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

Project Title: **ENRTF ID: 190-E**

Clean Combustion of Renewable Biofuels from Waste Biomass

Category: E. Air Quality, Climate Change, and Renewable Energy

Sub-Category:

Total Project Budget: $ 583,000

Proposed Project Time Period for the Funding Requested: June 30, 2022 (2 yrs)

Summary:

This proposal develops technology that enables clean combustion of waste biomass derived from agricultural or forest residue, and alsoperforms a life-cycle assessment of the environmental impact of this technology.

Name: Vinod Srinivasan

Sponsoring Organization: U of MN

Job Title: Dr

Department: College of Science and Engineering

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The graphic shows current techniques for converting biomass into a coal-like solid fuel, as well as the proposed, cheaper technique for creating a liquid fuel that can be burnt using novel technology.

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

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.

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

ENRTF BUDGET: $
Salaries $458403
Supplies 7211
Travel 1000

as glycerin or glycol.

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.

Budget
Salaries $45840
Supplies 7211
Travel 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.

Budget
Salaries: $ 76417
Supplies: $2835
Travel: $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 $0
Included 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: $0
Dultuh Steam has expressed interest in discussion

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.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Dr. Vinod Srinivasan
Project Title: Clean Combustion of Renewable Biofuels Derived from Waste Biomass Using a Novel Atomizer
Organization: University of Minnesota-Twin Cities
Project Budget: $583,000
Project Length and Completion Date: 2 years; completion date 06/30/2022
Today's Date: 04/10/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 539,000	$ -	$ 539,000
Dr. Vinod Srinivasan, PI, 1 month/year, 2 years, including 36.0% benefits (overall coordination and project management)	$ 31,000		
Dr. Alison Hoxie, Co-PI, 2 months/year, 2 years, including 36.0% benefits (assistance in project management, leader of combustion experiments)	$ 58,000		
Dr. Eric Singsaas, Co-PI, 0.6 months/year, 2 years, including 36.0% benefits (manager of biomass extraction processes, process development)	$ 18,000		
Matthew Aro (Scientist), 1.2 months/year, 2 years, including 36.0% benefits (lifecycle analysis of proposed technique)	$ 19,000		
Timothy Hagen (Researcher), 1.2 months/year, 2 years, including 36.0% benefits (biomass extraction process development)	$ 26,000		
Matthew Young (HTC Researcher), 1.2 months/year, 2 years, including 29.5% benefits	$ 12,000		
Post Doctoral Associate (MechE), 12 months/year, 2 years, including 24.3% benefits (designing atomization experiments, characterization of liquid properties, publishing)	$ 122,000		
Post Doctoral Associate (UMD), 12 months/year, 2nd year only, including 24.3% benefits (designing and conducting combustion experiments, documenting and dissemination)	$ 68,000		
1 UMN ME Graduate Research Assistant, 50%, 2 years, including 16.1% benefits plus $20.50/hr tuition (conducting atomization experiments and data interpretation)	$ 101,000		
1 UMD ME Graduate Research Assistant, 50%, 2 years, including 16.1% benefits plus $20.50/hr tuition (performing combustion experiments, data interpretation)	$ 84,000		
Equipment/Tools/Supplies	$ 35,000		
Lab supplies/Equipment- Non Capital	$ 29,000	$ -	$ 29,000
Lab services	$ 6,000	$ -	$ 6,000
Capital Expenditures Over $5,000			
Travel expenses in Minnesota			
Multiple visits from UMD to Coleraine facility for conducting biomass processing tests; technical conferences	$ 9,000	$ -	$ 9,000
COLUMN TOTAL	$583,000.00	$ -	$ 583,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: American Chemical Society (Effects of non-Newtonian Rheology on Atomization)	Secured	$ 110,000	$ -	$ 110,000
State:		$ -	$ -	$ -
In kind:		$ -	$ -	$ -

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

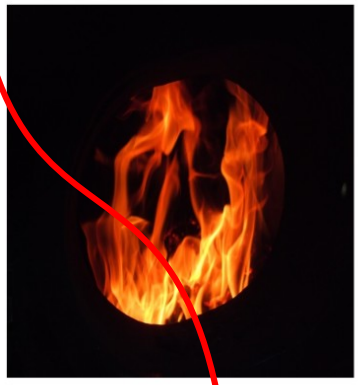
CURRENT PROCESS

Raw product of high temperature, pressure processing

Densification, pelletization, moisture removal

Coal

Biocoal

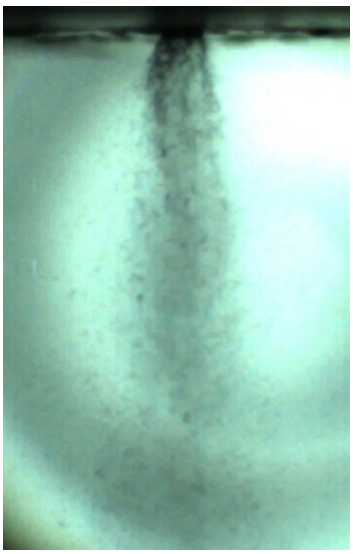


Coal

Biocoal

PROPOSED PROCESS

Viscous suspension of fuel in glycol/glycerol



Atomization/combustion of viscous liquid

VI. Project Manager Qualifications & Organization Description

Professor Vinod Srinivasan (Mechanical Engineering, University of Minnesota) is the Project Manager and he will work closely with Professor Alison Hoxie (Mechanical Engineering, University of Minnesota-Duluth) and researchers at the Natural Resources Research Institute (Dr. Eric Singsaas, Dr. Donald Fosnacht) to direct all aspects of the project. The qualifications of the personnel involved are below.

Dr. Vinod Srinivasan is the Richard and Barbara Nelson Assistant Professor of Mechanical Engineering at the Univesity of Minnesota. He received his PhD in Mechanical Engineering at the University of Minnesota in 2007. He worked as a Post-Doctoral Researcher at the University of California-Berkeey for 4 years before joining General Electric Global Research as a Heat Transfer Engineer. Before joining the University of Minnesota as faculty, he was Assistant Professor in Mechanical Engineering at the Indian Institute of Science, Bangalore. His research interests are in in the areas of fluid dynamics and heat transfer, as applied to energy efficiency and renewable energy systems. He has over 1000 citations, including many related to the topic of this proposal.

Dr. Alison Hoxie is Associate Professor of Mechanical Engineering at the University of Minnesota, Duluth. She received her PhD in Mechanical Engineering from the University of Minnesota in 2007. Before joining UMN as faculty, she worked at the University of Utah, Salt Lake City. Dr. Hoxie has extensive experience with biofuel combustion, atomization, and the complex laser diagnistics required for understanding combustion. Her current research focuses on cost effective methods for efficient utilization of biomass-derived oils in combustion applications. In addition to lab-scale research she focuses on renewable energy technologies, resiliency and energy efficiency at the community level. She led the effort to install small wind at UMD, developed student project teams to evaluate renewable energy and efficiency measures for local Duluth businesses and is currently working on energy storage demonstration projects in collaboration with UMN Morris and the Energy Transition Lab at UMTC.

Dr. Eric Singsaas is the Strategic Initiative Director of the Wood Products and Bioeconomy group at the Natural Resources Research Institute. Singsaas has a PhD in Botany from the University of Wisconsin, Madison, where he also served as Research Director for the Wisconsin Institute for Sustainable Technology. His research focuses on wood use and bio-product extraction while developing capabilities in biomass processing to support Minnesota's emerging renewable energy economy.

Matt Aro is an engineer at NRRI responsible for product, process, and business concept research and development services to organizations and agencies associated with the wood products industry. Matt has a Masters degrees in Management of Technology, and Natural Resource Science and Management from the University of Minnesota. He identifies market opportunities and forecasts market impact for a wide range of wood products. Activities including identifying funding sources, writing proposals, developing applied research project work plans and budgets, performing research tasks, producing technical reports, and conducting life-cycle assessments (LCA) of natural resource-based products and technologies.

Timothy Hagen is a Research Specialist at NRRI. He has significant experience in developing novel solutions for transforming woody biomass , lignite, recycled plastics, tear-off shingles and cotton linters into useful agglomerated, green-based products for re-use. Previously, he has successfully developed and defined a variety of torrefaction and hydrothermal techniques in which the combustion, handling, grinding and stowage properties of wood and ag-based biofuels are effectively prepared for briquetting and agglomeration. He has pioneered an agglomeration process in which delicate corn stover fibers are converted into highly absorptive, free flowing, granules uniquely capable of displacing inefficient clay type absorbents in the market place. He has a B.S. in Chemical Engineering from the University of North Dakota.