Project Title: **I**nnovative **M**aterials and **P**rocesses for **A**dvanced **C**ontainerboard **T**echnologies – **Center** (**IMPACT** Center)
Principal Investigator: Paper and Bioprocess Engineering (PBE)
Other Investigators: Drs. I. Gitsov, G. Leem (FCH); T. Volk, J. E. Wagner, D.Newman (FNRM); D. P. Kamdem, Michigan State University

The growth of online retailing has driven an explosive growth in the packaging industry. Globally packaging industry's projected growth is much higher than overall economic growth (revenues will increase to $980 billion in 5 years)[1]. Paperboard and flexible packaging materials constituted more than half of the current global consumption of packaging materials showing their importance. Paper as a biorenewable, recyclable, and biodegradable material presents an excellent sustainable alternative to petroleum-derived materials. The U.S. is naturally positioned for paper packaging, with abundant lignocellulosics, water, and human and capital resources. New York State has been a leader in the production of packaging paper with over 2 million ton annual capacity. New packaging paper mills companies employ more than 6,000 people and represent a significant sector of the state's economy. This also represents a significant growth engine for the future with the announcement of the new headquarters for Amazon in the state.
Project Description: This proposal leverages the historic legacy position of the College and the PBE Department to address the unique opportunities and challenges posed by the developing sustainable packaging revolution. The focus is on the *manufacture of sustainable packaging containers converting renewable materials by forming, shaping and assembling mechanisms*[1]. Packaging container technologies radically differ from communication paper technologies and are necessitated by performance emphasizing package failure, barrier, and environmental resistance characteristics. The rapid growth of packaging and shipping economy requires advancements of paper-packaging materials. Reducing the weight of packaging while maintaining or enhancing performance, i.e. increasing the strength-to-weight ratio will be a revolutionary development not only in reducing shipping and transportation costs, but also in reducing overall energy needs and the environmental load. Innovative smart packaging materials incorporating biorenewable, stimuli responsive and other advanced nanomaterials will lead to smart delivery solutions and improve overall sustainability. Improved functionality and package performance by design will also revolutionize the future as much as direct improvements to manufacturing productivity. LCA and TEA can direct processes for better utilization of natural resources, specifically with fast-growing hardwoods, such as willow, taking advantage of the ESF's extended properties. Through developing smart, flexible, and eco-friendly packaging technologies and providing related educational programs, the project will directly address the proposal call for Discovery Challenge Seed Grants. The activities of the proposed IMPACT Center are organized into three areas:
I: Research Inquiry: We propose to develop novel and sustainable technologies to enable high-impact innovations in manufacturing processes, products and performance of packaging materials. These will include advanced pulping processes for recycled and virgin packaging resources, advanced functional packaging products with biorenewable polymers, and understanding of fundamental properties of biomass and functionalities of

* Numbers ([1-7]) are the criteria in the RFP call.
[1] *The Future of Global Packaging to 2022*, Smithers Pira,

packaging products. The center's research projects will be organized into the following three thematic areas.

(a) Advanced High Yield Pulping Processes: Increasing the yield of pulp fibers from virgin resources will effect a very significant boost to the profitability of packaging papers. Even a few percentage points increase in yield will result in additional production of thousands of tons of pulp, translating into significant economic benefits and savings of natural resources. Studies of innovations to kraft pulping[2] have shown that yield increases of 6 percentage points, strength increase of 40% and increased production of 11.5% can be obtained with packaging-grade fibers from southern pine. On a global scale, such changes will be revolutionary in their impact on industrial economics (IMPLAN modeling) and the environment.

(b) Innovative Biopolymer-based Packaging Materials: Paper loses strength upon exposure to moisture which leads to overdesigned packaging using much more fiber than optimal. The light-weighting of paperboard, i.e. reducing the amount of fibers while maintaining strength and stiffness is a critical need in reducing fuel and transportation costs, the consumption of raw materials and energy, and lessening environmental burdens. Biochemical modification of lignin surfaces on fibers reinforce bonding and increase paper strength is possible[3]. Such advances can potentially change the entire industry's paradigm that has primarily viewed lignin as an interference material for strength. An LCA will guide innovations in materials and highlight their contribution to sustainability and improved environmental impact. Solutions can include packaging paper impregnated with hydrophobic biorenewable compounds, such as lignin, which is more resistant to moisture and withstand a wide range of changes in the environment. Functional materials such as nanocelluloses, nanolignins, electroconductives or stimuli-responsive materials can be incorporated into novel structures for smart packaging materials imparted with unique and novel functionalities. Novel chemistry at the surface of packaging fibers taking advantage of their unique structure and composition can functionalize materials that are tailored for new applications whether in the rapid detection of chemicals and other materials or enhanced absorbents for purification and remediation.

(c) Analytical and Technical Testing for Packaging Materials: A fundamental understanding of physicochemical properties of lignocellulosic biomass is essential to screen the best feedstocks for needed applications, designing the advanced materials, and developing a high efficiency process. Package failure and mechanical performance can be analyzed using full 3D X-Ray microtomography, SEM and TEM techniques, pioneered at the NC Brown Center and in the ESPRI, and coupled with digital simulation can yield optimal paper structures for enhanced performance. Packaging materials must be both durable and biodegradable; and also dimensionally stable under varying humidity. The performance of packaging materials will be tested for durability against microbes, and also analyzed for ease of biodegradation and/or recycling. Product durability involved with weather barriers, coatings and/or additives during their useful lifetime will also be analyzed. The characterization team will work closely with other research teams and establish the database for future research. A lead faculty position in packaging, leveraged through SUNY wide initiatives such as the Empire Innovations will be part of the future.

---

[2] Francis, R. C. Work in progress, 2018.

[3] Bujanovic, B. Ongoing studies in lignin 2018.

The PBE Department is a national and global leader in research programs in the pulp, paper, and related areas. The faculty's contributions to pulping and bleaching processes, lignin chemistry, moisture transport, role of structure on performance, and physics of paper are well recognized. Several modern physical testing techniques for pulp and paperboard have originated from the PBE laboratories. Faculties have excelled at translational research, winning several NSF grants in the GOALI, CMMI, and PFI programs. Commercialization of innovations has a long history, which continues with several patents granted recently[4]. The laboratories in Walters Hall are well equipped for package analysis, testing and process chemistry. Facilities in Baker laboratory, the NC Brown Center, and CJK Wang Wood degradation lab are excellent resources. Biomass such as willow can utilize the college's forest properties for field studies [5].

II: Educational Programs[2]: Current courses on Introduction to Papermaking, Paper Physics, Coating, and the senior capstone design courses include some packaging topics while more undergraduate and graduate courses focused on fundamental knowledge and applications of packaging materials and processes will be proposed, leading to certificates, minors, and options in packaging. In consultation with stakeholders and constituents, a new graduate and undergraduate degrees in Sustainable Packaging will be proposed. Additional faculty/staff specializing in packaging will be hired to increase the use of ESF assets[7]. The staff in PBE would also directly support the labs enabling instruction for coursework in MCR, RMS, PSE, FCH, and ENS.

III: Societal Impact of the Proposed Center[6]: The development of sustainable packaging materials is aimed at creating the most efficient environmental "footprint" by replacing fossil-based packaging materials with biorenewable materials, which would increase their recyclability. Increasing pulp yield will reduce the amount of biomass needed for the production of paperboard while improved performance through increased strength-to-weight ratio will reduce the environmental and energy footprints (e.g., lessened landfills and greenhouse gas emissions). The development of high-performance and innovative packaging materials will boost economic activity in a sustainable manner. LCA and TEA will be performed through all stages of the production, use, and recycling document advantages of biorenewable paper packaging over petroleum-based packaging.

Collaborations and Future Developmental Strategies[4]: ESPRI in the department has historically served as an academic research center. Its model serves well for the proposed center with industrial members contributing and collaborating in developing research projects. The PIs involved are well known in the pulp/paper and wood products industries, and woody biomass production systems/TEA. Our initial proposals have raised *significant interest and positive commitments* from Alsip Minimill, BASF/Solenis, WestRock and Domtar, all major producers of packaging paper with strong relationships with our department. The project's discoveries in sustainable packaging processes and materials are consistent with funding opportunities supported by USDA NIFA-AFRI and NSF CMMI[3]. Our past history of success with NSF, DOE and USDA grants in these and similar programs can be well leveraged. The Department's industrial connections through ESPRA and the SPPF since 1960 have supported PBE students. The program will have technical and product quality services and continuous partnerships with these companies for self-sustainability[7].

---

[4] Several patents have been granted to members of PBE, in the last 10 years. Almost all have been licensed or optioned to commercial enterprises.

Innovative Materials and Processes for Advanced Containerboard Technologies- Center

Feasibility: The IMPACT center's focus is the development of sustainable packaging materials, package design, and best environmental performance. Research and education programs utilize our established expertise in bio-renewable fiber, paper, and material/polymers production & characterization, with expansion to include utilization of sustainable materials into efficiently designed high-performance packages, for which industrial and consumer demand and market growth is highly expected.

The center's research will be in three general categories: Bio-Based Packaging Materials, Sustainable Packaging Design and Performance, and Technical Analysis of Advanced Packaging Material. Several interested industrial partners have already been identified, including WestRock, Domtar and Alsip. They, along with others to be recruited, will advise and help guide project selection, as well as provide cash and in-kind co-funding, in line with our highly-regarded 60-year ESPRI cooperative model.

Project PIs have significant experience in securing NSF, USDA, and other large competitive federal research grants with specific attention to renewable material industrial innovation, and it is expected that leverage of selected packaging projects will facilitate further industrial and federal sustainability interest. Focus areas described fundamentally lead to lower environmental impact, and such sustainability, economic activity and environmental aspects of developed packaging processes and materials will be evaluated through LCA, TEA, and IMPLAN modeling with FNRM members. Our material development team of PBE and FCH faculty and researchers will develop multi-functional and robust packaging materials. Sustainable Packaging will be developed initially as a multidisciplinary minor using current and new MCR, RMS, PSE, FCH, and ENS courses, with subsequent expansion into a PBE major program. The proposed program has great potential to increase student enrollment with its well-recognized field, and through established industry-related courses, collaboration and career opportunities.

Transformative Characteristics: While there are several packaging centers within the US, none focus on paper and paperboard packaging as a renewable, sustainable, biodegradable material. Our significant legacy and strength in this area complements the College's sustainability leadership positioning for the future, and in recruiting new students. Our competitive features in packaging related research and education include (1) broad scope of paper and wood science, process & material development, product testing, material analysis, and economic and environmental evaluation; (2) well-established industrial collaborations;(3) packaging related RMS national and international education programs; and (4) excellent resources including production facilities from lab scale to pilot scale, packaging product property testing laboratories, and forest properties for biomass field studies.

The IMPACT center will address current and future societal issues such as resource shortages and environmental degradation by developing impactful sustainable packaging and on-demand packaging solutions, which reduce and replace petroleum-based plastics with biodegradable, environmental and climate-friendly materials. As an educational institution, the ESF IMPACT center will address technical packaging challenges through research and training students with knowledge and skills to meet societal and company sustainability demands. Industrial partners will collaborate with development of standards for sustainable packaging, as well as certifications, outreach, and student internship and co-op programs, all of which will enhance ESF's reputation