

Environment and Natural Resources Trust Fund 2020 Request for Proposals (RFP)

Project Title:**ENRTF ID: 198-EH**

Eco-Friendly Plastics from Cloquet Pulp-Mill Lignin

Category: H. Proposals seeking \$200,000 or less in funding**Sub-Category:** E. Air Quality, Climate Change, and Renewable Energy**Total Project Budget:** \$ 193,967**Proposed Project Time Period for the Funding Requested:** June 30, 2022 (2 yrs)**Summary:**

We will reduce environmental pollution from plastics by creating eco-friendly replacements using lignin from the pulp mill in Cloquet. The lignin plastics will be similar in strength to polystyrene.

Name: Simo Sarkanen**Sponsoring Organization:** U of MN**Job Title:** Professor**Department:** Bioproducts & Biosystems Engineering**Address:** 2004 Folwell Ave

St. Paul MN 55108

Telephone Number: (612) 624-6227**Email** sarka001@umn.edu**Web Address:****Location:****Region:** Statewide**County Name:** Statewide**City / Township:****Alternate Text for Visual:**

Eco-friendly lignin plastics from Minnesota pulp mill will increase profitability of making paper by replacing polystyrene and other plastics from petrochemical sources.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____ %



PROJECT TITLE: Eco-friendly plastics from Cloquet pulp-mill lignin

I. PROJECT STATEMENT

- We will create eco-friendly plastics from the lignin that makes up 25% of the trunks and limbs of northern Minnesota aspen. The lignin will be the co-product generated when aspen wood is pulped using the “kraft” process to form cellulosic fibers for making paper. The closest such industrial process is located in Cloquet (Minnesota) at the Sappi mill, the most modern U.S. pulp mill.
- These eco-friendly lignin plastics will contain higher-than-90% levels of aspen kraft lignin. They will be similar in strength to polystyrene, which is produced from petrochemical sources. Polystyrene is notoriously resistant to biodegradation; it persists in the environment for centuries. In contrast, lignin plastics are eco-friendly: they will undergo complete biodegradation through a process open to total control (simply by adding a little sugar).
- Lignin plastics will increase the profitability of making paper by the traditional method of pulping wood chips. As cellulosic fibers are formed during the kraft pulping process, lignin separates into (so-called) kraft black liquor, from which it is easily isolated. Currently, the value of this kraft lignin is very low because it is burned as a fuel.
- Aspen kraft lignin from Cloquet will be thoroughly washed with water and then air-dried. For comparison, the effect of a simple methylation step will be evaluated. Thus, before and after chemical methylation, the purified kraft lignin will be solution-cast into plastic test pieces. At 10% or lower levels, commercially available blend components will be introduced to bring about changes in strength of these new lignin plastics.
- Economists estimate that the cost of producing lignin plastics is less than half of the polystyrene selling price. As a result, the profitability of making paper with cellulosic fibers from wood chips will increase. Sales of lignin plastics will highlight prospects for profitability in the conversion of other cellulosic residues from agricultural crops and trees to renewable fuels and organic chemicals.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Isolation, purification and characterization of aspen kraft lignin from Cloquet

Description: *Aspen kraft lignin will be isolated by acidifying kraft black liquor from Cloquet. It will be thoroughly washed with water and air-dried. Before and after methylation, the purified aspen kraft lignin will be characterized in regard to its molecular weight distribution (mwd by SEC), glass-transition temperature (T_g by DSC), structure (by NMR), and molecular organization (by X-ray powder diffraction).*

ENRTF BUDGET: \$ 95,376

Outcome	Completion Date
1. Methylated and unmethylated purified aspen kraft lignin for lignin plastics	12/31/20
2. Aspen kraft lignin molecular weight distributions and glass-transition temperatures	03/31/21
3. Aspen kraft lignin structure and molecular organization	06/30/21

Activity 2 Title: Formulations for aspen kraft lignin plastics and their strengths

Description: *Methylated and unmethylated aspen kraft lignin will be cast into plastic test pieces on their own and with commercially available blend components at levels below 10%. These plastics will be characterized with respect to tensile strength (Instron), glass-transition temperature (T_g by DSC) and molecular organization (by X-ray powder diffraction).*

ENRTF BUDGET: \$ 98,591



Environment and Natural Resources Trust Fund (ENRTF)
2020 Main Proposal Template

Outcome	Completion Date
<i>1. Formulations characterized for plastics from unmethylated aspen kraft lignin</i>	<i>12/31/21</i>
<i>2. Formulations characterized for plastics from methylated aspen kraft lignin</i>	<i>03/31/22</i>
<i>3. Tensile strengths of lignin plastics fall between polyethylene and polystyrene</i>	<i>06/30/22</i>

III. PROJECT PARTNERS AND COLLABORATORS:

Our only (unpaid) project partner will be Tom Radovich, Paper Production Manager at the Sappi mill in Cloquet, who will supply aspen black liquor for the work. At the present, it would be premature to involve other collaborators because Simo Sarkanen's group is currently the only one in the world with the expertise necessary to produce lignin plastics containing kraft lignin levels above 90%.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

As our LCCMR project nears completion, funds will be sought for an injection-molding apparatus that can produce test pieces under conditions more closely allied to industrial practice. Adequate funding will be requested from DOE and/or USDA. Otherwise, when our work becomes sufficiently far advanced, companies and/or entrepreneurs will be approached for bringing lignin plastics to the market place. Articles can take many forms, ranging from automobile dashboards through stackable auditorium chairs to garden furniture, etc.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:

A. Proposal Budget Spreadsheet

B. Visual Component or Map

F. Project Manager Qualifications and Organization Description

Attachment A: Project Budget Spreadsheet
 Environment and Natural Resources Trust Fund
 M.L. 2020 Budget Spreadsheet

Legal Citation:

Project Manager: Simo Sarkanen

Project Title: Eco-friendly plastics from Cloquet pulp-mill lignin

Organization: University of Minnesota

Project Budget: \$193,967

Project Length and Completion Date: 2 years - June 30, 2022

Today's Date: 4/10/19



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET		Budget	Amount Spent	Balance
BUDGET ITEM				
Personnel (Wages and Benefits)		\$ 163,967	\$ -	\$ 163,967
1 Researcher 6 (75% time for 2 years): development of plastics from aspen kraft lignin; 73.5% toward salary, 26.5% toward benefits				
Professional/Technical/Service Contracts				
Equipment repair and maintenance		\$ 2,000		\$ 2,000
Laboratory Services (NMR, X-ray powder diffraction, AFM) for plastic composition optimization		\$ 8,000	\$ -	\$ 8,000
Equipment/Tools/Supplies				
Supplies such as chemical reagents, nitrogen, solvents and laboratory consumables, etc.		\$ 20,000	\$ -	\$ 20,000
Capital Expenditures Over \$5,000				
		\$ -	\$ -	\$ -
Fee Title Acquisition				
		\$ -	\$ -	\$ -
Easement Acquisition				
		\$ -	\$ -	\$ -
Professional Services for Acquisition				
		\$ -	\$ -	\$ -
Printing				
		\$ -	\$ -	\$ -
Travel expenses in Minnesota				
		\$ -	\$ -	\$ -
Other				
		\$ -	\$ -	\$ -
COLUMN TOTAL		\$ 193,967	\$ -	\$ 193,967
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		\$ -	\$ -	\$ -
State:		\$ -	\$ -	\$ -
In kind: Unrecovered F&A	Secured	\$ 104,742	\$ -	\$ 104,742
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		\$ -	\$ -	\$ -

Eco-friendly lignin plastics from Minnesota pulp mill will increase profitability of making paper as they replace plastics from petrochemicals



Aspen often grows in nearly pure stands. Photo © University of Minnesota Extension



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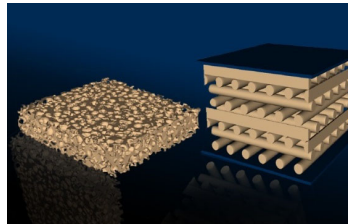
kraft pulp
for paper
from aspen
wood chips

Lignin Plastics

Broad Range of Lignin Plastic Products



automobile dashboard; <http://kinlane.com>



3-D printed foam; doi:10.1038/srep24871



CD jewel case



insulation foam; www.foambyemail.com



plastic chair, True Value



computer console, mainlinecomputer.com

**Reduced Climate Change, Less Pollution from Plastics
Better Environmental Stewardship**

SIMO SARKANEN

While a faculty member at the University of Minnesota, Simo Sarkanen has overturned a 60-year-old idea about lignin structure that has blocked progress in some important areas of lignin research. As a result, his group is the only one so far that has created useful plastics containing over 90% levels of lignin. His group has also identified the first functional lignin-degrading enzyme. Consequently, he and his coworkers are uniquely qualified to demonstrate whether their new lignin plastics are biodegradable.

Patents:

Compositions Including Lignin: Chen, Y.-r.; Sarkanen, S.; Wang, Y.-Y. U.S. Patent **2018**, No. *10,119,027* issued June 25.

Compositions Including Lignin and Methods for Making the Same: Chen, Y.-r.; Sarkanen, S. **2018**, U.S. Provisional Patent Application No. 62/645,940, filed March 21.

Lignin Degrading Methods and Compositions: Chen, Y.-r.; Sarkanen, S.; Wang, Y.-Y. *U.S. Patent* **2017**, No. *9,796,993* issued June 21.

Publications (Selected Publications Relevant to Proposed Research):

Wang, Y.-Y., Chen, Y.-r., Sarkanen, S., Blend configuration in functional polymeric materials with a high lignin content. *Faraday Discuss.* **2017**, *202*, 43-59.

Sarkanen, S.; Chen, Y.-r.; Wang, Y.-Y., Journey to polymeric materials composed exclusively of simple lignin derivatives. *ACS Sustainable Chem. Eng.* **2016**, *4*, 5223-5229.

Wang, Y.-Y., Chen, Y.-r., Sarkanen, S., Path to plastics composed of ligninsulphonates (lignosulfonates). *Green Chemistry* **2015**, *17*, 5069-5078.

Chen, Y.-r., Sarkanen, S., Macromolecular replication during lignin biosynthesis. *Phytochemistry* **2010**, *71*, 453-462.

Chen, Y.-r., Sarkanen, S., From the macromolecular behavior of lignin components to the mechanical properties of lignin-based plastics. *Cellulose Chem. Technol.* **2006**, *40*(3-4), 149-163.

Li, Y., Sarkanen, S., Miscible blends of kraft lignin derivatives with low-T_g polymers. *Macromolecules* **2005**, *38*, 2296-2306.

Chen, Y.-r., Sarkanen, S., Macromolecular lignin replication—a mechanistic working hypothesis. *Phytochemistry Reviews* 2003, *2*, 235-255 ©**2004**.

Li, Y., Sarkanen, S., Biodegradable kraft lignin-based thermoplastics. In *Biodegradable Polymers and Plastics*, E. Chiellini, R. Solaro (eds.), Kluwer Academic/Plenum Publishers: New York, **2003**, pp 121-139.

Li, Y., Sarkanen, S., Alkylated kraft lignin based thermoplastic blends with aliphatic polyesters. *Macromolecules* **2002**, *35*, 9707-9715.

Li, Y., Mlynár, J., Sarkanen, S., The first 85% kraft lignin-based thermoplastics. *J. Polym. Sci. B: Polym. Phys.* **1997**, *35*, 1899-1910.

Organization Description

The resources in the Department of Bioproducts & Biosystems Engineering along with those in the University of Minnesota Characterization Facility are sufficient to carry out the proposed research. The University of Minnesota Sponsored Projects Administration is the entity authorized by the Board of Regents to manage project agreements with LCCMR.