**PROJECT TITLE: *Clean Combustion of Renewable Biofuels Derived from Waste Biomass Using a Novel Atomizer***

**I. PROJECT STATEMENT**

As coal plants become less economically viable, power plants are switching to natural gas through costly retrofitting and/or new construction. Meanwhile, biomass-derived substitutes for coal have the potential to serve as a bridge fuel enabling transition from a coal/natural gas-dominated energy landscape towards a future based on renewable sources of energy, while reducing acidic emissions. Minnesota has a high potential for biomass production due to forest management practices and waste from agriculture and logging. Biomass production and utilization is a source of employment for many Minnesota residents, however, there are technical challenges to the clean combustion of these biofuels that prevent widespread adoption. Currently, cheaper liquid products from biomass are too viscous to be used as-is in conventional burners; instead, costlier pre-treatment techniques such as compaction and pelletization are used to produce a coal-like solid fuel that can be burnt in coal plants. This proposal describes research to be conducted at the University of Minnesota to develop a novel technology that can produce fine sprays from viscous biofuels, enabling clean and inexpensive combustion with extremely low emissions. This will allow the state to be less reliant on coal, support the sustainable use of forest resources and supplement agricultural income. The ENRTF funds will be used only for the development of technology. Any use of the technology by private companies will be done at their expense. Any patents arising from this research will be owned by the University of Minnesota.

**The problem:**

1. Renewable sources of energy such as wind and solar are intermittent, ensuring that combustion-based power generation will continue to be required.

2. Current technologies for producing coal-like solid fuels from biomass are not cost-competitive with coal.

3. Liquid biofuels have high viscosity, rendering them hard to spray into a fine mist necessary for burning using standard burner designs.

**The solution:**

1. Reduce the pre-treatment costs of biomass production by creating slurries of fuel particles in liquids.

2. Apply a novel design for atomization of viscous liquids to produce very fine sprays, facilitating clean combustion.

3. The result: fuel substitutes that can be used directly in existing coal plants with very minor modifications.

The success of this research will benefit Minnesota residents in multiple ways. It will make the state less reliant on external sources of energy and provide a technology to local power companies. It will help in developing a market for waste biomass from industry and farmland, and offset the cost of forest managements practices that reduce fire risk.

**II. PROJECT ACTIVITIES AND OUTCOMES**

The Natural Resources Research Institute has developed techniques to process biomass through high pressure and temperature conditions into fuel with similar energy content as coal. In this project, we will eliminate some steps of these processes to produce cheaper liquid fuels of high viscosity. We will solve the technical challenges associated with burning of viscous liquid fuels. The first goal of the project is to develop alternate fuel production techniques that are cheaper and competitive with coal. The second task is to produce fine sprays from the resulting fuels. The third task is to demonstrate clean combustion of these biofuels, showing reduced emissions of sulfur and nitrogen. The fourth task is to perform a lifecycle assessment of the proposed technology to explore long term implications of widepsread adoption of biomass as a fuel source. The fifth task is to work with Evergreen Energy and Duluth Steam in identifying design modifications to existing steam plants in order to accept the novel technology developed for biofuel combustion.

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| **Activity 1 Title: Synthesis of fuel slurries from biomass with energy content similar to coal** Engineers at NRRI conduct laboratory scale experiments for identifying high temperature/pressure processes that are inexpensive, yild products with similar chemical characteristics as coal but with less stringent physical properties (viscosity, density). Synthesie slurries of these particles by suspensing them in liquid products of agricultural processing, such as glycerin or glycol.  | **ENRTF BUDGET:** **$****Salaries $458403****Supplies 7211****Travel 1000** |
| **Activity 2: Atomization of Viscous Liquids**One graduate student and one post-doctoral researcher will conduct experiments on fuel spray production, and the dependence of spray parameters on injector design. Use standard fluid dynamic techniques to measure droplet size and distribution as a function of injector geometry and slurry properties. Patent, publish research, post on University website for public dissemination.  | BudgetSalaries $45840Supplies 7211Travel 1000 |
| **Activity 3: Clean Combustion of Biofuel Slurries**One graduate student and one post-doctoral researcher will conduct laboratory experiments documenting the combustion properties of these slurries, as well as scaling up experiments for addressing eventual industrial adoption.  | BudgetSalaries: $ 76417Supplies: $2835Travel: $1500 |
| **Activity 4: Lifecycle Assessment of Environmental Impacts of Slurry-Based Power Generation**One engineer at NRRI will conduct an assessment that tracks impacts starting from extraction of raw materials, through processing, manufacturing, transportation and end-of-life treatment/final disposal. The intended audience for this study includes biomass producers, traditional and biomass-based energy utilities, public energy stakeholders and policymakers, academia, and consumers. | Budget $0Included in salary for years 1 and 2. |
| **Activity 5: Discussion with Evergreen Energy and Duluth Steam for design modifications**The nozzle technology will be modified from laboratory prototypes to designs that are suitable for scale-up and operation in existing coal/gas power plants such as Duluth Steam. We will hold informal discussions with one engineer at Ever-Green Energy and Duluth Steam.  | Budget: $0Dultuh Steam has expressed interest in discussion |

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| **Outcome** | **Completion Date** |
| *1.* ***Synthesis of fuel slurries from biomass with energy content similar to coal***  | *12/31/2020* |
| *2.* ***Atomization of Viscous Liquids*** | *6/30/2021* |
| *3.* ***Clean Combustion of Biofuel Slurries*** | *12/31/2021* |
| 4. **Lifecycle Assessment of Environmental Impacts of Slurry-Based Power Generation** | *6/30/2022* |
| 5. **Discussion with Evergreen Energy and Duluth Steam for design modifications** | *6/30/2022* |

**III. PROJECT PARTNERS AND COLLABORATORS:**

**A. Project Team/Partners**

University of Minnesota: Srinivasan/Hoxie/Singsaas/Fosnacht- Project Managers: The managers for this project are professors at the University of Minnesota with extensive experience in biomass processing, fluid dynamics of spray generation and clean combustion. Collectively we have over 1500 citations in the literature, many related to the topic of this proposal, and over 20 years of industrial experience.

**B. Timeline:** This will be a 2-year project with most laboratory work conducted in year 1 and assessment of environmental and industrial impacts to be studied in year 2.

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

The project will develop a novel and needed technology that allows for the utilization of waste biomass, while reducing the impacts of intermittent supply from wind and solar energy. Reduced use of coal in Minnesota will help improve air quality. Any intellectual property developed during this project will be owned by the University of Minnesota. Successful demonstration of the ability to burn viscous fuels cleanly will likely generate interest in other states and promote the use of waste biomass as a sustainable energy source, supplementing farm income and offsetting the cost of forest management. Licenses granted to Minnesota companies for the use of the technology may generate jobs and bring in royalty that can be used to offset ENRTF funding.