WOOD SCIENCE AND TECHNOLOGY:
A NATIONAL RESEARCH NEEDS ASSESSMENT WORKSHOP

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EXECUTIVE SUMMARY

The mission of the Society of Wood Science and Technology (SWST) is to provide service to members; develop, maintain, and promulgate the educational, scientific, and ethical standards that define the profession; and advocate the socially responsible production and use of wood and lignocellulosic products. SWST believes that it is necessary to regularly review research needs in light of drivers and changes occurring within and external to the wood products community. Because of evolving social, economic and environmental priorities and perspectives, it has again become clear that a periodic review of research needs and priorities in wood science and technology was needed in light of today's drivers for change and emerging issues. Accordingly, SWST sponsored a National Research Needs Assessment (NRNA) Workshop (June 25, 2008) in St Louis, Missouri. The NRNA workshop was to provide a forum from which a unified and prioritized vision of research needs in wood science and technology (WS&T) would be created for SWST members. At the same time the American Society of Civil Engineers (ASCE) committed to having a parallel workshop on wood engineering needs and priorities. It was decided that both ASCE and SWST would conduct their respective workshops, then share the outcomes and seek to appropriately merge the two outcomes.

The purpose of this SWST NRNA workshop was to *develop a unified and prioritized consensus and then develop an agenda for wood products research needs and opportunities among industry, universities and government.*

The attendees at the SWST NRNA Workshop acknowledged that the following drivers variously affected societal, economic and environmental needs for research and development:

- Accelerating pace of science and technology
- Growing population and affluence and changing demographics
- Achieving National energy security
- Integration of the World economy with subsequent escalation of industrial quality and cost competitiveness
- Mitigating the impacts of climate change through reduced use of fossil fuels
- Reducing the environmental footprint of human activities
- Reducing the carbon footprint of products and manufacturing processes
- Increasing efficiency of energy- and materials-use
- Emergence of the concepts of Sustainability, Green Buildings, Green Chemistry, and Green Engineering
- Need for making rationale comparisons among competing products and materials via use of life cycle assessment

To address these societal, economic and environmental needs, the participants focused discussions on eight broad research areas in wood and lignocellulosic science and its technologies. Many of the social, economic and environmental drivers and critical research issues related to and affected more than one research area. Thus, while it may appear several times, the integrity of the individual research areas has been maintained. .

Those eight research areas were:

- Manufacturing and Processing
- Building Systems
- Fundamentals/Material Science
- Environmental Issues
- Education
- Sustainability
- Marketing
- Modification Technology

From these eight (8) Research Area reviews, the consensus of the participants, as documented in this report, recommends the following actions be undertaken by SWST:

- Influence policy makers about the need for research in the diverse areas in wood science and technology
- Influence public perception about the environmental benefits of using wood and similar bio-based lignocellulosic materials
- Communicate to congress and funding agencies about the need to support fundamental research in wood science and technology, advanced bio-based composites, and the use of wood as a means to achieve energy efficiency and improved carbon sequestration
- Engage and educate stakeholders and partners in other professions
- Obtain funding from government funding agencies and through partnerships with businesses and organizations
- Develop active research programs to provide fundamental knowledge on wood and lignocellulosic material properties to support development of advanced materials having improved energy footprints and environmental quality
- Transfer research findings to industry, codes and government agencies and incorporate them into user and industrial practices

INTRODUCTION

Drivers of Change

There are many diverse organizations and groups who have well-established interests and goals tied to the use of wood and the social, economic and environmental issues surrounding its use. These interests and goals include jobs and commercial exploitation, recycling and reuse, sustainable production and use, conservation, international competitiveness, and meeting the basic material needs of people for food, clothing, and shelter. Also arising both from within and exterior to the wood products community are other drivers for change. Significant drivers of change affecting the wood products sector as well as other product sectors include:

- o Accelerating pace of science and technology
- o Growing population and affluence and changing demographics
- o Achieving National energy security
- o Integration of the World economy and subsequent escalation of industrial quality and cost competitiveness
- o Mitigating the impacts of climate change through reduced use of fossil fuels
- o Reducing the environmental footprint of human activities
- o Reducing the carbon footprint of products and manufacturing processes
- o Increasing efficiency of energy and materials use
- o Emergence of the concepts of Sustainability, Green Buildings, Green Chemistry, and Green Engineering
- o Public acceptance for making science-based comparisons among competing products and materials via use of life cycle assessment

These drivers and resulting issues, concepts, and opportunities are either already affecting or are poised to affect the wood products sector as the 21st Century progresses. Resulting issues, concepts, and opportunities from these drivers of change include bioenergy, biofuels, and chemical feedstocks; nanotechnology; carbon sequestration and carbon markets; and genetically modified trees and purpose grown (i.e. properties tailored for certain end uses) trees. Other forest products drivers of change include: 1) industrial forest land ownership transitioning from vertically integrated forest products producers to Timber Investment Management Organizations (TIMOs) that acquire and manage land on behalf of large institutional investors; 2) conversion of some forest products companies to Real Estate Investment Trusts; 3) the impacts of information technology and the internet negatively affecting demand for printing and writing papers including newsprint and magazine grades; and 4) fragmentation, parcelization and conversion of privately held forestlands to non-forest uses. Additional emerging issues that will likely impact forestlands and forest products include the desire to determine and quantify the value of forest ecosystem services and carbon markets/carbon trading. In many cases the goals and objectives arising from these drivers of change and the resulting issues, concepts, and opportunities cannot be responded to or capitalized upon within the wood products sector without developing new enabling or underpinning fundamental wood science and technology.

Responding to Science and Technology Gaps

To allow the wood products sector to be responsive to challenges and opportunities, the wood products science community needs to be actively engaged by first assisting policymakers, industry and governmental officials with translating government and industry goals and objectives into the underlying and enabling wood science and technology needs and gaps. For example, an industry goal of reducing energy consumption in producing wood-based materials by 40 percent from current state-of-the-art capabilities is a very worthy and responsible goal. However to achieve this goal requires analysis to determine possible approaches followed by vetting and reaching consensus on the science and technology gaps that need to be bridged--such as understanding water-cellulose interactions at the nanoscale. The next step after identifying and reaching consensus on science and technology gaps is for the wood science community to then develop and deliver the enabling science and technology required.

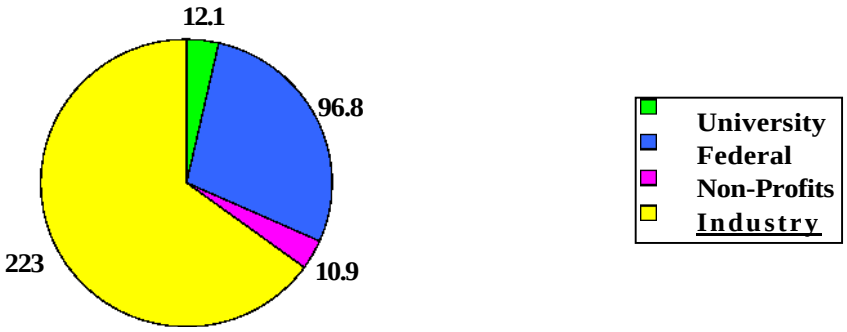
In bridging commonly agreed upon gaps in science and technology, the wood products community can pool resources and gain synergies by focusing on fundamental, pre-competitive research. **Focusing on pre-competitive fundamentals has many benefits.** It allows for broadly sharing information and new knowledge; reduces research costs; speeds up arrival at solutions to problems or capitalizing on new opportunities; allows for applications based upon first principles; reduces duplication of effort; and preserves the ability of private industry to reap the benefits of customize applications of fundamental or enabling science and technology results for their own individual company's advantage in the marketplace. In addition, industry traditionally does not focus on fundamental research but instead focuses on less risky but more costly development activities. These development activities are usually proprietary in nature and are biased heavily toward product development and product introductions into the marketplace.

While the forest products industry has become somewhat less fragmented through consolidation of companies through mergers and acquisitions and shutdowns and closures of older and less efficient production lines, companies generally have limited resources for research and development (R&D) and depend on government and government-sponsored entities for research. Because companies--whether large, medium or small--are facing increasing global competition for markets, research is even more important to maintaining the positive economic, social and ecological contributions of businesses and production facilities. Universities and government laboratories play a critically important role in conducting research. In addition, universities also play a unique and critical role in undergraduate and graduate education by preparing new workers to be successful in applying new science and technology within the industry.

With respect to funding, cumulatively across all economic sectors including forest products, the Federal government and industry are the largest contributors of R&D funding in the United States (Figure 1). Federal government funding and activity focuses more toward fundamental research on new and high-risk innovative science

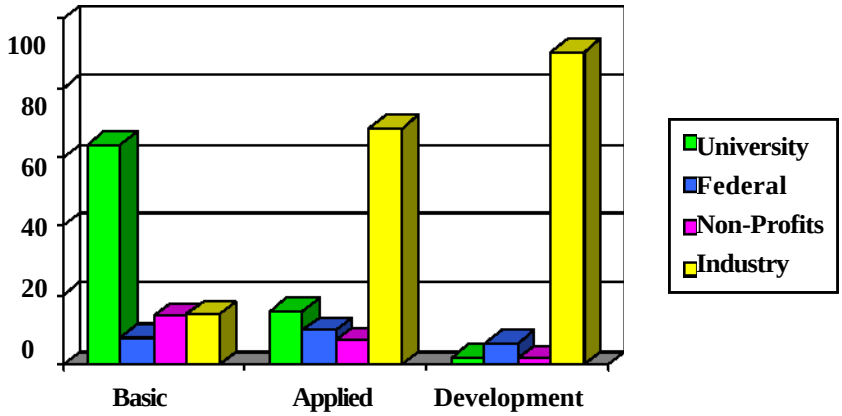
and technology whereas industry funding and activity focuses on development where risks are reduced and the path forward to commercialization is more clearly defined (Figure 2). **It is possible, if not critical, to forge a connection between public interests (i.e., Federal government) and industry/private sector interests.** This is because the challenges and opportunities faced by industry are very frequently strongly linked to Federal interests such as jobs/job creation; energy security; sustainable use of forest-based materials; offsetting the costs of sustainable forest management on public and private lands; maintaining open spaces and preserving the array of ecological services provided by forests to include clean water, clean air, animal habitat, aquifer recharging, recreation, open space esthetics, etc.; and exploiting unique features and characteristics of the U.S. wood supply to meet the material needs of citizens.

Figure 1 R&D Funding Sources—Billion of Dollars (*NSF 2006*)



Total 2006 US R&D Funding $342.9 Billion

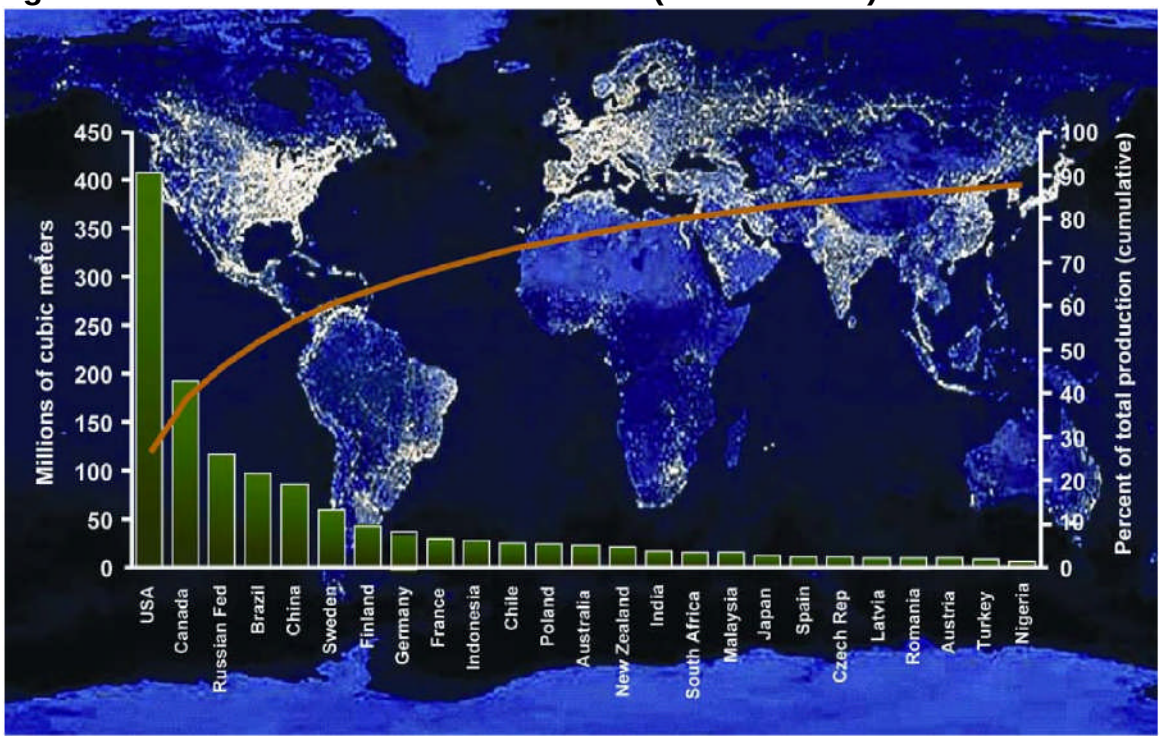
Figure 2 US R&D by who carries out the R&D (*NSF 2006*)



Wood and Wood Science-New Opportunities

World-wide, forests provide a vast timber resource that is geographically and geopolitically dispersed among 150 countries. These 150 countries account for 97.5% of the world's forests. **Globally, approximately 3.87 billion hectares (ha) (i.e., 29.6%) are covered by forests; out of a total land mass of 13.06 billion ha.** The forests of the world contain over 386 billion m^3 of standing timber with annual use being on the order of approximately 3.8 billion m^3 per year. The importance of wood in the economy of the U.S. and North America cannot be understated. With approximately 226 million ha of forestland, the US produces about 25% of the world's industrial roundwood. Together the US and Canada produce approximately 40% of the world's industrial roundwood (Figure 3).

Figure 3 Industrial Roundwood Production (*UN FAO 2005*)



Wood is a cellular hierarchical biocomposite (Figure 4) made up of cellulose, hemicellulose, lignin, extractives and trace elements. Wood, as with many other biological tissues, is a hierarchically structured composite in order to provide maximum strength with a minimum of material. Wood is approximately 30 – 40% cellulose by weight with about half of the cellulose in nanocrystalline form and half in amorphous form.

Cellulose is the most common organic polymer in the World representing about 1.5 x 10^{12} tons of the total annual biomass production. Cellulose is the major carbohydrate component of wood along with the hemicelluloses (20 – 35% by weight). Lignin, extractives, and trace amounts of other materials make up the remaining portion of

wood. Cellulose is expressed from enzyme rosettes as 3 - 5 nm diameter fibrils that aggregate into larger microfibrils up to 20 nm in diameter. These fibrils self assemble in a manner similar to liquid crystals leading to nanodimensional and larger structures seen in typical plant cell walls. The theoretical modulus of a cellulose molecule is around 250 GPa, but measurements for the stiffness of cellulose in the cell wall are around 130 GPa. This means that cellulose is a high performance material comparable with the best materials available anywhere.

While a great deal of valuable research has led to our understanding of many mechanisms relating to the properties of wood and wood-based products, the overall complexity structure of wood has limited discovery. Today we have new generations of analytical tools being developed in emerging science and technology areas such as nanotechnology that are allowing us to look at material structures down to the nanometer and atomic scales and quantify properties. In addition, **the nanoscale is also the dimension where quantum mechanics and classical mechanics intersect and many well-known, well characterized materials can display unique properties different from the bulk properties** in this 1 - 100 nanometer range. While these new analytical tools are fueling discovery in a wide range of inorganic and biomimetic materials, studies on wood are only now beginning. Simpler structures found in seashells, insect cuticles and bones are being investigated as relating to their hierarchical structures and we are at the point where we need to adapt and refine these techniques for application to wood and wood-based materials and products. While we have accomplished much in understanding and exploiting the capabilities of wood at the macro- to micro-scale levels, **there is much about wood that is yet to be understood and exploited at the nanoscale and atomic scales.**

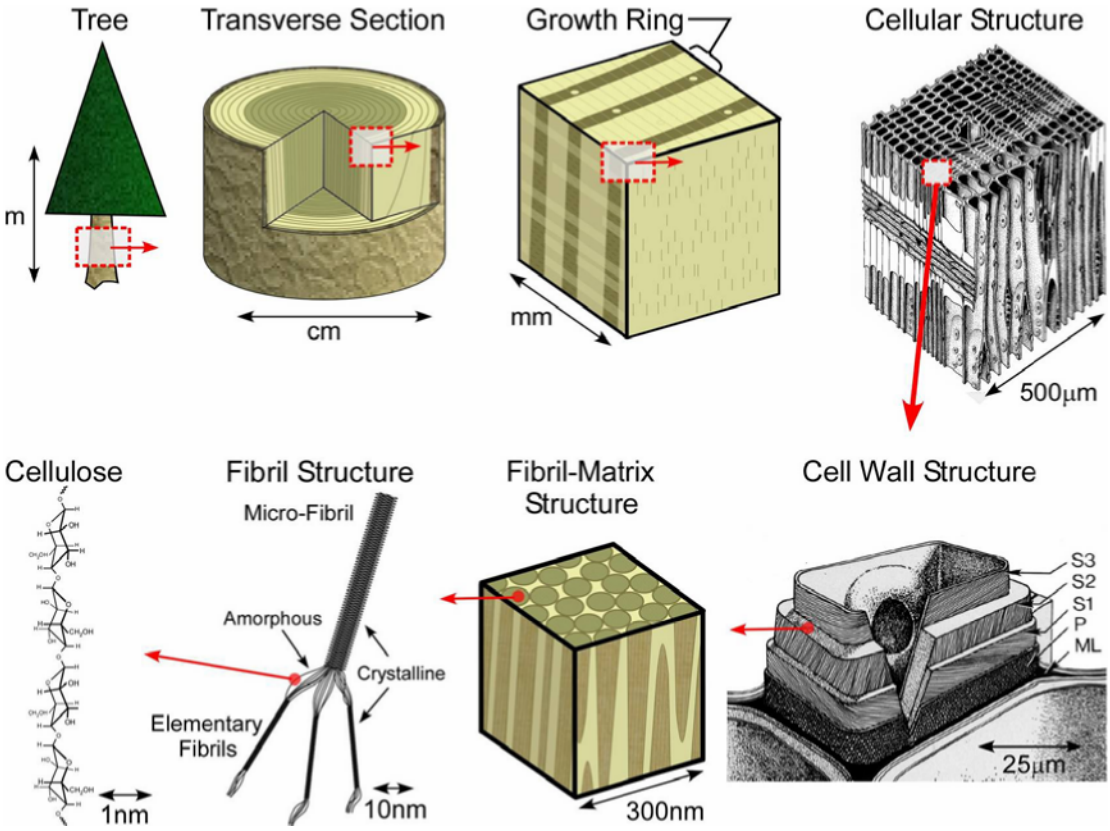
To date, the use of wood has been primarily focused on top down conversion applications in which larger scale pieces of wood are broken down to smaller ones, as low as the millimeter and micrometer scales, and converted to products. However as the 21st Century progresses, **it is expected that improved science and technology will allow many future value-added products to be made via bottoms up manufacturing processes where atomic and nanometer scale architectures are hierarchically- assembled into macro-scale products with unique properties and multifunctional capabilities.** This bottoms-up manufacturing concept is also expected to be achievable with wood-based products as we develop the needed science and technology of wood and its structures at the atomic and nanoscales. Also because we are utilizing a material produced by a living organism, tree biotechnology to include genetic modification will give us the tools to manipulate atomic and nanoscale structures in wood to produce new commercially important properties.

Setting Wood Science and Technology Research Priorities

Among the great strengths of the wood products industry and associated user industries is its large size, range in size of individual producers (i.e. small saw millers to large integrated producers of lumber and composites), diversity of wood products users, and the relatively large numbers of groups involved in setting its needs and research agenda. However, no single group seems to completely capture all of the aspects of the wood products sector needs and priorities. This makes it difficult for the wood products research and development community to adequately focus and bring to bear

finite research and development resources and capacity. With so many drivers of change giving rise to new needs and opportunities, it becomes very difficult to simultaneously

Figure 4 Wood Hierarchical Structure--From Tree to Cellulose (*Moon 2008*)



make adequate progress on all needs and opportunities. As a result, the R&D program of work carried out within the industry, universities, private research laboratories, and government laboratories may best be described as fragmented or diluted. While there is strength in this diversity of issues and priorities, **it is often difficult to convince government decision makers and other research funding groups to focus efforts on wood products research because there is no unified vision and consensus on research needs and priorities** for the short term (3-5 years), mid-term (5-10 years) and long term (10 – 20 years) nor has consensus been reached on the critical, underlying basic science needs. With so many needs and opportunities giving rise to an even greater number of resulting R&D science and technology needs, we need to come to consensus by adequately describing, prioritizing, and communicating our path forward in a unified way across a majority of the wood products community.

VISION & GOALS FOR NRNA WORKSHOP

The mission of the Society of Wood Science and Technology (SWST) is to provide service to members; develop, maintain, and promulgate the educational, scientific, and ethical standards that define the profession; and advocate the socially responsible production and use of wood and lignocellulosic products. In carrying out this mission, SWST has goals of:

- Developing and maintaining the unique body of knowledge distinctive to wood science, lignocellulosic materials, and their technologies
- Encouraging the communication and use of this knowledge
- Promoting policies and procedures which assure the wise use of wood and lignocellulosic materials
- Encouraging high standards for professional performance of wood scientists and technologists and acting as the professional organization for individuals who meet these standards
- Fostering education programs at all levels of wood science, lignocellulosic materials, and their technologies and furthering the quality of such programs.
- Representing the profession in public policy development

In carrying out the mission of SWST, it is necessary to regularly review research needs in light of drivers and changes occurring within and external to the wood products community. For many years each the fall (September – October time frame), the National Association of Professional Forestry Schools and Colleges (NAPFSC) and USDA Forest R&D co-hosted a series of 1.5 - 2 day research conferences to discuss national wood products utilization research needs and topics. This provided a forum for selected speakers to give presentations on research needs, new and emerging opportunities, and new science and technology. This annual research conference was held at the USDA Forest Service, Forest Products Laboratory (FPL) (Madison, WI) as the bulk of Forest Service utilization research is carried out at the FPL. The conference was regularly attended by a number of SWST members and effectively served the purpose of a periodic review of wood science and technology needs and emerging issues. However, over time, static or declining budgets for research within the USDA Forest Service resulted in fewer and fewer Forest Service Research funds being available for cooperative research conducted with universities. This led to reduced university interest and attendance at the conference and reduced attendance. Eventually the conference was discontinued, with the last NAPFSC - Forest Service R&D conference being held in September 2004.

Since that time, NAPFSC has become the National Association of University Forest Research Programs (NAUFRP) and no other forum has developed to fill the void. Over the ensuing years it has become clear that it is periodically necessary to review and prioritize wood science and technology needs in light of today's drivers of change and emerging issues. Recognition of this periodic need was the primary motivation for the SWST-sponsored National Research Needs Assessment (NRNA) Workshop (June 25, 2008 - St Louis, Missouri). **The NRNA workshop provided a forum from which**

a unified and prioritized vision of research needs in wood science and technology (WS&T) would be created for SWST members. At the same time, on a parallel path to also counter the loss of the NAUFRP – Forest Service R&D conference, the American Society of Civil Engineers (ASCE) decided to conduct a workshop related to wood engineering issues (May 2008 - World Structures Congress, Vancouver, British Columbia, Canada). While this ASCE workshop was very helpful, it would not fully encompass all the needs as a broader effort going beyond structures was needed for all disciplines and end-use applications of wood science and technology. Therefore, SWST decided that a NRNA workshop was needed with a focus on wood science and technology needs and priorities that encompassed the full array of applications and end uses. Because ASCE was committed to having a working conference on wood engineering needs and priorities, it was decide that both **ASCE and SWST would conduct their respective workshops, share the outcomes, and seek to appropriately merge the two outcomes.**

The purpose of this SWST NRNA workshop was to develop a unified and prioritized consensus and then develop an agenda for wood products research needs and opportunities among industry, universities and government. The expected benefits of having the NRNA Workshop and a unified and prioritized agenda are to help the wood products industry be more successful; unify and prioritize research needs from the several research agendas developed by various wood products stakeholder groups; increase research funding availability and better focus funding on critical research needs; identify underlying science required for new enabling technologies; increase undergraduate and graduate educational opportunities and train people for jobs in the industry; and provide a forum for increased networking, coordination, and leveraging of programs within the wood products research community.

INDIVIDUAL BREAKOUT GROUP WRITE-UPS

To address these economic, environmental and societal needs, the SWST NRNA Workshop participants focused discussions on eight broad research areas in wood and lignocellulosic science and its technologies.

- Manufacturing and Processing
- Building Systems
- Fundamentals/Material Science
- Environmental Issues
- Education
- Sustainability
- Marketing
- Modification Technology

Each of the eight research area write-up was developed from initial open-forum group discussions which led a group consensus and an eventual write-up of those concepts, issues and ideas that includes a:

1. Preface,
2. Vision,
3. Identification of Research Drivers and Needs,
4. Goals and Benefits of the identified Research, and
5. Steps to Achieve the Goals.

MANUFACTURING AND PROCESSING

Preface: Manufacturing and Processing are the paths by which trees are converted into value added products. The conversion of trees into lumber is often an issue of maximizing yield. More recently the conversion of trees into wood and bio-based composites largely addresses the yield issue to the extent that virtually all of the woody fiber, less the bark, can be converted into useable products. With composites, the problem is shifted from maximizing yield to maximizing production efficiency.

In a broad sense, products encompass all of the tangible and desirable outputs from conversion process. Some of these include wood composites, engineered products, wood plastic hybrids, chemicals and chemical feed stocks, energy and fuels, paper and paperboard, pharmaceuticals, and so on. Connected to the conceptual technical backbone of product conversion are a variety of systems and issues. This section of the National Research Needs Assessment addresses the issues most closely associated with manufacturing and processing.

Vision: Optimize the manufacturing and processing of wood and bio-based materials for the maximum sustainable economic, social, and environmental benefits.

The Problem (Drivers): As the housing market has recently declined and the economy has slowed the forest products industry has encountered monumental challenges. Combined with an increase in energy and transportation costs; it is likely that the US will see further mill consolidations, curtailments, and closures. Additionally, changes in woody raw materials, overall resources, environmental perceptions, and customer demands continually bring further challenges into the picture. With the recent decline of the economy in general and the housing sector in particular, industry activity and employment have declined precipitously. The immediate ripple effect radiates from mills both to timberland owners who see declines in tree values and to vendors, suppliers, and other support businesses.

Research and development of new products along with analysis of yield efficiencies have traditionally been the first areas that are eliminated by the forest products industry during challenging economic conditions. The development of new products, alternative outputs, and increased efficiency is, however, one of the key ways by which companies survive and thrive.

Another factor that influences domestic competitiveness is the ability to follow and track the supply chain of the manufacturing process to allow producers to compete at the global level with certified products. Increasing environmental policies will require that more and more products need to carry certification that identifies that the products were produced in a sustainable manner, that they will perform well in the environment, and

that they will have little or no impact on their environment. With increasing concerns about water, the importance of recycling, carbon sequestration, and the general health of the planet, it is important that the wood converting community both act and is perceived as the leader and not followers of these important issues.

The collective ability of SWST to provide technology transfer to the industry is a mixed bag, i.e., it is wonderful in some respects but lackluster in others. It is important that the Society maintains a focus on core issues such as production, innovation, design, and education.

Research Areas: With respect to processing and manufacturing, there are many direct and indirect research areas. Perhaps the greatest opportunities exist in the latter. Some of the most critical include the following.

Adoption and adaptation/modification of technology from allied industries: There are many ways by which roundwood is sawn, refined, and otherwise processed into smaller elements for direct use or reconstitution. New methods are continually being developed and refined for commercial viability. New ideas and new products are almost always associated with new machinery and equipment. Often a key to generating ideas about new products and equipment is cross pollination with other related disciplines. Another related avenue is through hybridization of products. Wood can be combined in innovative ways with wood and/or non-wood nanofibers, glass, resins, aluminum and other metals, inorganics, wood and/or non-wood recycled products to produce items that address societal needs. These should be explored. It is important that SWST maintain a contact network that allows for importing ideas and technology from outside the SWST group.

Product enhancement: Market consensus suggests that solid lumber and minimally refined engineered composites are favorable with respect to maximizing customer value in the housing sector (the largest market for wood products). A variety of research opportunities remain with respect to retaining maximum lumber value through the conversion chain, improving physical and mechanical properties of existing products, and enhancing durability such as to protect people's homes a major investment.

Optimization: Starting with production forestry, through conversion, final product architecture, and structural design, there is room for further merchandising and optimization. It is appropriate that machine-driven or machine-enhanced decision making be developed and implemented as early on in the conversion process as possible. Furthermore, optimization should be integrated throughout as a means of assuring the maximum possible return on each woody fiber.

Energy policy: There are many ways by which to extract energy from wood. From mundane to high-tech these include direct combustion, gasification, charcoaling, cellulosic ethanol, and bio oil among others. The carbon-based nature of wood has many attributes which make it attractive as a means of

producing green heat, electricity, or other energy. Research to date has largely focused on technical issues of conversion and production of exothermic fuels. More research is needed with respect to the economic, energetic, and environmental life cycle analysis of bio fuels and bio energy. Such information would be of significant value to SWST in the effort to contribute to the development of prudent national energy policy. Additionally, such research is of value not only to the U.S. but also internationally, especially in developing nations.

Environmental impacts: Over time, air, water, and solid waste regulations, permitting, and disposal/emission abatement costs appear to increase. Furthermore, waste generation is generally a detractor from green product value. Finally, there is often benefit associated with converting waste products into co-products. Meaning, rather than pay for permits and disposal fees, there are often opportunities to market co-products into the commerce stream. Some examples of successful co-products include selling bark for mulch, selling sawdust for fuel or animal bedding, and condensing vapor to bio-oil as part of the charcoaling process. Reducing waste and developing new markets for co-products is one of the single largest means by which the SWST community can address the issue of environmental impacts.

Resources that:

We have	We need
A great understanding of the materials we use	A better understanding of the utilization of wood with other materials
The knowledge about our own industry, to help optimize it.	Proper technology transfer/Extension programs to convey this knowledge. An increased knowledge of ways and means by which we are interconnected with other allied industries and commercial interests.
Network of manufacturers in place	Tighter connections and clustering of manufacturers to optimize what each plant makes.
Researchers in forest products business models	More global perspective that is more widely shared. A better ability to anticipate future trends such as a decreasing average house size houses, new markets for wood energy, opportunities for as fuel for electrical generation, etc.
A green material	Provide impact information about our environmental benefits.

An understanding of what is desirable in a raw material	Convey the optimum raw material description to those who grow the raw material. The divesting of forest resources by forest products companies will likely make this issue more prominent in the future.
	Continue to find ways and means to add value to underutilized species, such as through energy generation.
	An improved and far reaching campaign to educate and enlighten the general public about the environmental necessity associated with wood utilization.

Steps to Achieve Goals: The overarching goal of the research is to address the needs of a growing population and society with economically viable, environmentally sound, and socially responsible choices. Namely, these choices are centered around the adoption and adaptation of wood-based products and solutions that enhance people's quality of life. Specific goals in support thereof include:

- Promote healthy and sustainable forests and forest-based communities
- Develop technologies for protection and enhancement of housing performance such that homeowners' investments are protected.
- Encourage environmental stewardship with respect to air, water, and land.
- Foster responsible energy generation, management, and consumption.
- Develop materials that are higher in performance and lighter in weight.
- Promote international viability and integration.
- Enhance employment security

BUILDING SYSTEMS

Preface: Inclusion of Building Systems as a component in the national research agenda on wood and lignocellulosic materials provides recognition for the structural use of wood and engineered wood-based products in residential and commercial buildings, with further recognition that wood and wood-based building components sequester carbon, and provide a material that is both renewable and sustainable. Wood is the premier building material for residential construction requiring the least in energy costs for construction (CORRIM 2005). Building codes in some states are allowing use of wood for commercial structures up to three or more floors and fire retardant treatments provide safety for use in apartment complexes and dormitories.

Alternative Title and Components of the Building Systems Agenda: Wood-frame construction, residential construction, deconstruction, sustainable construction, building materials

Vision: To promote the utilization of wood and other lignocellulosic materials as components of building systems, and to promote to the public the benefits of utilizing renewable, carbon-based resources for energy efficiency in construction, reduced costs, and improved quality of life.

The Problem (Research Drivers):

Population growth: Population growth worldwide will increase the demand on resources for new residential construction; the demand for renewable, sustainable materials will increase.

Energy efficiency: The public's demand for energy efficiency will drive the construction industry to reduce costs during construction, while also focusing attention on energy efficient housing and high performance buildings.

Public demand for improved indoor environmental/air quality: It is estimated that people spend 90% of their time indoors; the public's awareness of the health effects related to moisture damage (mold) and materials (e.g. volatile organic compounds) used in buildings and furnishings is driving consumer demand for non-hazardous materials and well-designed structures that will provide a high quality indoor environment.

Changing resources: Resources are shifting from traditional petroleum based products to solar, wind, geothermal, heating systems. Building systems that are designed to incorporate, and be readily adaptable to such heating and ventilation systems will be in demand.

Need for disaster resistance of structures: Recent disasters such as Hurricane Katrina have highlighted the need for disaster resistance in structures, and the use of reusable materials when possible.

Need for efficient use of resources: Building systems composed of wood products that are designed to last, with moisture protection as an essential design consideration; and the use of small diameter timbers and short rotation crops that may provide efficient use of rapidly renewable resources.

Economic factors (cost benefits): The benefits of high quality construction; indoor air quality, energy efficiency, renewability and adaptability will drive the need for designing and building low-cost, energy efficient construction, for structures that can be easily maintained and provide a healthy indoor environment.

Building certification via environmental rating systems: The increasing demand by consumers and municipalities for certified or environmentally rated homes or workplaces, and for public acknowledgment of environmental stewardship, will provide impetus for utilization of materials with a low carbon footprint or which store carbon for long time periods, and are easily recyclable or renewable.

Research Areas

Develop products through creative use of wood resources; produce wood-based materials from short rotation woody crops, and small diameter timbers for use in building systems

Improve the design of building systems by maximizing structural performance of wall systems built with wood and wood-based products

Perform whole house evaluations on the comparative performance of building systems including energy to manufacture, cost to maintain, costs of utilities, air quality

Develop materials that are more reliable, and sustainable, with components that could be easily recycled or modified

Design building systems that are durable, that are designed to offer protection from moisture, minimize or prevent condensation, prolonging service life with improved means of protection

Develop high performance engineered wood products that are lightweight yet strong, with have good insulating properties, and enhanced dimensional stability

Develop methods for reuse/recycling of materials during construction, and for deconstruction

Evaluate the cost effectiveness of new building systems and materials; their manufacture and maintenance

Develop user-friendly building systems; adaptive technologies to monitor and control temperature, relative humidity, light, air quality

Improve the building standards, codes, and rating systems by determining and defining the critical performance measures, evaluating building performance with these measures, and modifying codes, rating systems and standards based on these results.

Expected Goals and Benefits

- Improve the quality of life through the use of building systems that are safe, reliable, and adaptable to new technologies as they develop.
- Make improvements to the long-term performance of building systems and materials
- Enhance the resistance of residences and commercial structures to natural disasters
- Improve the resistance of buildings to man-made disasters (improvements to Homeland Security)
- Develop a means for affordable housing through the development of materials that are cost effective to produce and maintain, with low environmental impact
- Maximize effective use of materials
- Improve building codes and standards
- Reduce waste during construction by identifying and improving methods for deconstruction, and for whole wood utilization

Resources that:

We have	We need
Design codes and specifications	Education to enable implementation of codes and specs
Wood resource	Assessment of materials and systems
Infrastructure to conduct research (small scale)	Funding for research Partnerships for research
Means to test material properties	Performance testing of wood-based and lignocellulosic-based commercial products developed for green construction
LCA/LCI tools	Education and implementation of LCI/LCA
Environmental rating systems (LEED, Green Globes, etc.)	Improvement of environmental rating systems
Small scale research on systems and materials	Large scale testing of building systems

Steps to Achieve Goals

- Influence policy makers about the need for research in building systems utilizing wood and wood-based materials
- Influence public perception about the benefits of using wood as a construction material for green construction
- Communicate to congress and funding agencies about the need to support research on building systems and the use of wood for energy efficiency and carbon sequestration
- Engage stakeholders and partners
- Obtain funding from government funding agencies and through partnerships with businesses and organizations
- Develop active research programs to provide fundamental knowledge on material properties and design of building systems to support new materials, new infrastructure for energy systems, improved indoor environmental quality
- Transfer research findings to industry and government agencies, to incorporate this knowledge into new design and construction practices, into building codes and by modifying to existing environmental rating systems

Leverage Points:

- Economic factors related to efficient use of materials and cost of construction
- Economic factors related to energy consumption
- Safety, homeland security, and health
- Durability and long-term performance
- Energy efficiency
- Adaptability to new technologies as they develop

FUNDAMENTALS/MATERIALS SCIENCE

Preface: If we hope to meet global need for consumer products and building materials in a sustainable, carbon-neutral future we must depend on renewable materials grown and processed in a sustainable manner. Such products must also exceed user needs for performance while minimizing social, environmental and energy costs of production and use. Thus, a materials science approach to material characterization, performance enhancement and processing/manufacturing will be a critical component of the national research agenda in wood science and lignocellulosic materials. To accomplish this we must learn to understand lignocellulosic materials at all scales (i.e. nano, micro, macro, etc) and then develop technology to control manufacturing processes at each level. This section of the National Research Needs Assessment addresses the needs for research in materials science.

Vision: Enhance the performance of wood and other lignocellulosic materials at all levels of awareness. Such enhancements will promote sustainability by allowing world populations to meet their needs of national and global consumer products and construction materials using renewable, bio-based resources. This in turn will increase quality of life and economic security.

Research Drivers and Critical Needs

Develop new tools to broaden our fundamental understanding of wood and other lignocellulosic materials. The premise of applying a materials science approach is required if we are to ensure the global conversion to a sustainable carbon-neutral world economy. As such, we must learn to understand lignocellulosic materials at all scales (i.e. nano, micro, macro, etc) of characterization and then develop technology to control manufacturing processes at each level.

Specific Research Needs in Materials Science:

Properties

- o Wood quality/Material characterization-- fundamental research on understanding basic wood quality for applications in both traditional and novel wood products is still needed. Wood material characterization applying newer rapid assessment technologies such as near infrared spectroscopy, microtomography, NMR, etc. along with the application of statistical analysis tools can help us better understand wood quality.

- o Nanotechnology-- forest products offer special opportunities at the nanoscale. The cellulosic nanocrystallite may provide bio-based nanomaterials for a fraction of the cost of synthetic materials such as carbon nanotubes. Thus, nanotechnology in forest products must continue to

be a significant focus area for research.

- Genetic Traits and Enhancement-- Significant work has been done in the area of tree genetic engineering. That work is now focused on understanding the genetic implications with respect to changing wood chemical properties for easier pulping and composite processing. Basic wood material characterization work needs to be done on genetically modified wood for physical, mechanical and chemical characterization, especially with respect to their interactions and rapid analysis.

- Assessment & Modeling—Hierarchical levels of material characterization are not independent. Molecular features of the natural polymers that comprise the cell wall impact material properties at the macro level. Thus understanding material behavior at any scale would benefit by the development of conceptual and mathematical models that link the various hierarchical scales.

Processing

- Adhesion/Adhesives-- Continuing fundamental work is still needed on understanding the mechanisms of durable wood adhesive bonds. Example areas of potential research topics include fundamental studies on electrostatic mechanism of adhesion in wood, the search for the “Holy Grail” of ascertaining whether covalent bonding occurs between wood and any polymer adhesive, the impact of solubility parameters on wood/adhesive bonding, understanding adhesion in wood/cellulose nanocomposites, and multi-scale modeling and simulation of wood adhesion. Although this is not an exhaustive list of topics, it does point out that there are some potentially fruitful areas for fundamental and applied research in the wood adhesion arena. In the adhesives area continuing work on bio-based adhesives should continue and be encouraged.

- Composite Optimization-- Research in optimizing wood composite products for particular end-product attributes as related to base materials physical, mechanical and chemical properties is necessary.

- Nanocomposites— The probable first application of nanotechnology with commercial implications will involve reinforcement of a variety of composite products with nanocrystaline cellulose and other nanomaterials. Process control of adhesion at nano-scale surfaces and quality control/assurance will need to be quantified, understood, and controlled to exploit these technologies.

- Composite Modeling— Computational modeling of micro- and nano-scale materials and their processes is necessary to provide both the understanding of the materials and control of the manufacturing processes.

Such modeling efforts are critical if new product and process development is desired.

- Process Interactions— Likewise, understanding the physical, material, and chemical interactions of micro- and nano-materials is critical to enhancing composite performance and controlling composite processing.

- Scaling up— Research funding must be made available for researchers to scale up successful bench scale processes to pilot- and commercial-scale applications. This critical area hasn't received enough attention. Programs are needed that can facilitate basic researchers working together with potential industrial partners for scale up. Often this area is high risk, but the potential benefits can be huge. We need to create a bridge over the 'valley of death" between basic research and commercialization of technologies.

Products

- Technology Transfer/Standardization-- As new materials are developed, technology transfer and standards development are necessary to move the new products into the industrial arena. A good example of this topic was the development of wood plastic composites. It took a concerted effort funded by U.S.Navy to a major land-grant university to develop materials and processing knowledge, then promulgate two new ASTM D7031 and D7032 standards.

- Hybrid Products/Intergrated Processing-- Research on hybrid wood-synthetic materials and integrated processing systems should receive continued research focus. There are great opportunities for commercial development of such technologies. Again, science and technology such as these are just beginning to move forward because of joint Federal and/or State funding at a major land-grant universities. However, their success is still severely limited by funding. Examples of the former are combinations of wood with glass, carbon and aramid fibers; and applications of alternative processing technologies, such as vacuum assisted resin transfer molding (VARTM), agglomeration, etc. Examples of the later are approaches like multiple forest bioproducts from the "forest biorefinery" or "value prior to processing" approaches.

- Nanoprocessing— Process control of adhesion at nano-scale surfaces and quality control/assurance will need to be quantified, understood, and controlled to exploit these technologies.

Steps to Achieve Goals

- We need to be better able to participate and/or lead research efforts in biomaterials, bioenergy, and environmental protection.
- We need to integrate our wood- and lignocellulosic-focused science and technology with all materials scientists as well as to the engineering community at large.
- We need to broaden our outlook by expanding our interdisciplinary collaboration, which will improve human capacity to benefit a growing population, provide sustainable materials and housing, and better protect the environment.

Leverage Points

- Enhanced consumer and building products
- Improved environment
- Improved quality of life
- Sustainable, carbon-neutral future for posterity
- Improved national security

ENVIRONMENTAL ISSUES

Preface: Our society has become increasingly aware of environmental issues. Environmental impact, climate change, sustainability and "greenness" have become major decision making criteria for important business and policy matters. Wood has tremendous environmental benefits throughout the life cycle of wood-based products. Lower embodied energy, use of small diameter trees, use of juvenile plantation wood, carbon sequestration and substitute for material with greater green house gas (GHG) emission are just a few examples. Unfortunately, our society has not recognized the environmental benefits of wood, wood-based products and the technology that brought these products to our society. In many cases, our society still perceives cutting trees and using wood as the culprit for shrinking forest lands. With future generations being more environmental conscious, there is a need in research to better explore and use environmental-friendly materials such as wood.

Alternative Titles and Components of the Environmental Issues Agenda

- Life cycle analyses
- Climate change mitigation
- Green material
- Renewable material
- Sustainability

Vision: Broaden the use of wood and wood-based products as an environment-friendly, renewable, carbon-based resource that is a major contributor to our green economy, create green jobs, can mitigate climate change, reduced GHG emission in the United States and preserve our environment for future generations.

The Problem (Drivers):

The National Environmental Policy Act (NEPA): The NEPA requires the federal government to use all practicable means to create and maintain conditions under which man and nature can exist in productive harmony. As required by NEPA, biomass removal from federal lands requires a detailed environmental assessment (EA). If the EA determines that the environmental consequences of biomass removal may be significant, an environmental impact statement (EIS) is prepared. After the final EIS, federal agencies are required to create a public record of its decisions addressing how the findings of the EIS, including alternatives, were incorporated into the agencies decision-making process.

Providing Wood Fiber is Part of Sustainable Forest Management: Although providing wood fiber has been part of sustainable forest management, there is public perception that cutting trees to provide the society with wood fiber for utilization will decrease the size of our forest and is destructive to the ecosystem.

Green Material: There is increased public awareness and demand for renewable, green material. Material that satisfies any one of the green building certification programs is one example.

Climate Change: Policy and decision makers in the U.S. have accepted climate change. The roll of wood utilization and forest management in relation to fiber supply in climate change mitigation needs to be explored and communicated to the general public. The forest-based industries needs to understand challenges and take advantage of the opportunities brought to our profession by the Kyoto Protocol/exchange of carbon credits, carbon cap-and-trade or carbon tax, carbon sequestration and material substitution (GHC offset).

Public Perception of Wood: The general public and the forest products industry needs to understand and benefit from the advantageous life cycle benefit of wood and wood-based products.

Use of recycled material: Landfill space has become scarce and recycling of wood-based material extends the carbon storage span of wood.

Advanced Biofuels: National energy security policy has created a demand for biofuels. Cellulosic biofuels do not compete with food source such as corn. There are also environmental benefits of using woody biofuels over corn-based biofuels. Using forest-based biofuels also replaces petroleum-based fuels with higher GHG emission.

Emissions: California's new formaldehyde emission standards from wood composites have brought the VOC and formaldehyde emissions issues of wood composites to the front page. This chain of events gives the forest products industry an opportunity to develop ultra-low emission products to address a market need.

"Green" Economy: The general public is unaware that the wood products industry is an industry that is built on renewable materials harvested from the forest with minimal impact to our environment. Wood and wood-based products has significant environmental benefits throughout a products life cycle. It has the potential of storing carbons from carbon dioxide absorbed from the atmosphere. The wood-to-customer value chain can be managed to be sustainable. Our profession and industry is a major contributor to the green economy and a major creator of green jobs.

Research Areas:

- Forest operations that does not impact the environment.
- Life cycle analyses of forest-based products including but not limited to carbon accounting, GHG emission, embodied energy, water use.
- Sustainability throughout forest-to-product value chain.
- Wood as a green building material.

- Material for green building certification programs
- Organic/metal free wood preservatives
- Durable green wood products

- Forest and ecosystem management to ensure the supply of wood for societal use is part of the sustainability of a forest.
- Particulates and organics emissions from wild fire.
- Educate policy makers and the general public on the environmental benefit of using wood products.
- Environmental impacts (positive/negative) of plantation forestry.
  - Irrigation water
  - Soil
  - Ground water
  - Biodiversity
  - Wood property

Expected Goals and Benefits: Our Nation's policy makers and consumers will better understand the environmental benefits of using wood and wood-based products. As the environmental benefits of wood are better understood and communicated, an environment-conscious nation will be more than willing to accept the use of wood which will in turn strengthen the health of our forest, and our environmental security.

Resources that:

We have	We need
Knowledge of forestry	Better utilize our existing expertise and infrastructure in wood science and wood-based products, so we can Better understand, characterize and take advantage of the environmental benefit of wood and wood based products. We need to educate the public and our nation's decision makers of the environmental benefits of wood and wood-based products.
Knowledge of our forest	
Understanding of the wood-to-customer value chain	
Core knowledge of wood science	
Core knowledge of forest products	
Understanding of sustainability	
Green material	
Green technology	
Wood scientist	

Steps to Achieve Goals

- Develop life cycle data for wood-based products for embodied energy, carbon storage, water use, GHG emission.
- Develop forest management techniques to ensure sustainability in forests and throughout the forest-to-customer value chain while maintaining an abundant supply of wood for our societal need.
- Develop green wood-based products (including but not limited to building material and paper products), green building systems and green building

construction techniques, green manufacturing technology. Green products are products that are renewable and sustainable. They are products that use recycled material. They are durable and environmentally friendly.

- Educate the public on the environmental benefits of using wood.
  - o Wood is a renewable material synthesized by trees using carbon dioxide absorbed from the atmosphere with solar energy.
  - o With proper value chain management, using wood can ensure the sustainability of our environment.
  - o Wood and wood-based products in service has the potential of storing carbon and reducing GHG emission.
- Educate K-1 2 on the environmental benefits of wood
- Develop white papers to convince decision makers on the environmental benefits of wood

Leverage Points:

- Wood is a green, renewable material.
- Forest Products is a major contributor to the green economy and a major creator of green jobs.
- Our society's increasing environmental consciousness
- Our society's reliance on wood-based products
- Federal and university R&D knowledge and organizations
- Existing forest to wood-based products infrastructure.
- Expertise and influence of the Forest Products Society and the Society of Wood Science and Technology.

EDUCATION

Preface: Education is a critical component of the national research agenda in wood science and lignocellulosic materials. The long-term vitality of materials science research requires that we educate the next generation of scientists and as well as practitioners capable of applying the latest scientific and technical innovations in the manufacturing and service sectors of the US economy. However, when we use the term "education" in this document, we mean it in its broadest sense. It is equally vital to the national interests that other academic disciplines, those who influence and make policy decisions and the public at large understand the need for renewable, carbon-based, natural resources to sustain humanities needs for energy, housing and building systems, pulp and paper, and the many other materials that are derived from those raw materials. This section of the National Research Needs Assessment addresses those educational needs.

Alternative Titles and Components of the Education Agenda:

- Communication
- Public Relations/Media Relations
- Influence
- Marketing
- Human Dimensions
- Extension/Technology Transfer
- K-12 Education
- Higher Education

Vision: Promote wood and other lignocellulosic materials as renewable, carbon-based resources with potential for increased use to improve the economic security of the United States.

The Problem (Drivers):

Public Perceptions: The public too often incorrectly perceives the use of wood and other lignocellulosics as a source of carbon emissions and environmental destruction.

Shrinking of Wood Science and Technology: The profession and scientific discipline of wood science and technology is shrinking in the US at a time when it is thriving in other parts of the world thus harming the country's global competitiveness.

Customers: In spite of negative perceptions, customers still specify and use wood and wood products for its economic and aesthetic attributes.

Climate Change: Too few Americans, including the media and public policy-makers do not know that increased use of wood will contribute to mitigation of carbon emissions by storing carbon in those products, Furthermore, young, growing trees have been shown to absorb more carbon than mature and dying trees. A case in point is the large quantities of carbon released into the atmosphere from catastrophic wildfires on Federal land in the western US that could be mitigated by thinning and using the woody biomass for energy and other products.

Jobs: The wood products industry has been a major employer of Americans and has contributed to the economic prosperity of the nation. The forest resource base will support these contributions to the economy through the foreseeable future.

Environmental education too often focuses on the negative perceptions of forest harvest while ignoring the renewability, low embodied energy, and reduced emissions of wood and lignocellulosic materials use.

Communications technologies are improving at a very rapid rate but wood science has been slow to adopt these technologies.

Poverty: Wood use contributes to the alleviation of poverty in the US and the rest of the world and potentially can make greater contributions.

Research Areas:

Develop new curricula at all levels that will educate the public about LCI/LCA, Carbon caps and trade, biomaterials, bioenergy, green building, and other topics related to wood and cellulosic materials science.

Develop vehicles for carrying wood science and technology education into other curricula at all educational levels. Teacher education is of particular importance to the effort to improve public perceptions and attitudes.

Develop educational and outreach materials that incorporate interactive technologies including web-based technology and interactive games and simulations.

Better integrate biomaterials science educational programs.

Improve the effectiveness of technology transfer in wood and biomaterials science. This includes improving the translation of science into popular materials for dissemination to the public and expanding audiences for technology transfer activities beyond the traditional industrial client base.

Expand collaborative linkages with other disciplines, in particular teacher education, public relations, and social sciences.

Develop means to successfully assess and evaluate the effectiveness of wood science

education.

Ensure the sustainability of the profession.

Expected Goals and Benefits:

We will expand our audiences both vertically (in the college curriculum) and horizontally (to elementary and secondary education as well as to the community at large.

This effort will result in better informed decision & policy-makers.

This in turn, will assist in avoiding counter-productive decisions.

We will increase awareness of, interest in, and appreciation for wood science and technology and the wood products industry.

We will broaden our outlook by expanding our interdisciplinary collaboration.

The US will achieve better control of our destiny.

We will attract more students to materials science and renewable resource curricula.

We will deliver new and cutting-edge curricula to benefit society.

We will be better able to lead research efforts in biomaterials, bioenergy, and environmental protection.

We will improve human capacity to benefit a growing population, provide sustainable housing, and better protect the environment.

We will improve perceptions of wood use, leading to a more sustainable future.

We will increase job opportunities as well as the productivity of American manufacturing industries.

Resources that:

We have	**We need**
Technical content	Delivery vehicles
Information	Integration of information
Wood departments	Partnerships
Scientific expertise	Human dimensions expertise
Wood Magic	More K-12 educational programs
Core wood science courses (higher education)	General education courses in wood science
Truth	Better public perception of credibility
Good intentions	Funds, people, and time

Steps to Achieve Goals

Educate early & often: Develop educational vehicles for K-12, other disciplines in higher education including teacher education and general education courses, interactive technologies for children, educational programs for youth organizations, and educational vehicles for adult, non-technical audiences.

Greater involvement in teacher education: There are not enough people in the wood and lignocellulosic sciences to have more than an insignificant impact with elementary and secondary school students. To be effective, we must educate the teachers who interact with the next generation on a daily basis.

Develop innovative delivery vehicles for youth and non-technical adult audiences: This includes but is not limited to short courses, hands-on workshops, interactive technologies, educational Internet sites, and distance learning.

Improve our public relations efforts and better package the message: Wood scientists are not public relations experts. Yet, we need to rethink our message and how it is "packaged" for youth audiences and the general public. This will require research into how past and existing messages from the wood products community is perceived by the public. In addition, there is room to create more effective and timely messages to meet the evolving needs of the American and global economy. Collaborative partnerships with researchers in disciplines with expertise in human dimensions are necessary.

Develop interdisciplinary/collaborative linkages: To achieve our goals, we need to expand our interdisciplinary linkages beyond the traditional partners in forestry, engineering, and the basic sciences. We have placed much emphasis in this document upon teacher education curricula, but we also need to partner with disciplines possessing expertise in the human dimensions of society. This includes but is not limited to journalism, psychology, public relations, sociology, political science, marketing, interactive learning, communications (including web-based technologies), recreation and parks, and tourism.

Improve industry support. We have had difficulty selling the educational agenda in wood science to funding agencies. Therefore, we must enlist industry including technical and trade organizations as allies in as we seek buy-in for the recommended

Leverage Points

- Interactive media
- Biomaterials/bioenergy/green building curricula
- Agricultural Experiment Station/Extension
- Youth organizations
- Better recruiting

SUSTAINABILITY

Preface: For many, the tree is a powerful symbol of environmental concern; an object that should be 'saved' and whose use for energy and products should be discouraged. By contrast, people who are familiar with wood and its use often have an intuitive sense that 'wood is good.' Wood has long been an important renewable natural resource for mankind and wood will play a vital role in efforts to pursue a sustainable future. The explicit consideration of sustainability is an increasingly important component of research related to wood and lignocellulosic materials. The favorable environmental profile of wood products and wood-based energy is a key characteristic that must be documented and incorporated in the development of new products and processes.

Problem (Drivers):

Population and income growth The explosive growth in human population has led to huge demand for renewable and finite natural resources.

Climate change The burning of fossil fuels is driving global climate change. In response, there is a desire to expand the use of renewable carbon products and energy.

Deforestation In some areas of the world deforestation is occurring, mainly due to land conversion to other uses. This raises questions of wood raw material supply and concerns over the environmental impacts of forest loss.

The 'Green' movement Changing public perception of the importance of environmental issues is prompting demand for green products and a greater scrutiny of the eco-ism pact of purchasing decisions.

Security Catastrophic wildfires in our native forests, the possible link of corn-based ethanol to food prices, and our dependence on foreign energy sources are focusing efforts to make the best use of domestic natural resources.

Research Areas:

Life cycle assessment LCA is the standard method for evaluating the environmental impact of products and processes. There is a need to expand the inventory of life cycle data for wood-based energy and products and document comparisons with substitutes.

Carbon dynamics One response to climate change is the attempt to sequester carbon in stable 'sinks.' The role of wood products in carbon sequestration is poorly understood and undervalued.

Industry sustainability The wood industry is experiencing significant challenges. Access to raw materials, globalized competition and product substitution are

important issues. A healthy and sustainable industry is critical to our continued ability to access our most sustainable building material and a significant renewable energy source. Ways to compensate the industry for its ecosystem services, to increase processing efficiency and to reward the production of 'green' products should be investigated.

Product durability and recycling Wood is a material with low environmental impact. However, increasing product service life and recovery and recycling options will further reduce environmental impacts. The important role of wood energy as part of product use and disposal must also be considered.

The forest resource Forests are the 'factories' that produce wood products and energy. Thus forest health and sustainability is the foundation for the sustainable use of wood. While forestry is the science that considers the maintenance of forests, wood science can play an important role, by developing and improving the forest products that provide financial and other incentives for maintaining forests as forests. The profitable use of small and low-value trees and the impact of forest biotechnology and forest certification are all areas of research interest.

Goals and Benefits: An improved understanding by policy makers and the public of the sustainability characteristics of wood energy and products will lead to the increased substitution of wood in place of fossil fuel-intensive products.

The increased and more intelligent use of wood and wood products will result in improved forest health, reduced environmental impact, a more competitive domestic forest industry and better quality of life.

Resources:

We have...	*We need...*
A good material – Wood is a material and energy resource with a smaller environmental footprint than its alternatives	*Acceptance and influence* – Forestry and wood products suffer from negative stereotypes. The public and policy-makers need to understand that 'wood is good.'
Information – data relating to sustainability exist for many components of wood products and energy use (e.g. durability, energy use, process efficiency)	*Integration* – the discrete datasets must be connected to provide holistic understanding of sustainability issues

Technology – equipment and methodology exist for evaluating sustainability of wood products	*Application* – the need for the explicit examination of sustainability issues in all aspects of wood science must be embraced
Individuals – there are many skilled and knowledgeable practitioners of wood science. Research efforts are generally conducted on a small scale in terms of resource investment.	*Groups* – research on sustainability issues will require collaborative and inter-disciplinary efforts. Resources must be coordinated for maximum impact.

Steps to Achieve Goals

Explicitly focus on the sustainability issue The merits of wood and wood products can no longer be assumed. It must be documented using standard methods (LCA) and new methods that fully account for the environmental impacts of wood must be developed. The sustainability of our energy and material choices must become as important a characteristic as the cost, strength, durability, etc. Thus, all new product development must include sustainability metrics.

Promote partnerships Because wood science has not traditionally included explicit examination of sustainability issues, partnerships with others with appropriate skills must be developed.

Communicate Sustainability is inherently multidisciplinary, thus members of the wood science community must collaborate to research sustainability issues. The findings of sustainability research must also be disseminated to policy makers and the public, who are ultimately those that support the research.

Leverage Points:

- Energy/Farm/Stimulus Legislation
- Carbon emission regulations
- Environmental standards
  - o Buildings
  - o Forests
- Standardization and acceptance of LCA data

MODIFICATION TECHNOLOGY

Preface: Wood utilization will continue to be a critically important component of this country's economy and quality of life to meet the need for manufactured goods in the United States. Products made from wood have a low impact on the environment and consume energy at a level significantly less than alternative materials. Perhaps the most important advantage is that wood is a renewable resource. The primary reason for these advantages has been that wood, for the most part, is processed and used in its natural form – how nature created it. All of the difficult work has been done by the tree. The polymer network and cellular structure of wood has been perfected after millions of years of evolution. Man has simply reduced the size, changed the shape, and sometimes bonded wood components back together again to make useful products. This is in contrast to many other materials, such as metal ores, minerals, and petroleum, which are first reduced to elemental or molecular form and then processed into products like steel, concrete and plastics. While there are new opportunities for wood as a chemical feedstock, we should not overlook opportunities for wood used in a form that resembles its natural state. Modification technology may be used to enhance selected material properties of wood, while retaining important features, such as its cellular structure and microfibril reinforcement. Modification technology includes chemical, thermal, mechanical, and radiation methods. Modified wood may be incorporated into composite materials, which can also include unmodified wood or non-wood materials. The products made from modified wood may have improved strength and stiffness, better resistance to water, more durability, or many other attributes that would enhance the value of wood and reduce dependence on other materials.

The properties of wood are the result of the chemistry of the cell wall components and the three-dimensional matrix they are in. Nature is programmed to recycle these resources, in a timely way, back into their basic building blocks of carbon dioxide and water through biological, thermal, aqueous, photochemical, chemical, and mechanical degradations. If the chemistry of the wood is changed at the molecular level, properties can be altered and performance changed. Based on performance requirements of wood-based resources, modifications can be carried out to result in a new generation of value-added, wood-based products that perform very well in adverse environments.

A key advantage of wood modification technology is the ability to utilize a broad array of wood species, log size and quality. On a large commercial scale, wood modification could change how we manage forest plantations. Tree breeding, silvicultural practice, species selection, and perhaps genetic engineering, could be optimized along with wood modification technology. One scenario may be to maximize end-product value per unit of forest land on a sustainable basis. Such a scenario might be possible with a harvest time of less than 10 years. A research program focused on wood modification would require expertise in such areas as market identification, biochemistry, mechanics, anatomy, thermodynamics, tree physiology, genetics, materials science, and other disciplines.

Alternative Titles and Components of the Modification Technology Agenda:

- Value-added manufacturing
- Advanced wood materials
- Wood property enhancement technology

Vision: Indentify new higher-value applications for wood that require enhanced performance, and then engineer the products and processes to meet the demand.

The Problem (Drivers):

Durability: The public perception is that wood products are not durable, but "durability" is not well defined as a measure of performance. The relationship between wood and water often leads to product failure.

Wood is not perceived as modern material: Wood has been, and forever will be, what it is. The technology used to produce wood products is old, the markets are mature, and this situation cannot change.

Commodity mentality: Industry is reluctant to add manufacturing cost to improve product performance because product value is not driven by product performance.

Demand for "green" materials is growing: Wood already dominates residential construction markets in North America. Material property specifications for potential applications often exceed what traditional wood products can offer. In a capitalistic society, value must be realized in "green" materials. Otherwise a commercial enterprise cannot succeed.

Wood supply: While there is no global shortage of wood, there are localized shortages of quality and species depending on market demand. The global wood supply could become critical as population continues to increase and more cultures demand a higher quality of life.

Jobs: Most wood product markets are already mature, so future growth tends to track population growth. New markets will require new products, which leads to job creation.

Research Areas

Develop advanced wood products that have mechanical properties that span the gap between traditional wood products and steel and concrete.

Develop technologies that prevent dimensional change of wood when exposed to changing humidity environments.

Investigate new treatment chemistries to eliminate degradation by fungi or insect attack.

Treatment must have low human toxicity, long-term effectiveness, and not leach into the environment. Understand the mechanisms that drive the effectiveness of these treatments.

Characterize the chemical and physical changes, from a holistic standpoint, that occur to the cell wall as a result of chemical, thermal, mechanical, and radiation treatments.

Develop engineering design tools, such as simulation models, to assist with the development of new modified wood products.

Model micromechanical behavior, supported by experimental measurements, to address questions about the mechanics of complex cellular materials like wood, particularly in the presence of changing temperature and humidity.

Explore new liquid phase, gas phase, and super critical fluid technologies to improve chemical treatment of wood currently hindered by wood's heterogeneity and closed cellular structure.

Research new adhesives and adhesive products targeted toward the manufacture of wood and wood-hybrid composite materials.

Stimulate the development of new forest-based biochemical technologies to produced bio-based wood modifications useful for next generation products.

Focus modification technology on underutilized wood species and wood from intensively managed forest plantations.

Scale research processes up to viable commercial operations.

Conduct life cycle assessment to include the impact of various wood modification processes, and include the impact on duration of useful life as a result of the modification.

Expected Goals and Benefits

New products, and new markets, will be realized for wood products.

Modified wood will have greater value added in manufacturing.

Modified wood will have a greater useful life span and sequester carbon longer.

Utilization of a broader array of tree species, log quality and size.

Wood products and advanced hybrid wood composites will become more competitive with concrete, metal products, and thermoplastics in regard to selected material properties and product applications.

Expanded use of wood will reduce the pressure on non-renewable materials.

New technology will required more highly trained workers in higher paid jobs.

Improvement in recycling and disposal at end of useful life.

Resources that:

We have	Are needed
Expertise in wood chemistry and anatomy	Expertise in micromechanics of biological systems
Conventional liquid pressure treatment facilities	Pressured gas phase and super critical fluid treatment facilities
Small scale specimen preparation (< 1 meter)	Large scale specimen preparation (> 1 meter)
Static mechanical testing equipment	Dynamic mechanical testing equipment in elevated temperature and pressure environments
Small scale accelerated aging facilities	Large scale accelerated aging facilities
Small scale fungal and decay insect resistance evaluation procedures	Facilities to evaluate durability performance of components in full-size structures
Light microscopy and electron microscopy facilities	Tomographic imaging in 1 0^{-8} m to 10^{-6} m range.
Experienced faculty members	Full-time technical staff

Steps to Achieve Goals

Educate funding agencies about the wonders of wood as a biological material. It is more than a chemical feedstock. Wood is a biocomposite composed of an interconnecting network of carbohydrate and phenolic polymers that function in a three-dimensional matrix. It is far more complex than any man-made material.

Rediscover the ultra structure of wood and enhance our understanding of between- species variation and variation within a tree.

Create institutional collaboration to share research facilities. This includes universities and government laboratories. Must integrate wood science with materials science.

Reach beyond the traditional wood manufacturing industry to identify financial resources to build research infrastructure. Offer incentives of intellectual property and new markets.

Leverage Points

- Public demand for green materials

- Green building leaders
- Demonstrated added value for commercial application
- Collaboration with world leaders in wood modification technology (Germany, France, Switzerland, Finland, Sweden, New Zealand, United Kingdom and Japan)
- Identifying needs for higher value products

MARKETING

Goal: The goal of the marketing session was to understand different needs related to marketing in the forest products industry in order to improve business competitiveness of the industry.

NRNA Participants: Approximately 10 participants were involved in identifying and examining various drivers and research issues related to marketing in the forest products industry. The participants included the following members:

- Bob Smith (Chair)
- Vik Yadama
- Bill Smith
- Nikki Brown
- Sudipta Dasmohaptatra
- Agron Bajraktari
- Rubin Shmulsky
- Dave Nicholls
- World Nieh
- Bob Bush

Marketing Drivers for the Forest Products Industry: The right marketing strategy will help a firm to target the most appropriate customers for a profit. The forest products industry has been undergoing numerous changes in the past decade that requires new approaches to reach the consumers and identify opportunities. The concept of a flat world is perhaps most relevant for this industry than any other. More than 50% of the US forest products manufacturing has either closed or has moved to outside of the US where cheaper labor and raw materials dominate the manufacturing sector. Additionally, greater mobility of capital, technological innovations, and lower transportation costs on trade routes has shifted comparative advantage to developing countries. ***Globalization*** is therefore, one of the major drivers of how the industry will look like in the future especially in relation to new markets (in emerging nations) that may require new communication strategies, new distribution channels, different pricing strategy and a different strategic focus to meet the needs of the new markets. The domestic market in the US is also changing with more consumers looking for cheaper products, better quality and services, and increased customization. The present generation ***customers*** are looking to reduce their inventory costs and need products to be delivered as quickly as possible (in many cases, in less than two weeks). This type of change requires customers and the suppliers to collaborate and work as partners in this system to improve the overall efficiencies in the supply chain. ***Creating value in the supply chains*** is another driver for the new marketing paradigm in the global world that requires replacement of inventories with information. Frequent and better

communication and information structure between suppliers and their customers will be the key to establishing efficiency – where both these members have to move from a transactional- based relationship to a partnership. Both the partners have to organize their supply and distribution networks by locating near major markets and ***using information technologies*** in shipping, ordering and delivery procedures (using GPS, inventory databases, information acquisition devices etc.) to get the maximum efficiencies out of their transportation systems.

The globalized forest products industry will also look towards a ***changing demographic structure*** across the world. As emerging markets in Asia and Latin America open their markets to international investments, the economy in these parts of the world is improving with the middle class population increasingly being able to spend their disposable income on wood and wood products both in the residential sector as well as in the commercial sector. Domestically, the population is growing older and more diverse at the same time. The large numbers of Baby Boomers retiring over the next decade have highly developed tastes with a need for services and products that have a luxury look or feel (Smith and Clurman in *Generation Ageless*, 2008). Although the population under eighteen will grow, it will constitute a smaller percent of the total population in years to come—dropping from 25.7% in 2000 to 23.6% in 2030 (The Center for Public Education, 2007). In addition, the Hispanic population and Asian population in the US continue to grow at a rapid rate (E.g., Hispanic population has grown from 393.9% in North Carolina to 7.8% in Hawaii from 1990 to 2000). Segmenting the markets for the forest products based on the individualized tastes for the diverse population will be very important in the next few years.

As the industry moves towards a more global arena, it will also be important for countries to review their ***trade policies and tax practices*** and make them as flexible as possible for improving the exchange of goods. Trade policies of some countries in Asia (especially China, India, Indonesia, Philippines, Malaysia and Vietnam), Latin America (e.g., Chile and Brazil), and Russia will have a very important affect on the forest products industry supply, demand and markets in the future.

Perhaps one of the most significant growth drivers for the forest products industry in this decade is the fact that it is a renewable resource and has a relatively small effect on the environment. The “energy star” labels on products ranging from a single light bulb to large residential structures shows the movement towards more environmental consciousness. With wood being the most ***environmentally friendly*** building and manufacturing material on this planet in conjunction with rapidly expanding global demand for small ***environmental footprint*** products that are made from renewable natural resources, it would seem that the forest products industry is poised for significant growth in the future. The merchandizing of products manufactured from a recovered natural resource will help broaden markets and the value added opportunities as the global economy turns “**GREEN**.” New and green bioenergy and biofuels are already creating new markets for woody biomass in the U.S. and beyond. As the demand for building materials that qualify for LEED and other green credits continues to

expand, there will be an increasing need to create ***innovative products*** and new strategies to market these products to the GREEN customers.

In summary, the main market and marketing drivers for the forest product industry currently and in the future are identified as the following:

- Globalization and free markets
- Changing consumer tastes
- Changing demographic structure
- Supply chain management
- Trade policies and tax practices
- Environmental awareness and carbon footprint
- Communication and use of information technologies
- Product innovation

Research Needs in Marketing of Forest Products: Based on the drivers identified in the above section, the following research needs were identified that would be helpful to improve the business competitiveness of the forest products industry, as a whole:

- Identify new market opportunities and efficiency in marketing through an educated workforce;
- Develop sustainable wood products from the forest to support local economies (reinvigorating the local economy of many states that have been dependent on wood products manufacturing);
- Create market-based mechanisms to match the forest resource to the changing needs of the global economy through more efficient supply chain management;
- Examine new promotional strategies to help improve the perception of the consumers about the forest products industry;
- Develop strategies to improve the awareness of the importance of forest products to the global consumer as well as to the GREEN consumer (may include the use of Life Cycle Analysis, Environmental and Carbon Footprint and other means).

Meeting the above research needs will benefit the overall state of the forest products industry by helping economic development in the rural communities of the U.S. that have been traditionally involved in forest –based operations, improve the management and utilization of the forests and promote forest health, have a positive influence on the carbon economy and promote energy independence, and improve the quality of life of the global population. These research needs could be targeted by increasing support for research and development in the above areas through a collaborative effort between the research institutions, the industry (companies and industry associations) and government organizations.

RECOMMENDATIONS

1. MANUFACTURING AND PROCESSING

Adopt and adapt technology from allied industries: There is a need to develop and support a contact network that allows for importing ideas and technology from outside the SWST group. New methods are continually being developed and refined for commercial viability for the conversion of roundwood to smaller elements for direct use or reconstitution, and the production of hybrid products combining wood with nanofibers, glass, resins, aluminum and other metals, inorganics, recycled products, etc. to produce items that address societal needs. New ideas and new products are almost always associated with new machinery and equipment, often through cross pollination of ideas with other related disciplines.

Product enhancement: Market consensus suggests that solid lumber and minimally refined engineered composites are favorable with respect to maximizing customer value in the housing sector, that is, the largest market for wood products. A variety of research opportunities remain with respect to retaining maximum lumber value through the conversion chain, improving physical and mechanical properties of existing products, and enhancing durability such as to protect people's homes a major investment.

Optimization: Starting with production forestry, through conversion, final product architecture, and structural design, there is room for further merchandising and optimization. It is appropriate that machine-driven or machine-enhanced decision making be developed and implemented as early on in the conversion process as possible. Furthermore, optimization should be integrated throughout as a means of assuring the maximum possible return on each woody fiber.

Energy policy: Methods to extract energy from wood include direct combustion, gasification, charcoaling, cellulosic ethanol, bio oil, and others. The carbon-based nature of wood makes it attractive as a means of producing green heat, electricity, or other energy. More research is needed with respect to the economic, energetic, and environmental life cycle analysis of bio fuels and bio energy. Such information would contribute to the development of prudent national energy policy, as well as internationally.

Environmental impacts: As an alternative to waste generation from manufacture of wood products, there are potential opportunities to market co-products into the stream of commerce. Waste generation is generally a detractor from green product value, while benefits are often associated with converting waste products into co-products, including cost reduction from the elimination of disposal fees. Examples include selling bark for mulch rather than storing it, selling sawdust for fuel or animal bedding rather than stockpiling it, and condensing vapor to bio-oil as part of the charcoaling process. Promoting waste reduction during manufacture, and the development of new markets for co-products are effective means of addressing the issue of environmental impacts.

2.BUILDING SYSTEMS

Develop products through creative use of wood resources; produce wood-based materials from short rotation woody crops, and small diameter timbers for use in building systems

Improve the design of building systems by maximizing structural performance of wall systems built with wood and wood-based products

Perform whole house evaluations on the comparative performance of building systems including energy to manufacture, cost to maintain, costs of utilities, air quality

Develop materials that are more reliable, and sustainable, with components that could be easily recycled or modified

Design building systems that are durable, that are designed to offer protection from moisture, minimize or prevent condensation, prolonging service life with improved means of protection

Develop high performance engineered wood products that are lightweight yet strong, with have good insulating properties, and dimensional stability

Develop methods for reuse/recycling of materials during construction, and for deconstruction

Evaluate the cost effectiveness of new building systems and materials; their manufacture and maintenance

Develop user-friendly building systems; adaptive technologies to monitor and control temperature, relative humidity, light, air quality

Improve the building standards, codes, and rating systems by determining and defining the critical performance measures, evaluating building performance with these measures, and modifying codes, rating systems and standards based on these results.

3. FUNDAMENTALS / MATERIALS SCIENCE

These discussions were focused in three areas: Properties, Processing and Products.

Properties

Wood quality/Material characterization-- Fundamental research is needed for assessing wood quality in traditional and novel products by applying newer rapid technologies such as near infrared spectroscopy, microtomography, NMR, etc. along with the application of statistical analysis tools can help us better understand wood quality.

Nanotechnology-- The cellulosic nanocrystallite may provide bio-based nanomaterials for a fraction of the cost of synthetic materials such as carbon nanotubes. Thus, the development of bio-based nanomaterials from forest products, and their properties must continue to be a significant focus area for research.

Genetic Traits and Enhancement—Although significant work has been done in the area of tree genetic engineering, and there is focus on changing wood chemical properties for easier pulping and composite processing, basic wood material characterization work is needed to assess genetically modified wood for physical, mechanical and chemical characterization,.

Assessment & Modeling—There is a need to develop conceptual and mathematical models that link the various hierarchical scales of wood structure, utilizing the molecular features of the natural polymers that comprise the wood cell wall to determine how they impact material properties at the macro level.

Processing

Adhesion/Adhesives-- Fundamental work is needed on understanding the mechanisms of durable wood adhesive bonds, including studies on electrostatic mechanism of adhesion in wood, the search for whether covalent bonding occurs between wood and any polymer adhesive, the impact of solubility parameters on wood/adhesive bonding, understanding adhesion in wood/cellulose nanocomposites, and multi-scale modeling and simulation of wood adhesion, and bio-based adhesives.

Composite Optimization-- Research on the processing parameters required to optimize wood composite products for particular end-product attributes as related to base materials physical, mechanical and chemical properties is necessary.

Nanocomposites and nanoprocessing— A probable first commercial application of nanotechnology may involve reinforcement of a variety of composite products with nanocrystaline cellulose and other nanomaterials. Process control of adhesion at nano-scale surfaces and quality control/assurance will need to be quantified, understood, and controlled to exploit these technologies.

Composite Modeling— Computational modeling of micro- and nano-scale materials and their processes is necessary to provide both the understanding of the materials and control of the manufacturing processes. Such modeling efforts are critical if new product and process development is desired.

Scaling up— Research funding must be made available for researchers to scale up successful bench scale processes to pilot- and commercial-scale applications, and to facilitate partnerships between researchers and potential industrial partners. Often this area is high risk, but the potential benefits can be huge. We need to create a bridge over the ‘valley of death” between basic research and commercialization of technologies.

Products

Technology Transfer/Standardization-- As new materials are developed, technology transfer and standards development are necessary to move the new products into the industrial arena.

Hybrid Products/Intergrated Processing-- Research on hybrid wood-synthetic materials and integrated processing systems should receive continued research focus. There are great opportunities for commercial development of such technologies.

4. ENVIRONMENTAL ISSUES Develop forest operations that do not impact the environment.

Life cycle analyses of forest-based products including but not limited to carbon accounting, GHG emission, embodied energy, water use.

Promote sustainability throughout forest-to-product value chain.

Promote wood as a green building material by development of green building certification programs, organic/metal free wood preservatives, and durable green wood products

Promote forest and ecosystem management to ensure the supply of wood for societal use is part of the sustainability of a forest.

Develop policies and practices that minimize particulates and organics emissions from wild fire.

Educate policy makers and the general public on the environmental benefit of using wood products.

Minimize environmental impacts (positive/negative) of plantation forestry relative to water, soil, biodiversity and wood properties

5. EDUCATION

Develop new curricula at all levels that will educate the public about LCI/LCA, Carbon caps and trade, biomaterials, bioenergy, green building, and other topics related to wood and cellulosic materials science.

Develop vehicles for carrying wood science and technology education into other curricula at all educational levels. Teacher education is of particular importance to the effort to improve public perceptions and attitudes.

Develop educational and outreach materials that incorporate interactive technologies including web-based technology and interactive games and simulations.

Better integrate biomaterials science educational programs.

Improve the effectiveness of technology transfer in wood and biomaterials science. This includes improving the translation of science into popular materials for dissemination to the public and expanding audiences for technology transfer activities beyond the traditional industrial client base.

Expand collaborative linkages with other disciplines, in particular teacher education, public relations, and social sciences.

Develop means to successfully assess and evaluate the effectiveness of wood science education.

6. SUSTAINABILITY

Life cycle assessment: LCA is the standard method for evaluating the environmental impact of products and processes. There is a need to expand the inventory of life cycle data for wood-based energy and products and document comparisons with substitutes.

Carbon dynamics: One response to climate change is the attempt to sequester carbon in stable 'sinks.' The role of wood products in carbon sequestration is poorly understood and undervalued. There is a need to promote the use of wood products as a means of carbon sequestration.

Industry sustainability: The wood industry is experiencing significant challenges. Access to raw materials, globalized competition and product substitution are important issues. A healthy and sustainable industry is critical to our continued ability to access our most sustainable building material and a significant renewable energy source. Ways to compensate the industry for its ecosystem services, to increase processing efficiency and to reward the production of 'green' products should be investigated.

Product durability and recycling: Wood is a material with low environmental impact. However, increasing product service life and recovery and recycling options will further reduce environmental impacts. The important role of wood energy as part of product use and disposal must also be considered.

The forest resource: Forests are the 'factories' that produce wood products and energy. Thus forest health and sustainability is the foundation for the sustainable use of wood. While forestry is the science that considers the maintenance of forests, wood science can play an important role, by developing and improving the forest products that provide financial and other incentives for maintaining forests as forests. The profitable use of small and low-value trees and the impact of forest biotechnology and forest certification are all areas of research interest.

7. MODIFICATION TECHNOLOGY

Develop advanced wood products that have mechanical properties that span the gap between traditional wood products and steel and concrete.

Develop practical technologies that prevent dimensional change of wood when exposed to changing humidity environments.

Investigate new treatment chemistries to eliminate degradation by fungi or insect attack. Treatment must have low human toxicity, long-term effectiveness, and not leach into the environment. Understand the mechanisms that drive the effectiveness of these treatments.

Characterize the chemical and physical changes, from a holistic standpoint, that occur to the cell wall as a result of chemical, thermal, mechanical, and radiation treatments.

Develop engineering design tools, such as simulation models, to assist with the development of new modified wood products.

Model micromechanical behavior, supported by experimental measurements to address questions about the mechanics of complex cellular materials like wood, particularly in the presence of changing temperature and humidity

Explore new liquid phase, gas phase, and super critical fluid technologies to improve chemical treatment of wood currently hindered by wood's heterogeneity and closed cellular structure.

Research new adhesives and adhesive products targeted toward the manufacture of wood and wood-hybrid composite materials.

Stimulate the development of new forest-based biochemical technologies to produced bio-based wood modifications useful for next generation products.

Focus modification technology on underutilized wood species and wood from intensively managed forest plantations.

Scale research processes up to viable commercial operations.

Conduct life cycle assessment to include the impact of various wood modification processes, and include the impact on duration of useful life as a result of the modification.

8. MARKETING

Based on the drivers identified in the above section, the following research needs were identified that would be helpful to improve the business competitiveness of the forest

products industry, as a whole:

- Identify new market opportunities and efficiency in marketing through an educated workforce;
- Develop sustainable wood products from the forest to support local economies (reinvigorating the local economy of many states that have been dependent on wood products manufacturing);
- Create market-based mechanisms to match the forest resource to the changing needs of the global economy through more efficient supply chain management;
- Examine new promotional strategies to help improve the perception of the consumers about the forest products industry;
- Develop strategies to improve the awareness of the importance of forest products to the global consumer as well as to the GREEN consumer (may include the use of Life Cycle Analysis, Environmental and Carbon Footprint and other means).

IMPLEMENTATION PLAN/NEXT STEPS

The public has a growing awareness of the controversy over our rich forested land in the United States. On one hand the forests have provided raw materials for consumer goods since the beginning of our country; on the other, forest biomass use has an environmental impact. This public controversy provides an opening for SWST to offer our knowledge and services through many avenues. Our profession must implement the NNRA program by providing information to the appropriate interested parties. Many of these parities are listed below.

Government Entities

Congress – The United States Congress Handbook is helpful for finding contacts. Key Congressmen should be contacted through their Chiefs of Staff. Committees in the Senate would include 1) Agriculture, Nutrition, and Forestry; 2) Appropriations Subcommittees on a) Energy and Water and Interior, Environment, and b) Related Agencies; and 3) Energy and Natural Resources Subcommittee on a)Energy and b) Public Lands and Forests. Committees in the House would include Appropriation Subcommittee on a) Energy and Water Development and b) Interior, Environment, and Related Agencies. Contacts should be made through the Majority Chief of Staff of each Committee.

Executive Branch – The Office of Science and Technology Policy and the Office of Management and Budget are key contacts. Also, members of the Biomass Board of Directors from Federal Agencies should be contacted.

Agencies – Key Under Secretaries in the Department of Energy, Department of Agriculture, and Environmental Protection Agency should be contacted.

State Foresters – The ones in those states where forestry is important such as California, Maine, North Carolina, South Carolina, Missouri, Tennessee, etc.

Non-Government Organizations (NGO's)

There are many associations and organizations that we should contact about his plan. They include a first tier of very relevant ones such as the American Forest and Paper Association (AF&PA), Forest Products Society (FPS), Society of American Foresters (SAF), American Institute of Architects (AIA), US Green Building Council, and Technical Association of the Pulp and Paper Industry (TAPPI), and the American Society of Testing and Materials (ASTM). Other organizations include American Forests, the American Society of Civil Engineers (ASCE), the American Chemical Society (ACS), the Renewable Natural Resource Foundation (RNRF), the American Institute of Chemical Engineers (AIChE), and the Environmental and Energy Study Institute (EESI).

Newspaper and magazines

SWST can reach a wide audience if it provides information to the correct person at some of our leading popular newspapers and magazines. Generally, each paper will

have a reporter that covers environmental, energy, or economic issues. Newspapers such as the New York Times, the Wall Street Journal, and the Washington Post and magazines such as Newsweek and Time should be contacted. If members know specific newspapers that are interested in wood products issues, these newspapers should be contacted as well.

TV/radio shows

SWST should have members ready to be speakers on TV and radio programs, mainly at the local level, but some at the national level. The information provided to the contacts above should offer some opportunities for mass media presentations.

Oral Presentations

Members of SWST should present this program at Conferences of organizations that are not directly involved in forest products or wood science research. Organizations such as ASCE, SAF, and various biofuels associations would be appropriate.

SWST needs to take an advocacy position on the effective use of wood and woody biomass in our society. Specific recommendations include:

- Support an increase in government and private funding for forest products research
- Encourage collaborative research and education projects that focuses on wood science and forest products
- Encourage identification of sustainable forestry supplies from public and private forests
- Educate the public, private enterprise, and the policy makers on the value of managing sustainable forest resources for products beneficial to society's needs

APPENDICES

Appendix 1 – WORKSHOP and AGENDA

SWST sponsored a National Research Needs Assessment (NRNA) Workshop (June 25, 2008) at the Hyatt Regency Union Station in St Louis, Missouri. The NRNA workshop was to provide a forum from which a unified and prioritized vision of research needs in wood science and technology (WS&T) would be created for SWST members.

AGENDA:

8:00	Welcome, introduction of committee, process, etc.
8:15	Overview of need for conference and desired outcomes
8:45	Overall group discussion of needs, benefits, vision, research drivers, and breakout topics
10:00	Break
10:15	Breakout Session #1
11:00	Breakout Session #2
12:00	Lunch
1:00	Breakout Session #3
1:45	Breakout Session #4
2:30	Break
2:45	Summaries of Breakout Sessions
3:30	Identification of potential overarching research needs from Breakout Sessions information
4:30	Identification of next steps
5:00	Adjourn

Appendix 2

SOCIETY OF WOOD SCIENCE AND TECHNOLOGY

(Approved Nov 4, 2006)

VISION:

Be the leader in advancing the profession of wood science.

MISSION:

Provide service to SWST members; develop, maintain, and promulgate the educational, scientific, and ethical standards that define the profession; advocate the socially responsible production and use of wood and wood- and lignocellulosic materials.

SOCIETY OBJECTIVES:

1. Developing and maintaining the unique body of knowledge distinctive to wood science, lignocellulosic materials, and their technologies

2. Encouraging the communication and use of this knowledge.

3. Encouraging policies and procedures which assure the wise use of wood and wood- and lignocellulosic materials.

4. Encouraging high standards for professional performance of wood scientists and technologists and acting as the professional organization for individuals who meet these standards

5. Fostering education programs at all levels of wood science, lignocellulosic materials, and their technologies and furthering the quality of such programs.

Appendix 3

NEED FOR A FOREST PRODUCTS UTILIZATION RESEARCH CONFERENCE

Background:

For many years the National Association of Professional Forestry Schools and Colleges (NAPFSC) and the USDA Forest Service, Forest Products Laboratory (FPL) co-hosted a 1 1/2 - 2 day annual research conference (September-October time frame) to discuss national utilization research needs and topics and provide a forum for selected speakers to give presentations on research needs, opportunities, and new science and technology. Over time, declining budgets for utilization research within the USDA Forest Service precluded much if any Forest Service R&D funds being generally available for cooperative university conducted research. This led to reduced university interest and attendance at the conference. The last conference was held in September 2004 at the Forest Products Laboratory, Madison, WI. Since that time, NAPFSC has become the National Association of University Forest Research Programs (NAUFRP). The conference has not been continued and Forest Service R&D has had stagnant or declining budgets for utilization research.

Current Situation:

- o SWST at its annual meeting provides some opportunity for presentations on emerging research areas and needs but not in a systematic, recurring, and focused way.
- o SWST has instituted a Research Initiatives Committee to focus on and highlight research needs, trends, and opportunities.

The following questions arise:

- o Would it be of value to have a separate and focused conference on research needs, opportunities, and cooperation among academia, industry and government?
- o If a conference is held, what would be our stated purposes for the conference?
- o What are the measures of success? (e.g. a national forest products research roadmap)
- o When and where should the conference be held?
- o How should costs be covered?

Options:

- o Decide there is no need to have such a conference
- o Decide to incorporate the basic need for such a conference into the SWST annual meeting

o Decide there is a recurring need for a separate conference on an annual, biannual or longer time frame (e.g. every three years)
  - Hold in conjunction with the SWST annual meeting
  - Hold in conjunction with another conference (e.g. woodfiber/plastic conference)
  - Hold as a standalone conference at FPL or university

o Decide there is a need for a recurring conference and look for other co-sponsoring partners (e.g. USDA Forest Service, USDA CSREES, FPS, NAU FRP)

o Refer to the SWST Research Initiatives Committee for study and recommendation to the SWST Board

APPENDIX 4

BREAKOUT GROUPS AND LEADERS:

Building Systems: Susan Anagnost

Education: James Armstrong

Environmental Issues: World Nieh

Fundamentals and Material Science: Les Groom and Doug las Gardner

Manufacturing and Processing: Rubin Shmulsky

Marketing: Bob Smith and Sudipta Dasmohaptra

Modification Technology: Fred Kamke

Sustainability: Adam Taylor

APPENDIX 5

LIST OF WORKSHOP ATTENDEES

Susan Anagnost
Jim Armstrong
Agron Bajraktari
Mike Barnes
Frank Beall
Nicole Brown
Bob Bush
Zhiyong Cai
Jim Dangerfield
Sudipta Dasmohapatra
Chip Frazier
Jim Funck
Doug Gardner
Mark Gibson
Les Groom
Eva Haviarova
Vicki Herian
Daniel Hindman
David Jones
Richard Lemaster
Bruce Lippke
Jeff Morrell
Dave Nicholls
World Nieh
Timothy Rials
Daniel Saloni
Rubin Shmulsky
Bob Smith
Bill Smith
Adam Taylor
William Tze
Jerry Winandy
Vikram Yadama

APPENDIX 6

ACKNOWLEDGMENTS

The *National Research Needs Assessment Workshop for Wood Science and Technology* was held June 25, 2008 at the Hyatt Regency Hotel in St. Louis, Missouri, USA. The workshop organizing committee members want to especially thank the workshop sponsors and acknowledge the valuable contributions of all the attendees and the individual group leaders. The presentations and discussions at this Workshop provided the basis for this report. We also wish to especially thank the members of the SWST Research Initiatives committee and the individual group leaders who served as the authors of this report.

WORKSHOP SPONSORS

Society of Wood Science and Technology
Forest Products Society
USDA Forest Service

WORKSHOP ORGANIZING COMMITTEE MEMBERS LIST

Jim Funck
Vicki Herian
Carol Lewis
World Nieh
Jerrold Wlnandy
Michael Barnes
Douglas Gardner
Chavonda Jacobs-Young
Theodore Wegner
V. J. Gopu

RESEARCH INITIATIVES COMMITTEE MEMBERS

Theodore Wegner
Steve Kelley
Mike Wolcott
Chunping Dai
Paridah Md. Tahir
Rich Vlosky
Sudipta Dasmopapatra
World Nieh
Howard Rosen
Robert Bush
Jerrold Winandy

APPENDIX 7

SELECTED WORKSHOP PRESENTATION GRAPHICS

National Research Needs Assessment Workshop

St. Louis, MO

June 25, 2008

National Research Needs Assessment Workshop Steering Committee Members

- Jim Funck, Manager, iLevel by Weyerhaeuser R&D - Committee Chair and SWST Vice President
- Mike Barnes, Professor, Mississippi State University, FPS President
- Doug Gardner, Professor, University of Maine, SWST Past President
- Vicki Herian, Executive Director, Society of Wood Science and Technology
- Chavonda Jacobs-Young, National Program Leader - Competitive Programs, USDA
- Carol Lewis, Executive Vice President, Forest Product Society
- World Nieh, National Program Leader - Forest Products and Utilization, USFS
- Ted Wegner, Assistant Director - Forest Product Lab, USFS
- Jerry Winandy - Project Leader - Forest Products Lab, USFS, SWST President Elect
- V.J. Gopu, Professor, Tulane University (ASCE National Research Needs Assessment liaison)

GOALS:

- create a unified vision of what research needs exist in wood science and technology
- identify priorities and requirements
- communicate vision to policy makers

Why Needed:

- Help the wood products and supporting industries be more successful
- Unify and prioritize research needs from the several research agendas developed by various wood products stakeholder groups
- Increase available funding and better target funding to critical research needs
- Identify underlying science required for new enabling technologies
- Increase undergraduate and graduate educational opportunities and educate people for jobs in the industry
- Provide a focused forum for increased networking, coordination, and leveraging of programs within the wood products research community

Process:

- Conduct this meeting
- Merge results of this workshop with those of a similar workshop conducted by the American Society of Civil Engineers in May at its 2008 World Structures Congress, Vancouver, BC, Canada, into a cohesive research needs assessment
- Present package of information to key policy makers, etc.

Ground Rules

Everyone's opinion counts

There are no bad ideas

No one has any existing projects

Your past doesn't count

No cell phones, etc.

National Research Needs Assessment Planning

1. What are the research drivers?
2. What research areas address those drivers?
3. What are the goals of those research areas?
4. What are the future benefits?
5. What steps are necessary to fulfill the vision/goals?
6. What resources (expertise, infrastructure, finances, etc.) exist?
7. What additional resources (expertise, infrastructure, finances, etc.) are needed?
8. How will we communicate the value and success of wood science and technology research, both on short-term and long-term bases?
9. What are the key leverage points?
10. What is the game plan from this point forward?

Potential Subject Areas

- Biomass to Energy
- Wood Quality
- Advanced Materials
- Durability
- Fundamental Properties (chemistry, physics, anatomy, mechanics)
- Marketing/Econ/Business
- Fiber Supply
- Advanced Processing
- Education
- Green Building/Products/Sustainability
- Nanotechnology
- Climate Change
- Others??????

Agenda

8:00 Welcome, introduction of committee, overview of process, etc.

8:15 Overview of need for conference and desired outcomes

8:45 Overall group discussion of needs, benefits, vision, research drivers, and breakout topics

10:00 Break

10:15 Breakout Session #1 – small groups

11:00 Breakout Session #2 – small groups

12:00 Lunch

1:00 Breakout Session #3 – small groups

1:45 Breakout Session #4 – small groups

2:30 Break

2:45 Summary of Breakout Sessions

3:30 Identification of potential overarching research needs from Breakout Sessions information

4:30 Identification of next steps

5:00 Adjourn

Next Steps:

- Summarize results from this meeting
- Seek input from rest of SWST
- Merge results of this workshop with those of a similar workshop conducted by the American Society of Civil Engineers in May at its 2008 World Structures Congress, Vancouver, BC, Canada, into a cohesive research needs assessment
- Present package of information to key policy makers, etc.

Potential Audience Groups

Congress/Staffers

American Home Furnishings Alliance
American Institute of Architects
American Institute of Timber Construction
American National Standards Institute
American Wood Protection Association
APA-The Engineered Wood Association
Appalachian Hardwood Manufacturer's Inc
Architectural Woodwork Institute
BOCA/ICBO/ICC/SBCCI (building code folks)
Business & Industrial Furniture Manufacturers Association
Composite Panel Association
Gov't research labs
Green Building Initiative
Hardwood Manufacturers Association
Hardwood Plywood and Veneer Association
Kitchen Cabinet Manufacturers Association
National Association of Home Builders
National Hardwood Lumber Association
Railway Tie Association
Society of American Foresters
Southern Forest Products Association
State Forest Products Associations
Structural Board Association
Technical Association of the Pulp & Paper Industry
University Deans/department heads
US Green Building Council
Western Wood Products Associations
Window & Door Manufacturers Association
Wood Component Manufacturers Assn
Wood Flooring Manufacturer's Assn
Wood I-Joist Manufacturers' Association

APPENDIX 8

REFERENCES

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