**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**

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| **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 (Tg* *by DSC), structure (by NMR), and molecular organization (by X-ray powder diffraction).***ENRTF BUDGET: $ 95,376** |

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| **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 (Tg by DSC) and molecular organization (by X-ray powder diffraction).*

**ENRTF BUDGET: $ 98,591**

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

**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**