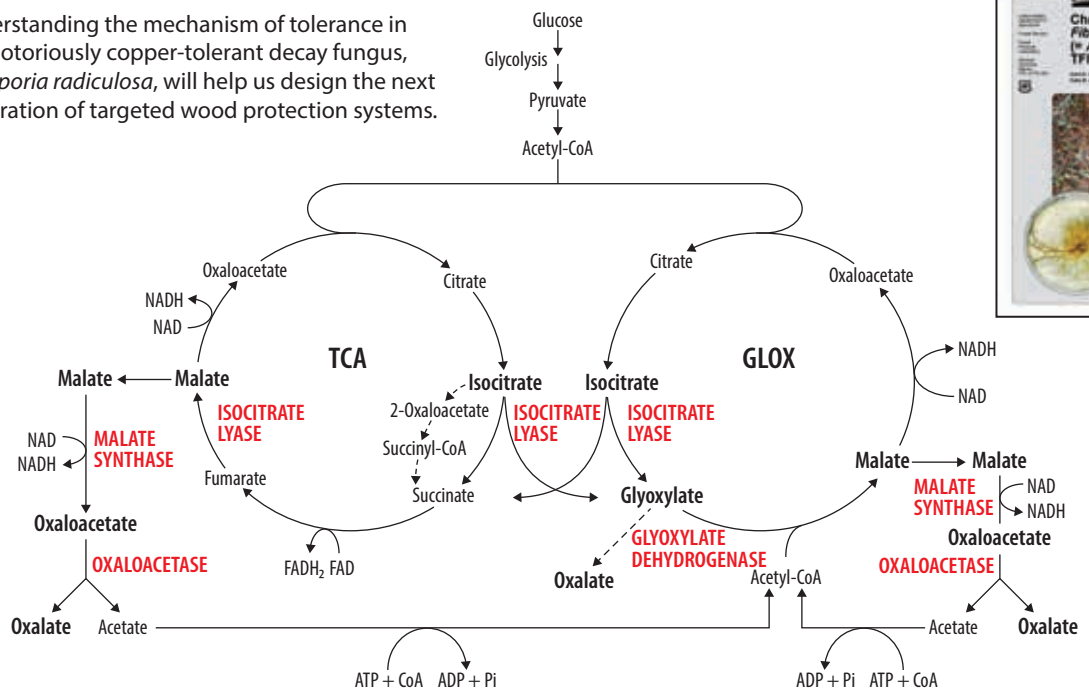
Mold growth and its impact on indoor air quality have become an increasingly problematic housing issue, despite the fact that mold fungi do not cause structural changes to wood. The presence of airborne spores can cause health problems in human occupants and is indicative of elevated moisture. Because mold spores are inherently resistant to chemical inactivation, the challenge is to develop inhibitors that can be used safely in the indoor environment.

Standardized laboratory soil block tests (AWPA E10) are instrumental in studies on fungal decay.

Laboratory method for evaluating the resistance of wood products to mold growth (AWPA E24).

Targeted wood protection based on physiological attributes of biodeteriorating organisms is needed to prevent economic and resource losses.

Understanding the mechanism of tolerance in the notoriously copper-tolerant decay fungus, *Fibroporia radiculosa*, will help us design the next generation of targeted wood protection systems.



Research Highlights

- Determined the pathway of enzymatic activity associated with copper tolerance in an aggressive decay fungus
- Developed and patented a multi-component biocide that is effective against mold, decay fungi, and termites and is safe for indoor use on structural building components
- Found evidence of seasonal patterns of fungal colonization through genetic analysis of naturally durable wood species exposed at northern and southern U.S. field sites, with a more defined pattern of colonization at the southern field site
- Developed accelerated laboratory methods for rapid, quantitative screening of new biocides
- Investigating plant essential oils and chemical extractives from durable woods as environmentally friendly biocides

Notable Publications

Clausen, C.A. 2010. Biodeterioration of wood. In: Wood handbook—Wood as an engineering material. General Technical Report FPL–GTR–190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p. Chapter 14.

Clausen, C.A. 2012. Enhancing durability of wood-based composites with nanotechnology. In: Cai, Z.; Niska, K.O., eds. Nanocelluloses: Potential materials for advanced forest products—Proceedings of nanotechnology in wood composites symposium. General Technical Report FPL–GTR–218. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 8–12.

Jenkins, K.M.; Diehl S.V.; Clausen, C.A.; Green, F. III. 2012. Enzymatic mechanism of oxalate production in the TCA and glyoxylate using various isolates of *Antrodia radiculosa*. In: Proceedings, American Wood Protection Association. Vol. 107. Birmingham, AL: AWPA: 108–113.

Kirker, G.T. 2014. Genetic identification of fungi involved in wood decay. In: Deterioration and Protection of Sustainable Biomaterials. ACS Symposium Series 1158. Washington, DC: American Chemical Society. Chapter 4.

Termite Research

Subterranean termites play dual roles as wood decomposers.

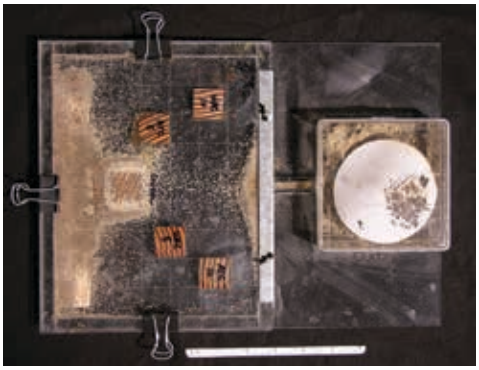
- *Ecologically, termites benefit forest health through nutrient cycling, soil fertility, and carbon flow.*
- *Economically, termites are a leading cause of destruction of in-service wood products and structures.*

Field test examining the distance of termite foraging away from certain soil termiticides.

Conditions regulating native subterranean termites in natural habitats are poorly understood. As primary wood decomposers, termites contribute to nutrient cycling, soil fertility and stability, and forest productivity, so alterations to ecosystems from climate change are critical. Research is needed to investigate biological, ecological, and physical parameters associated with diversity and distribution of termites in forest ecosystems. This research will provide an understanding of habitat requirements supporting different termite species and serve as the platform for more complex studies on termite colony, population, and community dynamics that support the development and implementation of improved integrated treatment strategies directed against termites.

A concrete slab test evaluates soil-applied termiticides.

Research on temporal and spatial effects of sub-lethal doses of termiticides on foraging behavior and termite physiology is needed. Likewise, distribution and fate of termiticides in soil may be intimately linked to termite control failures and means of prevention. Understanding the role of symbiotic microbiota of termites in regulating colony health may elucidate factors that allow some termite species to survive control measures. Research findings may point to a specific microbial metabolite from termite gut microorganisms that can be used to develop targeted and integrated pest control methods.



Laboratory choice test allows researchers to compare different wood treatments for resistance to termite damage.

Costs of repairs associated with structural damage caused by termites and protection measures to prevent termite damage are estimated to be $10 billion annually in the United States. Economic losses resulting from the northward spread of termites are projected to grow as a result of changes in climate, underscoring the importance of protecting structural building components from this pest through the development of environmentally safe and effective biocides and targeted baiting techniques.

Subterranean termite damage accounts for over $10 billion annually in treatment and remediation costs to wooden structures in the United States.

Termite field study in cooperation with Louisiana State University (Sam Houston Jones State Park, Lake Charles, Louisiana).

Laboratory no-choice test provides information on repellency of wood treatments and termite survival after feeding.

Damage caused by Formosan subterranean termites after only 6 months.

Research Highlights

- Developed community-wide termite eradication program utilizing an experimental termiticide and successfully rid a rural Wisconsin community of a chronic termite infestation
- Demonstrated that oleic acid induced building behavior in wood blocks by *Reticulitermes virginicus* Banks, suggesting strong synergism between tactile and chemical cues
- Examined disturbance of termite foraging stations at various intervals to determine the effect of minor disturbance on *Reticulitermes* sp. trap affinity in the field, which is important for bait scheduling during remedial termite control
- Conducted studies on termiticide transfer in *Reticulitermes virginicus* Banks that suggest toxicant transfer by contact may be influenced by crowding
- Conducting field tests to generate data needed for EPA termiticide registration of new products

Notable Publications

Green III, F.; Arango, R.A.; Esenther, G.R. 2010. Observations on colony collapse in *Reticulitermes flavipes* (Kollar) in laboratory and field settings in Wisconsin. International Research Group on Wood Protection, Stockholm, Sweden. IRG/WP/10-10709. 12 p.

Shelton, T.G. 2013. The influence of fipronil on *Reticulitermes flavipes* (Isoptera:Rhinotermitidae) feeding beyond treated plots. Journal of Economic Entomology. 106(5): 2160–2166.

Shelton, T.G.; Wagner, T.L.; Peterson, C.J.; Mulrooney, J.E. 2014. Subterranean termite control evaluations on current and former experimental forests and ranges. In: USDA Forest Service experimental forests and ranges—research for the long term. New York: Springer. 672 p. Chapter 12.

Ulyshen, M.D.; Wagner, T.L.; Mulrooney, J.E. 2014. Contrasting effects of insect exclusion on wood loss in a temperate forest. Ecosphere 5(4): Article 47. 15 p.

Wood Preservation

The use of chromated copper arsenate (CCA), creosote, and pentachlorophenol will continue for many industrial and commercial applications. However, these conventional preservatives and newer copper-based systems may face increasing environmental regulatory pressures. More environmentally compatible preservatives are needed to replace conventional broad-spectrum biocides.

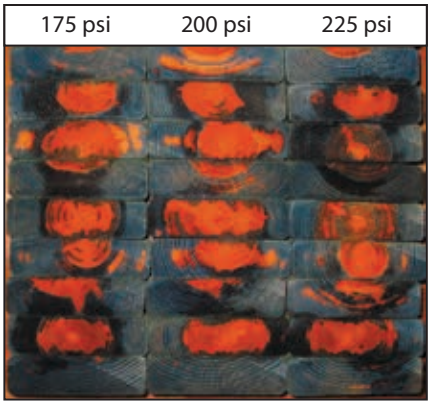
Evaluating the use of treated wood in sensitive environments.

One way to reduce environmental impact is to target the treatment to a specific application (above-ground or in-ground) in a specific environment.

Reducing the environmental impact of preservative-treated wood, including its potential adverse effects on water quality, is critical and requires research to identify best practices that reduce leaching from treated wood in laboratory and field tests.

To bring a new preservative to the marketplace, comprehensive performance data must be obtained. Current methodologies to determine the durability of test specimens are insufficient, and long-term field testing is required to ensure that a treatment is effective. Better accelerated test methods will reduce the time needed for development and acceptance of new environmentally preferable preservatives and allow the use of preservative treatments that are more closely matched to the severity of the deterioration hazards for each use.

Maintaining a diversity of tree species is important for improving the health and biodiversity of our national forests. Thus, increasing the market potential of a diverse range of hardwood and softwood species is in the public interest, and preservative treatments could markedly improve such market potential. Low-cost treatment options for small-diameter materials are needed to develop value-added markets for excess biomass and help reduce the wildfire hazard.



Improving treatment processes.

Evaluating naturally durable, invasive, and underutilized wood species for above-ground applications. Chemical extractives from these wood species may be used to develop environmentally benign wood preservatives.

To bring a new preservative to the marketplace, comprehensive performance data must be obtained.

Field treatments to preserve historic covered bridges.

Experimental preservative treatments, naturally durable domestic woods, and wood–plastic composites are being evaluated side-by-side in the boardwalk leading to the advanced housing demonstration and research facility at FPL.

Research Highlights

- Demonstrated that minimum length of time currently required by industry standards for field testing preservative-treated wood provides only about 50% confidence that a product will be durable in the long term but extending the testing by only 2 more years increases that confidence to 85%
- Showed that small test specimens that degrade an average of 2.2 times faster may not reflect performance of larger commercial products
- Published manuals providing guidelines on preservative treatment specifications for new timber bridges and bridge components, preservation and rehabilitation of historic covered bridges, and use of treated wood in boardwalks and structures in National Forests, including structures over sensitive wetlands
- Evaluate and periodically summarize efficacy of preservatives in softwoods and hardwoods in long-term field studies

Notable Publications

Lebow, S.T. 2010. Wood preservation. In: Wood handbook—Wood as an engineering material. General Technical Report FPL–GTR–190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p. Chapter 15.

Woodward, B.M.; Hatfield, C.A.; Lebow, S.T. 2011. Comparison of wood preservative in stake tests. Research Note FPL–RN–0327. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 120 p.

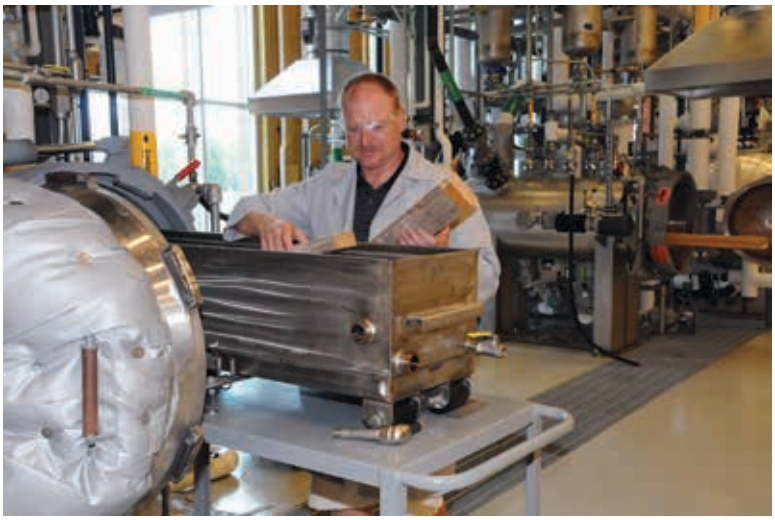
Kirker, G.T.; Blodgett, A.B.; Lebow, S.T.; Clausen, C.A. 2012. Above ground field evaluation and GC-MS analysis of naturally durable wood species. Stockholm, Sweden: International Research Group on Wood Protection: IRG/WP 12-10764. 13 p. ISSN 2000-8953.

Hayward, D.; Lebow, S.T.; Brooks, K.M. 2012. Methods for mitigating the environmental risks associated with wood preservatives. In: Morrell, J.J.; Brooks, K.M.; Davis, C.M., eds. Managing treated wood in aquatic environments. Madison, WI: Forest Products Society: 407–434. Chapter 11.

Durability and Wood Protection

Research facilities

- Pilot-scale pressure treatment facility
- Microbiology, entomology and chemistry laboratories
- Fungal cellar
- Field test exposure sites:
  - Green Valley, Arizona (Hazard Class 1)
  - Clarksdale, Florida (Hazard Class 5)
  - Starkville, Mississippi (Hazard Class 4)
  - Saucier, Mississippi (Hazard Class 5)
  - Union, South Carolina (Hazard Class 4)
  - Madison, Wisconsin (Hazard Class 2)



Pilot-scale treatment plant at the Forest Products Laboratory.

Research capabilities

Decay resistance tests are important for many products exposed to moisture:

- AWPA E10—Soil block fungal culture laboratory test
- AWPA E9, E16, E18, and E21—Tests for wood used above ground
- AWPA E7 and E9—Tests for wood used in ground contact

Termite protection is important for wood used either indoors or outdoors:

- AWPA E1—Laboratory termite method
- AWPA E21—Field termite method

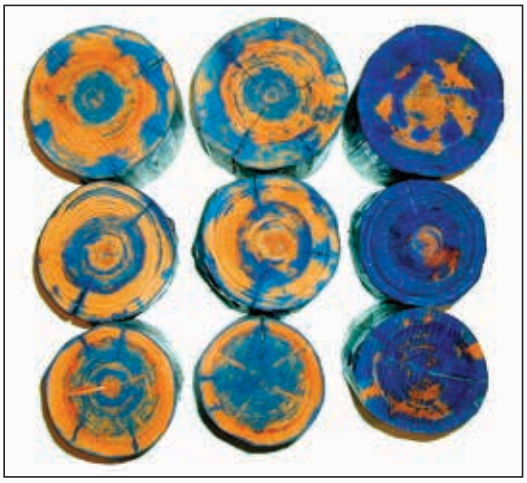
Specific field tests are required for federal registration of soil-applied termiticides:

- Ground board test—Monitors efficacy of a soil treatment when exposed to weathering
- Concrete slab test—Evaluates efficacy of a soil treatment when protected from weathering
- Stake test—Monitors efficacy of deep treatments in soil exposed to weathering
- New protocols for soil-applied termiticides—Developed in cooperation with EPA and ASPCRO

Treatability tests are conducted to determine how well a preservative penetrates the wood during pressure treatment.

Leaching resistance must be evaluated for treated wood exposed outdoors.

Concrete slab test simulates a soil-applied termiticide protected from direct exposure to weather.



Treatability test.

Durability and Wood Protection

How can we help you?

Durable wood products benefit the public and promote sustainable use of our forest resources.

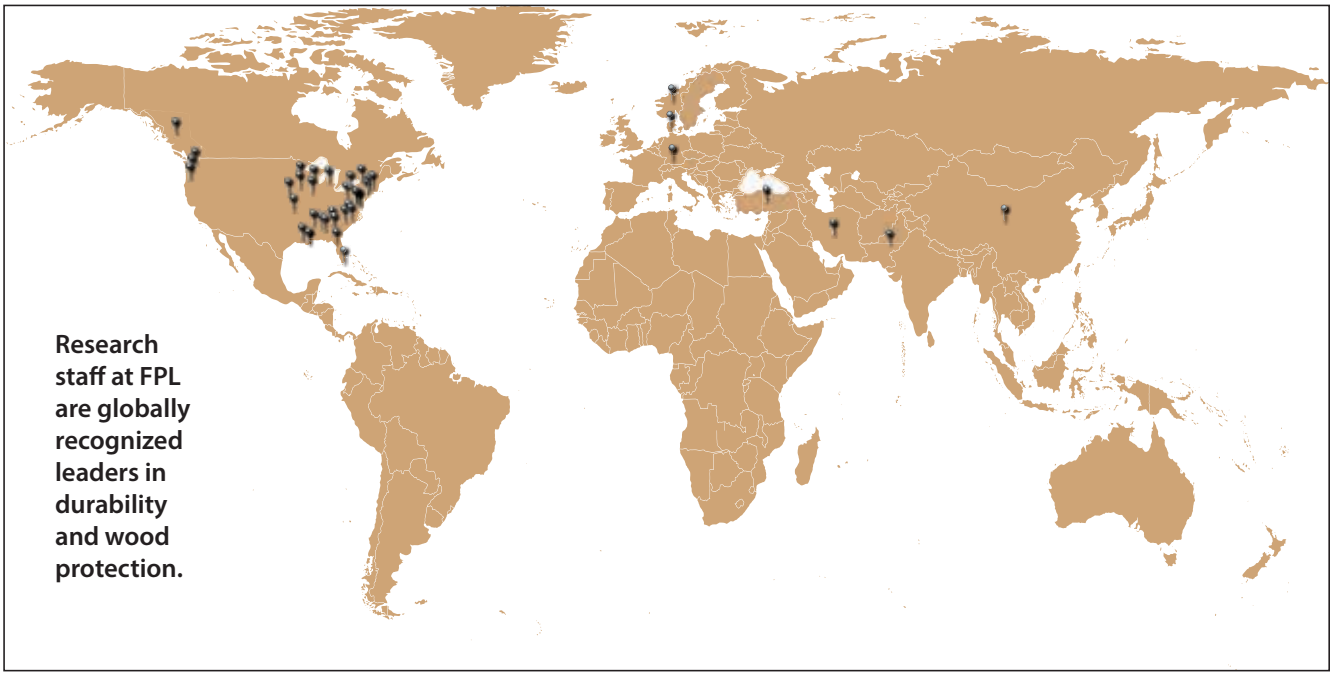
Our research continually explores innovative methods for making wood more durable. We work with internal and external cooperators to conduct a wide range of standardized and experimental tests that evaluate how well a product might perform in different applications.

Our durability and wood protection scientists have a broad background in wood science, forest products, entomology, biochemistry, and microbiology.

We welcome the opportunity to partner with industry, academia, trade associations, non-government organizations, and federal, state, and local government agencies to convert research into usable information and technology.

Centennial Research Facility at the Forest Products Laboratory.

***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.*



Forest Products Laboratory

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

Our Mission

To promote healthy forests and forest-based economies through the efficient, sustainable use of our wood resources

Current Focus Areas

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

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

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

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

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

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