**PROJECT TITLE: Nitrogen Fixation for Fertilizers and Hydrogen Fuels Production**

**I. PROJECT STATEMENT**

The US agriculture and other industries use a large amount of nitrogen fertilizers such as anhydrous ammonia and ammonia nitrate. Minnesota alone imports $400 million to $800 million retail value of nitrogen fertilizer annually. Current industrial technology for nitrogen fertilizer production is non-renewable, expensive, dangerous, and environmentally unfriendly. Application of ammonia to land causes pollution of surface and ground water and air due to runoff and evaporation because it takes a long time for crops to utilize ammonia. This project is intended to demonstrate a new process to ***fix nitrogen from water and air*** to produce nitrogen-rich water using **renewable electricity from wind or solar energy**, eliminating the need for fossil resources and avoiding pollutant emissions. The nitrogen-rich water can be used as fertilizer directly on cropland or hydroponics system to reduce nitrogen runoff and water needs. The ammonia produced alongside may be used as fertilizer and a source of clean, zero-carbon emission energy for direct combustion and hydrogen fuel cells that provides a vehicle to store wind and solar electric energy through the ammonia-to-hydrogen-fuel-cell route, a potentially more energy efficient alternative to hydrogen production through direct water electrolysis. And better yet, storage of ammonia is much easier, safer, and cheaper than storage of hydrogen gas.

This proposed nitrogen fixation technology is built on ***state of the art non-thermal plasma (NTP) process*** that has been investigated and developed by the U of MN researchers for over two decades. An LCCMR funded project proved the feasibility of synthesizing ammonia, nitrite, and nitrate using NTP process. The ***objectives of the project*** are to (1) further develop and optimize the NTP based ammonia and nitrogen-rich water processes through conducting objective-oriented laboratory work, (2) team up with scientists and engineers at West Central Research and Outreach Center (WCROC) to develop a small pilot system integrated with a wind or solar energy system, (3) test and demonstrate the pilot system to stakeholders, (4) evaluate the techno-economic feasibility and environmental impacts of the technology, and (5) develop recommendations for further R&D and technology transfer efforts.

To achieve these intended objectives, we assemble a team of engineers and scientists with background and experience in NTP physics and engineering, nitrogen fixation chemistry, renewable energy production and adaptation, systems engineering and assessment. Both the BBE and WCROC have access to most of the necessary equipment and facilities to execute the planned work.

Application of nitrogen-rich water to cropland or hydroponics system also has many ***benefits***, including:

* Reducing environmental impacts through clean production technology and use of low concentration nitrogen fertilizers to avoid runoff of excessive nitrogen;
* Capturing the value of nitrogen industry and products locally without the use of hydrogen; and
* Disinfecting the microorganisms and oxidize contaminants that will hinder plants growth and pose threat to consumer safety, and
* Therefore generating significant tax revenue and jobs in the regions by reducing imports of much needed nitrogen fertilizers and in turn reducing most transportation related greenhouse gas emission and air pollutions.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1:** *Improve and optimize the non-thermal plasma based ammonia and nitrogen fertilizer processes*  Synthesis of ammonia via catalytic processes assisted by dielectric barrier discharge (DBD) in gaseous state at atmospheric pressure has been studied and demonstrated in labs; the concept of generating nitrogen-rich water containing ammonia (NH3), ammonium (NH4+), nitrate (NO3-), and nitrite (NO2-) using an NTP jet or concentrated high intensity electric field (CHIEF) discharge in water directly at atmospheric pressure has also been proven in lab. In this Activity, researchers in UMN Center for Biorefining (CB) and Department of Bioproducts and Biosystems Engineering (BBE) will carry out objective-oriented laboratory work to expand our knowledge base on some important process parameters and more importantly improve conversion efficiency, increase concentration, reduce energy consumption, and develop optimized process.  **ENRTF BUDGET: 150,000** | | |
| **Outcome** | **Completion Date** |
| *1. Key processing variables will be identified and quantified and basic reaction mechanisms will be delineated* | *06/30/2021* |
| *2. Conversion efficiency, concentration of nitrogen derived compounds, and energy efficiency will be increased by 30-50% over the current performance* | *12/31/2021* |
| *3. An optimized process flow diagram will be delivered* | *12/31/2022* |
| **Activity 2:** *Develop and demonstrate an integrated nitrogen fixation system*  With the knowledge, experience, and optimized process flow diagrams obtained from Activity 1, researchers in CB and BBE will work closely with researchers at WCROC to design an integrated system and construct a skid mount pilot system for comprehensive evaluation of the process and demonstration of the technology to general public for education and outreach purpose. The system is powered by wind or solar energy. The system will be demonstrated to stakeholders in the Morris Research and Outreach Center.  **ENRTF BUDGET: 170,000** | | |
| **Outcome** | **Completion Date** |
| *1. Scale-up parameters will be determined for the optimized process flow* | *03/31/2022* |
| *2. System design will be completed* | *06/30/2022* |
| *3. The skid mount system will be fabricated and tested in lab and on fields* | *12/31/2022* |
| *4. The skid mount system will be demonstrated in* WCROC *to the stakeholders* | *06/30/2023* |
| **Activity 3:** *Evaluate the environmental impacts and economic performance of the NTP based nitrogen fixation process and system*  The data obtained from lab and field tests will be used to establish models for evaluation of environmental impacts and techno-economic performance. An assessment report will be written, which will also include recommendations for further development and technology transfer.  **ENRTF BUDGET: 167,000** | | |
| **Outcome** | **Completion Date** |
| *1. Data obtained from lab and field tests of the pilot system will be generated* | *12/31/2022* |
| *2. Models will be established for analysis of environmental impacts and techno-economic performance* | *06/30/2023* |
| *3. Formulate a development and commercialization strategic plan* | *06/30/2023* |

**III. PROJECT PARTNERS:**

**A. Project team:**

Roger Ruan (BBE, UMN), Cory Marquart (UMN West Central Research & Outreach Ctr), Paul Chen (BBE, UMN)

**B. Partners not receiving ENRTF funding**

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| **Name** | **Title** | **Affiliation** | **Role** |
| John Snyder | President | Minnesga | Pilot system development & demonstration |
| Michael Reese | Renewable Energy Director | UMN WCROC | Field testing and demonstration |

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

New scientific knowledge on plasma based nitrogen fixation process will be acquired through research, and the demonstration will help raise significant interests from the public. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

**V. TIME LINE REQUIREMENTS:**

This 3 years project will begin on 07/01/20 and end on 06/30/23. The first 18 months will be focused on process improvement and parameter optimization, and full understanding of the proposed process, and the second 18 months will be focused on development, evaluation, and demonstration of the small pilot scale integrated system.