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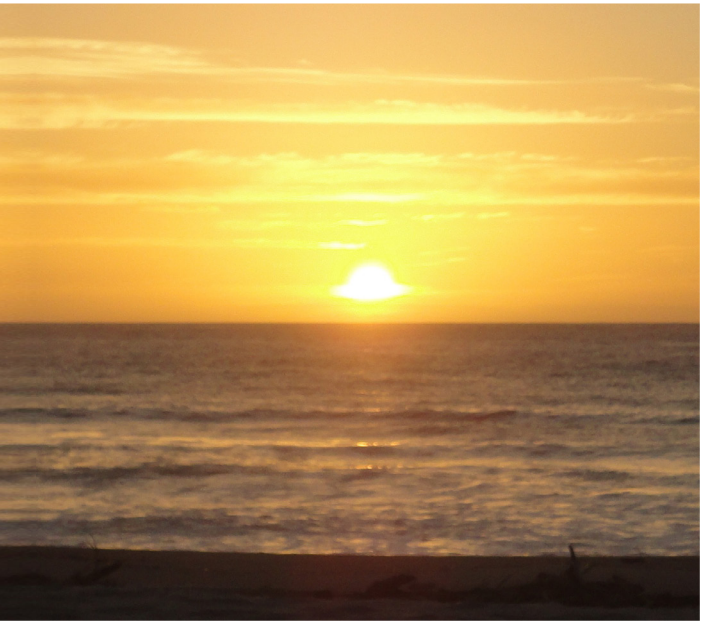
Process Technologies for the Forest & Biobased Products Industries

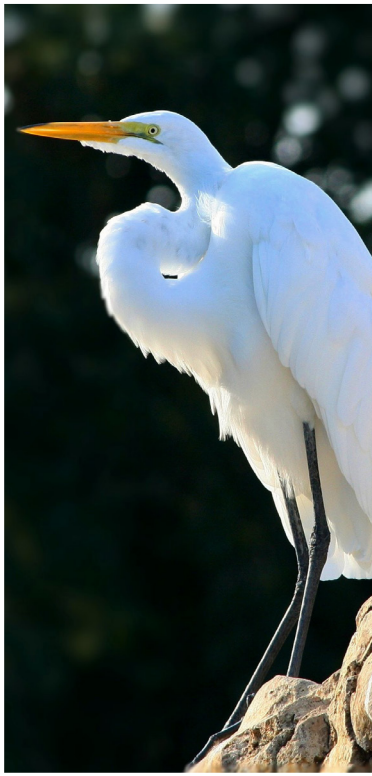
PTF BPI 2016

October 25-26, 2016

St. Simons Island, Georgia

Book of Abstracts





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Process Technologies
for the Forest & Biobased Products Industries

Book of Abstracts

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PTF BPI 2016

October 25-26, 2016
St. Simons, Georgia, USA

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The first international conference on *Process Technologies for the Forest and Biobased Products Industries* (PTF BPI 2010) was organized by Salzburg University of Applied Sciences in Kuchl Austria. The goal of PTF BPI 2010 was to bring practitioners from the forest products industries together with academic researchers to provide an international forum for valuable networking and exchange of research and innovation ideas. Since PTF BPI 2010, the conference has been held biennially between Kuchl Austria and St. Simons Island GA.

The 4th edition, PTF BPI 2016 is organized by The University of Tennessee (UT), Center for Renewable Carbon, Salzburg University of Applied Sciences, and the Forest Products Society (FPS) at St. Simons Island, GA, USA. This year's conference is dedicated to the exchange of research findings on process and product innovation.

Topics covered in the conference are:

Processing & Product Innovation
Advances in Material Technology
Marketing and Education
Wood and the Environment
Wood in Construction
Furniture Design

Our main objective is to welcome papers that have a great potential in solving real-life manufacturing problems, and offer new methods, analytical tools, and practices that will advance process and product innovation. The high standard of the conference is guaranteed by our strong international scientific committee.

Special thanks to our speakers, reviewers, both scientific and organizing committees, and all of the conference attendees. We greatly appreciate the generous contributions of our sponsors: Hexion Corp., Georgia-Pacific Chemicals, The Engineered Wood Association (APA), Assured Bio, Huber Engineered Woods, and UT Center for Renewable Carbon.

October 24, 2016

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Process Technologies for the Forest and Biobased Products Industries

KEYNOTE PRESENTATIONS

Plenary Session 1

INDUSTRY 4.0 - A NEW PERSPECTIVE FOR FOREST PRODUCTS INDUSTRY

A.J. Petutschnigg[1]*

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The concept of 'Industry 4.0' and the term 'digitalization' is used very often in discussion about the future of industry in industrialized countries. The key elements of this concept are I) production networks II) fusion of virtual and real world and III) cyber physical systems.

Within this key note the concepts and possible perspectives for the forest products industry are discussed and shown by examples.

Keywords: Industry 4.0, production networks, hybride products, 3D printing.

CONTEMPORARY SOLID WOOD RESEARCH AND DEVELOPMENT AT MISSISSIPPI STATE UNIVERSITY

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In or around 2010-2012, in the midst of a significant U.S.A. housing slump, commodity softwood lumber in North America began a reevaluation of mechanical properties. Multiple decades of changes in forestry practices as well as conversion technologies brought about this reassessment. As a result, the mechanical design properties of southern pine lumber were reduced, on the order of 15-25%. The hundreds of millions of acres of pine timberland holdings in the U.S.A. southern region are largely private and commercial. In an effort of maximize landowner value, the Department of Sustainable Bioproducts is actively researching improved valuation techniques and standards. As part of a major seven plus year initiative, commodity softwood dimension lumber has been sampled from throughout the 18 separate pine growth regions. This study works across dimension lumber sizes and grades in an effort to identify ways and means to better valuate anticipated performance and thus enhance utility

value. Additional work reaches into other solid and laminated wood products including utility poles, cross arms, equipment mats, and stair and guard systems. Additional work is underway developing novel adhesives and termiticides from plant based materials and extracts, specifically from cotton and guayule, respectively. This work is of broad interest because the current major timberland market goes into these products. For 2013, U.S.A. roundwood production was on the order of 13.1 billion cubic feet, primarily as pulp and paper, lumber, and composite products. At a specific gravity of 0.50, this volume is approximately equal to 184 million metric tons.

Keywords: Lumber, Composites, Standards, Wood Durability and Protection, Termites.

ADVANCEMENTS IN FOREST AND BIO-BASED PRODUCTS: THIS ISN'T YOUR MOTHER'S WOOD TECHNOLOGY

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The advancement of wood research in the Department of Sustainable Biomaterials at Virginia Tech has been guided by the underlying theme of increasing the competitiveness of our forest products industry through the development of new products, a better understanding of market forces, improving efficiencies in our mills, and enhancing product quality, performance, safety, and durability.

This presentation will highlight current research efforts by 16 faculty in the department. Innovative new products include biodegradable polymers that can replace traditional plastics in uses for packaging, cross laminated timber that can be used for mass timber construction, and Nano-cellulose used in targeted drug delivery procedures and bone replacements. Faculty are studying biological methods to break down cellulose into carbohydrates for conversion into bioethanol. The largest single use of softwoods remains the housing market and we have a regular publication that tracks all the economic indicators that impact housing. The department is looking at the potential for prefabricated wood housing for low income needs in Latin America. We have looked at barriers and incentives to exporting lumber to Asia, Europe and Latin America. The department has faculty that focus on introducing lean manufacturing techniques in mills and evaluate energy consumption to identify areas of improvement. The department has two industry affiliated research Centers that focus in specific areas. The Center for Packaging and Unit Load Design investigates one of the largest markets for wood (pallets) through different designs, connectors and species. The Center for Wood Based Composites studies the different aspects of research with adhesives, additives, and wood in new composites.

Plenary Session 2

WHY ARE THE IB'S DROPPING? QUICK, ADD COST!

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The Internal Bond (IB) test is utilized in many mills as a process control factor. However, variations in mill parameters such as moisture content, density, or wood species can result in a great deal of variation in IB test results. Variation attributable to the test method may erroneously be attributed to mill parameters and may result in the mill making costly and unnecessary process changes based on incorrect assumptions. This talk will address how to reduce error in the test for less process variation and can allow the mill to run closer to the minimum allowable IB without risking excursions.

Keywords: Internal bond, test method, erroneous errors, variation.

HOW DO YOU MAKE PRODUCT INNOVATION WORK IN THE REAL WORLD?

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Implementation of new technology, new products and new operating techniques often follow similar paths. Most of the time, change follows the classical change progression but it is useful to get ready to adjust since conditions are often not how you predicted they would be. Even the best laid plans and most obvious improvements are often difficult when it is time to make them work. This brief talk will describe some of what works well and some of the opportunities that show up.

Keywords: Change implementation, real-word setting, flexibility.

Session 3.1 Advances in Materials Technology I

MAPPING THE MECHANICAL PROPERTIES OF BIOPOLYMER COMPOSITE USING ADVANCED INSTRUMENTED INDENTATION

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The advantage of biopolymer composite's biodegradable, sustainable, hierarchical structure has attracted much attention from materials scientist recently. Investigating the mechanical and physical response of biopolymer in cell wall level is essential for better understanding the mechanism and expanding its application fields. In this research, we investigated the mechanical properties and ultra microstructure relationship of wood based biopolymer composite by advanced instrumented indentation technique (NanoBlitz 3D) from Nanomechanics, Inc. The average Young's modulus of cell wall's S2 layer is measured to be 18 GPa and the hardness value is 0.5GPa. By performing array of indentation in a fast way, we generated mechanical-properties maps of wood cell wall which enables direct visualization of the modulus, hardness and stiffness properties among different phases.

LIGNIN-BASED CARBON FIBERS: IMPROVE SPINNING AND CONVERSION PROCESS TO CARBON FIBER

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Lignin has received much interest in the manufacture of value-added chemicals and materials, especially carbon fibers. Low cost, renewability, and high carbon content of lignin make it an attractive precursor for production of low-cost carbon fiber. Unlike synthetic polymers, lignin is not uniform and contains polymers with varying properties. In addition, impurities (both organic an inorganics) are also present in lignin. There are several factors contributing to the resistance to adopting lignin as a carbon fiber precursor, which includes difficulty in melt processing lignin into fibers, especially from different biomass sources and pulping processes, slow conversion rate and low mechanical properties of carbon fibers.

In this study, we improved the spinnability and processing of lignin to carbon fibers optimizing an organosolv fractionation process. Additionally, sequential solvent extraction was used to improve melt-spinning performance of both organosolv and kraft lignins. This extraction process removed impurities and high molecular weight compounds, which significantly improved melt-spinning performance of lignin. Also blending a lignin with low spinnability (grass lignin)

and a lignin with highly spinnable lignin (hardwood) improved processing. Blending resulted in decreased processing time (thermostabilization), since lignin from grasses contains larger portion of guaiacyl units which can thermostabilize and crosslink faster than dominate units in hardwood lignins (syringyl), and improved carbon fiber performance.

Keywords: lignin, organosolve fractionation, melt-spinning, thermostabilization, carbon fiber.

NANOCELLUOSE AND ITS BIODEGRADABLE NANOCOMPOSITES

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Nanocellulose and its nanocomposites are expected to be the next generation of materials opening up the opportunity for replacement of conventional petroleum-based composites resulting in new, biodegradable, high performance, lightweight green materials. Cellulosic nanofibers (CNF) were isolated from different cellulose raw materials by mechanical and chemical methods. After spray drying, cellulosic nanofibers were blended with biodegradable polymer, poly(lactic acid). And the film casting method was employed to fabricate biodegradable nanocomposites from cellulosic nanofibers and poly(vinyl alcohol). Cellulosic nanofibers were characterized using differential interface contract microscope and scanning electron microscopy. The size distribution of the cellulosic nanofibers ranged from tens of nanometers to several microns. The mechanical, morphological, and thermal properties of the nanocomposites were analyzed by tensile test, SEM observations, and thermogravimetric analysis. The elastic moduli of PLA and PVA were significantly improved with CNF addition while the strength of the composites was comparable with that of pure PLA and PVA. Significant differences of thermal behavior were observed according to the amount of nanofibers used as reinforcement. These materials are expected to be useful as packaging for food or similar applications. Formation of cellulosic nanocomposites utilizing cellulosic material could be beneficial for the wood-related industries by incorporating wasted materials into new environmental friendly products.

Keywords: Nanocellulose, nanocomposite, isolation, fabrication, characterization.

3D STEREOLITHOGRAPHY PRINTED LIGNIN-COATED CELLULOSE NANOCRYSTAL/PHOTOPOLYMER NANOCOMPOSITES: MECHANICAL AND THERMAL PROPERTIES

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3D stereolithography (3D-SL) printing, commonly known as rapid prototyping, one of additive manufacturing techniques, has been widely utilized for decades to create models, prototypes, and production parts via layer by layer through photopolymerization. Photopolymers used in 3D-SL printing are commonly acrylate resins, epoxy resins and Polyurethanes. They can produce high quality products which have been widely used in manufacturing and industry areas. However, there still some defects happened whenever during processing or applying in the reality, like dimensional instability (shrinkages), poor mechanical properties. Also, the flexibility of the photopolymer based products still need to be improved when used in some special conditions. Moreover, few research on the mechanical and thermal properties of 3D-SL printed photopolymers with postcure was found, even for 3D-SL printed nanocomposites.

In present study we produced the lignin-coated cellulose nanocrystal/photopolymer nanocomposites by 3D-SL, then the printed nanocomposites were postcured under elevated temperature and the mechanical and thermal properties of the nanocomposites were elaborately analyzed. The effect of L-CNC on the properties of printed nanocomposites was investigated by its dispersion and interactions with the matrix through SEM and FTIR, respectively. The postcure effect on the mechanical and thermal properties of printed nanocomposites was thoroughly discussed.

Keywords: 3D printing, Stereolithography, Cellulose nanocrystal, Photopolymer, Nanocomposite.

Session 3.2 Processing and Product Innovation I

CROSS-LAMINATED TIMBER: RESEARCH NEEDS AS PERCEIVED BY EXPERTS

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Cross Laminated Timber (CLT) is a relatively new building system that has attracted the attention of construction professionals, developers, and researchers across the world; in part due to its environmental, economic, and aesthetic advantages. However, CLT markets are still in their early stages of development, and awareness is low in most locations and professions. This presentation summarizes major findings from a series of surveys carried out in four continents during 2015-2016 about the status of Cross Laminated Timber; specifically, about level of awareness and research needs for the advancement of CLT, as perceived by experts in Europe, North America, Oceania, and South America.

Keywords: Cross Laminated Timber, CLT, engineered wood products, awareness, research needs.

TALL WOOD RISES HIGH WITH CLT AND MASS TIMBER

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Research was conducted to discover how the U.S. building construction and forest products sectors could benefit from the development of tall, cross-laminated timber (CLT) and mass timber buildings. Barriers that may restrict such development were also investigated. The primary benefits were discovered to be eco-performance and job creation. Code restrictions and material performance misconceptions were found to be the largest obstacles. Many believe that steel and concrete are better for building tall structures and that mass timber does not perform well during fires. Case studies of the Treet, Tamedia, and WIDC buildings were conducted to demonstrate the benefits of tall wood buildings and the various paths around potential barriers. Opportunities for tall wood buildings in the U.S. are also discussed. This research discovered that a tall wood movement is gathering momentum in the U.S. To fully realize this potential, accurate information regarding the use of wood and the performance capacities of mass timber systems needs to be

disseminated. Cooperation between academia and industry will also be necessary.

Keywords: cross laminated timber, tall buildings, mass timber, mass timber systems, forest products.

CONTROL OF ENVIRONMENTAL BLACKENING ON EXTERIOR SURFACES OF THE BUILT-ENVIRONMENT

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The exterior of buildings, including monuments and virtually all human built structures are susceptible to the phenomena of blackening. Often blackening is attributed to soot accumulation; however, research has shown that the soot, while often an important contributor near areas of high interstate commerce, and heavy industrialized locations, may be a small factor contributing to blackening of most structures. A more important factor in blackening is microbial biofilms. These biofilms comprise a variety of oligotrophic microbes. Oligotrophic bacteria and molds are expert scavengers and are often found colonizing extreme environments where most microbes are incapable of growing. Built-environment surfaces that are exposed to high temperatures, intense ultraviolet light, and desert-like conditions are prime substrates for oligotrophic biofilms. The microbes in these biofilms form darkly pigmented cell walls to protect themselves from the UV light. They have genetic components that prevent heat damage. In addition, they are excellent at absorbing moisture from the environment, and supplementing their dietary needs by scavenging airborne volatile organic compounds rich in carbon. This presentation will provide an overview of environmental blackening and suggest approaches to removing and preventing discoloration of the built-environment.

Keywords: blackening, microbial biofilms, oligotrophic microbes, discoloration, built-environment

MODELLING LONG TERM EMISSION BEHAVIOUR IN THE BUILT ENVIRONMENT?

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Besides formaldehyde, VOC (volatile organic compounds) emissions from wooden products are of interest throughout Europe. Mandatory and voluntary certification systems mainly focus on product emissions. However, due to the complexity of the indoor environment, indoor air quality currently can´t be calculated based on such. Long term emissions of wooden buildings were accessed in model rooms, office containers, and residential houses. Whereas

the emission rates often start at an elevated level during the phase of construction, usually a steep decrease can be observed throughout the first months. Additional emissions most likely appear as the object gets used due to new sources (e.g. furniture) and human activities. Mechanical ventilation as well as the construction design strongly influences the emission behavior. The current results suggest that reasonable results for indoor air emissions can be gained a few months after object use (e.g. move-in, daily office use, etc.). However, product testing is commonly based on an evaluation after 28 days exposure in testing chambers. Wood based products typically show a further decrease of emissions thereafter, which could also be seen in the long term tests. Applying the non-linear regression model for formaldehyde emissions as described in the European standard EN 717-1 towards the observed VOC emissions showed a good model fit even under real room conditions. This might help creating an indoor air quality model based on product characteristics.

Keywords: VOC, formaldehyde, long term emission, real room, modelling.

Session 3.3 Marketing and Education

THERMALLY MODIFIED WOOD – HOW CAN THIS PROCESS HELP THE INDUSTRY UTILIZE NON-COMMERCIAL SPECIES FOR PRODUCTION OF VALUE-ADDED PRODUCTS.

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The processing and drying of wood on a large scale has occurred for over one hundred years. The use of key commercial species globally such as pine and spruce has enabled society to build a lengthy list of products. The management of our forests has seen a change in species and their inherent wood properties. More recently with the demand for forest products increasing and available wood resources becoming limited there is the need to better utilize the commercial species we harvest as well as under-valued or non-commercial species. With changes in the properties of commercial species and many non-commercial species displaying properties that are difficult to process, alternate processes are needed to address these issues. One process that is efficient at dealing with internal stresses etc. is the high-temperature thermowood process kiln system. This system runs at double the wood temperature of normal wood kilns and produces stable, moisture and fungal resistant wood with significant increases in aesthetic appearances. In addition, the process can maintain most wood physical and mechanical properties and allows the control of high internal wood stresses in certain species during the process. This talk will look at the technology, what modifications are made to wood, existing products on the market as well as new products and how it can help meet market demand in areas of wood processing such as flooring, furniture, interior paneling and products as well as outdoor products such as decking, docks, furniture and boat components using under-valued or non-commercial species.

Keywords: thermal modification, value-adding, underutilized species, wood properties, wood products.

INTERNATIONALIZATION OF SYSTEM BUILT WOOD CONSTRUCTION INDUSTRY: MARKET ASSESSMENT IN DEVELOPING COUNTRIES

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A considerable portion of the developing world is living in substandard houses. Developed countries like United States have substantially improved the residential construction sector by engineering new materials and developing efficient systems. Composite materials, factory built prefabricated houses,

advanced production methods, better designs and access to abundant resources makes the U.S. a world leader in wood construction industry.

This study attempts to link the supply capacity of the system-built wood construction sector in the U.S. to urban low income housing markets in Peru, Ecuador and Colombia. Linking the manufacturer with potential buyers overseas would require efficient production, logistics and marketing systems. Research is focused on product development for bottom-of-the pyramid buyers to give them an affordable yet sustainable alternative to traditional systems. Case studies and surveys were used to assess key aspects of housing deficits in target demographics. Production and supply capabilities of system built wood construction manufacturers in the U.S. will also be evaluated for adaptation to foreign markets. Preliminary findings indicate developing products for social housing programs can provide access to potential untapped markets. Lack of existing wood construction in markets indicates a possibility of resistance to acceptance but also assures no local competition. This research will contribute to opening of new markets for exports of prefabricated wooden buildings in other housing sectors. The same approach can be extended to improve U.S. exports of value-added wood products to Latin America.

Keywords: Exports, System Built wood construction, Panelized housing, Social Housing, Internationalization.

ATTITUDES OF FOREST LANDOWNERS AND FORESTRY PROFESSIONALS TOWARDS SALVAGING TIMBER DISASTER IN THE GULF SOUTH

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Natural disasters such as hurricanes, tornadoes, wildfires, and floods impact vast areas of timberland in the Gulf South. Timber damage from Hurricane Katrina devastated the forestry industry in 2005 and created an estimated $1.3 billion in timber damage. Within the estimated timber damage many trees could have been reclaimed if salvage operations were accelerated. There is a need to increase the availability of timber salvage operations after a significant disturbance; to help decrease timber waste post natural disaster. Research is needed to assess the best venues to share information to private forest landowners and forestry professionals related to preparing and recovering from destructive natural events that cause timber damage. Focus groups were conducted across the Gulf South with private forest landowners and forestry professionals to determine if websites such as Windwood Utilization would be a good way for the forestry community to get information associated with recovery, response, and preparation for large-scale wind events. Phenomenology qualitative research approach was used to understand the focus group participant's experiences with dealing with natural disasters and

salvaging timber. Focus groups allowed themes of racial influence, gender dominance, and potential website exploration. Participants concluded user-friendly online venues of forestry information are more likely to be used by forestry professionals and private forest landowners below the age of fifty and are possibly absentee landowners. Individuals above the age of fifty are more likely not to use online sources because of pre-existing professional connections. This group preferred using detailed newsletters describing important forestry related attributes.

Keywords: Natural Disaster, Wind Wood Utilization, Private Forest Landowner, Timber Salvage.

CONSUMER DEMANDS AND THE PRESENT CONDITION OF TURKISH FURNITURE MANUFACTURERS

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Furniture plays an important role in human life. It takes place in every condition of life. People need furnitures both while working in the office and when they want to relax after a long tired day. For this reason the consumers have different demands for different purposes of use when buying furnitures. In this study, with the light of previous researches about Turkish consumer demands, the condition of the furniture manufacturers were investigated. A survey for the manufacturers was performed to find out their conditions and their evaluation about the consumer demands. Turkish Companies in the country with over 50 workers were taken in the concept of the study. The survey contained questions referring the foundation date of the companies, their design tendency, customer profiles, design strategies, changes in design strategies in time. The participant companies were also asked about their suggestions to the consumers while making decisions to buy furniture. As the result of the study, 47% of the companies declared that brand image was important for the consumers and their most important goal in manufacturing was to be one of the best brands company in Turkey. 58% of the manufacturers emphasized their changes in design strategy due to the consumer demands. Consumer demands were influenced by corporate image, cleanability of the product, reliability of the company and price by 36%, 32%, 23% and 9%, respectively. However, quality of the product (58%), price and easy payment methods attract the consumers at the stage of purchasing.

Keywords: furniture design, consumer demands, furniture manufacturing, furniture industry, Turkish furniture.

Session 4.1 Advances in Materials Technology II

DROP IN SOY FLOUR FOR SUBSTITUTION INTO ADHESIVES IN ORIENTED STRAND BOARD

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Oriented Strand Board (OSB) is a cost competitive market and failure to be economically viable can result in a plant shutdown. Companies are always looking for new innovations to make a cheaper material of equivalent mechanical and physical properties. Soy flour is one possible way to make a cheaper wood composite. Substitution into phenol formaldehyde (~$0.70/lb) or MDI (~$1.00/lb) adhesives are possible due to a low cost of ~ $0.35/lb of the soy flour. But in order to be quality compliant, the addition of soy cannot lower key properties such as dimensional stability or strength. Our studies have found that up to 20 – 30% replacement of adhesives (PF and MDI) at the blender is possible resulting in an increase in strength and no loss or slight improvement in dimensional stability. It was found that mixing the soy into the adhesive before blending resulted in viscosity issues either during the blend or during the 1st day of shelf life. To overcome this problem, we found that we could add the soy flour into the blender separately resulting in an easy no-preparation drop in soy feedstock for OSB manufacturers. This innovative finding has resulted in a patent that is pending.

Keywords: soy, wood composite, OSB, MDI, phenol formaldehyde.

STABLE AND DURABLE WOOD COMPOSITES BASED ON MOLECULAR LEVEL CHEMICAL MODIFICATION

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Wood is referred to as a material but in the true material science definition, a material is uniform, predictable, continuous, and reproducible. No two pieces of wood are the same even if they came from the same tree and the same board. Wood is better describes as a composite and more accurately, a porous three dimensional, hydroscopic, viscoelastic, anisotropic bio-polymer composite composed of an interconnecting matrix of cellulose, hemicelluloses and lignin with minor amounts of inorganic elements and organic extractives. So, even solid wood is a composite. Wood can also be reduced in size to make a wide variety of composites including plywood, flake board, strand board, particle board, and fiber board. As the size of the furnish gets smaller, it becomes more consistent uniform, predictable and reproducible.

The performance we deal with at the solid wood level (swelling/shrinking, biological attack and strength) are derived from the properties at the cell wall

matrix and polymer level. Moisture sorption and desorption in the cell wall polymers results in dimensional instability and changing mechanical properties. Many different types of microorganisms recognize wood as a food source and are able to break it down resulting in both weight and strength losses.

One technology that has now been commercialized to achieve high levels of stability, durability and stablized mechanical properties is acetylation: a reaction between the hydroxyl groups on the wood cell wall polymers with acetic anhydride. While all woods contain a low level of acetyl groups, increasing this acetyl content changes the properties and, therefore, the performance of the reacted wood. When a substantial number of the accessible hydroxyl groups are acetylated consistently across the entire cell wall, the wood reaches its highest level of stability and durability. History, chemistry, performance, properties, of wood acetylation will be covered in this presentation.

Keywords: wood, cell wall chemistry, moisture, decay, mechanical properties, chemical modification, acetylation.

DEVELOPMENT OF 100% LIGNIN-BASED ADHESIVE FOR EMGINEERED WOOD PRODUCTS

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Phenol formaldehyde (PF) resin is the most commonly used adhesive in the production of engineered wood products due to its exceptional moisture resistance, thermal resistance, chemical durability and bonding strength. Concern about environmental impacts of phenol is the main reason industry is looking for a renewable alternative. Lignin, produced as byproduct of pulp and paper and bioethanol industry, is a natural polyphenolic compound that has excellent potential to be used as phenol replacement in the production of phenolic resin. In this study, phenol has been entirely replaced by an agricultural-based lignin in PF resin formulation. First pure lignin was isolated from lignin cake using dilute acid precipitation method. Then, the isolated (pure) lignin was used to formulate PF resin under alkaline condition. Chemical, physical and thermal properties of isolated lignin and PF resin were measured using advanced analytical techniques such as: Fourier transform infrared spectroscopy (FTIR), size exclusion chromatography (SEC), phosphorus nuclear magnetic resonance spectroscopy (^{31}P NMR), thermogravimetric analysis (TGA), and differential scanning calorimetry (DSC). The 100% lignin-based adhesive were used to prepare plywood samples along with a commercially phenol resorcinol formaldehyde (PRF) as control following exactly the same cure parameters (time, pressure and temperature) recommended for PRF resin. Analysis of lap shear strengths of plywood samples made with 100% lignin-based adhesive showed similar results as of plywood samples made with commercial PRF adhesive.

Keywords: Lignin, Poly phenolic compound, Phenol Formaldehyde Resin, Renewable Materials, Wood Composite.

MODIFICATION OF WOOD PROPERTIES USING A 4-STEP THERMOMECHANICAL PROCESS

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This study evaluated thermal treatment combined with compression as means to improve dimensional stability and mitigate the negative effects of thermal treatments on mechanical properties. Local-*Pinus* wood was subjected to thermomechanical treatments using a hydraulic press with temperature, time and pressure control. We used 30 boards measuring 140 mm x 320 mm x 22 mm. Five treatments with 6 replications included two temperatures (180ºC and 210ºC) with pressure corresponding to 50% of the resistance to perpendicular compression of the wood; pre-treatment or not (wood initially put in the oven until it reaches 100ºC) and a post-treatment of 10 minutes. The physical, mechanical and colorimetric properties were analyzed by the Turkey and paired t tests. The treatments reduced the negative effects of conventional thermal treatments on the mechanical strength of the wood. They also improved the physical and colorimetric properties but did not improve dimensional stability. The treatment darkened the wood. With density increase, the mechanical properties increased. The absence of pre-treatment at 210ºC and 10-minute post-treatment resulted in improvement of the properties analyzed, with exception of thickness swelling. Equilibrium moisture content was also reduced in comparison with untreated material. It could be concluded that proposed thermomechanical treatment improved physical, mechanical and colorimetric properties of pinus wood, but dimensional instability remains as a concern. In this context, future studies should be performed as means to release the internal stresses which are responsible for this instability.

Keywords: compression stresses, densification, dimensional stability, pinus wood, post-treatment.

Session 4.2 Processing and Product Innovation II

PROCESS OPTIMIZATION IN A COMMERCIAL WOOD TREATING PLANT

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Commercial wood preservation by means of pressure treatment is fundamentally a batch chemical process. Process optimization depends on maintenance of mechanical equipment, management of material inputs, operator training, quality control and data analysis. It is an ongoing process and one that is especially challenging because of the variability of one of the major material inputs to the process: wood. Wood creates a second challenge in the variability it imposes in the quality control portion of the process. This is why some, perhaps even most, in the pressure treating industry will still refer to treating as "an art." It is not an art; it is a batch process in which one of the process inputs and the process output is variable. It is no more of an art than designing a wood structure where the variability of wood strength values has been addressed using standard statistical means.

Keywords: batch chemical process, process optimization, variability, wood.

DIGITAL IMAGE AKQUISITION TO ACHIEVE LOG TRACEABILITY – A FIELD STUDY

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Customers of wooden products are getting more and more interested on the origin of the raw material used. Furthermore the legal framework in the European Union (EU Regulation 995/2010 of the European Parliament) demands the traceability of materials for wooden producs. For this reason traceability of the material flows is gaining increasing importance also in forest products industries.

One main challenge in the supply chain of wood is the traceability of logs from forest to sawmill. Within this paper a possible method to achieve traceability from forest to sawmill is shown. Digital images of the log crosscut are collected in the forest and in the sawmill and afterwards their usability to follow the log is shown and discussed.

The results are meaningfull and show, that the identification of logs by digital image processing might be possible in the future. It is shown that further work has to be done on the specific conditions of data collection in the forest as well as the specific properties of log crosscut images.

Keywords: log traceability, digital image processing, log crosscut, supply chain.

ASSESSMENT OF VOLATILE METABOLITES FOR IN SITU DETECTION OF FUNGAL DECAY OF WOOD

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In this study we describe a method of examining volatile organic compounds (VOCs) released by two brown rot (*Gloeophyllum trabeum* and *Postia placenta*) and two white rot (*Trametes versicolor* and *Irpex lacteus*), based on solid phase microextraction (SPME) coupled to gas chromatography–mass spectrometry (GC-MS).

Despite the fact that incipient decay may be difficult to detect visually or by weight loss with certainty, it causes significant decrease in wood mechanical properties. Due to high costs of replacement of decayed wood or destructive identification methods it is necessary to develop reliable methods of wood decay identification.

Volatile emissions from the cultures of four decay fungi on pine and aspen were investigated and comparison among fungi and wood species and also mechanical strength was performed during 12 weeks. VOCs analyzing of studied fungi resulted in mono- and sesquiterpenes, aldehydes, ketones, as well as many aliphatic alcohols, and aromatic compounds.
SPME combined with GC-MS as a non-destructive method showed results in indicating the incipient decay in wooden structures.

Keywords: Volatile Organic Compounds, Solid Phase Microextraction, Gas Chromatography- Mass Spectrometry, Brown Rot, White Rot, Mechanical Strength.

TOTAL PHENOLIC, FLAVONOID, TANNIN CONTENTS AND ANTIOXIDANT PROPERTIES OF *Pleurotus ostreatus* AND *Pleurotus citrinopileatus* CULTIVATED ON VARIOUS SAWDUSTS

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In this study, the possibility of using of chestnut (*Castanea sativa*) sawdust in *Pleurotus ostretatus* and *Pleurotus citrinopileatus* cultivation and mixture of *Populus nigra* and *Picea orientalis* with *Castanea sativa* in *Pleurotus ostreatus* cultivation. Additionally; some bioactive properties of these mushrooms and their substrate mediums were investigated. While the *Pleurotus citrinopileatus* was cultivated on *Castanea sativa* sawdust, 3 different mixtures (100% *Castanea sativa*, 50% *Populus nigra* + 50% *Castanea sativa*, 50% *Picea orientalis* + 50% *Castanea sativa*) were used for *Pleurotus ostreatus* cultivation. After a

successful harvest, total phenolic, flavonoid, tannin contents and antioxidant properties of mushrooms' methanolic extracts were examined. Same analyses were also performed for substrate mediums. The highest total phenolic content (2.529 ± 0.010 mg GAE/g) was found in *Pleurotus citrinopileatus* cultivated on *Castanea sativa* sawdust. Total flavonoid could not be determined for both mushroom species. The highest total tannin (3.691 ± 0.011 CE mg/g) was found in *Pleurotus ostreatus* cultivated on *Castanea sativa* sawdust; the highest ferric reducing antioxidant power (11.761 ± 0.020 µmol FeSO4.7H2O/g) in *Pleurotus ostreatus* cultivated on 50% *Picea orientalis* + 50% *Castanea sativa* and the highest free radical scavenging activity of DPPH (22.922 ± 0.002 mg/mL) in *Pleurotus ostreatus* mushroom cultivated on 50% *Populus nigra* + 50% *Castanea* sativa.

Keywords: antioxidant, chestnut sawdust, mushroom, tannin content, total phenolic.

Session 4.3 Wood and the Environment

INTEGRATING LEAN THINKING, LOGISTICS, AND LIFE CYCLE ASSESSMENT: A CASE OF STUDY IN THE FOREST PRODUCTS INDUSTRY

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Lean Thinking continues to be an accepted philosophy to increase process efficiencies and customer satisfaction levels. The focus of lean thinking has been on manufacturing processes but in the last 10 years lean thinking principles have been expanded and applied to service, medical and government processes as well. A more challenging and recent development is the integration of lean thinking principles with logistics and life cycle assessment (LCA) tools. In many industries including forest products, transportation and logistics processes continue to be an important component of the cost. In addition, the environmental impact of logistic operations in forest products industries is hard to measure with conventional tools.

This paper proposes a new methodology to integrate logistics operations and LCA data with lean thinking principles through value-streamed mapping (VSM). Results show that the expansion of lean thinking principles to logistic operations in forest products, have a significant impact on the reduction of waste such as excess of inventory, transportation, energy consumption, waiting times, and the reduction of the environmental impact of logistic operations.

Keywords: Lean Thinking, Logistics, LCA.

USE OF LINEAR PROGRAMMING TO OPTIMIZE THE SOCIAL, ENVIRONMENTAL, AND ECONOMIC IMPACTS OF USING WOODY FEEDSTOCKS FOR PELLET AND TORREFIED PELLET PRODUCTION

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Linear programming was used to optimize the environmental, economic, and social impacts of forest biomass used for bioenergy production. Two feedstocks - roundwood and wood residues -, two densified bioenergy products - white pellet (WP), torrefied pellet (TP) -, two markets - domestic, international -, and two end uses -power generation, district heating - were evaluated. The social, environmental, and economic sustainability attributes were quantified and monetized by using peer-reviewed literature to analyze the trade-offs. Using the economic criteria alone, the model showed that the best solution was use of 70% roundwood and 30% forest residue feedstock to produce TP sold for district heating in the EU. The model predicts $5.4 million annual profit which is driven by the use of lower cost forest residue feedstocks and relatively higher prices for the heating market in the EU. The inclusion of all three sustainability

attributes led to a different optimized solution. TP produced from roundwood and sold to the EU market for heating was the optimum, due to the social benefits derived from increased local income to landowners, and reduced shipping costs. It also had added benefits of reductions in emissions across the transportation system on an energy basis. TP consistently had higher social benefits than WP due to the need for more biomass per unit of final product and providing more local jobs and income from feedstock production. The increasing costs of carbon emissions increased the environmental benefits of TP compared to WP or coal.

Keywords: Bioenergy, Linear Programming, Optimization, Sustainability, Woody Biomass.

RESOURCE EFFICIENCY OF CASCADING WOOD USING LCA AND EXERGY ANALYSIS

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To satisfy the growing demand for wood in the future by increasing the efficiency of wood utilization, the concept of cascading, defined as the sequential use of one unit of a material in material applications with its energetic use as a final step is widely recognized in science and policy. The objective of this study is to determine the resource consumption as well as the resource efficiency of wood cascading.

A LCA study comparing a cascading system using recovered wood with a reference system providing the same multiple functions using primary wood was conducted. System expansion was applied to achieve functional equivalence. To account for the multi-functional nature and the internal recycling processes of cascading systems, exergy-based methodology was applied. Using exergy flow analysis, the exergy dissipation was determined to identify hotspots for improvements. Exergetic-LCA was used to determine resource use and the resource efficiency at life cycle level.

The resource consumption of the cascading scenarios is significantly lower (up to 80 %) compared to the reference scenario using primary wood. System analysis revealed that technological adaptations referring to the processing of recovered wood have minor effects on the cumulative resource consumption. The resource efficiency of the cascading system is 53 %, compared to 33 % of the reference system.

The results show the potential of cascading wood to save primary natural resources and how cascading can contribute to an efficient use of limited resources. The exergy-based approach proved to be a viable option for resource efficiency calculations of multi-functional systems.

Keywords: Resource Efficiency, Cascading, Waste Wood, Cumulative Degree of Perfection, Exergy.

FOREST CERTIFICATION AND ITS EFFECTS ON TURKISH FOREST PRODUCTS INDUSTRY

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The rapid increase in the global population causes plenty of problems in various fields. Global heating and climate change are the basic problems coming forward. Environmental problems have been increasing especially after the last quarter of the 20th century and these problems effect also the forests in a negative way. The rapid increase in deforestation has also effected the industry using forest products negatively. The industry searching for the best quality raw material before has been in to lack of raw material these days. The tropical and semi-tropical forests which constitute approximately the half of the global forest area are now extremely destructed to fulfill the raw material need. The increasing demand for raw material have increased illegal utilization besides legal utilization. Certification period has appeared at this point to prevent the illegal utilization. Today many of the countries have adopted and re applying forest certification which includes wood raw material production period. In the study forest certification in Turkey and its effects were researched. Data of General Directorate of Forestry in Turkey, Unites Nations and FAO and document summarization techniques were used. As the result, the certification applications which started in 2010 in Turkey have reached 1,5 million ha certified forest area by 2015. General Directorate of Forestry having FSC certificate appears with the policy of increasing chance of competition in global market with processed forest products as it is the main raw material provider for forest products industry. It is determined that furniture export doubled and reached the value of 2,2 billion dollars in the last 5 years while a descend in export to the developed countries was observed due to the demand of certificated products.

Keywords: forest certification, forest products industry, forestry, Turkey, forest administration.

Session 5.1 Analytical Methods

ESTIMATION OF MOISTURE CONTENT IN WOOD USING DUAL X-RAY ENERGIES IN A MEDICAL CT-SCANNER

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This study shows the first attempts to test a method based on dual-energy using a medical computed tomography (CT)-scanner. The different CT techniques that have been traditionally used to estimate moisture content (MC) in wood require two CT-images: one showing the unknown moisture distribution and a second one at a known reference MC level. The scans are then compared. In addition to the challenge of moving and conditioning the samples, dimensional changes below the fiber saturation point create another problem when comparing the two scans.

Dual-energy X-ray absorptiometry (DXA) enables estimation of MC simply by performing two consecutive scans at two different X-ray energies. The problems mentioned above are thus avoided. The measurements can be made within a few seconds.

Two scans at 80 and 130 kV were performed on a group of specimens. The division between the CT numbers in the two images was used to create a regression model against the measured MC that showed an R^2 of 0.97. Predictions for MC were made on a different group of specimens, resulting in a root mean square error of 1.99 MC percentage points. Results are promising and suggest DXA is applicable to a range of medical CT-scanning energies. The relatively low error suggests that, with further refinement, the method could achieve a high level of precision.

Keywords: Computed tomography, CT-scanning, dual energy, wood moisture content, x-ray.

SKI PAIRING BY EVOLUTIONARY ALGORITHM METHODS – AN APPLIED MATHEMATICAL EDUCATION EXAMPLE

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In ski industries the pairing of skies is from huge importance, as the customer expects similar properties of his skies. Especially in the high price cross country ski market, the properties in usage are from main importance. Statistical Process Control methods are standard in this industry, but the high portion of

handcraft and manual works as well as the variation of mechanical properties of wood leads to a variation that cannot be diminished completely.
For this reason a process of pairing is installed, where the best ski pairs of a production lot are built. Within this paper a method to optimize this process based on Evolutionary Algorithms is shown. As the development of the optimization method was included in a lecturing program at the University of Applied Sciences in Salzburg, the educational experiences are also shown.

Keywords: optimization, ski industry,evolutionary algorithms, ski pairing.

COMPARING MULTI-ATTRIBUTE DECISION SUPPORTING TOOLS

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A qualitative and a quantitative decision supporting tool were applied to assess and optimize forestry supply chain environmental, social, and economic impacts.
The used quantitative tool was linear programming. The environmental, economic, and social impacts of forest biomass used for bioenergy production were monetized and optimized by attributes, pairwise, and all three attributes together. The combinations of feedstocks, products, markets, and end use were studied, and trade-offs of social, environmental and economic impacts were introduced.

A qualitative multi-attribute decision supporting tool - a decision tree in DEXi software - was applied to assess the environmental, social, and economic impacts of bioenergy production. An indicator system, a decision tree, and decision rules were established by a panel of experts and stakeholders. Delphi method was applied building the model. Experts added the values of the individual indicators, and the results were interpreted and visualized to support stakeholders' discussions.
The advantages and disadvantages of the two tools were evaluated, compared, and future applications, and development opportunities concluded.

Keywords: Bioenergy, Linear Programming, Optimization, Sustainability, Woody Biomass.

COMPUTER INTEGRATED MANUFACTURING PROBLEMS OF TURKISH FURNITURE INDUSTRY

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Computer Integrated Manufacturing(CIM) started to take place in the industrial applications in the 1990's. It has been into furniture industry in the last 20 years as it conducts the integration of administrational and manufactural operations. Furniture industry, with its expectation of dynamism about design and variation of product types, indicates a need for the collaboration of flexibility and otomation. In this study, evaluations and problems related to CIM are investigated with a survey considering the companies in Turkey. The survey was applied on the selected Turkish large scale furniture companies using CAD, CAM and CAD/CAM systems. According to the results, Turkish furniture companies using CAD/CAM systems use CNC edge banding machine (95%), CNC panel saw machine, CNC Routers (75%), CNC drilling machine (65%), CNC calibrating and sanding machines (55%) for manufacturing process. The major problem of the companies was the lack of qualified and experienced operators. According to the research, 37% of the furniture companies were beginning to use the integrated manufacturing system, 26% had CAD and CAM systems without the integration and 37% were fully using the CIM system in their manufacturing process. The prominent challanges about CNC machinary operations were employment of the operators and their sustainability at the company (45%) and maintenance (18%). The challanges about the application of CAD systems were lack of qualified software users (22%), adaptation of the software with other software programs (15%) and technical support after purchase (14%).

Keywords: computer integrated manufacturing, furniture industry, CIM problems, CAD/CAM, Turkish furniture.

Session 5.2 Processing and Product Innovation III

EFFICACY OF DIFFERENT FLAME RETARDANTS FOR WOOD PRODUCTS - DETERMINATION OF RESIDUAL LENGTH AND MASS BURNING RATE AFTER FIRE SHAFT TESTS

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In the course of a research project for the development of wooden doors with elevated fire resistance, preliminary fire shaft tests according to the draft DIN 4102-16 were conducted to compare the efficacy of different flame retardants. Spruce and pine solid wood and blockboards designed to be the middle layer of the fire doors were treated with different flame retardants (solid wood: vacuum pressure impregnation; blockboards: vacuum pressure impregnation and surface coatings) and tested in the fire shaft test for ten minutes. To evaluate the effectiveness of the flame retardant treatments, residual length and mass burning rate were determined.

Flame retardants treated with vacuum pressure impregnation showed high residual length values from 30 cm up to 45 cm with blockboards and between 15 cm and 30 cm with solid wood. The residual length increased with the amount of flame retardant absorbed by the test specimens. Performance of surface coating products differed significantly between 0 cm (non-foaming products) and 44 cm (intumescent coatings).

Mass burning rate is not commonly applied for fire shaft tests. It was adapted for this investigation to save time and effort, because of the high number of tests. Mass burning rate was measured on six different levels above flame position. In comparison to untreated blockboards, the mass burning rate was significantly lower after treatment with flame retardants. The reduction was between 33 % and 75 %. The 75 % reduction was reached by three products (two foaming paints and one impregnant) which significantly outreached the performance of the other products. The fire shaft tests allowed for a more efficient evaluation of flame retardants for improvement of fire resistance of wooden doors.

Keywords: flame retardants, fire shaft test, wooden fire doors, residual length, mass burning rate.

STRATEGIES FOR REDUCING FINES IN ORIENT STRAND BOARD PRODUCTION

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Our mill studies show that, orient strand board (OSB) mills in the southern United States (U.S.) typically generated 30% fines at green end section and after drying the fines amounted 40-60%, indicating that about half of southern pine logs were converted into waste during OSB production. The fines in OSB panel will consume more resin; reduce panel strength and increase panel thickness swelling and linear expansion. To address the fines issue and to keep a high log-to-products ratio, normally an OSB mill has to use more resin, increase panel to ensure that the fines addition in the panels will not affect the panel performance, which increases cost in using this "overweight" product, in terms of excess energy consumed during transportation of the products and unnecessary mass in the products. Globally, people have used different technologies to reduce fines generation during flaking such as using only straight sorted logs, getting rid of decay and crooked wood, wetting and softening wood, cutting longer strands, slowing flaking speed, improving knife quality and flaking thick strands. The mill observations have shown that not many mills in the southern U. S. have adopted a technology to specifically reduce fines. This on the one hand indicates the necessity to show the benefit of reducing fines to the US mills and on the other hand indicates we need systematic approaches to reduce fines and to engineer the use of the strands and fines in OSB production, for the sustainable development of the U.S. OSB mills.

Keywords: Fines, log-orientation, flaking, moisture-content, flaking-speed.

DEVELOPMENT AND APPLICATION OF OSB AND ITS FINISHING TECHNOLOGY IN CHINA

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The OSB is a good sort of materials widely used as wall, roofing,and flooring in house construction in the United States and Europe. The Chinese government encourages development of the OSB industry given that it imports more than 150000 $m^3$of OSB, mainly from Europe and Canada. Now there are four companies producing OSB with a total annual output of approximately one million, two hundred thousand m^3. Due to huge timber consumption every year, the large population and environmental pressure in China, the government does not encourage the development of wooden structure house. It is important to develop the new application of OSB in China.

Because OSB's surface is rough, bigger particle morphology, most Chinese do not like the product as an interior decoration material. It is necessary to select some suitable cover materials and study the finishing processing technology of OSB. This paper introduces the finishing processing of OSB and the technical standards of six series products of OSB produced with popular woods by the Baoyuan wood company. Wood veneer, melamine paper, thinner fiberboard, thin color aluminum plate, clear painting and brush-paint were selected to be used for its facing materials. Their sizes are 2440 x 1220, board thickness range is 6-40 mm, mainly 6 mm, 12 mm, 18 mm, 40 mm. These products are mainly used for external and interior walls of house, external and interior decoration, wooden door, wood keel, bearing furniture, mechanical packaging, building templates, roof, kitchen furniture, waterproof and heating floor, container, vehicle and ship floor, etc. These products can create a unique environment with fashion and personalized decoration.

Keywords: Development and application of OSB in China; Cover materials; Finishing technology; Technical standards of OSB.

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MOISTURE-RELATED BEHAVIOUR OF BONDED ASH (*FRAXINUS EXCELSIOR* L.) FOR STRUCTURAL APPLICATIONS

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The use of ash wood (*Fraxinus excelsior* L.) helps to significantly enhance the load-bearing capacity of glued laminated timber (glulam) compared to spruce (*Picea abies* L. Karst.) glulam. One prerequisite for this is that the durability of ash bonds in structural applications can be guaranteed. The aim of this study was to investigate the durability of adhesively bonded ash. Melamine-urea-formaldehyde (MUF), phenol-resorcinol-formaldehyde (PRF) and one-component polyurethane (PUR) which are commonly applied in the glulam industry were tested. Bond durability was evaluated by means of delamination tests according to EN 302-2. Furthermore, the behavior of bonded ash in case of wood moisture change was examined using digital image correlation (DIC).

This investigation showed that adhesive types which are regarded to be equally well suited for structural bonding of softwoods perform differently when used with ash wood. In delamination tests, PRF proved to be the most appropriate

adhesive type to produce durable structural bonds with ash. In DIC measurements, the focus was on moisture-induced shear strains in bonded ash. Deformations in and adjacent to the glueline were greatly influenced by adhesive elasticity. The investigation also revealed that the thickness of melamine-urea-formaldehyde (MUF) gluelines has an effect on moisture-induced shear strains in bonded ash. The results indicate higher interfacial stress for thin gluelines and a buffering effect of thicker gluelines. This may explain the lower moisture-related durability of ash bonds with thin gluelines as determined in delamination tests.

Keywords: Ash, Adhesive, Delamination, Digital Image Correlation.

Session 5.3 Economics and Decision Support

BARRIERS IMPACTING UNITED STATES ADVANCED BIOFUEL PROJECTS

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Although the 2005 Environmental Policy Act was enacted to help bolster the emerging biofuel industry, 52% of advanced biofuel projects were closed or shut down by 2015. However, no complete lists of barriers that impeded these projects were located. The goal of this study was to develop a list of barriers impeding biofuel projects by conducting a literature review of barriers, spatial analysis of status, survey, and determination of coproducts and byproducts and their marketing and distribution barriers from the industry stakeholders.

The spatial analysis indicated 59 biofuel projects were attempted, and their Eastern and Western location by status was not a barrier. Using Grounded Theory, nine barriers were derived and aggregated in major categories, including product development, strategy, technology, competition, energy costs, funding, government, suppliers, and third-party relations. An analysis was conducted relating their status to internal and external barriers, indicating no relationship between type of closing. Next, the number of barriers was expanded to 23, and a survey was conducted to gain knowledge on these barriers from industry stakeholders. Comparing the barriers by stakeholders, there were differences based on status, type, and technology of the projects. The survey and discussion identified 79 barriers different across years, type of industry (pilot, demonstration, or commercial), status (open, closed, or planning), and technology (thermochemical, biochemical, or hybrid). Forty-seven coproducts and byproducts and many barriers to their marketability and distribution were determined and ranked by primary and secondary barriers. This research will aid future biofuels projects in planning, research, and development stages.

Keywords: Advanced biofuel barriers, coproducts, Renewable Fuel Standard (RFS), renewable volume obligation (RVO), and renewable identification numbers (RINs).

AN OVERVIEW OF THE ROLE OF LIGNO-NANOCELLULOSICS IN THE BIOREFINERY CONCEPT

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Due to its availability and composition, lignocellulosic biomass is one of the main candidates as an alternative raw material for the production of bio-chemicals, fuels and products to reduce the world's petroleum-based dependence. This not only adds value to- but also decreases the carbon footprint of both, biomass and products. Efforts on the development of an integrated biorefinery concept are the main focus of several research groups around the world. With the target of improving to its maximum the profitability of each of the biomass streams, production of nanocellulose is gaining increased attention, since it is a versatile material with superior properties that can increase the potential of lignocellulosics.

Obtained by mechanical fibrillation of wood pulps, traditionally by refining, homogenization or a combination, the manufacture of cellulose nanofibrils (CNF) usually involves either chemical or enzymatic pre-treatment. Processing method as well as composition of the raw materials, dominate the properties of the CNF suspensions and their effect in the final product and they make a great addition to the value chain of commodities like sugar and ethanol production.
In this contribution, an overview of production of CNF obtained from different raw materials will be discussed in terms of properties of suspensions and end-products, such as self-standing films, as well as the utilization of unbleached cellulose pulps as source for CNF and the impact of the remaining lignin on the CNF final properties. Additionally, an overview of applications of CNF will be presented, with an emphasis in large-scale CNF film production.

Keywords: biorefinery, nanocellulose, nanocellulose films, lignin-containing biomass.

OPTIMIZATION OF BIOREFINERY FRACTIONATION APPLIED TO LOBLOLLY PINE USING RESPONSE SURFACE DESIGN: MAXIMIZATION OF PROCESS YIELDS AND MINIMIZATION OF LIGNIN GLASS TRANSITION TEMPERATURES

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Lignin, a low value by-product of biomass fractionation, is currently of particular interest for the production of value added materials such as carbon fibers within a biorefinery. Accordingly, we have isolated lignin, hemicellulose, and cellulose

by organosolv fractionation of loblolly pine (*Pinus taeda*) under the influence different fractionation severities (2.50-3.31). This study targeted maximum lignin and pulp yields as a function of process parameters such as temperature (140-150˚C), sulfuric acid concentration (0.1-0.15 M), runtime (90-120 min), solvent composition (16-62 wt% methyl isobutyl ketone), and feedstock particle size (coarse and fine). Furthermore, the impact of process parameters on the glass transition temperature (T_g) of lignins was investigated as an important parameter for the manufacture of carbon fibers. Response surface methodology (RSM) was applied to find optimal fractionation conditions. To correlate thermal properties with the chemical structure of lignins, Fourier transform infrared (FTIR) spectroscopy was employed.

The most significant factors were found to be temperature, particle size, and solvent composition, with solvent composition displaying the most significant influence on lignin and pulp yields (p-value < 0.0001). A maximum lignin yield of 87.00 wt% and maximum pulp yield of 65.75 wt% were determined at combined severities of 3.21 and 2.63, respectively. The lowest T_g of 132.83˚C was found at a combined severity of 2.82. Results of yields and thermal properties show agreement with preliminary studies performed on softwood and may offer a benchmark for the prediction and design of advanced value added materials within a biorefinery.

Keywords: softwood, experimental design, biorefinery, pulp yield, thermal property.

ECONOMIC ASSESSMENT OF WOODY BIOMASS SUPPLY IN THE STATE OF KANSAS

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This research study assessed the geospatial economic supply of cellulosic feedstocks for potential mill sites in the state of Kansas (KS) with procurement zones extending to Arkansas, Iowa, Missouri, Oklahoma, and Nebraska. A web-based modeling system Kansas Biomass Supply Assessment Tool was developed to identify least cost sourcing areas for logging residues and upland hardwood roundwood biomass feedstocks. An exclusion criteria was developed to improve the geospatial supply and cost estimates. The criteria restricted supply zones given certain geographic features (unsuitable ecological regions), federal land restrictions (e.g., military bases, national grasslands, etc.), and areas with high population densities. Geospatial boundaries were developed at the 5-digit zip

code tabulation area (ZCTA). This higher level of resolution for assessing economic biomass supply of cellulosic feedstocks is unique relative to prior studies.

Comparative analyses were conducted for six sub-regions within Kansas as identified by the US Forest Service as suitable for forest habitat (Chanute, Effingham, El Dorado, Manhattan, Ottawa, and Pratt). The Chanute, Ottawa, and Effingham regions have larger biomass supply for upland hardwood roundwood within a 130-km procurement zone. Atchison County (Effingham City, ZCTA 66023) for Effingham region has the least marginal costs for upland hardwood roundwood. Marginal costs for this roundwood ranged from $92.59 to $108.68 dry metric ton^{-1} with an annual supply of approximately 72 thousand dry metric tons. The least favorable was the El Dorado region where marginal costs ranged from $97.32 to $108.05 metric ton^{-1} with an annual supply of approximately 4.4 thousand dry metric tons.

Keywords: cellulosic feedstocks, woody biomass, economic supply, geospatial assessment, Kansas, BioSAT.

Session 6.1 Analytical Methods for Process Improvement

RELATIVITY AND THE CONTROL CHART

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Neither space-time nor the control chart are new ideas. The concept of space-time adds time, the fourth dimension, to the three primary dimensions of space. Physics uses space-time to better understand relativity. The concept of a control chart follows a measurement over time to determine stability. Continuous improvement can add the dimensions of space to better understand variation. Traditional variable or attribute control charts rely on the time dimension to drive the analysis as they attempt to measure variation. Control charts answer the question, "Is the current measurement consistent with previous measurements?" Variation not only occurs over time, but in space. Control charts can also answer the question, "Are local measurements consistent?"

A multiple opening press is a common machine center in many forest products plants. Variation between press loads, shifts, days, months, etc. is the common analysis for these presses in time. By sampling a full press load, variation of a measurement can be evaluated in space. By changing the dimension from extensive sampling in time to intensive sampling in space, additional insight about how the process varies is revealed. Examining press variation with a control chart from top to bottom, side to side, or infeed to outfeed identifies problem areas that need corrective action. A process should be stable in space as well as time.

Keywords: Control Chart, Multiple Opening Press, Continuous Improvement, Spatial Variation.

CONTROL BANDS FOR DATA SIGNATURES

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Improving product quality and reducing sources of variation that lead to unnecessary costs are common goals for most companies. Statistical process control (SPC) primarily involves the implementation of control charts and is an analytical method that is used to improve product quality in industrial applications. SPC involves primarily the use of Shewhart control charts, which are used to quantify natural variation of product quality, or of a process (Shewhart 1931). Univariate Shewhart control charts have been used

extensively for over 60 years. The aim of this paper is to improve the diffusion of research to the practitioner on the use of control chart methods in the context of *data signatures*. Rhyne and Treinish (2000) appropriately define a *data signature* as a mathematical data vector designed to characterize a portion of the data set, such as an individual time-frame of a scientific simulation or an article within a corpus. Two methods are examined for developing *control bands* for *data signatures*. The first is Bonferroni's method where a pointwise prediction interval is constructed on *k* observations at each value of *x*. Nonparametric smoothing splines in the context of Bayesian confidence intervals is the second method examined. The control band methods were applied to NIR spectral data of woody cellulosic feedstocks and to vertical density profiles of medium density fiberboard. In simulation, the Bonferroni method was closer to the Shewhart probability of quantifying natural variation of the data signatures. The nonparametric smoothing spline tended to over-estimate the natural variation of the data signatures.

Keywords: Control bands, data signatures, vertical density profile, woody cellulosic, near infrared spectroscopy.

DESIGN OF EXPERIMENT – TAKING THE GUT OUT OF SOLVING REAL WORLD PROBLEMS

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Even in the twenty-first century with the ubiquitous presence of computing technology and advanced statistical processing and design software, many people still rely on prior experience and gut instinct to solve problems. From troubleshooting processes and investigating quality issues to developing new products, it often seems more expedient to trust the gut rather than invest the time to reap the benefits of a well prepared Design of Experiment (DOE). The reasons for this are based on misconceptions of when, where and why DOE should be used. Some think this is more of an academic tool reserved for university research in science, medicine and engineering. Others feel that only industries such as drug, auto or aerospace would benefit from using DOE during concept and development phases. The truth is; DOE can be applied in almost every aspect of professional and personal life. It's not only a powerful tool for developing new products or processes, it can also optimize and improve current conditions and indicate factors that have the biggest influence on the process or end product. Forest Products is one of many industries that can gain from utilizing DOE for aspects such as optimizing manufacturing and quality to reducing cost and waste. While relying on hard work, experience and gut instinct may have built today's real world industries, the power of DOE can elevate them to run world class processes and produce products with an unprecedented level of quality and value.

Keywords: Design of Experiment, DOE, optimization, process, quality.

OK THE TRIAL DID NOT WORK. IS IT MY IDEA OR MY EXPERIMENT?

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We all have been there in the lab when all the preliminary data looked good or the idea sounded great but when it was trialed in the mill, it did not go well. What could be the cause of the difference? Was it the resin, wax, press changes? Or did the idea just not work? Or was it how the experiment was designed and conducted that drove the failure? In a second situation, has a first trial gone so well that you shifted to the new state only to find out later that the good effects seen in the initial trials were not seen when concept was commercialized? What are some of the factors that could lead to this result and how can they be taken into consideration in order to improve the ability to accurately evaluate new ideas in the field?

Keywords: New idea, lab, trial, mill trial, factors.

Session 6.2 Processing and Product Innovation IV

REDUCED VOLUME SAMPLING FOR TREATED WOOD PRESERVATIVE RETENTION ANALYSIS

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Standard methods for treated wood preservative retention analysis pool a large number of small wood samples (cores) to provide an average retention value with no estimate of variability within the charge. Recently a statistical tool for estimating variability has been described, which uses multiple subsamples. If this method were to be adopted, either more cores in total would be required to provide the same volume of wood sample per analysis, or the analysis would need to use less sample volume. This presentation reports on attempts at the latter approach, using commercially-available, reduced-volume x-ray fluorescence (XRF) sample cups for the analysis of wood treated to varying levels of preservative retention.

Keywords: quality, treated wood, variability, sampling.

THIRD PARTY INSPECTION FOR THE RESIDENTIAL TREATED WOOD INDUSTRY

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A presentation covering the third party inspection process for the residential treated wood industry. Topics discuss are AWPA's M22, M23 and newly formed M25 standards. AWPA M22 provides a method for third party agencies to evaluate inspection data based on preservative penetration and retention results. AWPA M23 establishes a system for inspection agencies to audit and quantify treating plant internal quality control processes required by AWPA. AWPA M25 contains minimum requirements for treating plant quality control and inspection agencies to monitor the treating plant products and processes, sample treated products, and determine conformance to applicable portions of the U1 and T1 Standards.

Keywords: residential treated wood industry, standards, conformance, quality control.

TREATMENT AND SPECIES OPTIONS FOR GLUED-LAMINATED TIMBER ("GLULAM") USED IN EXTERIOR STRUCTURES AND TIMBER BRIDGES

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Glued-laminated timber (glulam) is widely used in exterior applications, ranging from park shelters, utility poles, guard-rail systems and timber bridges. This paper/presentation will discuss the various types of preservative treatments used in glulam manufacture, and their allowable above-ground or ground-contact applications. Naturally, decay-resistant wood species will also be presented, with a discussion on allowable design values and end uses.

A common misconception about timber structures exposed to the weather is that their service life is approximately 20 years. Recent research activities by the Federal Highway Administration (FHWA) and the U.S. Forest Service conducted a life-cycle analysis on a large sample of timber bridges made from preservative-treated timbers. Based on inspections across several decay hazard zones, it was determined that modern timber bridges could be assigned the same 75-year life cycle assessment as steel or concrete bridges. This presentation will briefly describe these research activities, and also present pre-engineered timber bridge designs that are available for Departments of Transportation (DoT) across the country.

Keywords: glulam, preservative treatment, decay-resistance, Life Cycle Assessment, timber bridges.

TESTING WOOD DOWEL WELDING IN WOOD BASED MATERIALS

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One recent technology to connect two pieces of wood is friction welding. Different methods are known and analysed according to their properties and applicability. Within this paper an automated welding process is analysed and used to connect a beech bolt to particle board, medium density fibre board, three layer board and plywood. A welding method with constant speed was applied for all samples. After production all samples were tested according to there mechanical strength properties and compared to standard PVAc glued bolts.

The results show, that the friction welding is an interesting option for furniture connections with industrial wood based panels. While plywood showed acceptable values (mean pull out force 1209N) medium density fibre board did not reach acceptable pull out forces (222 N). As the behavior of the joints differ substancially depending on the materials used, the development of specific welding process parameters is necessary depending on the welded materials.

Keywords: wood welding, wood based materials, PVAC glue, pull out test, furniture construction.

Session 6.3 Processing and Product Innovation V

LABORATORY PERFORMANCE EVALUATION OF SOME COMMERCIAL WOOD FINISHING SYSTEMS

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Wood finishing systems such as paint, varnish and stain are used to protect wood surfaces, prevent color changes, and provide a cleanable surface. Preservative wood finish products are a special group of wood finishes that contain additives include fungicides and mildewcides. Little information is available about laboratory performance evaluation of this kind of wood finish. The objective of this study was to determine the adhesion strength (ASTM D 7234) , water repellency/dimensional stability (TS 4085), surface roughness (DIN 4768), color change (ISO 7724-2), mechanical (TS 2595) and biological performance (modified EN 113)of wood coated with some commercial preservative wood finish products. Solid block samples of yellow pine (*Pinus sylvestris*) and beech (*Fagus orientalis*) were used in experimental runs. The blocks were finished by brush application of four coats of the wood finishes.

The finished samples had higher adhesion strength, and parallel-to-grain compressive strength values than the control samples. Results showed that the color stability after exposure for finished wood is better than untreated wood. The applied finishes reduced the erosion rate of the surfaces and stabilized the surface roughness. The finished samples exhibited better water repellent properties than the control groups, whilst their dimensional stabilization was less. Finally, biological tests showed that the finished beech samples had higher durability properties than those of yellow pine samples, but the preservative wood finish products can-not be considered as true wood preservatives.

VISUAL PERCEPTION OF ADHERENCE OF DIFFERENT WOOD FINISH PRODUCTS

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The major functions of wood finishes are to protect the surface, improve the appearance and facilitate cleaning. The most common treatment is applying finishing products to the wood surface. This, closes the pores and prevents or minimizes the contact with air and moisture present in the environment. Wood finishes are influenced by the surface characteristics of the material, the type of product employed, environmental conditions and by application techniques. The main objective of this study was to visually evaluate the adherence of three different types of wood finishes on MDF and plywood. Lacquer paints with and without a primer, varnish and sealant were tested. Finishes were applied with a 1" brush and paint roller, while for the lacquer paint a pneumatic spray gun was

used. The coat test of adhesion of each type of finish was per NBR 14535 (2000), a Brazilian Standard. The finished films were evaluated by 25 evaluators, including designers, technicians in furniture manufacturing, professionals at furniture production areas and furniture users. The MDF panels with lacquer finishing with and without primer were more highly rated, while for plywood only the coating with black lacquer with primer application presented satisfactory results. This is due the fact of plywood panels use wood veneers in theirs outer layers, providing the wood profile, with figures and features cracks in the material, differently from MDF panels which have homogeneous surface due to the use of wood fibers in theirs manufacturing process. Thus, it was concluded that for a better surface finish the application of primer assists in the finished film adhesion and improves the perception of the surface quality.

Keywords: visual evaluation, lacquer, varnish, sealant, furniture.

DETERMINATION OF CNC MACHINING PARAMETERS FOR MDF

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Medium Density Fiberboard (MDF) is prime product to be used in furniture and cabinet production that it is one of the most intensive used composite panel products. The surface roughness is a significant index of wood surface quality. The wood surface quality play an important role on quality of surface coating. In this study a mathematical model was developed to predict the surface roughness and to determine optimal machining condition of MDF. 2^k full factorial design was used to study the effect of CNC machining parameters such as spindle speed, feed rate and depth of cut on arithmetic average roughness (Ra). The results were analyzed using 3D surface graphs and demonstrated that the machining parameters interaction are highly effective on surface roughness parameter for Ra. These factors effecting the surface roughness were examined and evaluated by applying analysis of variance (ANOVA). The validity of the developed model necessary for estimation of the surface roughness value was 98.78 %. Optimum values of wood machining parameters to achieve the minimum surface roughness were determined by desirability function. The optimum values obtained for spindle speed, feed rate and depth of cut were 18000 rpm, 8 m/min and 2 mm, respectively.

Keyword: optimization, modelling, surface roughness, MDF, design of experiment.

Many say mankind now lives in a *digital society* composed of *digital citizens*. Product and process innovations were direct contributors to this *digital society* as *disruptive innovation* in the late 20th and 21st centuries advanced mankind's ability to use information to improve product design, product quality, and greatly improve manufacturing processes. Innovations in sustainable biomaterials have resulted in *disruptive innovation* in nanotechnologies, carbon fiber spinning, new adhesives, wood designs, etc. Many research studies are dedicated to advancing product innovation that promote the use of sustainable materials that have improved performance and reliability. Process innovations must continue to advance to be able to manufacture new product technologies at competitive costs.

The 57 papers and keynotes presented during the 4th PTF BPI 2016 Conference represent studies that directly promote *disruptive innovation* for improved sustainable biomaterials. The organizers of this conference hope industrial partners will consider this research the genesis of new innovative projects.

We would like to thank all of the contributors to PTF BPI 2016. Special thanks go to our corporate sponsors and the Forest Products Society for organizing this year's conference to ensure the success of the event. We hope you enjoy the seaside location of PTF BPI 2016.

Timothy M. Young

Alexander Petutschnigg

Marius Barbu

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