Application

Project Title: Smart Holistic Zero Waste Utilization Paradigm (SHOWUP) for Reusing Thermosets and Effectively Recovering Fibers via Mechanical, Thermal, Biological, and Chemical Pathways

Applicant: University of North Dakota

Principal Investigator: Surojit Gupta

Date of Application: 09/28/2023

Amount of Request: $500,000

Total Amount of Proposed Project: Estimated total budget: $3,780,360 (DOE Funding Requested: $3,000,000)

Duration of Project: 3 years

Point of Contact (POC): Surojit Gupta

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POC Email: Surojit.gupta@und.edu

Renewable Energy Program

North Dakota Industrial Commission

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Project Location (s): Department of Mechanical Engineering, University of North Dakota, Grand Forks; Drilling and Completion Lab (DRACOLA), Grand Forks; Grand Forks Landfill location of SET LLC

Acknowledgement: Dr. Anna Crowell for editing the proposal

Appendix A: DOE Award Acceptance, NDIC Support Letter, Support Letters from Strata, GRE and LM Windpower and Commitment Letters from SET-led Consortium of Companies

ABSTRACT

Objectives: We propose interconnective sustainable technologies that will have a transformative effect on blade recycling via a University-Industry-National Lab collaboration. A critical aspect of this call is designing materials with innovative tagging methods and separating the constituents for effective wind blade reuse. We will develop a smart interface to sort blades into different functional components using Artificial Intelligence (AI) and Machine Learning (ML) (Objective-A). Heavily damaged blades will be recycled into Syngas using a propriety Sandwich Gasifier Technology (Objective-B). Medium-damaged blades will be mechanically milled to generate thermoset powder that will be integrated into 3D-printed structures (Objective-C). High-quality wind turbine waste will be recycled into thermoset polymers and fibers using propriety solvent-based (Objective-D) and enzymatic processes (Objective-E). A Life Cycle Analysis (LCA) for the entire process will be performed (Objective-F).

Expected Results: We will establish a holistic approach to increase thermoset and incorporated fiber sustainability and recyclability. Current pyrolysis-based technologies are destructive, destroy the polymeric components, and decrease fiber quality.

Duration: 3 years

Total Project Cost: Estimated total budget: $3,780,360 (NDIC Funding Requested: $500,000)

Participants: Collaborators and institutions (Drs. Gupta and Ji will manage the NDIC cost share grant):

UND: Co-PI: Yun Ji, Chemical Engineering; Co-PI: Hallie Chelmo, Mechanical Engineering; Co-PI: Beth Klemetsrud, Chemical Engineering; **University of Idaho**: Co-PI: Hasan Jamil; **National Lab Collaborator**: Yingqian Lin, Research Scientist, INL; **Industrial Partners**: Nikhil Patel, President, Singularity Energy Technologies LLC (SET); CEO at Dakota Green Power Co (DGP); Scott Homstad, Tristeel Manufacturing Company; Michael D. Mann, CEO and Founder, MDM Energy Consulting LLC.

PROJECT DESCRIPTION

Objectives: (a) Develop a smart image-based database and design an AI and ML-driven interface to sort and tag windmill waste into different categories, (b) Use heavily damaged blades as a source of Syngas via the gasification process at a 5-ton/day capacity, (c) Recycle thermoset powders to build functional components, such as 3D-printed non-wind turbine components, (d) Develop technology to recycle blades using propriety liquids in a pilot setting, (e) Validate biological agents as an effective medium for recycling green-coded turbine blades, (f) Evaluate all steps holistically to determine overall greenhouse gas emissions and cumulative energy demand for recycled wind turbine blades and overall life cycle analysis.

Methodology and Anticipated Results: We propose an innovative, Smart, Holistic Zero-Waste Utilization Paradigm (SH0WUP) to reuse thermosets and recover fibers effectively with minimal damage by integrating next-generation technologies developed at UND and SET. The integral components of this design paradigm are: (i) Blade wastes, including Offshore Wind (OSW) blades, will be tagged with ultrasonic and image evaluations. We will develop a smart interface to sort blades into functional components using Artificial Intelligence (AI) and Machine Learning (ML). Heavily contaminated damaged blades will be sent to SET for fuel generation product evaluation. ii) The screened system containing fibers and resin will be separated into milled powders and fibers with thermoset residues. The recovered thermoset powders will be used as a recyclable feedstock to develop wear-resistant and hydrophobic coatings and 3D-printed structures for rapid commercialization. Replacing different PTFE-based components is one of the program's inherent challenges. Ice accretion causes an 80% power loss; therefore, ice-phobicity will be quantified using our setup and chiller that can reach -40^{o}C. iii) Fibers containing thermoset residue will be treated with ILs and an enzymatic degradation process. Determining the enzymatic degradation and IL pathways will involve studying the degradation kinetics at different conditions, such as temperature, pH, and humidity, to optimize the degradation process and mechanical behaviors. We will build the first pilot plant of its kind in the U.S. to process and recycle 50 Kg of thermoset

residue per batch. iv) We will assess the process' environmental impacts by examining the degradation products and their potential toxicity. Useful chemical products will be derived from the green treatment process. The left-over fibers will be extracted and integrated with the composites.

Facilities and Resources: MMI and the Department of Mechanical Engineering at UND have the following equipment for Advanced Materials Research: two 3.5" tube furnaces (controlled atmosphere, 1600°C and 1700°C), grinding and polishing equipment, Shimadzu AG-50 Universal Testing Machine (screw driven, 50 kN capacity), high-temperature furnace (< 1600°C and extensometer), and box furnaces. We also have Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) printers. The Department of Chemical Engineering (Chem E) has a 500 MHz NMR (Avance 500, Bruker), High-resolution HPLC-MS TOF/ESI/APCI (Agilent G1969A), FTIR spectrophotometers (Perkin-Elmer Spectrum 400), several UV-vis spectrophotometers (Carry 50, Varian Inc.), Beckman Multipurpose Liquid Scintillation Counter Model LS6500, two state-of-the-art gas chromatographs (Agilent 6890N,7890) equipped with autosamplers, and Quadruple MS instruments with EI, CI, and NICI ionization sources (Agilent 5975C). One of the instruments is equipped with a pyroprobe 5200 (CDS Analytical).

The UND Drilling & Completion Lab (DRACOLA) is a state-of-the-art pilot development facility with on-site welders, plumbers, and electricians. Pilot studies for completing Objectives C and D will be located at DRACOLA. We have requested large-scale reactors and ancillaries for the project.

SET Technologies and Tri-Steel Manufacturing will provide access to the current 5-ton/day truck-mounted gasifier as part of the cost share requirements for this proposal.

Techniques to Be Used, Their Availability and Capability:

Objective A: UND will tag and differentiate drone blades into red (heavily damaged), yellow (matrix damaged), and green (reasonable condition) using ultrasonic, 3D imaging and drone-based imaging. UoI will use a transfer learning approach for pipeline design to detect and classify wind turbine damage using a ML/AI system. DOE will fund the imaging procurement system. **Objective B**: Procure Wind Turbine

Blades (WTB) to create a rejected WTB (R-WTB) sample for SET to analyze. Design, construct, and commission a table-top bench scale test unit to evaluate the preliminary conversion features of rejected WTB using SET's patented gasification process. Operate the 5-ton/day Sandwich gasification system after conducting recommended modifications. **Objective C**: Create recycled thermoset feedstocks from cured adhesives, thermoset components, and yellow-coded blades using mechanical milling, (b) Use Stereolithography (SL) and Selective Laser Sintering (SLS) to fabricate functional composites with recycled thermoset particulates. Design and manufacture non-Wind Turbine component prototypes and test prototype coatings in a pilot setting. Funds are requested from the NDIC for a state-of-the-art 3D printer as a cost share. UND has ball milling and other facilities. **Objective D:** Perform dissolution kinetics, absorption limits, and pathways of different types of thermosets in ILs by varying the chemistry of ILs and different solutions, characterizing recycled monomers/oligomers and fibers through imaging, FTIR, and Zeta-potential measurements. Integrate recycled monomers and fibers into composites and characterize the mechanical and physical behavior of the recycled composites. Design a pilot scale process at a level of TRL-5 using 50 Kg/batch feedstock. The stretch goal is processing 100-500 Kg of feedstock weekly. UND will have the capability to set up a pilot plant with DOE funding. **Objective E**: Explore the biodegradation kinetics and mechanisms at mild conditions (35°C) and design a pilot scale process at a level of TRL-4 with a stretch goal of TRL-5 using lignolytic or similar enzymes. **Objective F:** Complete a holistic LCA for SH0WUP. These results will be integrated into the technology commercialization plan to showcase the technology and inform potential investors on thermoset reutilization "greening.".

Environmental and Economic Impacts While Project is Underway: The project's economic and environmental impacts are: (a) Sending heavily damaged blades to a Sandwich Gasifier (red code). This process is already commercialized and can be potentially scaled up to 5 tons per day within three years. (b) Using medium-damaged blades to generate and recycle thermosets into functional 3D-printed components for non-wind blade structures. (c) Processing the least damaged blades using IL solvents and

a biological recycling process. We used this technology to recycle epoxy in the feasibility study. We propose building an Ionic Liquid-Solvent-based plant in Grand Forks that is based on the experimental data and design paradigm. The innovation aspect is the usage of low Ionic Liquid concentrations in tailored solvents coupled with recyclability to design a state-of-the-art, first-of-its-kind, chemical pilot plant co-located with 3D printing technology as a "bootstrapping" philosophy of entrepreneurship.

Ultimate Technological and Economic Impacts: The proposed technology is based on smart and AI-driven processes that will streamline and sort blades into different categories. Tailored thermoset particles have not been explored as commercially available solid lubricants or integrated into 3D-printed structures. We will integrate these particles into coatings and 3D-printed structures that can be used for non-blade components, such as molds, bushings, towers, and platforms. The synergistic use of ionic solvents and enzymatic degradation will effectively remove fibers from the thermoset matrix with minimal disruption. The recovered fiber process can be extended to Carbon-fibers and used in construction applications. Completely rejected and corroded blades will be analyzed for energy generation. Degradation using ILs and enzymatic processes is a blue-ocean market space, and there are no commercial competitors that can recycle thermosets and fibers at a temperature <200°C in ambient air without using supercritical solvents.

Why the Project is Needed: North Dakota has continuous wind energy resources. Wind energy has doubled in the state from 2016 to 2022. According to the latest data, North Dakota has about 4,300 megawatts of installed wind power generating capacity and a site near Williston is the largest farm and has a 300 megawatts capacity. As a summary, North Dakota ranks fourth in terms of electricity generated from wind energy[1]. Currently, there are no viable solutions for recycling wind turbine blades and only a few disposable sites in North Dakota. North Dakota solid waste management law encourages recycling

[1] https://www.eia.gov/state/analysis.php?sid=ND#:~:text=At%20the%20beginning%20of%202023,came%20online%20in%20early%202021.

wind turbine blades but there are no or limited options[2]. The successful completion of this project will potentially lead to successful recycling of wind turbine blades commercially, boost a new cluster of interconnected technologies which will further boost the state's economy, and will stimulate further development of wind energy in North Dakota.

STANDARDS OF SUCCESS

List of Measurable Deliverables Indicative of Program Success:

Year 1: (a) Protocol for tagging wind blades and sorting them into three major categories, (b) table-top bench scale unit for evaluating the conversion features of WTB, (c) Method to create thermoset feedstocks using mechanical milling, (d) Methods to use SL and SLS to fabricate composites, (e) characterization of monomers/oligomers and fibers, and (f) annual report.

Year 2: (a) R-WTD parametric testing using the bench-scale unit, (b) create an improvement strategy for the sandwich gasification system, (c) comprehensive characterization of physical and mechanical properties of composites, (d) Pilot scale process design process and mini pilot plant, and (e) annual report.

Year 3: (a) Optimized ML/AI system, (b) sandwich gasification system operation at 5 ton/day, (c) non-wind turbine component protypes to replace PTFE-based components, (d) IL-based and 3D printing pilot plants process operating at TRL 5, (e) holistic LCA for SH0WUP, and (f) annual and final report.

Value to North Dakota: Wind energy is a major source of energy in North Dakota[3]. In ND, the renewable energy supports 2,200 jobs, > $22.5 million in annual state and local tax payments, and $8 billion in total capital investments. Wind farm technician is also the fastest growing job opportunity in US[4]. Based on these statistics, we can summarize that the design and development of next generation recycling technologies as a part of this proposal will further stimulate the Wind Energy sector in ND, create more

[2] https://bismarcktribune.com/news/state-and-regional/govt-and-politics/bill-requires-state-ok-for-wind-turbine-blade-disposal-in-north-dakota/article_77fa97f2-9ccc-11ed-ac65-97166ce26501.html
[3] https://windexchange.energy.gov/states/nd
[4] https://bismarckstate.edu/news/wind-energy-boom/

wind energy-based jobs, can be directly integrated with different wind mills and will further ND's vision of commerciable recycling process. Further details are given in the Invest in America sub-section.

Commercialization Pathway via Public Private Partnerships and Potential for Job Creation: We plan to transition all proposed technologies to TRL levels of 5-6. We plan to install two co-existing pilot plants: a 3D printer to create functional components from thermoset waste and a pilot plant based on IL solvent technology, backed by a solid LCA from two independent researchers. These new plants will require personnel from a diverse workforce, creating a significant number of local jobs. We plan to process a ton of waste/batch after successfully completing pilot testing in Year 3. There are 1,500 turbines with 4,500 blades in the northern plains region that will be upgraded soon, creating significant market potential. Existing local companies, such as LM Wind Power, will also be able to benefit from this technology, expanding their market share and workforce, which will create even more local jobs.

Education Component, Invest in America's Workforce, and Job Creation: Two co-existing pilots will be set up on the University of North Dakota campus for 3D printing and the Ionic Solvent-based recycling process. The proposed research will train at least five graduate students, one post-doc, and one research scientist, and will hire electricians, plumbers, and several other technicians. This project will aid in mitigating the wind power-based waste problem in Grand Forks, where LM Wind Power is located. The green energy sector is growing exponentially; therefore, the project can generate job opportunities for U.S. workers in related skilled and semi-skilled categories. Reputable companies, such as Great River Energy, LM Wind Power, and Strata, support the project since they want to leverage this program to create new opportunities in the Northern Plains region. In addition, the SET-led team has many start-ups and small local business-based companies that are active program participants. The project will popularize sustainability research among different stakeholders and expand America's workforce in Wind Energy. The SH0WUP model envisioned in this program will create an ecosystem for recycling Wind Blades and advance the Wind Turbine industry, significantly bolstering local, state, and US economies. The support

of the North Dakota Industrial Corporation (NDIC) will showcase the importance of the proposed research in generating job opportunities, which is a direct investment in America's workforce at the state level.

BACKGROUND/QUALIFICATIONS

University of North Dakota: Dr. Surojit Gupta, Professor and Director of the Materials Manufacturing Initiative (MMI) at the University of North Dakota (UND), will be the PI from UND. Dr. Gupta will manage the project and lead thermoset utilization and IL optimization efforts. He will be the point of contact between the NDIC, EERE, and other project participants/sponsors. Dr. Gupta has over 15 years of experience in fundamental research, technology development, and commercialization. His research has been consistently supported by the DOE, DOD, Navy, NSF, ND Research Council, ND Corn Council, and Department of Agriculture, and he has managed a multi-million-dollar research portfolio.

Dr. Yun Ji, Professor of Chemical Engineering at UND, will be a Co-PI on this project. Dr. Ji has over 15 years of experience in biochemical engineering and biomass utilization and over 50 peer-reviewed publications. She also has experience in proven chemical design and feasibility studies. Dr. Ji will oversee enzymatic degradation, reactor design, quality control, and CMP implementation.

Dr. Bethany Klemetsrud, Assistant Professor at UND, will be a Co-PI on this project. Dr. Klemetsrud has extensive experience conducting life cycle assessments, collaborating with companies such as the Gas Technologies Institute, and participating in several DOE and NETL projects conducting LCAs.

Dr. Hallie Boyer Chelmo is an Assistant Professor at UND and will serve as a Co-PI on this project. Dr. Chelmo will lead studies on the ice-phobicity behavior of coatings.

Mr. Harry Feilen is the Director of Operations at the Drilling and Completion Lab (DRACOLA) and has over 40 years of experience in construction, fabrication, troubleshooting, and repairing equipment experience. Mr. Feilen will work on the development of an IL-based and 3D printing plants.

Singularity Energy Technologies, LLC (SET) – Dr. Nikhil Patel, founder and President of SET, is the inventor and patent holder for the sandwich gasifier technology. Dr. Patel has over 25 years of research,

development, and technology commercialization experience in waste-to-energy conversion using thermochemical processes involving combustion and the partial oxidation or gasification of biomass, coal, and unconventional feedstock. Table 1 summarizes the roles of the team members in the SET-led team.

Table 1: Roles of the Team Members

Team Member	Role
Singularity Energy Technologies LLC	UND prime sub-recipient and Objective B Task 2 lead. Owner of Sandwich Gasification patents
Dakota Green Power	Manufacturer of Sandwich gasifier systems
Tri-Steel Manufacturing	Manufacturer of gasifier components through established relationship with DGP and SET and owner of 5 TPD system
City of Grand Forks	Host site for the 5 TPD system
Sage Green N.R.G.	Provide support for permitting, marketing, and communications
MDM Energy Consulting	Provide support for project management, design, and reporting

MANAGEMENT

We summarized the team member roles in the task summary and the project summary chart in Figure 1. UND is the primary recipient. UoI and SET LLC are sub-contractors of the DOE Grant. We have divided the project into Objectives with hierarchic tasks for better management. Each task will be professionally managed and compiled via individual reports every quarter, where we will determine if the quarterly milestones have been fulfilled.

TIMETABLE

Schedule for Interim Report Submission: An interim report will be submitted to the NDIC annually. Quarterly reports will be available upon request.

Task description summary (Table 2 summarizes the GANTT Chart): The work plan is hierarchically structured to fulfill the following objectives: Task 0.A: PI (Gupta) will manage the project and submit reports. Task 0.B: Co-PI (Ji) will oversee Community Management Plan (CMP) implementation.

Tasks for Completing Objective A: Year 1: Task 1.1: Procure Unmanned Aerial Vehicle (UAV)-based digital, ultrasonic, and optical imaging systems and commence wind blade imaging. Task 1.2: Use a transfer learning approach to ML pipeline design for wind turbine damage detection and classification.

Year 2: Task 1.3: Design and develop a collaborative work environment to streamline research between the partner institutions. Year 3: Tasks 1.4-1.5: Enhance the reinforcement learning techniques and train users.

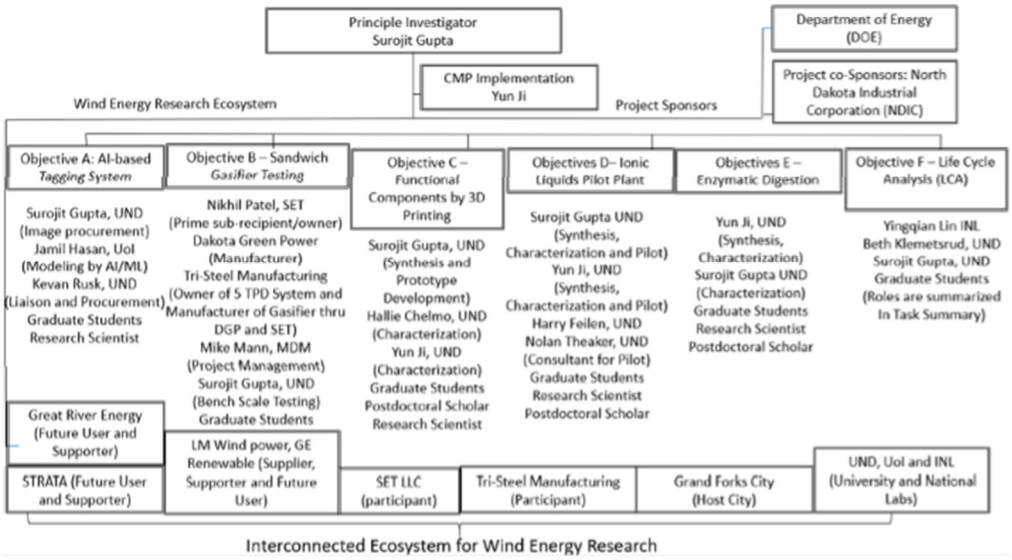


Figure 1: Project Chart summarizing the roles of the PIs

Tasks for completing Objective B: Year 1: Task 2.1: Bench-scale testing of the blade material. Year 2: Task 2.2: Bench-scale testing and 5-ton/day system design modification. Year 3: Task 2.3: 5 ton/day system modification, testing, and reporting.

Tasks for completing Objective C: Year 1: Task 3.1: Mechanically mill wasted cured adhesives and yellow-coded blades to extract thermosets. Task 3.2: 3D-print small-scale coupons using SL. Task 3.3: 3D print small-scale coupons using SLS. Year 2: Task 3.4: Document detailed measurements of the composites' ice phobicity and mechanical, tribological, and microstructural behaviors. Year 3: Task 3.5: Design and manufacture prototype non-wind turbine components in a pilot setting.

Tasks for completing Objective D: Year 1**:** Task 4.1: Procure and validate batch reactors with a daily process capability of 1 Kg of feedstock. Task 4.2: Perform dissolution kinetics, absorption limits, and characterization of different types of thermosets in ILs by varying IL chemistry. Task 4.3: Perform dissolution kinetics of thermosets by making solutions of ILs and solvents with a boiling point >200^{o}C. Year

2: Task 4.5**:** Procure and validate a batch reactor that can process 10 Kg of thermosets per batch. Task 4.6: Integrate recycled fibers and polymers into composites. Year 3: Task 4.7: Procure batch reactors with a processing capability of 50 Kg of thermosets per batch and implement a pilot plant.

Tasks for completing Objective E: Year 1: Task 5.1: Identify promising enzymes and conduct lab-scale experiments at 20g/batch. Task 5.2: Characterize degradation products and explore biological degradation pathways. Task 5.3: Optimize reaction conditions to find the highest bioconversion rate. Year 2: Task 5.4: Conduct experiments with selected enzymes at 100g/batch. Task 5.5: Characterize biodegrading products using analytical instruments. Task 5.6: Explore applications for degraded polymers and recycled fibers.

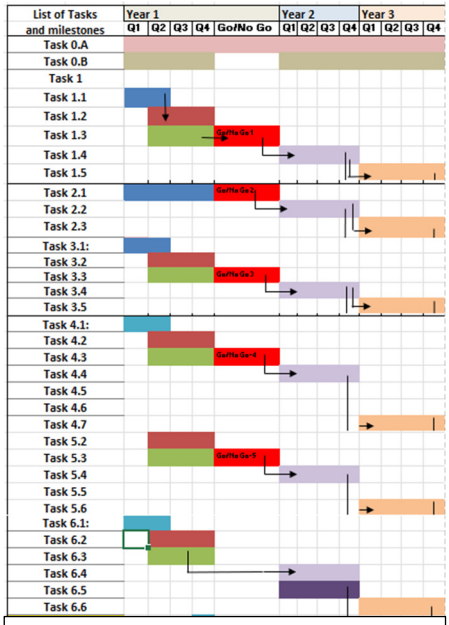


Table 2: GANTT Chart

Year 3: Task 5.7: Conduct experiments at 1 kg per day. Task 5.8: Explore the biodegrading process at a level of TRL-4. Task 5.9: Conduct a techno-economic analysis.

Tasks for completing Objective F: Year 1: Task 6.1: Collect initial life cycle assessment data for wind turbine blade production. Task 6.2: Develop a process model for the proposed recycling system. Task 6.3: INL will develop a baseline process simulation model using Aspen Plus Year 2: Task 6.4: Conduct a sensitivity analysis to reveal the impacts of specific parameters on the system's total footprint. Year 3: Task 6.5: Complete the LCA analysis of SH0WUP holistically.

BUDGET

The DOE has selected this project to receive $3,000,000 in funding after a highly competitive process. Mr. Reice Hasse from the NDIC has kindly issued a support letter of $500,000 to support this project as UND's cost share partner. Table 3 summarizes the NDIC's cost share for this project on a year-by-year basis.

Table 3: NDIC Cost Share

Project Associated Expense	NDIC's Share (Itemized List)	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Other Project Sponsor's Share
1,330,758 (year 1)	$193,845 3D Printer-$81,250; Staff Salary-$79,855; F&A -$32,740	Table 5	Table 5	Table 5
1,043,522 (year 2)	$125,827 Staff Salary: $74,239 DRACOLA Lease: $15,000 F&A:$36,588	Table 5	Table 5	Table 5
1,406,289 (year 3)	$180,328 Staff and PI (s) salary: $92,891 Travel:$5,000; DRACOLA Lease: $15,000; Professional Fees: $15001; F&A: $52,436	Table 5	Table 5	Table 5
Total	$500,000	NA	$25,111	$187,993+67,466

The cost share from the NDIC is vital for successfully completing this project. Tables 4 and 5 list the overall cost share and cost share contributed by different project partners, respectively.

Table 4: Overall cost share

	Federal	Cost Share	Total Costs	Cost Share %
Budget Period 1	$1,062,693	$268,065	$1,330,758	20.14%
Budget Period 2	$821,300	$222,222	$1,043,522	21.30%
Budget Period 3	$1,116,006	$290,283	$1,406,289	20.64%
Total	$2,999,999	$780,570	$3,780,569	20.65%

Table 5: Cost share from different partners

NDIC	Cash	DRACOLA lease; precursor powders for Tasks 3,4, and 5; Research Staff salary for tasks 3 and 4; 3D printer for Task 3	$193,845	$125,827	$180,328	**$500,000**
UND	In Kind	5% of salary and fringe for PI, Co-PIs,	$0	$25,111	$0	**$25,111**
Tri-Steel Manufacturing	In Kind	Labor and equipment rental	$52,393	$48,802	$86,798	**$187,993**
University of Idaho	In Kind	20 % Co-PI salary, associated fringe and F&A	$21,827	$22,482	$23,157	**$67,466**

CONFIDENTIAL INFORMATION and PATENTS/RIGHTS TO TECHNICAL DATA

N/A

STATE PROGRAMS AND INCENTIVES

A. The NDIC Contract No. is FY22-XCVII-242. The title is "Development of Novel Sintered Coal Building Materials." Project length is 10/1/2021 - 2/29/2024; Total amount is $649,407

B. R-050-C – Enhanced Sweep Efficiency for Geothermal Renewable Energy Using Bio-Polymer Supplement, PI: Dongmei Wang, co-PI: Dr. Ji, Funding: $468,877.

C. Drs. Gupta and Ji are also funded by APUC, ND Corn Council, and ND Soybean Council.

UNIVERSITY OF NORTH DAKOTA

September 28, 2023

Reice Haase, Deputy Executive Director
North Dakota Industrial Commission
State Capitol – 14th floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840

Subject: "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP) for Reusing Thermosets and Effectively Recovering Fibers via Mechanical, Thermal, Biological, and Chemical Pathways," Proposal to the Renewable Energy Program by Dr. Surojit Gupta, Principal Investigator

Dear Mr. Haase:

On behalf of the University of North Dakota, I am pleased to write this letter of transmittal for Dr. Surojit Gupta's proposal on "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP) for Reusing Thermosets and Effectively Recovering Fibers via Mechanical, Thermal, Biological, and Chemical Pathways," for consideration by the NDIC's Renewable Energy Program. Dr. Gupta is an Associate Professor in UND's College of Engineering and Mines, Department of Mechanical Engineering, and is the Principal Investigator for this project. Dr. Gupta is conducting a three-year project with a total requested amount from NDIC of $500,000. The NDIC funding is being requested as a match to the DOE portion of the project, which has been awarded by DOE for $2,899,999 with a start date of 10/1/2023.

Please contact Dr. Gupta with any technical questions about the project at (701) 777-1632 or surojit.gupta@und.edu. If the NDIC selects this proposal for an award, please send any award documents and related communications to Sherry Zeman at sherry.zeman@und.edu for processing on behalf of UND.

The $100 application fee is being handled as an electronic payment by UND and should reach your office in a timely manner. Thank you very much for your consideration of this proposal.

Sincerely yours,

Karen A. Katrinak

Karen A. Katrinak, Ph.D.
Proposal Development Officer / Authorized Organizational Representative
Research & Sponsored Program Development
Division of Research & Economic Development
(701) 777-2505 / Karen.katrinak@und.edu

Industrial Commission

Tax Liability Statement

Applicant:
University of North Dakota

Application Title:
Smart Holistic Zero Waste Utilization Paradigm (SH0WUP) for Reusing Thermosets and Effectively Recovering Fibers via Mechanical, Thermal, Biological, and Chemical Pathways

Program:

- ☐ Lignite Research, Development and Marketing Program
- ☑ Renewable Energy Program
- ☐ Oil & Gas Research Program
- ☐ Clean Sustainable Energy Authority

Certification:
I hereby certify that the applicant listed above does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Karen Katrinak

Signature

Karen Katrinak
Proposal Development Officer

Title

September 28, 2023

Date

Appendix A (Supporting Documents):

1. Evidence of submission of remittance
2. Selection by DOE for the Award
3. Support letter from Mr. Reice Hasse from NDIC
4. Support letters from LM Windpower, STRATA and GRE
5. Commitment letters from SET, MDM and other members of the SET-led consortium

Invoice Summary - Supplier Invoice No. SH0WUP-Gupta 092123 (Doc. No. V3334013)

Supplier Invoice No. SH0WUP-Gupta 092123
Supplier Name INDUSTRIAL COMMISSION,ND

General

Invoice Type	Invoice
Pay Status	Paid
Invoice Number	V3334013
Supplier Invoice No.	SH0WUP-Gupta 092123
Supplier Name	INDUSTRIAL COMMISSION,ND
Invoice Owner	Tonya Parton
Business Purpose	Required Grant Application fee for NDIC proposal-Smart Holistic Zero Waste (SH0WUP)
Invoice Date	9/21/2023
Discount Date	
Due Date	9/21/2023
Terms	0% 0, Net 0
Terms Discount	0.00 USD
Invoice Name	2023-09-25 0399535 01
Bypass Treasury	✗
Invoiced By	Tonya Parton
Match Status	Do Not Match
Invoice Source	Automated
Contains substituted item(s)	✗
Amount Only PO	✗

Addresses

Remit To

Remit To Location List edit

CAPITOL TOWER 14 FLOOR
600 E BOULEVARD AVENUE
BISMARCK, North Dakota 58505

USA
Address Id 1

Bill To

UND PAYMENT SERVICES
TWAMLEY HALL ROOM 409
264 CENTENNIAL DRIVE
STOP 8356
GRAND FORKS, ND
58202-8356
United States

Note/Attachments

External Note ***** Seq: 1 | Payment Ref: 262355 | Payment Date: 2023-09-26

Internal Note *no note*

External Attachments

Internal Attachments

Payment Information

Accounting Date	9/25/2023
F.O.B.	FOB Destination or as per executed agreement
Payment Method	ACH
Payment Record No.	262355

Discount, Tax, Shipping & Handling

Discount, tax, shipping & handling

Allocation	Sum of All Header-level	Sum of lines
Terms Discount	0.00 USD	
Discount	0.00 USD	0.00 USD
Tax 1	0.00 USD	0.00 USD
Tax 2	0.00 USD	0.00 USD

Origin	*no value*
Origin Ref Field	*no value*

Payment Record Date	9/26/2023
Payment Message	*no value*
Hold Check	✗

Shipping	0.00 USD	0.00 USD
Handling	0.00 USD	0.00 USD
Total		100.00 USD

Codes

LINE

Account	Department	Fund - Dept	Project	Program Code
623155 Other Professional Fees	2725 Mechanical Engineering	22619-2725 F&A S Gupta	*no value*	*no value*

Line Item Details

J000103557

		PO Line	Product Description	Catalog No	Size / Packaging	Unit Price	Quantity	Ext. Price
1	✓	1	**Payment Request**			**100.00 USD**	**1**	**100.00 USD**

Business Purpose	Required Grant Application fee for NDIC proposal- Smart Holistic Zero Waste (SH0WUP)
Special Invoice Instructions	None of the above (standard payment by ACH or Check)

PO Number	J000103557
PO Department	*no value*
Substitute Item	✗
Line Match Status	Do Not Match

Matching Summary

	Ordered	Received	Net Invoiced
Quantity:	1	--	1
Ext. Price:	100.00 USD	--	100.00 USD

Related Documents
Invoices: 0 / Credits: 0 / Receipts: 0

External Note	*no note*
Internal Note	*no note*

External Line Attachments

Internal Line Attachments

Discount, tax, shipping & handling

	Line-level
Discount	0.00 USD
Tax 1	0.00 USD
Tax 2	0.00 USD
Shipping	0.00 USD

	Contract No.		Handling 0.00 USD
	Commodity Code	93151517 License or registration fee	
	WO/CP Number	*no value*	

Subtotal	**100.00**
Discount	0.00
Tax	0.00
Tax2	0.00
Shipping	0.00
Handling	0.00
Total	**100.00 USD**

ASSISTANCE AGREEMENT

1. Award No.	2. Modification No.	3. Effective Date	4. CFDA No.
DE-EE0011014		10/01/2023	81.086

5. Awarded To	6. Sponsoring Office	7. Period of Performance
University of North Dakota Attn: John Mihelich 4201 James Ray Drive, Stop 8367 Grand Forks ND 582028367	Energy Effcy & Renewable Energy EE-1 U.S. Department of Energy 1000 Independence Avenue, S.W. Washington DC 20585	10/01/2023 through 09/30/2024

8. Type of Agreement	9. Authority	10. Purchase Request or Funding Document No.
☐ Grant ☒ Cooperative Agreement ☐ Other	PL 109-58 EPAct 2005	23EE002985

11. Remittance Address	12. Total Amount	13. Funds Obligated
University of North Dakota Attn: UNIVERSITY OF NORTH DAKOTA TWAMLEY HALL CENTENNIAL DRIVE 264 Centennial Drive, Stop 7306 GRAND FORKS ND 582027306	Govt. Share: $2,900,000.00 Cost Share : $780,570.00 Total : $3,680,570.00	This action: $2,900,000.00 Total : $2,900,000.00

14. Principal Investigator	15. Program Manager	16. Administrator
	Luke Kandris Phone: 720-636-1087	Golden Field Office U.S. Department of Energy Golden Field Office 15013 Denver West Parkway Golden CO 80401

17. Submit Payment Requests To	18. Paying Office	19. Submit Reports To
Payment - Direct Payment from U.S. Dept of Treasury	Payment - Direct Payment from U.S. Dept of Treasury	

20. Accounting and Appropriation Data

05450-2022-31-200835-41010-1009209-0000000-0000000-0000000

21. Research Title and/or Description of Project

Smart Holistic Zero Waste Utilization Paradigm (SHOWUP) for reusing thermosets and effectively recovering fibers via mechanical, thermal, biological,

For the Recipient		For the United States of America	
22. Signature of Person Authorized to Sign		25. Signature of Grants/Agreements Officer Signature on File	
23. Name and Title	24. Date Signed	26. Name of Officer Christina Kouch	27. Date Signed 09/27/2023

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	UEI: RSWNKK6J8CF3 1. This is a conditional award, comprised of this Assistance Agreement and the Special Terms and Conditions. Upon successful completion of negotiations, this award will be modified to lift its conditional status, to revise the Special Terms and Conditions, and to add additional attachments, such as Attachment 1, Statement of Project Objectives and Milestone Summary Table; Attachment 2, Federal Assistance Reporting Checklist and Instructions; Attachment 3, Budget Information SF-424A; Attachment 4, Intellectual Property Provisions; and Attachment 5, Community Benefits Plan. 2. The award was prepared using the proposed budget information in the Recipient's application. Term 1 of the Special Terms and Conditions states that the Recipient is prohibited from spending Federal funds at this time. DOE will not release the funding obligated by this award until successful completion of negotiations are reached to the satisfaction of the Contracting Officer. Performance against this award is, therefore, at the Recipient's own risk, and payments for costs incurred for Recipient's project will not be made until the parties complete negotiations and the Contracting Officer issues a modification to this award. 3. A representative of the DOE office will contact the Recipient to request additional and/or revised information needed to supplement and clarify the Recipient's application, to complete the negotiations of an amended award. In Block 7 of the Assistance Agreement, the Period of Performance reflects the beginning of the Project Period through the end of the current Budget Period. Additional future DOE funding and additional budget periods are not contemplated under this award. Funding for all awards and future budget periods is contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority. The total amounts reflected in Blocks 12 and 13 of the Assistance Agreement do not include the Continued ...				

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	Federally Funded Research and Development Center (FFRDC) funding amount of $100,000, which was funded directly. DOE Award Administrator: Wilma (Amy) Abalos E-mail: wilma.abalos@ee.doe.gov Phone: 240-562-1338 DOE Project Officer: Luke Kandaris E-mail: luke.kandaris@ee.doe.gov Phone: 720-636-1087 Recipient Business Officer: Karen Katrinak E-mail: Karen.katrinak@und.edu Phone: 701-777-2505 Recipient Principal Investigator: Surojit Gupta E-mail: surojit.gupta@und.edu Phone: 701-777-1632 "Electronic signature or signatures as used in this document means a method of signing an electronic message that-- (A) Identifies and authenticates a particular person as the source of the electronic message; (B) Indicates such person's approval of the information contained in the electronic message; and, (C) Submission via FedConnect constitutes electronically signed documents." ASAP: YES Extent Competed: COMPETED Davis-Bacon Act: NO PI: Gupta, Surojit Fund: 05450 Appr Year: 2022 Allottee: 31 Report Entity: 200835 Object Class: 41010 Program: 1009209 Project: 0000000 WFO: 0000000 Local Use: 0000000				

INDUSTRIAL COMMISSION OF NORTH DAKOTA

Doug Burgum
Governor

Drew H. Wrigley
Attorney General

Doug Goehring
Agriculture Commissioner

May 2, 2023

Dr. Surojit Gupta
Associate Professor
Advanced Materials Research Group
Dept. of Mechanical Engineering
University of North Dakota
243 Centennial Drive
Grand Forks, ND

Re: Support for the proposal entitled "Smart Holistic Zero Waste Utilization Paradigm (SHOWUP) for reusing thermosets and effectively recovering fibers via mechanical, thermal, biological, and chemical pathways" submitted in response to U.S. Department of Energy funding opportunity DE-FOA-0002960

Dear Dr. Gupta,

Please accept this letter of support for the University of North Dakota's (UND) proposal entitled "Smart Holistic Zero Waste Utilization Paradigm (SHOWUP) for reusing thermosets and effectively recovering fibers via mechanical, thermal, biological, and chemical pathways".

The North Dakota Industrial Commission (NDIC) Renewable Energy Program's mission is to promote the growth of North Dakota's renewable energy industries through research, development, marketing, and education. The proposed effort aims to study the integration of smart blade sorting using advanced imaging and machine learning, sandwich gasifiers, recycled thermoset-based structures, and enzymatic-based technologies into a single platform. This scope of work aligns with the Renewable Energy Program's mission.

This project is eligible for up to $500,000 of cash cost share from the Renewable Energy Program. Support is contingent on submittal of a proposal to the NDIC and subsequent proposal approval by both the Renewable Energy Council and the NDIC.

If successful, this project will provide a valuable resource for our nation's renewable energy industry. Thank you for working to advance North Dakota's clean energy goals.

Sincerely,

Reice Haase, Deputy Executive Director

GREAT RIVER ENERGY™

12300 Elm Creek Boulevard
Maple Grove, Minnesota 55369-4718
763-445-5000
greatriverenergy.com

May 16, 2023

Dr. Surojit Gupta
Associate Professor
Department of Mechanical Engineering
University of North Dakota

Re: Letter of Interest in the University of North Dakota application entitled "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP) for reusing thermosets and effectively recovery fibers via mechanical, thermal, biological, and chemical pathways."

Dear Dr. Gupta,

Great River Energy is pleased to provide this letter of interest in support of your team's application to the U.S. Department of Energy to demonstrate a novel technology to cost-effectively reuse materials in end-of-life wind turbine blades.

Great River Energy is a not-for-profit generation and transmission electric cooperative, headquartered in Maple Grove, Minnesota. Together with our 27 member-owner distribution cooperatives and customers, we provide reliable and affordable electricity to 1.7 million people. Great River Energy's power supply portfolio has transformed over the past decade, and our cooperative now has power purchase agreements for the output of nine wind facilities located throughout Minnesota, North Dakota, South Dakota, and Iowa.

Great River Energy believes in the responsible use of natural resources, including maximizing the useful life of materials in wind turbine blades. Based on discussion with members of your team, we feel your technology has significant commercial potential and we plan to follow the progress of your development and demonstration efforts.

We wish you luck in your proposal to the Department of Energy and look forward to following your project going forward.

Sincerely,

GREAT RIVER ENERGY

David Saggau
President and Chief Executive Officer

LM WIND POWER
a GE Renewable Energy business

05/09/2023

DOE Program Manager,

LM Wind Power, a GE Renewable Energy business, would like to support the proposal titled, "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP)" for reusing thermosets and effectively recovering fibers via mechanical, thermal, biological, and chemical pathways".

LM Wind Power is a leading supplier of blades for wind turbines, offering blade development, manufacturing, service, and logistics. Approximately one in five turbines installed around the world are LM Wind Power blades. To keep our leading position LM Wind Power is keen on innovating their product and processes. Key to future sustainable business is the need for manufacturing zero waste blades by 2030. To meet this strategy, it means developing a way to utilize all excess materials from manufacturing.

The proposal is very timely as it envisions a zero-waste paradigm by using a collaborative model to solve a challenging problem of recycling thermoset waste both during manufacturing and post-manufacturing. Research and development of wind turbine research and utilization cluster in the University of North Dakota will be beneficial to us as it will create pathways for thermoset reutilization and recycling which tunes well with our own recycling and sustainability efforts. In addition, there is an urgent requirement of trained manufacturing engineers in the plant. This program has the potential to create pilot facilities and provide work force trained in different aspects of wind blade manufacturing who could join our plant in the future.

We are excited to support this proposal and hope to see results that benefit our world-wide wind power business.

Best Regards,

Tricia Weber
Sr Manufacturing Staff Manager

May 11, 2023

Mr. Kevan Rusk
Director of Business Development
College of Engineering and Mines
University of North Dakota

RE: "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP)

I have genuine interest in the research as described in the proposal entitled, "Smart Holistic Zero Waste Utilization Paradigm (SH0WUP). The reuse of thermosets and effectively recovering fibers via mechanical, thermal, biological, and chemical pathways has great merit.

The proposal is very timely as it envisions a zero-waste paradigm by using a collaborative model to solve a challenging problem of recycling thermoset waste, both during and after manufacturing. We are very interested to evaluate the recycled fibers from the pilot testing for construction-based applications.

The environmental benefits: saving natural resources, using recycled materials, and reducing pollution and greenhouse gas emissions will contribute to the concrete construction industries efforts for building sustainable projects.

Thank you for your consideration in this matter.

Henry Hauge | Director of Technical Services
STRATA CORPORATION
p: 701-277-1432 c: 701-238-6556
e: hank.hauge@stratacorporation.com
102 12th Ave NW | West Fargo, ND 58078

BUILD WITH STRENGTH
A COALITION OF THE NATIONAL READY MIXED CONCRETE ASSOCIATION

SINGULARITY ENERGY TECHNOLOGIES, LLC
WASTE TO ENERGY

DR. NIKHIL PATEL
President

Suite 201, 4200 James Ray Dr.
Grand Forks, ND 58202
Cell Phone: 701-739-8720
https://www.singularet.com

May 9, 2023

Dr. Surojit Gupta,
Associate Professor and Director of Materials Manufacturing Initiative (MMI)
Department of Mechanical Engineering
University of North Dakota

Subject: Letter of Commitment from Singularity Energy Technologies in support of the University of North Dakota's response to U.S. Department of Energy DE-FOA-0002960

Dear Dr. Gupta,

I am happy to provide support for your proposed project to the U.S. Department of Energy in response to DE-FOA-0002960. Singularity Energy Technologies (SET) is the inventor of the Sandwich gasifier and has been working diligently the past several years to fully commercialize the technology. SET has developed a strong supporting team over time and continues to work with this team on projects such as that proposed herein. Our team can assist you in meeting the goals of your project, specifically those in support of Objective B as outlined in your proposal.

I have worked closely with you to develop the workplan for Objective B and have read SET's commitments as presented in your final proposal to DOE. We fully support the three subtasks outlined in the proposal, namely Task 2.1 Bench-Scale Testing of the Blade Material; Task 2.2 Bench-Scale Testing and 5 ton/day System Design Modification; and Task 2.3 5 ton/day System Modification, Testing and Reporting. We will perform our tasks in accordance to the attached schedule and milestones. The start date of our work and sub-task timeline will be adjusted as needed to match the start date of your project if an award in made by DOE.

The total cost of the services provided is $939,968. SET will provide a portion of these services to UND as in-kind cost share towards the DOE cost-share requirements. As presented in the attached Budget Justification workbook, this represents a cost to DOE of $751,975 with a cost share commitment from SET (met by our subrecipient Tri-Steel Manufacturing) of $187,993.

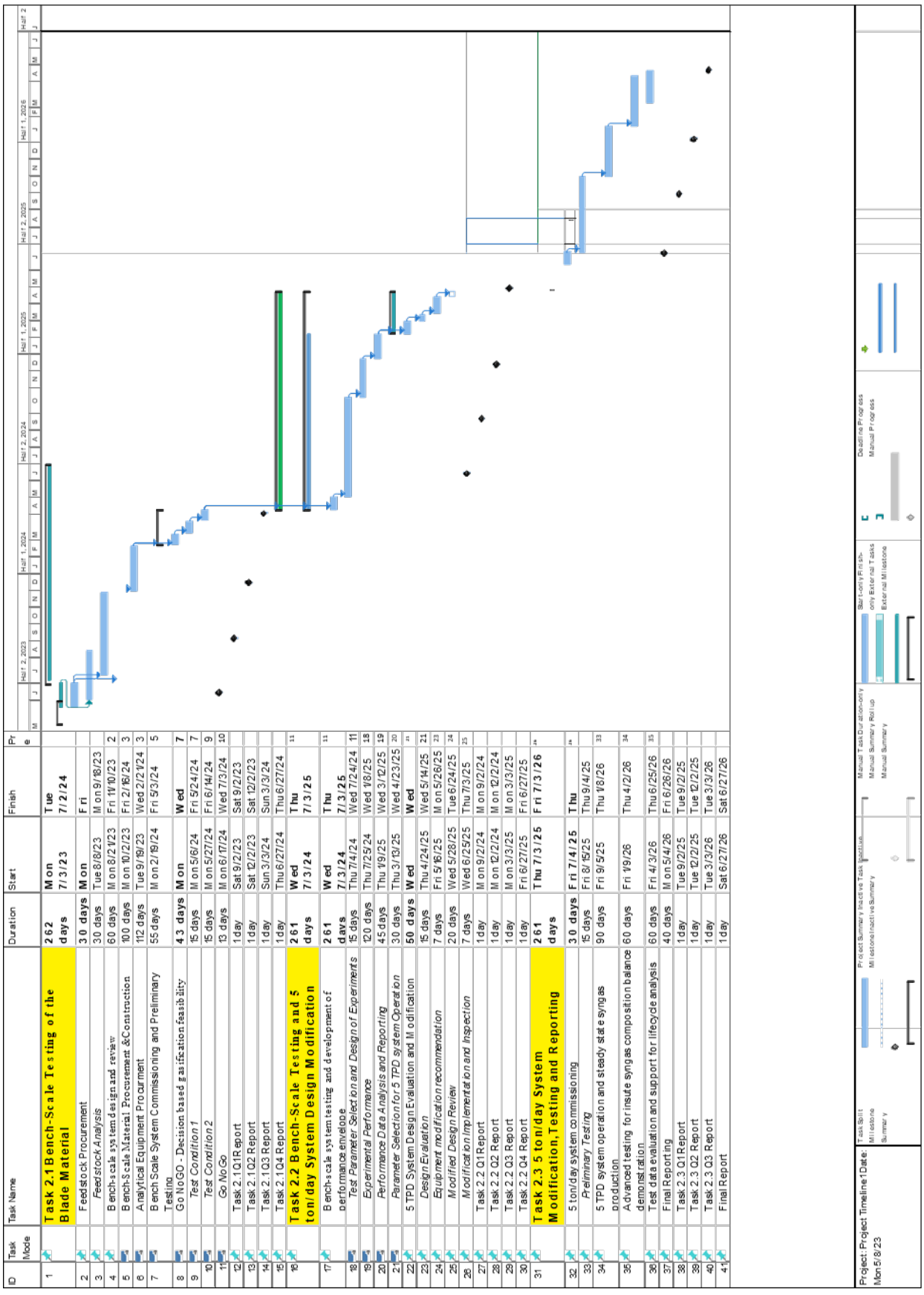
We are looking forward to working with you on this important and exciting project.

Sincerely,

Nikhil Patel
President, Singularity Energy Technologies, LLC

DR. NIKHIL PATEL
President

Suite 201, 4200 James Ray Dr.
Grand Forks, ND 58202
Cell Phone: 701-739-8720
https://www.singularet.com



ID	Task Mode	Task Name	Duration	Start	Finish	Pre
1		**Task 2.1 Bench-Scale Testing of the Blade Material**	**262 days**	**Mon 7/3/23**	**Tue 7/2/24**	
2		Feedstock Procurement	**30 days**	**Mon**	**Fri**	
3		*Feedstock Analysis*	30 days	Tue 8/8/23	Mon 9/18/23	
4		Bench-scale system design and review	60 days	Mon 8/21/23	Fri 11/10/23	2
5		Bench-Scale Material Procurement &Construction	100 days	Mon 10/2/23	Fri 2/16/24	3
6		Analytical Equipment Procurment	112 days	Tue 9/19/23	Wed 2/21/24	3
7		Bench Scale System Commissioning and Preliminary Testing	55 days	Mon 2/19/24	Fri 5/3/24	5
8		Go NoGO - Decision based gasification feasibility	**43 days**	**Mon**	**Wed**	**7**
9		*Test Condition 1*	15 days	Mon 5/6/24	Fri 5/24/24	7
10		*Test Condition 2*	15 days	Mon 5/27/24	Fri 6/14/24	9
11		*Go NoGo*	13 days	Mon 6/17/24	Wed 7/3/24	10
12		Task 2.1 Q1 Report	1 day	Sat 9/2/23	Sat 9/2/23	
13		Task 2.1 Q2 Report	1 day	Sat 12/2/23	Sat 12/2/23	
14		Task 2.1 Q3 Report	1 day	Sun 3/3/24	Sun 3/3/24	
15		Task 2.1 Q4 Report	1 day	Thu 6/27/24	Thu 6/27/24	
16		**Task 2.2 Bench-Scale Testing aad 5 ton/day System Design Modification**	**261 days**	**Wed 7/3/24**	**Thu 7/3/25**	11
17		Bench-scale system testing and development of performance envelope	**261 days**	**Wed 7/3/24**	**Thu 7/3/25**	11
18		*Test Parameter Selection and Design of Experiments*	15 days	Thu 7/4/24	Wed 7/24/24	11
19		*Experimental Performance*	120 days	Thu 7/25/24	Wed 1/8/25	18
20		*Performance Data Analysis and Reporting*	45 days	Thu 1/9/25	Wed 3/12/25	19
21		*Parameter Selection for 5 TPD system Operation*	30 days	Thu 3/13/25	Wed 4/23/25	20
22		5 TPD System Design Evaluation and Modification	**50 days**	**Wed**	**Wed**	21
23		*Design Evaluation*	15 days	Thu 4/24/25	Wed 5/14/25	21
24		*Equipment modification recommendation*	7 days	Fri 5/16/25	Mon 5/26/25	23
25		*Modified Design Review*	20 days	Wed 5/28/25	Tue 6/24/25	24
26		*Modification Implementation and Inspection*	7 days	Wed 6/25/25	Thu 7/3/25	25
27		Task 2.2 Q1 Report	1 day	Mon 9/2/24	Mon 9/2/24	
28		Task 2.2 Q2 Report	1 day	Mon 12/2/24	Mon 12/2/24	
29		Task 2.2 Q3 Report	1 day	Mon 3/3/25	Mon 3/3/25	
30		Task 2.2 Q4 Report	1 day	Fri 6/27/25	Fri 6/27/25	
31		**Task 2.3 5 ton/day System Modification,Testing and Reporting**	**261 days**	**Thu 7/3/25**	**Fri 7/3/26**	
32		5 ton/day system commissioning	**30 days**	**Fri 7/4/25**	**Thu**	
33		*Preliminary Testing*	15 days	Fri 8/15/25	Thu 9/4/25	
34		5 TPD system operation and steady state syngas production	90 days	Fri 9/5/25	Thu 1/8/26	33
35		Advanced testing for insute syngas composition balance demonstration	60 days	Fri 1/9/26	Thu 4/2/26	34
36		Test data evaluation and support for lifecycle analysis	60 days	Fri 4/3/26	Thu 6/25/26	35
37		Final Reporting	40 days	Mon 5/4/26	Fri 6/26/26	
38		Task 2.3 Q1 Report	1 day	Tue 9/2/25	Tue 9/2/25	
39		Task 2.3 Q2 Report	1 day	Tue 12/2/25	Tue 12/2/25	
40		Task 2.3 Q3 Report	1 day	Tue 3/3/26	Tue 3/3/26	
41		Final Report	1 day	Sat 6/27/26	Sat 6/27/26	

Dr. Edwin S. Olson

Phone: 701 330 2522
Email: eolson@gra.midco.net

May 7, 2023

Dr. Nikhil Patel
President, Singularity Energy Technologies
4200 James Ray Drive
Grand Forks, ND 58202

Subject: Letter of Commitment for the Singularity Energy Technologies proposal to the University of North Dakota in response to U.S. Department of Energy DE-FOA-0002960

Dear Dr. Patel,

I am happy to provide support for your proposed project to the University of North Dakota's proposal to the U.S. Department of Energy in response to DE-FOA-0002960. I feel the experience I gained during my many years working with the Energy & Environmental Research Center provide me with an excellent background to assist you with development and implementation of a strong analytical plan.

I am committing to provide consulting support in chemistry at a fee of $1000 for budget period one and $2000 each for budget periods two and three ($5000 total). I have reviewed your proposal and detailed budget and agree with the allocation of my time between tasks and the roles as described in the Project Management Plan.

Sincerely,

Edwin S. Olson
Principal Scientific Advisor
Singularity Energy Technologies, LLC

mdm energy consulting, llc

701.215.2900 • mike.mann@mdmenergy.net • thompson, nd

May 7, 2023

Dr. Nikhil Patel
President, Singularity Energy Technologies
4200 James Ray Drive
Grand Forks, ND 58202

Subject: Letter of Commitment for the Singularity Energy Technologies proposal to the University of North Dakota in response to U.S. Department of Energy DE-FOA-0002960

Dear Dr. Patel,

I am happy to provide support for your proposed project to the University of North Dakota's proposal to the U.S. Department of Energy in response to DE-FOA-0002960. I feel the experience I gained during my 18 years working with the Energy & Environmental Research Center and the 23 years with the College of Engineering and Mines provide me with an excellent background to assist you with the overall project management of your proposed efforts including development and execution of your testing campaign and support with report writing.

I am committing one month of my time per year for a total of 519 hours in support of your proposed project in accordance to the attached budget. I have reviewed your proposal and detailed budget and agree with the allocation of my time between tasks and the roles as described in the Project Management Plan.

Sincerely

Michael D. Mann

Michael D. Mann
Principal
MDM Energy Consulting LLC

mdm energy consulting, llc

701.215.2900 • mike.mann@mdmenergy.net • thompson, nd

Support for Singularity Energy Technologies proposal to the University of North Dakota in response to U.S. Department of Energy DE-FOA-0002960.

Budget Period 1: 173 hours at $150/hr for a total of $25,950
Budget Period 2: 173 hours at $150/hr for a total of $25,950
Budget Period 3: 173 hours at $150/hr for a total of $25,950

Total Cost: $77,850

Note: Any travel costs will be paid directly by SET or UND

May 8, 2023

Dr. Nikhil Patel
President, Singularity Energy Technologies
4200 James Ray Drive
Grand Forks, ND 58202

Subject: Letter of Commitment for the Singularity Energy Technologies proposal to the University of North Dakota in response to U.S. Department of Energy DE-FOA-0002960

Dear Dr. Patel,

I am happy to provide support for the University of North Dakota's project proposal to the U.S. Department of Energy in response to DE-FOA-0002960. I will use my connections and expertise to procure the windmill blades required for the proposed work, provide support developing analytical protocols, analyzing data, report writing, and will use my connections to develop relationships with long-term customers and identify potential buyers of your technology.

I will commit 12% of my time per year for each of the annual budget periods at a fee of $10,000 per year ($30,000 total). I have reviewed your proposal and detailed budget and agree with the allocation of my time between tasks and the roles as described in the Project Management Plan.

Sincerely,

Dr. Nicholas Ralston
Director, Sage Green NRG
Nick.Ralston@SageGreenNRG.com
218-791-2838

May 7, 2023

Dr. Nikhil Patel
President, Singularity Energy Technologies
4200 James Ray Drive
Grand Forks, ND 58202

Subject: Letter of Commitment for the Singularity Energy Technologies proposal to the University of North Dakota in response to U.S. Department of Energy DE-FOA-0002960

Dear Dr. Patel,

I am happy to provide support for your proposed project to the University of North Dakota's proposal to the U.S. Department of Energy in response to DE-FOA-0002960. My experience over the years educating, as well as learning from, entrepreneurs, strategists, and family business leaders, provide me with an excellent background to assist you with the development of a strong business plan for your technology.

In consideration of my time, I accede to a fee of $2500 per year ($5000 total) for each of budget periods two and three. I have reviewed your proposal and detailed budget and agree with the allocation of my time between tasks and the roles as described in the Project Management Plan.

Sincerely,

Sanjay Goel

Sanjay Goel, PhD
3700 Ruemmele Rd Apt 300
Grand Forks ND 58201