United States Department of Agriculture

Final Report

Title:	Supporting Sustainable Forest Products Development (LCA on Furniture)

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Performing Department

Forestry & Natural Resources

Non-Technical Summary

Wood plays a significant role in our lives and culture because it is a renewable, recyclable, and biodegradable construction material. Products made of wood are in general highly sustainable, produced often from local certified resources, yet wood and wood products are in general poorly understood in terms of their environmental contribution by designers and the general public. Waste, pollution, and excessive use of non-renewable resources are signs of design and product development failure. We can minimize the cradle-to-grave flow of non-renewable materials from factory to landfill and the environmentally costly burning of fossil fuels by encouraging the design and production of sustainable cradle-to-cradle products made of renewable materials with low environmental footprint. These processes could be quantified scientifically with life cycle analysis (LCA) methods in almost all products. LCA models and environmental product declarations (EPDs) on these products will help to better inform designers, product developers and consumers and should increase demand for products (such as furniture) produced from wood and certified resources.

CORRIM, the Consortium for Research on Renewable Industrial Materials, is a non-profit research group of universities and major industry partners that has been conducting life cycle inventory and assessment research since 1996. CORRIM produced all the publicly accessible wood products life cycle inventory data (available through the US Department of Energy) consistent with international ISO 14044 standard. The CORRIM database contains most wood based materials used in housing construction, but does not include furniture. Purdue University is a founding institution of CORRIM and Dr. Haviarova serves on CORRIM's board of directors. The lack of furniture related LCA data is a major gap that the proposed research would address. Long term research goal is to provide information about the environmental footprint of various furniture products for both producers and consumers.

Moreover, by following a well-developed knowledge transfer plan, information dissemination will make a significant change in the forest products industry sector and in consumer perception of wood products and its sustainability. Research outcomes will also contribute directly to a "Cradle to Cradle World". Main objective of this application is to Facilitate Sustainable Furniture Products Development and Engineering in order to better understand sustainable design and manufacturing options for producers, and to provide product sustainability benchmarking information for consumers.

PIs expertise lays in furniture design and product development. Three components typically comprise today's furniture design: design for aesthetics, design for strength, and design for manufacture. By adding a fourth component, design for sustainability, manufacturers of wooden furniture could distinguish their products from non-wood products and become more competitive. Consumers could make more environmentally-conscious decisions while selecting a sustainable product.

To our knowledge, this is a unique project addressing the problem of sustainable wood furniture production (and related products) with a broad, systematic approach and quantitative methods, and it could make a significant difference, initially on a national scale, and then globally.

The proposed research will be of significance because its outcomes will help to enhance sustainability practices in the furniture industry, decrease the environmental footprint of its products, develop new knowledge in sustainable furniture design and manufacturing, improve business efficiency, and stimulate industry growth. Implementation of sustainable forest products by LCA tools ultimately will have strong economic and financial benefits. It will enhance growth of sustainable products and hopefully establish the wood products (furniture) industry as producers of low environmental impact products, viable on national

and international markets. In the end, it will be of significant value to future generations and contribute to a "Cradle to Cradle World".

In conclusion - There is a critical need for science-based comparative measures in sustainable product development processes. Needed LCA models supporting forest products engineering and production will be generated leading to a set of science-based engineering guidelines for product developers and users in order to promote sustainable use of global natural resources to balance economic and environmental aspects. LCA application is essential for long term viability and competitiveness of the U.S. forest products sector.

Accomplishments

Major goals of the project

General Goal:

Facilitate Sustainable Forest Products (Furniture) Development and Engineering

In summary, the general goal is to conduct Life Cycle Analysis (LCA) on different types of furniture, benchmark results, find the most environmental options in terms of product development, and determine the way how to facilitate this process for furniture producers, mainly for small and mid-size companies. Ultimately, to develop a Sustainable Design Tool to be used for sustainable product development by US forest products industry.

Goal #1: Develop Life Cycle Analysis (LCA) Models Based on Current Furniture Design and Manufacturing Practices

1A. LCA on solid wood chair

1B. LCA on comparable chairs made of non-renewable materials (steel, plastic, aluminum)

1C. LCA on several simple types of furniture obtained from industry (chairs, tables, cabinets) made of assortment materials (wood based and non-wood materials).

Goal #2: Develop Sustainable Furniture Design and Manufacturing Solutions

Goal #3: Address and Incorporate End of Life Options (EoL) into a Product Development Processes

Goal #4: Develop Comprehensive Sustainability Design Tool

Products/Outputs:

The proposed activities should lead to the development of the following products:

- LCA models of wooden chairs including the variables within the product;
- LCA of steel, aluminum, plastic chairs;
- LCA of current furniture obtained from local producers and made of assorted materials;
- End of Life (EoL) Options for variable furniture systems;
- Product comparison and presentation of sustainable models;
- Sustainability Design Tool - cumulative presentation of research outcomes in a user-friendly form.

Results of the proposed research will also lead to scientific and extension publications and presentations targeting: a) the research community, presented during scientific conferences b) industry, presented during trade shows or industry workshops, and c) the general public, presented in several public venues with the objective to raise awareness on the importance of wood in our society and how its use plays a key role in a sustainable future (LCA recommendation).

What was accomplished under these goals?

Life Cycle Analysis ware performed on different types of products using SimaPro 8 LCA software. Data were collected and used for development of education material and comprehensive design tool. LCA training tool was created, used for education and training, and shared online. A web-based LCA training tool was completed for fast computing environment and it is based on serval methods. The designer now could type in a few required parameters and check product environmental score. We simplify the LCA computing process by carefully checking inventory data and converting them directly to environmental scores. The linear assumptions under LCA help to speed up the computation time, which makes the web tool efficient. Geographical parameters, material sourcing and manufacturing data also contributed to the results. This LCA training tool could serves as a guideline for students and manufacturers for better decision-making in the process of sustainable product development. The tool is showing LCA examples and demonstrates changes in product environmental impact that could be influenced by product developer's decisions. Tool is facilitating science-based information dissemination of product and production environment impact to the forest products community.

Parallel to the LCA studies, research on product lifespan expansion by establishing the proper design values for joints was navigated to the final outputs. The joint system affects directly the product strength. Lower Tolerance Limits for furniture

joinery systems were established, results were published in thesis and several scientific publications. Specifically, during last year, the lower tolerance limits (LTLs) for screw withdrawal strength in wood were investigated. For this purpose, specimens were prepared from white oak and red oak wood, a material widely used in furniture industry. Screw withdrawal tests were performed from transverse, radial, and tangential sections of wood specimens and LTLs were obtained from data sets in each sample group. The study provides a systematic procedure to estimate design values for screws joints. Similar study was conducted to estimate design values for dowel joints with LTL approach. To improve basic manufacturing feasibility and load carrying capacity of CNC router joints, comparative study of these joint designs was conducted. Information generated during these studies will be continually update and disseminated mainly during extension activities, such as education and training related to product development, product sustainability, environmental impact, and on the end advancement of forest products industry.

What opportunities for training and professional development has the project provided?

Two graduate students were partially involved in the project and were trained on products development method, LCA and environmental impact. Several undergraduate students were also trained in assessment of product environmental footprint. Workshops for furniture designers and manufacturers were prepared and conducted. Outcomes of the research were presented on several national and international conferences to the research community. Workshops for national furniture manufacturers were prepared and conducted, such as large convention, Day of Wood. Individual consultations with product designers were conducted as part of extension activities. The information on furniture strength design is available to furniture manufacturers and researchers through published articles and through Wood Research Laboratory information dissemination efforts - short courses, workshops, website, and mailings.

How have the results been disseminated to communities of interest?

Dissemination of results continued through scientific publications, presentation during conferences and workshops, teaching, and consultations with national stakeholders (mainly furniture companies). PI is actively involved with several associations and reaching out through them to the intended audience: Society or Wood Since and Technology; Indiana, Hardwood Lumbermen's Association, and Consortium of Removable Materials (CORRIM). Future work is developing with CORRIM in the area of Circular Economy for Frost Products Industry, where outcomes of this project are going to be utilized.

What do you plan to do during the next reporting period to accomplish the goals?

{Nothing to report}

Participants

Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	0.3	0	0	0	0.3
Professional	1.3	0	0.5	0	1.8
Technical	0	0	0	0	0
Administrative	0	0	0	0	0
Other	0	0	0	0	0
Computed Total	1.6	0	0.5	0	2.1

Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
	1		04.04 Environmental Design.

Target Audience

Furniture product developers and manufacturers; Forest products industry leaders; Associations (IHLA; AHEC, CORRIM, SWST); Wood science community; Graduate and undergraduate students.

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Products

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2019	YES

Citation

Uysal, M. and E. Haviarova. 2019. Lower tolerance limits for screw withdrawal in wood. Wood and Fiber Science VOL. 51(4):375-386.

Type	Status	Year Published	NIFA Support Acknowledged
Journal Articles	Published	2019	YES

Citation

Uysal, M., Tasdemir, C., Haviarova, E. and Gazo, R. 2019. Basic Manufacturing Feasibility and Load Carrying Capacity of CNC Router Cut Joints Constructed of Medium Density Fiberboard and Plywood. Bioresources 14(1): 1525-1544.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2018	YES

Citation

Uysal, M., and E. Haviarova. 2018. A review based on reliability of furniture. Proceedings of the 61st International Convention of Society of Wood Science and Technology and Japan Wood Research Society, Nagoya, Japan, November 5-9. (Pg. 454-461).

Type	Status	Year Published	NIFA Support Acknowledged
Theses/Dissertations	Published	2019	YES

Citation

Uysal, M. 2019. A Rational Approach to Estimate Reasonable Design Values of Selected Joints by Using Lower Tolerance Limits, Ph.D. Thesis, Purdue University, West Lafayette, Indiana.

Type	Status	Year Published	NIFA Support Acknowledged
Websites	Other	2019	YES

Citation

Haviarova, E. and F. Wu. 2019. LCA Training Tool for Furniture: https://www.purdue.edu/woodresearch/lca-on-furniture/

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2018	YES

Citation

Painter, G., E. Haviarova, and M. Uysal 2018. Day of Wood – Secondary Wood Products Perspective. Daylong educational seminar for furniture industry. Vincennes University, Jasper, IN (September; 60 participants).

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2018	YES

Citation

Haviarova, E. 2018. Workforce Training for Purposeful Design – Session 4: Overview of Engineered Materials. Indianapolis, IN (October; 15 participants).

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Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2018	YES

Citation

Haviarova, E. and H. Quesada 2018. Use of Low Value Hardwoods for Cross Laminated Timber and Other Value Added Products in Central Hardwood Region, Seminar and Round Table discussion. In cooperation with the Indiana Hardwood Lumber Association. (April, 19 Participants).

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2017	NO

Citation

Haviarova, E 2017. Designing and Building with Wood – The Most Sustainable Biomaterial. Workshop for PU Experience Students, Purdue University, West Lafayette, IN. (July 30 participants).

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2016	NO

Citation

Haviarova E., Z. Toncikova, H.P. 2016. Sustainable Product Development and its Education. Trends in the Furniture Industry, Brno, Czech Republic (May, 45 participants).

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2016	YES

Citation

Haviarova, E 2016. Sustainable Biomaterials – Process and Product Design. Workshop for 4H students, Purdue University, West Lafayette, IN. (May, 35 participants).

Type	Status	Year Published	NIFA Support Acknowledged
Other	Other	2016	YES

Citation

Haviarova, E 2016. Designing and Building with Wood – The Most Sustainable Biomaterial. Workshop for PU Experience Students, Purdue University, West Lafayette, IN. (July, 20 participants).

Other Products

{Nothing to report}

Changes/Problems

Challenge was to obtain consistent data from industry regarding production data on specific products and energy consumption. Industry either do not collect such data or it is available only in aggregated format. Alternative methods were used to develop needed outputs.