Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-050

Proposal Title: Remove pollutants from landfill air emissions

Project Manager Information

Name: Roger Ruan

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

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Project Basic Information

Project Summary: Develop and evaluate catalytic nonthermal plasma based process to compose hazardous gaseous compounds in landfill emissions.

Funds Requested: $200,000

Proposed Project Completion: June 30 2025

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?

During the Project and In the Future

Narrative

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

Landfill gas (LFG) emissions pose a significant threat to both the environment and human health. In a landfill, organic wastes anaerobically decompose into methane (55-60 vol.%) and CO2 (40-45 vol.%), along with other gases including PFAS in trace amounts. While CO2 from landfill is biogenic and therefore not accountable for greenhouse effect, methane is a potent greenhouse gas, with a greenhouse effect 25 times greater than CO2, and methane from landfill accounted for 17% of total U.S. methane emission in 2018. LFG is also a significant source of offensive odors associated with trace gases such as NH3, H2S, and aldehydes (<1 vol.%), which also relate to other problems such as harmful effects on human health and atmospheric pollution. Currently the mitigation strategies mainly include 1) capture of LFG typically by gas collection wells followed by flaring or combustion for energy recovery, and 2) microbial aerobic methane oxidation in a landfill cover. However, the LFG-to-energy approach suffers from the low and fluctuating energy content of LFG which results in low performance in combustion processes, while efficiency of the biofiltration approach heavily relies on environmental conditions. And both approaches are ineffective in treating the trace gases in LFG.

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.

Catalytic nonthermal plasma (cNTP) is a promising LFG mitigation approach capable of treating both methane and trace gases under atmospheric pressure and low temperature conditions. In a NTP process, electrons, accelerated by the high electric field, collide with bulk gas molecules and generate highly reactive species such as ions and radicals. When combined with heterogeneous catalysts, cNTP can form new reactive species, facilitating chemical reactions with higher energy efficiency and selectivity. This process has great flexibility in adjusting various process parameters to achieve desirable products and efficiency. cNTP can either selectively oxidize methane into CO2 and water or convert methane into more valuable fuel products such as syngas (CO and H2) and methanol. In addition, trace gases such as NH3 and H2S can also be effectively decomposed by cNTP process without producing undesirable byproducts. The objectives of the project are to (1) develop a lab-scale cNTP process and optimize process parameters for various potential pathways of methane conversion before determining the most feasible one based on evaluations of energy efficiency and environmental impacts, (2) study the effectiveness of cNTP in treating trace gases including PFAS, and (3) develop recommendations for technology transfer and further R&D efforts.

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 specific project outcome will include a process developed for LFG treatment with optimized process conditions, and a lab-scale system for analysis and demonstration. These outcomes will advance the technology closer to industrial application of this technology, which will reduce hazardous and greenhouse gas emission from landfills and improve the air quality in the vicinity of landfills within the state of Minnesota.

Activities and Milestones

Activity 1: Develop a lab-scale cNTP process and determine the most feasible LFG methane conversion pathway

Activity Budget: $100,000

Activity Description:
The concept of methane conversion into various target products by cNPT has been proven in several recent publications, yet it remains unclear which pathway is most feasible for treating LFG methane in terms of energy efficiency and environmental impact. In addition, cost effective catalysts need to be developed and processing parameters, such as atmosphere, plasma power and reactor characteristics, need to be optimized for this process. In this activity, we will develop a dielectric barrier discharge (DBD) NTP reactor for testing various catalysts and processing parameters. For each potential target product, such as CO2, syngas, and methanol, catalyst screening and processing parameters optimization will be conducted, and the results will be used for preliminary evaluations of energy efficiency and environmental impact. The best pathway will be selected for future studies.

Activity Milestones:

Description	Completion Date
A lab-scale DBD reactor will be developed and operational	October 31 2022
Catalysts for each potential product will be prepared and characterized	December 31 2022
New knowledge from catalyst screening and process optimization will be obtained	August 31 2023
A preliminary evaluation of energy efficiency and environmental impact will be conducted	December 31 2023

Activity 2: Study the effectiveness of cNTP in treating trace gases

Activity Budget: $60,000

Activity Description:
Trace gases, especially PFAS, ammonia and H2S, are hazardous and the causes of the offensive odors of LFG. Many studies have shown that NTP is effective in decomposing these gases in trace concentrations, but a complete analysis of the byproduct profile and the process energy efficiency is lacking. In this activity, a methodology to quantitatively measure the product profile will be developed. Then a catalyst screening and processing parameter optimization will be conducted. Finally, energy consumption and environmental impact of the optimized process will be evaluated.

Activity Milestones:

Description	Completion Date
Establish protocols to generate simulated LFG and measure decomposed products	February 28 2024
Results of catalyst screening and process optimization are obtained	October 31 2024
A preliminary evaluation of energy efficiency and environmental impact will be conducted	December 31 2024

Activity 3: Develop recommendations for technology transfer and further R&D efforts

Activity Budget: $40,000

Activity Description:
The mass and energy balance data, together with energy consumption data, will be used to evaluate the environmental and economic performance of a scaled-up industrial implementation of this technology. Further R&D efforts and commercialization strategy will be recommended.

Activity Milestones:

Description	Completion Date
Evaluation of economic performance and environmental impact of a scaled-up system	March 31 2025
Further R&D and commercialization strategy will be recommended	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	Co-PI	No

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?

The scientific findings and engineering experience generated from this project will be used for 1) evaluating the technical and economic feasibility of and 2) building a scaled-up system for industrial application of this technology. We will implement an integrated strategy to communicate with internal and external stakeholders and seek funding to further develop and eventually commercialize this technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

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

Dr. Roger Ruan, Professor and Director of Graduate Studies, Department of Bioproducts and Biosystems Engineering, and Director of Center for Biorefining at University of Minnesota, is a Fellow of ASABE and a Fellow of IFT. Dr. Ruan's research focuses on renewable energy and environment technologies for sustainable development and circular economy. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) pyrolysis and gasification, airborne and other pathogen disinfection and pollutant control, catalysis, non-thermal plasma, and nitrogen fixation, etc. He is a top-cited author with an h-index of 69, i10-index of 301, and over 19,000 citations. He has supervised over 75 graduate students, 140 post-doctors, research fellows, and other engineers and scientists, and 21 of his Ph.D. students and post-doctors hold university faculty positions. He has also been invited to give over 300 keynote lectures, invited symposium presentations, company seminars, and short courses. Professor Ruan has received and managed over 200 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He has served as guest editor or editorial board member of Bioresource Technology, Renewable Energy, Engineering, Applied Catalysis and Chemical Engineering, Journal of Food Process Engineering, The Open Plasma Physics Journal, and Associate Editor of Transactions of ASABE, Engineering Applications in Agriculture, and Transactions of CSAE, and Chairman of Editorial Board and Editor-in-Chief of International Journal of Agricultural and Biological Engineering, etc. His earlier LCCMR funded projects have resulted in several patented technologies which have been

successfully licensed to the industry. Therefore, he has the technical expertise and project management experience to ensure the execution of proposed projects.

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

Organization Description:
The Center for Biorefining is a University of Minnesota research center affiliated with the College of Food, Agricultural and Natural Sciences and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research and provide education on science and technology for environment protection and circular economy; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor/faculty		PI - summer salary only			36.5%	0.12		$23,622
Professor/faculty		Co-PI- contract faculty member			36.5%	0.24		$33,460
1 Graduate Research Assistant		Researcher			45%	2.25		$126,289
							Sub Total	**$183,371**
Contracts and Services								
University of Minnesota	Internal services or fees (uncommon)	Lab services				-		$5,000
							Sub Total	**$5,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Purchase power supply, power control, catalysts, glassware, pumps, chemicals, supplies for instrumental analysis,	For setting up experimental apparatus and conducting experiments in labs					$10,243
							Sub Total	**$10,243**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	9 one-day 2-person trips, 100 miles each round trip ($0.56/mile), meals @$49/person	Travel to landfill sites to collect samples and conduct on-site testing					$1,386

							Sub Total	**$1,386**
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				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Optional Attachments

Support Letter or Other

Title	File
Institutional Approval to Submit	fc2e51d7-774.pdf
Visual graphic	88168321-b23.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

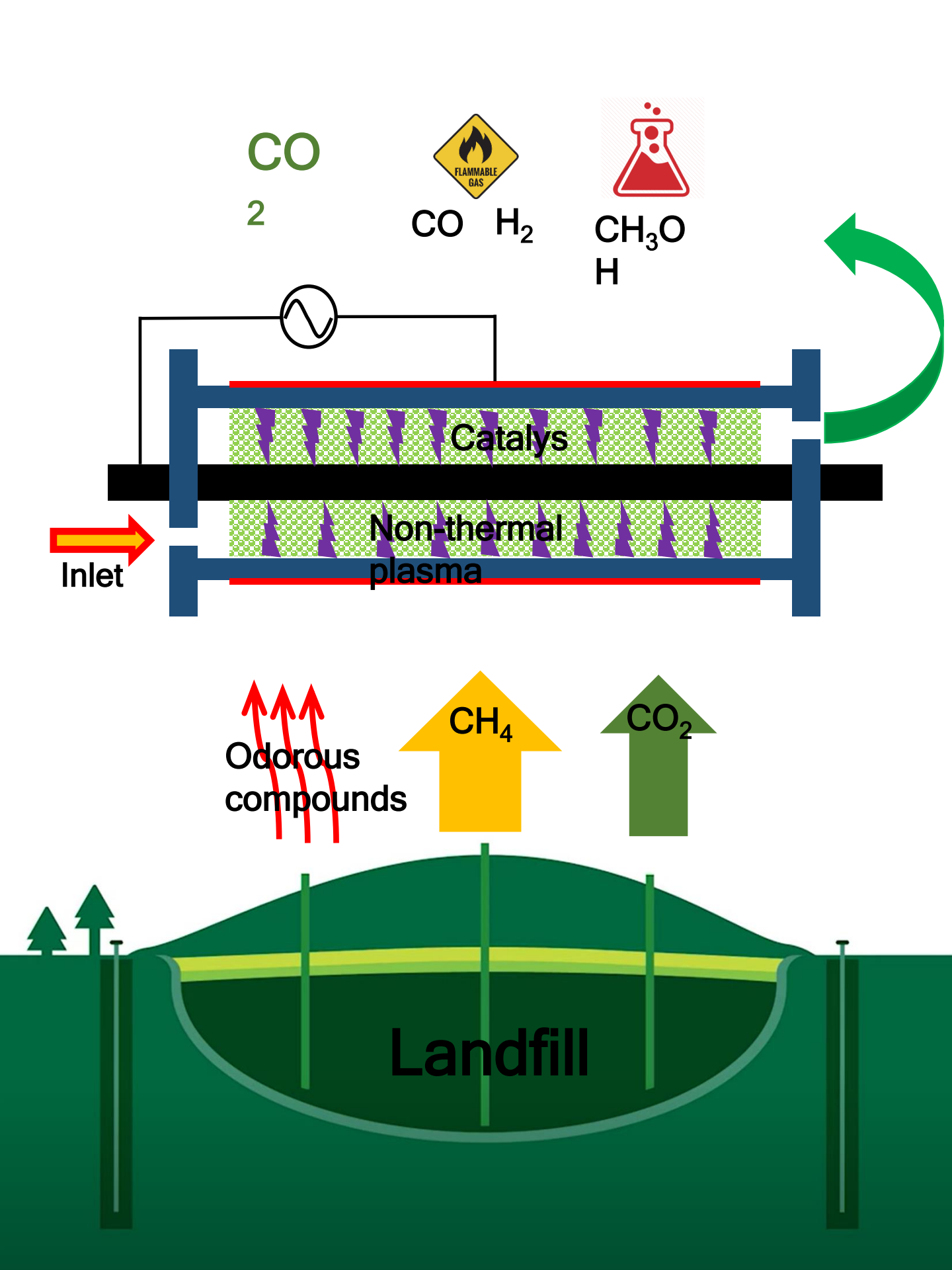
No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No


CO
2
FLAMMABLE GAS
CO H2
CH3O
H
Catalys
Non-thermal
plasma
Inlet
Odorous
compounds
CH4
CO2
Landfill