Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-098

Proposal Title: Biomass Inventory for Minnesota Renewable Natural Gas Production

Project Manager Information

Name: Bo Hu

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: This study aims to inventory statewide biomass waste streams for renewable natural gas (RNG) production and provide technical suggestions on policy implementation and RNG facilities development and distribution.

Funds Requested: $200,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Minnesota has always been a leader in the nation in the field of renewable energy. Besides 10% ethanol blend with gasoline, it was the first state to require use of biodiesel, a 20% blend (B20) standard during the summer months. Currently, there is a great potential to develop renewable natural gas (RNG) generated through anaerobic digestion (AD) of organic wastes and then legally mandate the blend of RNG to the natural gas grid. AD is a commercially available process generating biogas from a wide range of organic-rich wastes, typically including agricultural and forestry residue, dairy, swine and poultry manure, food waste, organic fraction of municipal solids and sewage sludge, etc. Oregon, Washington, Colorado, and California have directed state agencies to conduct biomass inventories and make recommendations to promote the development of RNG, including the creation of quality standards and incentives to support production. However, in Minnesota, since many other environmental benefits from AD cannot be monetarized, the economic feasibility of the operating digesters is challenged. The price energy companies want to pay for the electricity generated through biogas combustion cannot cover the investments, thus leaving it for direct flaring or emission, and preventing further adoptions of AD technology.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

The proposed study aims to enhance the existing non-renewable natural gas grid to a more environmentally sustainable one through quantified substitution of RNG produced from waste streams in Minnesota. Alternative to direct combustion for electricity generation, biogas can be purified to the level similar to natural gas, namely RNG, which can be injected to the existing natural gas grid without any influence on its overall quality or any changes to home appliances. The delicate balance of this great opportunity here is to mandate the blend ratio of RNG with natural gas in the full consideration of available resources the state has for RNG generation while keeping the natural gas price low. Therefore, the objectives of this proposed study include for: (1) inventory the available biomass wastes for RNG supplies (quantity of substrates, geographic locations, and conversion potential to biogas); (2) evaluate the impact of varying incentive levels and maximum allowable plant sizes on total RNG production and theoretical resource utilization of each waste stream; and (3) assess the potential locations for large centralized anaerobic digesters for RNG production and natural gas grid injection, and rank them in terms of financial viability considering the matrix of influencing factors above.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The expected outcomes of this project include for: (1) a comprehensive inventory of biomass wastes available for RNG production in Minnesota; (2) the optimal incentive levels and plant sizes that provide sustainable development of RNG production from biomass wastes; and (3) the optimal natural gas pipeline injection points for large centralized anaerobic digestion facilities that are financially viable and without large reforming of existing infrastructures. A viable AD industry will enable Minnesotans to treat and more effectively utilize our organic wastes, minimize greenhouse gas emissions, generate more revenue to farmers, and create more job opportunities in the rural area.

Activities and Milestones

Activity 1: Inventory the available biomass wastes for RNG supplies

Activity Budget: $99,395

Activity Description:
The biomass wastes suitable for biogas production via AD can be typically categorized into organic fraction of municipal solid waste, food/food processing waste, agricultural and forestry residues, livestock and poultry manure, and sewage sludge. However, these waste streams vary greatly in both amounts and generation sites. Meanwhile, the biological and chemical compositions of different waste streams differ from each other, leading to varied biogas production potentials. Therefore, the comprehensive grasp of the biomass wastes available for AD is the very first step essentially and fundamentally to evaluate the RNG production potentials statewide. The objective of this activity is to geographically identify, categorize, and map the available biomass wastes for the transition towards RNG supplies in MN. This comprehensive biomass inventory of MN will include for: (1) the statewide quantities and geographic distribution of categorized biomass wastes suitable for biogas production, and (2) the detailed characterization (e.g., biological & chemical composition, physicochemical properties, etc.) and the overall conversion potential of these biomass wastes to RNG.

Activity Milestones:

Description	Completion Date
Detailed characterization and overall conversion potential of biomass wastes to RNG in MN.	2022-06-30
Geographic distribution of categorized biomass wastes suitable for RNG production.	2022-06-30
The statewide quantities of categorized biomass wastes suitable for RNG production.	2022-06-30

Activity 2: Size estimation and distribution of RNG facilities

Activity Budget: $50,303

Activity Description:
With the comprehensive biomass inventory and the overall theoretical RNG conversion potential, the calculation of how much natural gas can be substituted by RNG is feasible. To increase the energy and cost efficiency, large centralized AD plants are preferable over dispersed small-scale digesters. However, due to the imbalance of biomass waste amounts and generation locations throughout the state, the total weighted transportation costs of biomass wastes from generation sites to selected AD plants greatly vary, thus affecting the financial viability. Furthermore, the coupling of the RNG production from AD plants and the subsequent injection to the existing natural gas pipelines also requires optimization with minimum facility addition or pipeline extension. Therefore, the objectives of this activity are: (1) to evaluate the maximum allowable AD plant sizes to minimize the transportation costs of biomass wastes considering the theoretical utilization efficiency and the collection radius; and (2) to assess the potential locations of these large centralized AD facilities for RNG production and injection into the existing natural gas grid.

Activity Milestones:

Description	Completion Date
Maximum allowable AD plant sizes with minimized biomass transportation costs.	2022-09-30
Optimal locations for injection into existing natural gas grid.	2022-12-31
Optimal locations of AD facilities coupling RNG production.	2022-12-31

Activity 3: Financial viability ranking of plants and incentive policy suggestions

Activity Budget: $50,302

Activity Description:

With the completion of Activity 1 and Activity 2, the RNG production potential from biomass wastes and the corresponding maximum allowable AD plant sizes and optimal locations will be obtained. However, the financial profitability of these plants is key to the sustainable operations. Thus, this activity will firstly develop cost curves outlining the RNG quantity that can be produced at a given levelized cost of energy, and then rank these AD plants in terms of financial viability considering the matrix of influencing factors including biomass waste amounts and sources, transportation costs, RNG production potential, and plant sizes. In addition to the gains from the sale of RNG to natural gas grid, the disposal of biomass wastes, the sale of digestate, and the reduction of greenhouse gas emissions will be monetarized to further evaluate the profitability of these AD plants. Consequently, the effects of financial incentives on the installation and operation of AD plants with sustainable profitability will be evaluated, and a final report will be generated to provide policy suggestions.

Activity Milestones:

Description	Completion Date
Ranking of AD plants in terms of financial viability considering the matrix of influencing factors.	2023-03-31
Develop corresponding policy suggestions.	2023-06-30
Effects of financial incentives on sustainable operation of AD plants.	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
William Lazarus	University of Minnesota	Dr. William Lazarus will serve as the Co-PI. He is a professor and extension economist at Department of Applied Economics at UMN. He will work with the group to assist on the areas of agricultural policy, farm management and production economics of the project.	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

MN already has at least 67 operating anaerobic digesters and more are under consideration to process organic wastes. The proposed project will generate inventories on how much resources we have and provide methods for those ADs to upgrade biogas to generate RNG. This study is intended to inform policy makers, planners, and researchers involved in the establishment and development of industrial RNG production from biomass wastes within the specific State of Minnesota. This information can be used for future statewide policy change, and it will also provide a technical guideline for industrial implementations. Future funds will come from the industry.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Extracting Deicing Salt from Roadside Soils with Plants	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04i	$360,000
Next Generation Large-Scale Septic Tank Systems	M.L. 2014, Chp. 226, Sec. 2, Subd. 08g	$258,000

Project Manager and Organization Qualifications

Project Manager Name: Bo Hu

Job Title: Associate professor

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Bo Hu is an associate professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 18 years of active research experience specifically in bioprocessing development, nutrient removal, and waste management, he is leading projects to remove phosphorus from manure and from wastewater in the septic tank systems, projects to reveal the myth of recent swine manure foaming in Midwestern states, projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi. He has finished projects to develop a community microbial electrochemical septic system and a fungal biofilm system for water treatment. Dr. Hu's team at UMN has set up several standard procedures such as 16s rDNA based microbial analysis by using high-throughput pyrosequencing methods to study the microbial species in the waste treatment processes, ITS sequences to identify fungal species, etc. His team is also developing several conversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-solid state fermentation of filamentous fungi, to produce bioproducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water. Dr. Hu will design and coordinate the research; and his postdoc researcher Dr. Ding will assist in design and experimentation as well as data collection and dissertation.

Dr. Hu's laboratory has all the necessary equipment and facilities for this project, including: New Brunswick refrigerated incubation shaker INNOVA 42R, New Brunswick shaker Excella E-24, Beckman Allegra X-15R Refrigerated Centrifuge,

VWR refrigerated water heater circulator, Bioreactor/fermenter, Agilent 7820 A GC-FID-TCD, Agilent Micro-GC, Agilent 1260, and Dionex ICS 2100/ ICS 1100 bundle ThermoFisher Scientific. The lab is also equipped with two incubation rooms with full range of temperature control, a walk-in refrigeration room and a walk-in cold room.

Organization: U of MN - College of Food, Agriculture and Natural Resource Sciences

Organization Description:
As the core department of UMN to tackle agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program. As a participating faculty of Biotechnology Institute of UMN, Dr. Hu has the access to the Biotechnology Resource Center, which is a 4000 square-foot laboratory/pilot plant facility with state-of-the-art equipment for research and development in fermentation, animal cell culture technology, molecular biology, protein expression, and separation of a wide range of biological molecules. The facility has a wide range of bench-scale to pilot-scale fermenters available, ranging in size from 6 L to 300 L. The university also has the following facility that can be accessed with payment: Center for Mass Spectrometry and Proteomics. This facility is house in the basement of the Gortner / Snyder complex and provides support, equipment and expertise for analyzing complex protein mixtures. This facility has several full-time staff trained to run and troubleshoot experiments. It is home to the UMN Mass Spectrometry and Proteomics Initiative.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Associate Professor		Principal Investigator, coordinate the research efforts, design experiments and write project reports			36.5%	0.16		$30,480
Professor		Co-Principle Investigator, guiding postdoc researcher on economic analysis and agricultural policy			36.5%	0.16		$29,012
Postdoc researcher		Postdoc researcher, working on experimental design and data collection			25.4%	2		$132,373
							Sub Total	**$191,865**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Chemicals, analysis kits, and personal protection supplies	materials for lab experiments					$6,340
							Sub Total	**$6,340**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Within-state travel using university vehicles, standard rate applies	Trips to go to site for collection of waste samples					$1,795
							Sub Total	**$1,795**

Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$200,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
In-Kind	Since this project does not charge any indirect cost, therefore University of Minnesota matches the in kind service F&A. The current indirect cost rate is 54% of the direct total project cost	UM F&A	Secured	$108,000
			State Sub Total	**$108,000**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$108,000**

Attachments

Required Attachments

Visual Component

File: eac3474f-7aa.pdf

Alternate Text for Visual Component

This visual shows the aim and scope of the research project. We want to inventory the available biomass resources the state of Minnesota has to generate renewable natural gas, and develop a technology road map on how to implement this industry so that renewable natural gas can be injected to natural gas grid.

Optional Attachments

Support Letter or Other

Title	File
Approval from SPA UMN	6d35bec8-604.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

No

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

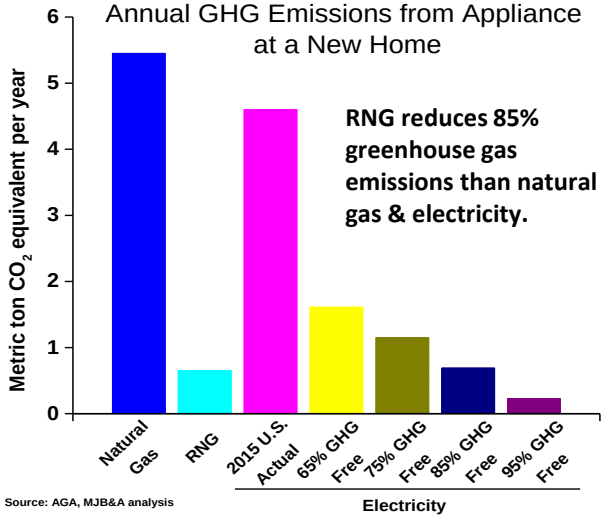
Biomass Inventory for Minnesota Renewable Natural Gas Production

Bo Hu, Lingkan Ding, and William F. Lazarus, University of Minnesota

Environment and Natural Resources Trust Fund-2021

- **Renewable Natural Gas (RNG) is a carbon neutral fuel produced from biomass wastes via anaerobic digestion (AD) and can be directly injected to natural gas grid.**
- **A new study in California shows that mandatory blend of 20% RNG in natural gas can achieve greenhouse gas (GHG) emission reductions equivalent to overhauling 100% of buildings to all-electric by 2030.**

How expensive is RNG compared to natural gas?	Price $/1000ft^3
Natural Gas	3.2-13.0
RNG (Methane) from Manure	6.2-10.9
RNG (Methane) from Industrial Waste	3.1-14.0



Research Questions: Do we have enough resources in MN and how to implement?

Activity 1: Inventory of available biomass wastes for RNG supplies in MN

Food waste

Livestock manure

Sewage sludge

Agricultural residue

- **Statewide quantities**
- **Geological distribution**
- **Characterization and RNG potential**

Example: RNG production in a dairy farm			
Manure (lb/cow/day) →	Biogas (cf/cow/day) →	RNG (BTU/cow/day) →	RNG residential sale ($/cow/day)
125	45-68	27,000-40,800	0.17-0.25

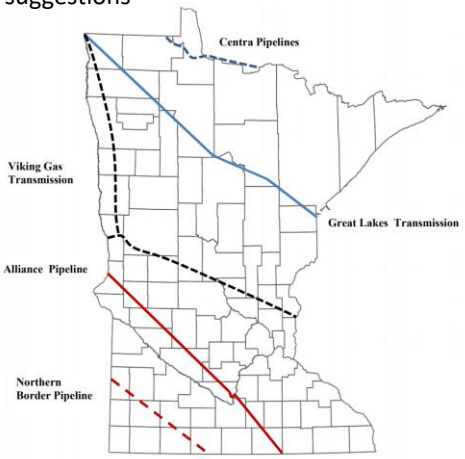
Activity 2: Size estimation and distribution of AD facilities

Anaerobic Digesters

Natural Gas Pipeline

- **Maximum allowable AD plant sizes** with minimized biomass transportation costs.
- **Optimal locations of AD facilities** coupling RNG production and injection into existing natural gas grid.

Activity 3: Financial viability ranking of plants and incentive policy suggestions



Major Natural Gas Pipelines in MN

- **Ranking of AD plants in terms of financial viability** considering the matrix of factors in Activities 1 & 2.
- **Effects of financial incentives** on sustainable operation of AD plants and corresponding policy suggestions.