APPLICATION CHECKLIST

Use this checklist as a tool to ensure that you have all of the components of the application package. Please note, this checklist is for your use only and does not need to be included in the package.

☐	Application
☐	Transmittal Letter
☐	$100 Application Fee
☐	Tax Liability Statement
☐	Letters of Support (If Applicable)
☐	Other Appendices (If Applicable)

When the package is completed, send an electronic version to the Industrial Commission at ndicgrants@nd.gov. Send payment to:

North Dakota Industrial Commission
Attention: Renewable Energy Program
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

For more information on the application process please visit:
https://www.ndic.nd.gov/renewable-energy-program/rep-applicant-council-information

Questions can be addressed by calling 701-328-3722.

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Accelerating the Waste-to-Fuels Commercialization for the Sandwich Gasifier

Applicant: Singularity Energy Technologies

Principal Investigator: Dr. Nikhil Patel

Date of Application: August 1, 2024

Amount of Request: $486,950

Total Amount of Proposed Project: $978,950

Duration of Project: 24 months

Point of Contact (POC): Dr. Nikhil Patel

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POC Email: npatel@singularet.com

POC Address: Center of Innovation
4200 James Ray Drive
Grand Forks, ND 58202

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ABSTRACT

Objective:

The primary objective of this project is to demonstrate and prove the capabilities of the Sandwich Gasifier and integrated systems to produce clean and composition-balanced syngas under self-sustained steady-state operation. We will validate the integrated technology and improvement in techno-economics of producing low-cost syngas suitable for direct conversion into sustainable liquid fuels, renewable natural gas, and/or green hydrogen. The scale-up and integrated operation will fast-track our plan to develop a viable customer base and build future commercial-scale facilities. The Sandwich gasification technology has been proven to produce clean syngas from challenging waste streams with net carbon dioxide equivalent emission reduction, and therefore our integrated setup will provide a marketable waste-to-fuels technology using North Dakota biomass, agriculture/animal wastes and MSW. Job creation and training of a future workforce to support the industry are also important goals.

Expected Results:

This project seeks to generate tangible evidence, data, and insights that will inform decision-making processes regarding the adoption and implementation of the gasifier technology. Ultimately, the goal is to contribute to the development of a more sustainable and environmentally friendly energy sector by enabling the utilization of locally available biomass resources for clean and renewable biofuel and bio-material production. In achieving these goals, this project will demonstrate the performance and efficiency of the Sandwich gasifier in converting North Dakota biomass feedstocks (agricultural waste, manure, municipal solid waste, etc.) into syngas of suitable quality for production of sustainable liquid fuels, renewable natural gas, or green hydrogen. It will provide valuable insights and recommendations for improving the overall efficiency, cost-effectiveness, and sustainability of biomass-to-syngas conversion. This project will contribute to the advancement of renewable energy technologies by showcasing the potential of the Sandwich gasifier in utilizing diverse biomass feedstocks for biofuel production, and advancing the technology towards commercialization. Finally, this project will facilitate the transition towards a more sustainable energy sector by promoting the use of locally available biomass resources for clean and renewable fuel production.

Duration:

Twenty-four months (Suggested: January 1, 2025 – December 26, 2026)

Total Project Cost:

$486,950 is requested from NDIC of the $978,950 total project cost.

Participants:

Dakota Green Power (DGP), Singularity Energy Technologies, LLC (SET), Tri-Steel Manufacturing, Sage Green N.R.G. LLC, MDM Energy Consulting, LLC, Dr. Edwin Olson

PROJECT DESCRIPTION

The primary objective of this project is to demonstrate and prove the capabilities of the Sandwich Gasifier (SG) and integrated systems to produce clean and composition-balanced syngas under self-sustained steady-state operation by a clinker-free system producing gas-to-liquid (GTL), renewable natural gas (RNG) and hydrogen (H_2) quality syngas. Singularity Energy Technology's (SET) Sandwich gasifier has been proven to operate on a range of complex feedstocks, including municipal solid waste (MSW), biodigester waste, high moisture forestry and agricultural wastes including poultry and livestock manure, railroad ties, tires, and other difficult to process waste materials. SET's technology is viable at 25 tons/day, making it ideal for localized use for feedstocks traditionally difficult and expensive to transport. The unique design of the Sandwich gasifier allows clinker-free operation on difficult feedstocks while producing a syngas low in tar. Our strategy for the production of GTL/RNG/H_2-ready syngas includes the use of off-the-shelf sorbents, solvents and technologies and their optimized combinations, thereby minimizing the required development time and improving the overall economics of the system. Understanding the unique characteristics of each feedstock allows tweaking of the gasifier operating conditions and optimization of the backend scrubbing system to obtain the required syngas purity at the lowest cost. The ability to reinject waste streams makes this a near-zero discharge gasifier, including low to negative carbon emissions. Figure 1 provides an overview of the integrated technology, which comprises a waste processing unit, the Sandwich Gasifier, a syngas processing unit and a renewable liquid synthesis system.

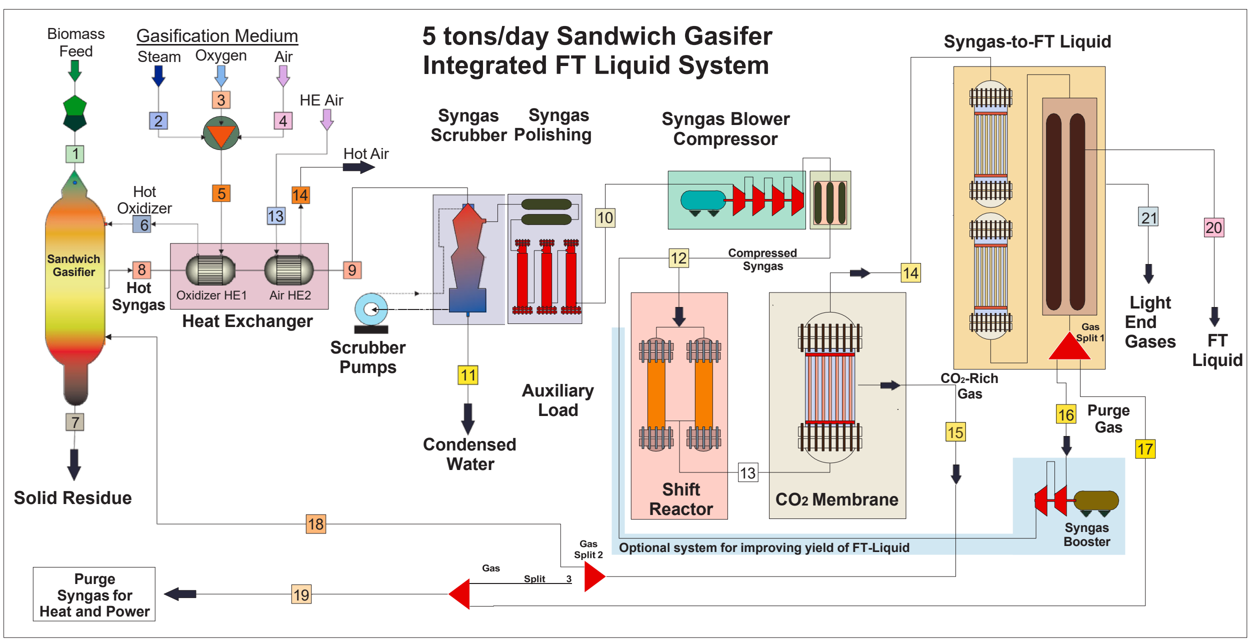

Figure 1: High-Level Process Flow Diagram the integrated Sandwich gasification system

Objectives:

The primary objective of this project is to demonstrate and prove the capabilities of the Sandwich Gasifier (SG) and integrated systems to produce clean and composition-balanced syngas under self-sustained steady-state operation by a clinker-free system producing GTL/RNG/H_2-ready quality syngas. We will validate the integrated technology to meet the stringent syngas purity and composition standards and demonstrate an improvement in techno-economics of producing low-cost GTL/RNG/H_2-ready syngas. Our team's major strength is our ability to integrate additional components into the gasification architecture at different scales to achieve high-quality liquid-based fuels and intermediates for lubricants and chemicals. Our target is the integration of technically and economically viable gas cleanup technology with the Sandwich gasifier to produce syngas suitable for commercial and near-commercial GTL/RNG/H_2 systems.

The scale-up and integrated operation will fast-track our plan to build future commercial-scale facilities. Our integrated setup will provide a marketable waste-to-fuels technology. The SG technology has been proven to produce clean syngas from challenging waste streams with net carbon dioxide equivalent emission reduction.

Methodology:

Overview: The key technical risk is integrating the Sandwich Gasifier (SG) with a GTL/RNG/H_2 system and associated subsystems. Specifically, our proposed project is designed to address the need for a narrow range of H_2/CO, with near zero concentrations of trace contaminants in syngas for achieving desired conversion, and ensuring high yields and adequate catalyst performance/longevity when using distributed low energy-dense and complex composition feedstocks. The gasifier design philosophy is based on the production of clean syngas with high fuel conversion efficiency while achieving near-zero-effluent discharge from the overall system. Clean syngas is produced by converting complex organics into energy-rich gaseous forms in the hot zones of the gasifier. The near-zero-effluent discharge is achieved by recycling the small fraction of unconverted organics in the syngas into the gasifier hot zones, to ensure production of favorable syngas compositions. One of the main features of the Sandwich gasifier is the unique gas–solid distribution afforded by the second oxidation zone that creates uniformly high-temperatures throughout the reaction chamber. This ensures a higher level of in situ tar and carbon conversion, thereby eliminating the need for secondary carbon/char converters, large syngas scrubbers, waste disposal systems, and extensive syngas processing. When operated according to specifications, downdraft gasifiers (including the first stage of the Sandwich gasifier) produce clean syngas with very low (on the order of 1 g/Nm^3) tar loading.[(1)] The production of low amounts of tar in the downdraft gasifier is due to the long residence time of high-molecular-weight devolatilized gases in a uniform high-temperature zone, which results in thermal conversion to simple short-chain hydrocarbons. SG's second oxidation zone enhances tar reduction and carbon conversion.

Several strategies are utilized to obtain the gas purity and the optimal H_2/CO ratio for liquid-to-gas production. Low temperature and pressure tar removal and acid gas removal is accomplished using conventional scrubbing technology. Tar recycling in the gasifier increases yields and reduces environmental harm from tar disposal. Effluent streams from wet scrubbing filtered through enhanced surface area char produced within the gasifier which are then recycled back into the gasifier, thus minimizing generation of solid as well as liquid waste. The trace impurities removal in packed beds of low temperature sorbent prior to syngas balance allows low pressure operation thus offering low capital cost and ease of operation. Conventional water-gas-shift catalysts further maximize overall yields and produce a syngas with a H_2/CO ratio in the range needed for GTL/RNG/H_2 production. The H_2/CO ratio is fine-tuned by incorporating a bypass and recycle loop in the system. Prior to the GTL/RNG/H_2 processing, CO_2 can be removed from the system via several different commercially available technologies including solvent-based and membrane-based approaches, both of which will be tested during this project. We also propose to recycle a portion of the CO_2 back into the gasifier to be used to help moderate gasifier temperatures

[1] Graham, R.G.; Bain, R. *Biomass Gasification: Hot-Gas Clean-Up*; International Energy Agency, Biomass Gasification Working Group, Dec 21, **1993**; 33–44.

while simultaneously serving to reform a portion of the CO_2 into CO, thereby increasing liquid fuel yields while reducing CO_2 emissions.

The variable compositions of the various waste materials to be tested during this project (and others which are of interest to our commercial clients), and in particular their effects on the Sandwich gasifier's ability to minimize tar and char formation represents a significant challenge. The SG has successfully converted mixed wastes containing plastic waste materials and modifications to the truck-mounted system incorporate design changes suggested from that earlier work. Captured tars are recycled into the gasifier to maintain the near-zero discharge attribute and additional tar removal equipment can be added if needed. Low-cost commercially available gas cleanup systems are available that can be readily integrated into the Sandwich gasification island for the production of GTL-ready syngas.

Innovation and Impacts: The Sandwich Gasifier has overcome two important barriers: cost (figure 2) and reliability (Appendix A). The Sandwich Gasifier design has high heat transfer, isothermicity, scalability, enhanced control over operating conditions, good gas-solid contact, and high specific capacity. The Sandwich Gasifier design is fully scalable, relying on single or multiple modules to accommodate both rural and urban requirements for converting feedstocks to heat, chemicals, and power. The scalable feature of the system allows sizing of the commercial Sandwich gasification technology such that it can be located at or near the feedstock source, enabling zero to near-zero feedstock transportation cost. The system is capable of converting waste on an "as-received" basis without requiring feed densification. The heat integration capability allows the system to tolerate moisture variation while minimizing or completely eliminating energy-intensive feed preparation.

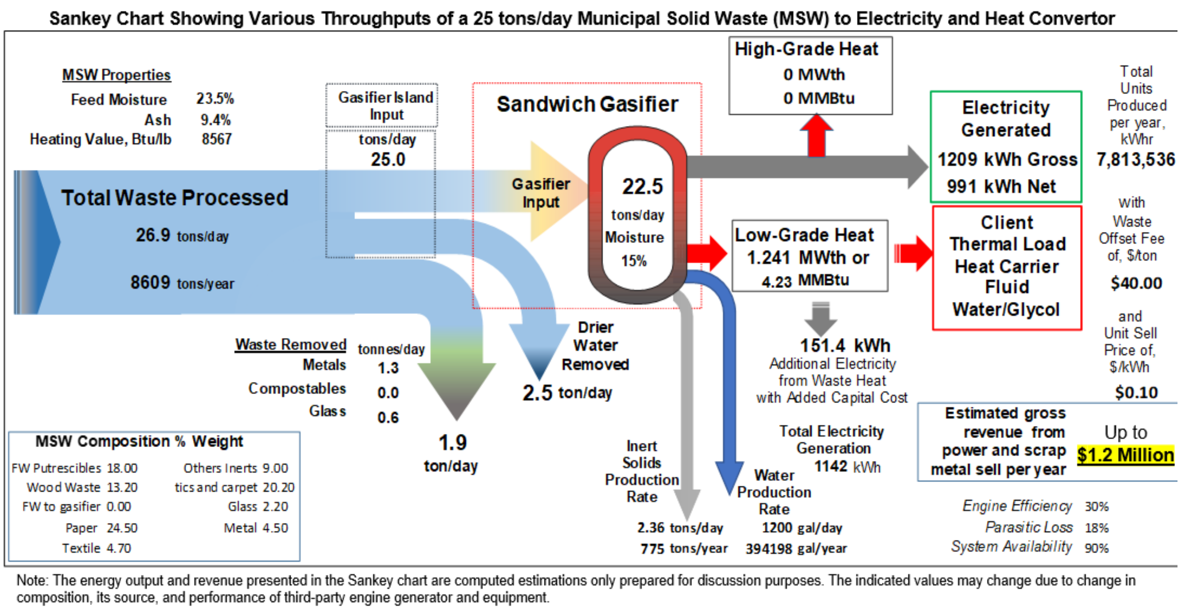

Figure 2. High level material and energy balance showing economic viability of SG technology.

This optimized gasifier significantly reduces the demands on the downstream cleanup system, thereby allowing for significant simplification of the required gas purification equipment. The tar condenser and wet scrubber are effective in removing soluble tars, alkalis, and gas-phase chlorine not captured in the inorganics associated with the ash. The staged low- and high-pressure sorbent removal as presented above operates at low temperature and take advantage of the abilities of newer water-gas-shift catalyst and CO_2 capture solvents in removal of trace contaminants providing synergies in syngas composition balance and cleaning. Stage two cleaning is also critical in capturing secondary release of sorbent-captured species and aerosols escaping the demister from upstream solvent scrubber. This approach supports cost reduction, ease of operation and GTL/RNG/H_2 catalyst protection goals.

Additionally, we propose to tailor the downstream equipment based upon the specific characteristics of each feedstock, thereby ensuring the necessary equipment is present to produce the desired quality syngas, but not including extra and un-necessary equipment (avoiding the one size fits all feedstock approach), thereby minimizing overall capital and operating costs. Based upon previous studies at the EERC and vendor assurances, we are confident that commercially available sorbents and solvents are available which allows rapid deployment of the integrated system. The high-quality syngas produced from the Sandwich gasifier can be upcycled using Fischer-Tropsch technology.

Anticipated Results:

The outcome of the proposed project will be an optimized and simple waste-to-fuels platform that provides economic GTL/RNG/H_2-ready syngas production from a variety of negative cost (tipping fee generating) wastes that pose significant environmental challenges. SET will work with team member organizations to streamline integration of the SG technology with available commercial or near-commercial subsystems that include:

- Syngas cleanup system to remove trace contaminants detrimental to catalysts such as tar and particulate matter, trace gaseous contaminants including species of sulfur (H_2S, COS and mercaptans), nitrogen (NH_3 and HCN), halogen (HCl), volatile alkali, Si (silane) arsenic and trace volatile organic compounds (VOC's).
  - Condensation of tars by gas cooling followed by wet scrubbing
  - Wet scrubbing for removing tars and soluble inorganic contaminants using conventional and non-conventional solvents that provide recycling options
  - Activated carbon, iron- and zinc-based polishing sorbents for removal of sulfur
  - Zocarbs sorbents to adsorb impurities including sulfur, nitrogen, and trace VOC
- Syngas composition balance by demonstration of integrated water-gas-shift reactor to optimize the H_2/CO ratio.
- CO_2 capture with recycle and H_2 separation technologies to optimize the H_2/CO ratio for increasing yield of fuel production.

Facilities:

The Sandwich gasifier was invented at the Energy and Environmental Research Center (EERC) in Grand Forks, ND by Dr. Nikhil Patel in 2006 (Dr. Patel is the President of SET). The technology's research and deployment efforts have gone through extensive peer review and has benefited from the EERC's long experience and expertise in gasifier development. The EERC Foundation transferred the technology to SET which is the sole owner and licensor of the technologies. Dakota Green Power, of which Dr. Patel is the CEO, is the licensee of the technology with rights to manufacture, commission, and sell these systems to clients. Figure 3 provides a history of the technology development and commercialization efforts for the Sandwich gasifier.

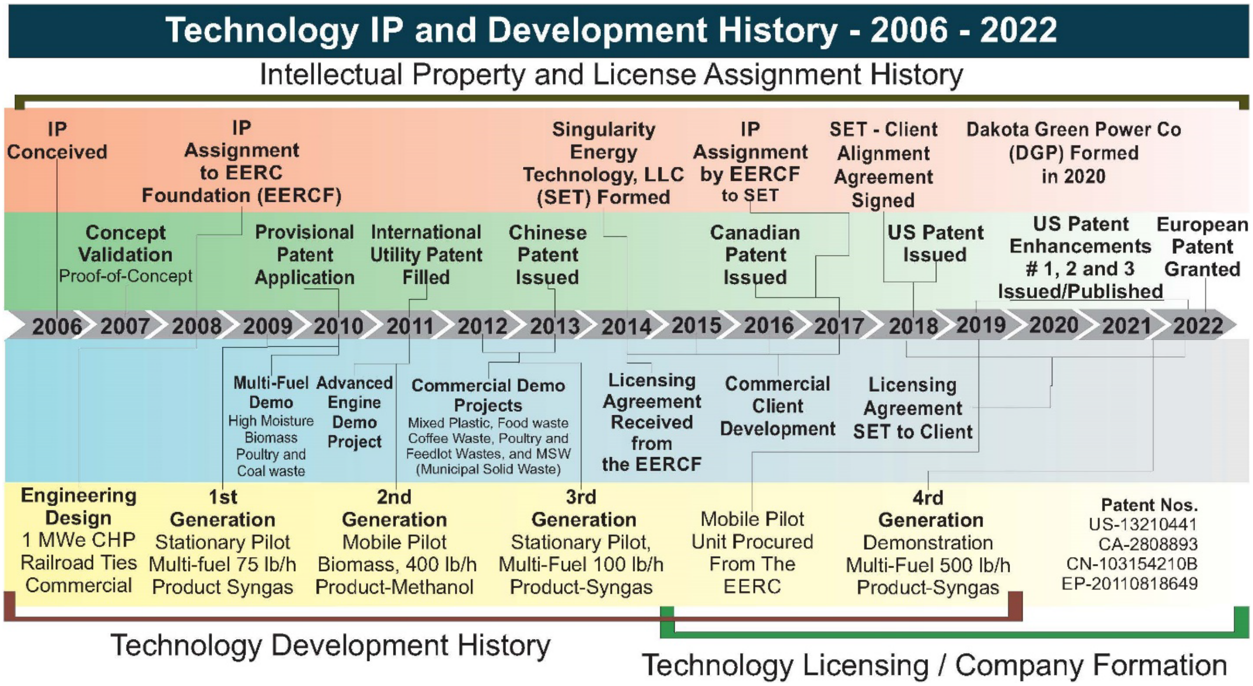

Figure 3. Technology and Intellectual Property Development for the Sandwich Gasifier

The Sandwich gasifier is at a technology readiness level (TRL) of 5. Development has progressed through several scales, including a 2 lb/hr laboratory system operated by the University of North Dakota Institute for Energy Studies (IES), a 70 lb/hr pilot-scale system operated by the EERC, and a 5 ton per day truck mounted system shown in Figure 4, originally built at the EERC and currently owned by Tri-Steel Manufacturing. Many tests, the longest of which was 5 days of continuous steady-state operation, have been performed on a variety of feedstock, including turkey litter, manure, railroad ties, and coffee roaster's waste, including plastic and food processing waste and wet wood on the 70 lb/hr bench-scale system. The 5 TPD truck mounted system has successfully processed railroad ties, shredded tree trimmings, and high-moisture wood waste and produced both electricity and methanol. Various gas cleanup strategies have been employed at these different scales. These tests have illustrated the benefits of the Sandwich gasification concept on challenging feedstocks and led to the enhancements necessary to further optimize the system performance and enable continuous steady-state operation over long periods of time (>10 days). Results from previous testing and justification of the proposed approach are discussed in Appendix A.

Figure 4. Five ton/day truck mounted Sandwich gasifier currently located at Tri-Steel Manufacturing.

Resources:

The current 5 ton/day truck mounted gasifier (see figure 3) owned by Tri-Steel Manufacturing will be relocated to the Grand Forks City Landfill. This system was originally conceived by Dr. Patel while he worked at the EERC. Funding for the original gasifier was provided primarily by the U.S. Department of Energy and Xcel Energy. The unit was mothballed in 2011 due to difficulties in developing sponsors to commercialize the technology. Patents for the technology were transferred to SET and its owner, Dr. Patel. Tri-Steel Manufacturing purchased the truck mounted system from the EERC and invested approximately $1,500,000 to refurbish and enhance the system to its current operating condition. The truck mounted system has been successfully operated on railroad ties, shredded tree trimmings, and high-moisture wood waste. Tri-Steel will provide access to the truck-mounted system to SET for this program and will perform necessary modifications. Steffes Manufacturing, a Grand Forks, North Dakota company can provide ASME stamped pressure vessels. In addition, the EERC has a pilot-scale system and the UND Engineering has a bench-scale system that can be used to support the development efforts if needed. SET/DGE has a three-year, rent-free lease from the City of Grand Forks to use the building that housed the former bailing facility for this and other projects focused on developing and commercializing the Sandwich Gasifier technology.

Techniques to Be Used, Their Availability and Capability:

This project aims to demonstrate the capabilities of the Sandwich Gasifier (SG) and integrated systems in producing uninterrupted, high-quality syngas suitable for gas-to-liquid (GTL) production. The project will integrate a cost-effective gas cleanup technology and assess the techno-economic improvements in producing low-cost GTL/RNG/H_2-ready syngas. By showcasing the potential of the SG system, this project seeks to advance efficient and economically viable GTL/RNG/H_2 production.

In this project, the SET Sandwich Gasifier will be integrated with existing or nearly commercial subsystems, including:

- Syngas cleanup system: Removes harmful contaminants like tar, particulate matter, sulfur species (H_2S, COS, mercaptans), nitrogen species (NH_3, HCN), halogen (HCl), volatile alkali, silane, arsenic, an d trace volatile organic compounds (VOCs). This is achieved through tar condensation by gas cooling, wet scrubbing using conventional and non-conventional solvents, activated carbon, iron- and zinc-based sorbents for sulfur removal, and Zeocarb sorbents for impurity adsorption.
- Syngas composition balance: Demonstrates the use of an integrated water-gas-shift reactor to optimize the ratio of H_2 to CO in the syngas.
- CO_2 capture with recycle and H_2 separation technologies: Utilizes methods to capture CO_2 and separate H_2, aiming to optimize the H_2/CO ratio for increased yield of liquid fuel production.

The following provided details of the five tasks proposed to meet the project objectives.

Task 1: Feedstock Selection and Analysis

MSW will be used as the primary feedstock based upon interest from SET's potential clients (see letters of support in Appendix). Other suitable feedstocks will be identified based on their availability and market demand for disposal and with input from the ND Department of Commerce and Xcel Energy. SET will procure the biomass feedstocks locally and/or from other localities with potential interest to serve as a site(s) for the commercial installation(s). Small representative samples will be subjected to fuel analysis such as proximate, ultimate, dynamic, and differential thermal analysis (TG/DTA) and inorganic analysis. Selected samples will be gasified using a laboratory gasifier. Ash composition analysis will include bulk species and trace metals in the feed material. Data will supplement a request for an extension to the current temporary environmental permit.

Milestone 1: Feedstocks procured and analyzed. Supplemental permit request filed.

Task 2: Syngas Composition Balance Equipment Design, Vendor Selection and Procurement

Task 2 focuses on designing, selecting vendors and procuring equipment that will enable us to achieve syngas composition balance to meet with third-party GTL/RNG vendor syngas specification. This involves selection of the Shift Reactor and catalyst for conversion for achieving targeted H_2/CO ratio in the syngas and a CO_2 Removal System. The sorbents and solvents are selected based upon results from work performed at the Energy and Environmental Research Center (EERC) in conjunction with DOE. The train tested included WGS and removal of sulfur, chlorine, and trace metals (including mercury). The technologies utilized are considered either commercial or near-commercial.[2] An example configuration tested included Johnson Matthey's KATALCO® K8-11 sour shift catalyst, fixed beds for sulfur capture (hydrogen sulfide and carbonyl sulfide) with a regenerable adsorbent (RVS-1, a regenerable zinc oxide-based adsorbent developed by DOE NETL and manufactured by RTI for Süd-Chemie (now Clariant)). High purity (95%+) CO_2 is obtained via the Selexol process using NETL-recommended solvents including ARG2[3].

Included in Task 2 is the procurement and testing of analytical equipment necessary for measuring the primary syngas components and trace concentrations of sulfur and nitrogen species. The procured analytical equipment will be integrated into the syngas production system, ensuring proper connectivity and functionality. Compatibility with existing control systems and data acquisition systems is considered to enable seamless integration and data exchange. The performance of the analytical equipment is evaluated through comprehensive testing and validation.

Upon completion of Task 2 we will have a well-designed and balanced syngas composition system, with the necessary equipment and safeguards in place. This will enable us to achieve our project goals of producing syngas with the desired composition of clean syngas. The efficacy of the process and sorbent will help determine cost effective option for production of syngas of desired composition.

Milestone 2: Syngas cleanup and compositional balancing equipment selected and procured. A HAZOP for system integration completed.

Task 3: 5 TPD System Modification and Commissioning

Task 3 will involve the modification and commissioning of the 5 TPD system at the Grand Forks City Landfill. Data from the feedstock analysis and estimated performance will be used in obtaining necessary permits and drive a thorough HAZOPS review to identify and address any potential hazards. The equipment identified and procured in Task 2 will be installed and commissioned. This includes ensuring proper installation, connectivity, and functionality of the equipment within the syngas production and cleanup system. A commissioning test will be conducted using the baseline feedstock to assess the system's functionality and identify any potential issues or areas for improvement. A set of preidentified sorbents will be utilized during the preliminary commissioning. The necessary preparations will be made for contaminant sampling, including system upgrades, commissioning, and testing. This will ensure accurate and reliable sampling of trace gas contaminants and will enable effective detection and analysis of contaminants in the syngas produced. This task will include optimizing the system for efficient on-site sampling and analysis of trace contaminants in a third-party lab. All prescribed quality control protocols will be adhered to during the sampling. By completing Task 3, the 5 TPD system will undergo necessary modifications and upgrades, ensuring its compatibility with the selected feedstocks and operability of the added syngas balance and cleanup equipment. Preliminary commissioning tests will help verify the

[2] Subtask 2.1 – Pathway to Low-Carbon Lignite Utilization, Topical Report for the Period September 15, 2015 through May 31, 2017. Cooperative Agreement Number DE-FE0024233. May 17, 2017

[3] Biomass Cofiring with Precombustion Carbon Capture Baseline Testing at UND EERC, Final Report. Dec 2021.

system's performance, and the sampling system will be optimized for accurate contaminant sampling. These efforts will contribute to the overall success and efficiency of the syngas production process.

Milestone 3: Syngas cleanup equipment fully integrated and operational on the 5 TPD system. System ready for clean syngas production.

Task 4: Clean Syngas Production with Composition Balance

In Task 4, gasification tests with syngas and measurement of scrubber water contaminants will be conducted in the 5 TPD system. Baseline testing will establish the initial performance and characteristics of the syngas produced. Contaminant sampling and analysis will be carried out to identify and quantify any trace contaminants present in the syngas. The scrubber water generated during the gasification process will undergo treatment using gasifier char or activated carbon to remove contaminants from the water and improve its quality before disposal or reuse, while reinjecting the spent sorbent into the gasifier. Baseline testing provides a comprehensive understanding of the syngas composition and contaminant levels will be obtained through baseline testing and analysis. Additionally, the treatment of scrubber water with gasifier char or activated carbon will help ensure the efficient management of water contaminants, contributing to environmental sustainability and process optimization.

Once the baseline testing is complete, clean syngas production with composition balance will be achieved using the selected feedstocks; Municipal Solid Waste (MSW) and/or a Municipal/Industrial Wood Waste mix; and potentially forestry wastes, poultry waste; and/or biosolids. Gasification tests will involve at least one 8-hour shift and continuous operation for 24 hours for each feedstock. Additionally, a 5-day continuous operation will be performed on a feedstock selected by the client to support commercialization goals. During the tests on the 5 TPD system, the syngas composition will be continuously monitored. This will include the implementation of appropriate sampling methodologies and colorimetric trace-gas detection techniques to ensure accurate measurement and analysis of the syngas composition. By completing Task 4, clean syngas production with composition balance will be achieved for various feedstocks. The gasification tests and continuous monitoring will provide valuable data on the syngas composition, enabling optimization of the process and supporting the commercialization objectives of the project.

Milestone 4: Baseline testing with selected feedstock completed and optimal configuration and operation of syngas equipment determined.

Milestone 5: Clean syngas produced from selected feedstocks for 8-, 24-, and 100- hours operation using the selected feedstocks.

Task 5: Final Report Preparation

In Task 5, the project team will undertake the preparation of the final report and the submission to the North Dakota Industrial Commission (NDIC) and Xcel Energy. The report will encompass the data collected, data analysis, and recommendations for future studies. Additionally, it will feature a technoeconomic of the feedstock-specific technology implementation at a selected location. By completing Task 5, the project team will provide a valuable resource for future studies, providing insights and guidance for further advancements in the field. Additionally, the submission of the final report will signify the successful conclusion of the project and the fulfillment of all obligations.

In addition to the final report, SET will submit quarterly progress reports to the NDIC and Xcel Energy for assessment. These reports will provide updates on the project's progress, outlining the milestones achieved, challenges encountered, and future plans. The progress reports will serve as a means to ensure alignment with the project goals and objectives. Through regular reporting, SET aims to maintain transparency and accountability in project execution and foster effective communication with both the NDIC and Xcel Energy regarding the project's advancement.

Milestone 6: Final report submitted to and accepted by DOE.

Environmental and Economic Impacts while Project is Underway:

We do not anticipate any significant environmental impacts while the project is underway. The Sandwich gasifier achieves near-zero effluent discharge by injecting the condensed tar and particulate matter (PM) along with a small fraction of water into the reactor hot bed such that the thermodynamics of the reactor temperature profile are not affected. The inert inorganic ash residue removed from the gasifier is the only disposable material generated from the system and will be disposed of at the City Landfill. The produced syngas will be oxidized via a thermal oxidizer or flare and/or used for heating or electricity generation while the project is underway. Solid, liquid, and gaseous effluents will be collected and analyzed before being disposed of in compliance with the environmental permits that will be obtained for this project as a standard procedure. The data generated will be used for reporting and other permit application purposes.

Approximately one hundred tons of biomass will be processed during the testing phase of the project. The volume reduction of the waste coupled with the "green" electricity and fuels produced represent a positive environmental impact of the project.

Ultimate Technological and Economic Impacts:

The technological impact of the Sandwich gasifier is vested in its ability to promote complete waste conversion to produce clean syngas. The robust operational flexibility of the technology means that it can drive down costs for valuable fuel production in rural and urban areas. The system has the potential for higher revenues due to its higher conversion efficiency and improved quality of syngas produced. The Sandwich gasifier's net production is ~850 kWh/ton compared to 500 – 617 kWh/ton for 4 different competing technologies, and 500 kWh/ton for existing combustion-based waste-to-energy plants when using municipal solid waste (MSW) as a comparison.[4]

The Sandwich Gasifier design has high heat transfer, isothermicity, scalability, good control over operating conditions, good gas-solid contact, and high specific capacity. The scalable feature of the system allows the sizing of the commercial Sandwich gasification technology such that it can be located at or near the feedstock source, thus requiring zero to near-zero transportation cost. This feature makes it ideal for remote locations that require low-cost biomass and plastic waste processing systems for valuable fuels production.

Once the technology's commercial operation is demonstrated, DGP is projecting they can manufacture and sell initially up to five systems per year resulting in annual net sales of $30,000,000 - 40,000,000 and development of up to 35-40 high paying jobs. Manufacturing will occur in Grand Forks, ND. Even during the initial growth phase it is anticipated that DGP will generate 24 jobs in its 4th year.

Why the Project is Needed:

[4] Ducharme, C.; "Technical and Economic Analysis of Plasma-Assisted Waste-to-Energy Process", Columbia University, 2010.

The Sandwich gasifier has the potential to provide consistent-quality biomass-derived air-blown and enriched-oxygen/air-blown syngas for liquid fuels production. However, technical risks remain because of a lack of experience for long-term continuous operation and the performance challenges associated with challenging feedstocks that possess elevated and variable moisture, ash, and inorganic content. Further, the strict purity requirements for downstream GTL/RNG/H_2 systems are economically difficult to meet at a small scale for most gasification systems. These risks prevent commercial investment. Potential clients are interested in seeing the operation of a fully integrated system before investing in the technology (see letters of support).

NDIC funding will allow this project team to make the necessary system modifications, achieve step-change improvements to system performance and cost-effectiveness, full integration of the gasifier with gas cleanup systems and demonstrate longer-duration operation. With these three accomplishments, the project team will have the information needed to secure commercial investment to take the next step of scale-up design and fabrication of a first-generation commercial Sandwich gasifier suitable for integration with GTL/RNG/H_2 conversion systems.

The funding provided by NDIC through this grant, coupled with funding that will be raised as cost share commitments will facilitate the market expansion of gasification technologies.

STANDARDS OF SUCCESS

The end of project goal is a technically and economically viable gas cleanup technology integrated with the Sandwich gasifier capable of producing syngas suitable for commercial and near-commercial GTL/RNG/H_2 systems. In accomplishing this goal, this project will produce a gasification system that is fully scalable, relying on single or multiple modules to accommodate both rural and urban requirements for converting feedstocks to heat, chemicals, and power. The sizing of the commercial Sandwich gasification technology is such that it can be located at or near the feedstock source, enabling zero to near-zero feedstock transportation cost. Further, the system will be capable of converting waste on an “as-received” basis without requiring feed densification or drying, minimizing, or completely eliminating energy-intensive feed preparation.

This project will assess the technical and economic viability of the Sandwich gasifier as a reliable and efficient method for converting diverse North Dakota biomass sources, such as municipal solid waste, agricultural and forestry waste, and manure, into high-quality syngas suitable for biofuel synthesis and production of bio-materials. The project seeks to generate tangible evidence, data, and insights that will inform decision-making processes regarding the adoption and implementation of the gasifier technology. Ultimately, the goal is to contribute to the development of a more sustainable and environmentally friendly energy sector by enabling the utilization of locally available biomass resources for clean and renewable biofuel and bio-material production. To meet this broader goal, the following individual goals will have been met.

1. Demonstrate the performance and efficiency of the Sandwich gasifier in converting North Dakota biomass feedstocks (municipal solid waste, agricultural and forestry waste, manure, etc.) into syngas of suitable quality for production of sustainable liquid fuels, renewable natural gas, or green hydrogen.

2. Optimize the operation of the Sandwich gasifier to maximize the conversion efficiency and overall performance.

3. Generate comprehensive data supporting an engineering feasibility study for implementing the gasifier technology.

4. Develop a technoeconomic cost model to assess the economic viability and potential commercialization of the gasification process.

5. Provide valuable insights and recommendations for improving the overall efficiency, cost-effectiveness, and sustainability of biomass-to-syngas conversion.

6. Contribute to the advancement of renewable energy technologies by showcasing the potential of the Sandwich gasifier in utilizing diverse biomass feedstocks for biofuel production.

7. Facilitate the transition towards a more sustainable energy sector by promoting the use of locally available biomass resources for clean and renewable fuel production.

BACKGROUND/QUALIFICIATIONS

The team members and their primary roles of the team are summarized in Table 1. Resumes of key personnel are included in Appendix B.

Table 1. Primary Roles of Project Participants

Team Member	**Role**
Singularity Energy Technologies LLC	Prime contractor and project lead. Owner of patents. License patent rights to DGP. Input into long-term potential projects.
Dakota Green Power (DGP)	Manufactures Sandwich gasifier systems in partnership with SET and Tri-Steel Manufacturing. Will provide engineering support.
Tri-Steel Manufacturing	Manufacturer of gasifier components through established relationship with DGP and SET. Will provide operations support and perform system modifications.
Sage Green N.R.G.	Provide support for permitting, marketing, and communications
MDM Energy Consulting	Provide support for project management, design, and reporting
Dr. Ed Olson	Develop and implement advanced analytical techniques

Singularity Energy Technologies, LLC (SET) – Dr. Nikhil Patel, founder and President of SET, is the inventor and patent holder for the technology. He will lead the project, serving as the Primary Investigator (PI) to direct the technical and scientific aspects, managing resources, scheduling, and budgets. He will be the point of contact between the EERE and other project participants/sponsors. He has over 25 years of research, development, and technology commercialization experience in waste-to-energy conversion using thermochemical processes involving combustion and partial oxidation or gasification of biomass, coal, and unconventional, difficult-to-burn liquid and solid, industrial, and municipal solid wastes. He spent 23 years working with the Energy and Environmental Research Center (EERC) where he focused on inventing and advancing gasification-based conversion technologies.

Tri-Steel Manufacturing – Mr. Scott Homstad is the Manager/Secretary Treasurer at Tri-Steel Manufacturing Co. Tri-Steel will provide manufacturing services for the required modifications to the system. Tri-Steel will rent the 5 TPD gasifier to the project as in-kind cost share to the project. The company, located in Grand Forks, ND was established in 1962 and serves the upper Midwest as a manufacturer and supplier of agriculture equipment. In an effort led by Mr. Homstad, Tri-Steel procured the current truck-mounted Sandwich gasifier from EERC and has invested into refurbishing and updating the previously mothballed system into a fully operational system.

Dakota Green Power (DGP) - Mr. Scott Homstad serves as the President of Dakota Green Power. Mr. Scott Homstad will assist the PI in the development of the commercialization strategy and identification of potential customers for the integrated biofuels production system. Mr. Homstad and Dr. Patel co-founded Dakota Green Power. Their goal is to serve as a manufacturer of 25, and 50 ton/day Sandwich Gasifier integrated waste-to-energy systems. They have established an engineering team who is responsible for preparing initial piping, instrumentation, and manufacturing drawings and will provide similar engineering support to the project.

Sage Green N.R.G., LLC – Dr. Nicholas Ralston, Director of Sage Green NRG, provides advice and support in business considerations, marketing, networking, and outreach presentations, publications, and communications. He will work performed to comply with environmental permits. Dr. Ralston will also use his expertise to help develop a long-term customer base and establish relationships with potential buyers of the Sandwich gasifier. Dr. Ralston has over 40 years of experience in applied research and has particular expertise in environmental aspects related to energy production.

MDM Energy Consulting LLC – Dr. Michael Mann, founder of MDM Energy Consulting, will provide assistance in design review, developing test plans, meeting project-reporting requirements, and will provide input into the development of commercialization plans and developing the end-user marketing material. He has extensive experience in management of large multi-organizational projects of similar scale and scope during his 40+ years' work in the energy field. While at the University of North Dakota, he served as the principal investigator on a three-phase $12 million project to extract rare earth elements and other critical materials from North Dakota lignite, including the design, construction, and operation of a 12 ton per day pilot plant located in Grand Forks. Previously while at the EERC, he was responsible for the design and installation of their 1-MW transport gasifier and associated hot-gas cleanup unit.

Dr. Edwin Olson – Dr. Edwin Olson, Consultant, will assist in developing comprehensive analytical techniques to measure performance of the gas cleanup modules. He will assist in training personnel in proper sampling techniques and with sample collection during testing. Dr. Olson, an organic chemist by training, spent 16 years in the academic arena before joining the EERC. While at the EERC, he has conducted extensive research programs in the development of novel methods for CO_2 capture and has developed and patented a novel levulinate biorefinery, an algae-to-fuels and chemicals biorefinery, a dual fermentation biorefinery, a biomass pyrolysis biorefinery, a method for preparing polyamines from biomass pyrolysis products.

MANAGEMENT

The team brings together the expertise required to advance our waste-to-fuels technology to commercialization. The project structure is designed to facilitate management of the project by task. Dr. Nikhil Patel, SET President and CEO for DGP will lead the project, serving to direct the technical and scientific aspects, managing resources, scheduling, and budgets, and will be the point of contact between the DOE Project Officer and other project participants/sponsors. SET/DGP will utilize current accounting personnel from Tri-Steel Manufacturing to assist in the cost management of the project, including tracking all costs for each of the project tasks.

Nicholas Ralston, Michael Mann, and Ed Olson have been working with SET, the technology licenser since its inception. For this project, Dr. Ralston will take the lead on maintaining permits. Michael Mann will use his many years of experience in developing and managing large research, development, and demonstration projects to help keep the proposed work on schedule and within budget. Dr. Mann will provide assistance in design review, developing test plans, meeting project reporting requirements. Dr. Olson will use his extensive experience in developing and applying complex analytical techniques to ensure accurate gas analysis around each unit operation.

Project meetings and conference calls with the core project management team will be held, at least, on a biweekly basis to conduct project activities, review project timelines, upcoming milestones/deliverables, costs, and challenges associated with the completion of the project tasks. Microsoft Project management tools will be utilized. Review meetings with sponsors (NDIC and Xcel Energy) will be held quarterly to ensure communication and discussion of accomplishments, plans and management of project risks. Intellectual property management and discussions have been initiated. During the course of the project, any new findings will be promptly documented and patent applications to protect the intellectual property filed as necessary. Discussions with potential commercial sponsors have been initiated regarding further development and scale-up of the technology and will be continued on a semi-annual basis as the project progresses.

A preliminary list of the perceived risks associated with completing the project is summarized in Table 2. Project risks will be continuously analyzed, and appropriate measures taken to address and mitigate said risks. A risk analysis will be included as an agenda item for the monthly project management team meetings and updated during the course of the project. Deviations and corrective actions will be discussed in quarterly reports.

Table 2. Perceived Risks and Mitigation Strategies

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability	Impact	Overall	
	(Low, Med, High)			
Cost/Schedule Risks:				
Plant construction costs exceed budget	Low	Med	Low	Vendor quotes have been obtained for major pieces of equipment. Installation costs based on previous experience. Used equipment can be purchased to help control costs.
Equipment delivery delayed	Low	Med	Med	Long lead times will be identified during design. Extra “flex” time built into schedule. Alternate vendors will be identified.
A crucial activity unexpectedly requires substantial additional funds	Low	Med	Low	Project and task managers will evaluate modifications to reduce cost and still meet project objectives. Additional funding will be sought if necessary. The City of Grand Forks, Grand Forks Regional Economic Development and the State of North Dakota offer programs to provide bridge funding.
Technical/Scope Risks:				
Integration of back-end processing equipment	Low	High	Med	Product gas specifications for various down-stream applications have been reviewed. Current design indicates good compatibility. The gasifier island can be tailored with additional gas cleanup, process recycling, and additional reactors/catalysts added to impact gas quality as needed.
Gas cleanup system not performing to vendor specifications	Med	High	Med	For lower cost sorbents/solvents, residence times will be increased and polishing steps added. If this is not effective, other more expensive (but still commercially available) materials will be tested, followed by the use of near-commercial materials.
Management, Planning, and Oversight Risks:				

Personnel availability	Low	High	Low	Explore options with EERC for a subcontract to supply operators and technicians. Utilize wide range of personnel expertise available at UND including students. Offer competitive internships to upper-level engineering students. Key personnel identified are committed and available at their specified labor hours.
Equipment availability	Low	High	Med	System design maximizes the use of off-the-shelf equipment. Work with engineering firms to identify preferred vendors. Identify long-lead items early in the design effort and initiate ordering. Coordinate manufacturing schedule with Tri-Steel Manufacturing to ensure their schedule can accommodate project needs.
Cost tracking	Low	High	Low	SET/DGP will utilize the accounting services of Tri-Steel Manufacturing's CPA to assist the project manager in tracking costs. Utilization of Project cost tracking system.
ES&H Risks:				
Organic emissions	Moderate	Low	Low	The temperature regime in the Sandwich gasifier is designed to minimize the formation of tars and other organic compounds. Recycle options are available to capture and reprocess organics in the gasifier (capture on activated carbon followed by gasification for example). Additional backend polishing systems will be added if needed.
Fugitive emissions related to feedstock storage	Low	Moderate	Moderate	Facility is located outside the city limits adjacent to the city landfill. Dust control measures such as water spray of storage piles used as needed. Feedstocks stored and fed from truck and or similarly designed feed bin. Train all personnel on the proper handling and use of feed equipment.

TIMETABLE

Table 3 presents an overview of the project schedule and major milestones.

Table 3. Project Schedule and Major Deliverables

	Task	Milestone	Milestone Description	Milestone Verification Process (What, How, Who, Where)	Duration / Months from Start of the Project
1	Feedstock Selection and Analysis	M1	Feedstocks procured and analyzed. Supplemental permit request filed.	Test results submitted to NDIC and summarized in quarterly progress reports	0 - 3
2	Syngas composition balance equipment design and procurement	M2	Syngas cleanup and compositional balancing equipment selected and procured. A HAZOP for system integration completed	Equipment procured and HAZOP of integrated system completed. Final design summarized in quarterly progress reports	0 - 12
3	5 TPD System Modification and Commissioning	M3	Syngas cleanup and composition balance equipment fully integrated on the 5 TPD system	Test results submitted to NDIC and summarized in quarterly progress reports	7 - 14
4	Clean Syngas Production with Composition Balance	M4	Baseline testing with selected feedstock completed and optimal configuration and operation of syngas equipment determined.	Test results submitted to NDIC and summarized in quarterly progress reports	14 - 16
		M5	Clean syngas produced from selected feedstocks for 8-, 24-, and 100- hours operation.	Test results submitted to NDIC and summarized in Final Report	17 - 22
5	Final Report Preparation and Submission	M6	Final report submitted to and accepted by NDIC.	Final report which includes updated economic models, and plant performance (inputs, outputs, yields, etc.) as defined in the deliverable requirements	22 - 24

BUDGET

Project Associated Expense	NDIC's Share	Applicant's Share (Cash)	Applicant's Share (In-Kind)	Xcel Energy Share
Personnel	$249,400	$189,000	$0	$86,250
Equipment	$157,000		$0	$63,000
Supplies	$46,250		$0	$20,500
Contractual	$30,250		$0	$19,750
Other Direct	$4,050		$108,000	$5,500
Total	$486,950	$189,000	$108,000	$195,000

Direct salaries are for a portion of Nikhil Patel, engineers' and the operations/technician salaries required to complete the proposed project. Fringe benefits are included in the personnel costs. The salaries shown as cost share will be contributed by Tri-Steel Manufacturing and SET.

Equipment will be purchased to clean the raw syngas from the gasifier to the purity and composition required to directly convert the syngas to bio-based fuels. This includes a shift reactor, CO_2 removal, solvent and sorbent gas cleanup systems. Analytical equipment to allow measurement and control of the syngas quality will be purchased through a $150,000 grant from the North Dakota Department of Agriculture Bioscience Innovation Grant Program (this $150,000 is not shown on the budget as it is not allowed as cost share towards this application).

Small parts, piping, electrical wiring, etc. is required to support the modifications and upgrades to the system. Supply dollars will be used to procure and ship the various feedstocks to be tested as a part of the program. These dollars are also required to replace the consumables used during proposed tests.

SET has a small work force and relies on consultants to provide expertise needed to support their project. These include Tri-Steel Manufacturing, MDM Energy Consulting LLC, and Sage Green NRG.

Oher direct costs provide analytical support required to obtain detailed characterization of all streams (solid, liquid, and gaseous). This information will be required by potential customers to evaluate our technology and apply for permits. An independent certified laboratory will be used for all critical analysis. Rental of the 5 ton/day gasifier from Tri-Steel Manufacturing is also included in the budget and shown as a part of the cost share. The DOE approved rental rate is $20,000/month. It is estimated that the gasifier would need to be committed to this project for approximately 30% of the time, and therefore the rent was prorated to $6,000/month (30% of $20,000)

No indirect costs are included in this budget.

The applicants share of budget includes salaries paid by Singularity Energy Technologies and Tri-Steel Manufacturing. Xcel Energy has included this project as a part of their Natural Gas Innovation Act (NGIA) filing at a value of $195,000. Final approval from the Commission is expected soon. As noted in the equipment section, SET has received an award for $150,000 from the Bioscience Innovation Grant program. These funds, in addition to the required $75,000 match will be used in support of this project as the goals of the two projects overlap. These dollars are not included in the budget shown above and are not counted as cost share towards this project. This budget also does not include the estimated value ($71,820/yr) of the lease agreement with the City of Grand Forks. When these costs are included in the budget, NDIC's share of the total project costs are 38%.

A detailed budget is presented in the appendix.

TAX LIABILITY

Singularity Energy Technologies does not have an outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

CONFIDENTIAL INFORMATION

No confidential information is presented in this application.

PATENTS/RIGHTS TO TECHNICAL DATA

The patented Sandwich gasification technology is owned by SET. The technology was invented at UND's Energy & Environmental Research Center (EERC) by Dr. Patel (founder of SET), and the IP rights were transferred to his company. DGP has permission to use the patented technology and associated technical/design information for the execution of the proposed project. In certain cases, our unique understanding that we would gain from our testing efforts will lead to new procedure design/operation for which we will file domestic and foreign patent applications as necessary. Finally, the performance data and experience we develop with increasing deployment of our technology will represent a competitive advantage and a barrier for new entrants. Patents in the SET portfolio include:

U.S. Patent No. 10,011,792. Date of Patent: July 3, 2018.U.S.

U.S. Patent No. 10,550,343 B2. Date of Patent: February 4, 2020.

U.S. Patent No. 11,220,641. Date of Patent: January 11, 2022.

U.S. Patent No. 11,702,604 B2. Date of Patent: July 18, 2023

Canada Patent No. 2808893. Date of Patent: June 5, 2018.

China Patent No. CN103154210, (issued 2015)

European Patent No. EP2606105, Published on 26th October 2022

European Patent Application, 22199757.0. Divisional from 11818649.3.

STATE PROGRAMS AND INCENTIVES

Title: Support for the Commercialization of the Sandwich Gasifier; 3/2020 – 6/2021; $237,000 (North Dakota Department of Commerce Research ND), $474,000 (Total Project).
Title: Biofuel and Biomaterial Production from North Dakota Biomass using the Sandwich Gasifier; 10/2023 – 6/2025; North Dakota Bioscience Innovation Grant, $150,000 with a $75,000 match.

Transmittal Letter

SET SINGULARITY ENERGY TECHNOLOGIES, LLC
WASTE TO ENERGY

Dr. Nikhil Patel
Founder and CEO

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

July 31, 2024

North Dakota Industrial Commission
Attention: Renewable Energy Program
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Subject: Singularity Energy Technologies proposal entitled "Accelerating the Waste-to-Fuels Commercialization for the Sandwich Gasifier"

Enclosed, please find an electronic copy of the subject proposal entitled " Accelerating the Waste-to-Fuels Commercialization for the Sandwich Gasifier", which is being submitted to the NDIC Renewable Energy Program.

This proposal seeks to test technology and devise improvements, enabling reliable gasification of renewable feedstocks to produce sustainable liquid fuels, renewable natural gas, and green hydrogen in a reduced carbon emissions context. The proposed work's main benefit is in developing a production technology that is modular giving it the ability to be located in rural or urban settings, close to the feedstock source. The Sandwich gasifier technology can provide flexibility to operations as it can accommodate various feedstocks without pre-blending, which is an important consideration when using biomass and waste materials with changing availability due to seasonal variations.

Successful completion of this project will greatly expand the understanding of how to utilize North Dakota's vast biomass resources, including municipal solid wastes, to produce sustainable liquid fuels, renewable natural gas, and green hydrogen. This will provide the State with options to reduce carbon emissions through renewable feedstock utilization.

If you have any questions, please contact me by telephone at (701) 739-8720 or by e-mail at npatel@singularET.com

Sincerely,

Nikhil Patel
CEO
Singularity Energy Technologies, LLC

Industrial Commission

Tax Liability Statement

Applicant:

Singularity Energy Technologies, LLC

Application Title:

Accelerating the Waste-to-Fuels Commercialization for the Sandwich Gasifier

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.

[signature]

Signature

Founder and CEO

Title

July 29, 2024

Date

Accelerating the Waste-to-Fuels Commercialization for the Sandwich Gasifier

Application to the NDIC Renewable Energy Program

Appendices

APPENDIX A

RATIONALE FOR PROPOSED APPROACH

RATIONALE FOR PROPOSED APPROACH

The following subsections first present details on the Sandwich gasifier itself, which is critical to fully meeting the goals of this proposal. Secondly, results from previous testing demonstrating the potential of the integrated system to meet the required specifications while still obtaining near-zero effluent/emissions will be presented.

Gasifier Island: Unlike typical gasifiers which can only maintain gasification temperatures in limited zones, the unique configuration of the Sandwich Gasifier enables it to process feedstocks of varying compositions and moistures while maintaining optimal temperatures for higher syngas qualities and quantities. The Sandwich configuration (see Figure A1) incorporates an endothermic reduction zone sandwiched between two high-temperature oxidation zones, thus maintaining uniform gasification temperatures throughout extended reaction zones. This enables complete gasification of the material, maximizing syngas production while preventing formation of tar residues.

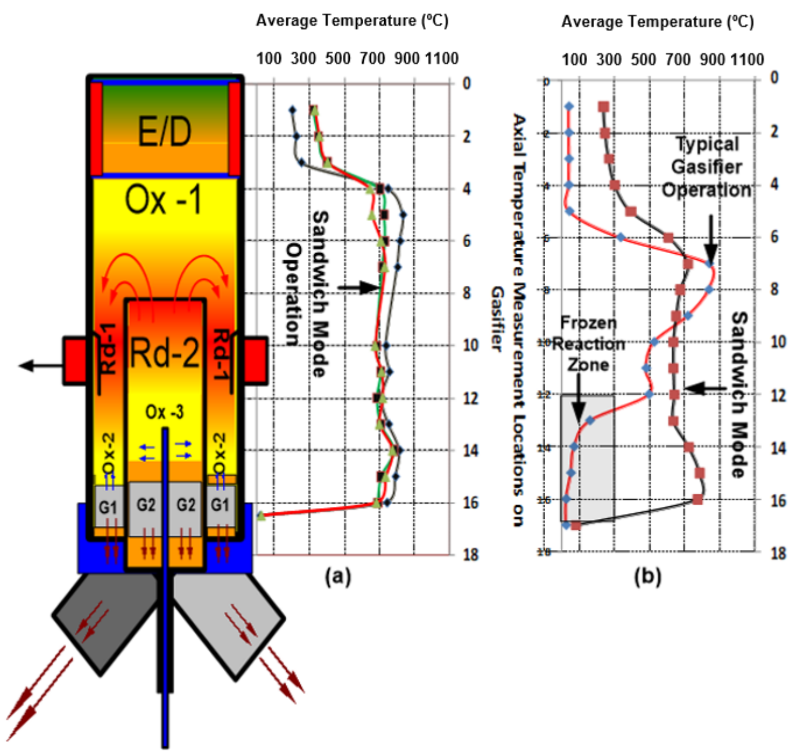

Figure A1. Schematic of the Sandwich Gasifier and its interior temperature profile showing oxidation (Ox) zones where limited combustion occurs and reduction (Rd) zones where syngas forms (gasification) and is extracted. The crucial aspect of the Sandwich Gasifier design is its ability to maintain uniform high temperature zones which increase syngas production efficiency, composition control, and diminishes production of tar and char materials. As seen in (a), this enables the Sandwich Gasifier to process multiple feedstocks with different compositions. As seen in (b) although processing identical fuels, a downdraft gasifier cannot maintain the temperatures required to produce clean syngas. This results in partial gasification and formation of excessive char and tar, degrading efficiency and increasing syngas production costs.
(US PTO 13210441)

The project team has tested a wide variety of fuels at a variety of scales, including the 2 lb/hr laboratory-scale system, the 70 lb/hr bench-scale system, and the 5 ton/day truck-mounted system, with moisture content of the feedstocks tested ranging from 5.6% to 47% and the volatile-to-fixed carbon ratios ranging from 0.26 to 7.9. This shows the ability of the Sandwich gasifier to accommodate feedstocks with a wide and variable range of properties. Figure A2 shows results from the nominal 14-hour tests, demonstrating the uniform temperature distribution in the gasifier and the quality of the syngas produced.

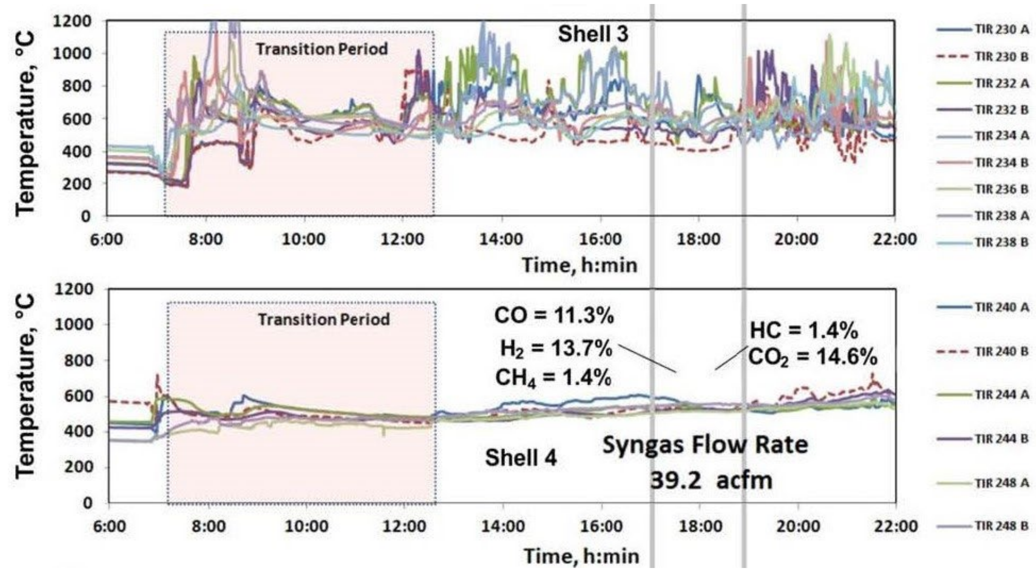

Figure A2. Temperature and syngas compositions for testing with high-moisture white spruce chips

Gas and Effluent Cleanup: To maintain distributed scale operation within the constraints of low capital and operating cost the gasification and the bulk of the syngas cleaning occurs at atmospheric pressure and low-temperature which allows use of conventional carbon-based sorbents. As stated previously, the Sandwich gasifier inherently produces a low-level of tar (<1 g/Nm^3), simplifying the steps required to meet tar specifications. The proposed wet scrubber removes the water-soluble tar species and a portion of the non-water solubles. Results from tar sampling performed during gasification testing of railroad ties show virtually no water-soluble tars with a total tar level in the effluent from the scrubber at approximately 0.2 g/m^3 (~25 ppmv). While this is low, additional tar removal will be necessary to meet the GTL/RNG/H_2 specifications. As discussed in the work scope, this will be accomplished via condensation in a syngas cooler. This cooler (heat exchanger) is designed to accommodate tar buildup on its surfaces. Tar removal will be accomplished via a solvent wash. Two heat exchangers in parallel allows taking one exchanger off line for "tar washing" without disrupting the operation of the system.

Final polishing of the syngas to meet the stringent guidelines for GTL/RNG/H_2 production occurs in two stages, **the first stage** uses a series of sorbent filled packed beds and or solvent columns at room temperature and at close to atmospheric pressure. Since a prior study revealed difficulty in capturing Hg in hot (>200 F) beds, the proposed strategy helps address some of the prior limitations in hot-syngas cleanup. The sorbents and any solvents used will be selected based upon the expected syngas impurities (determined for each feedstock via screening tests). The **second-stage** polishing will occur post syngas-shift and CO_2 scrubbing processes at GTL/RNG/H_2 system operating pressure, prior to syngas preheating. This will allow the system to be optimized choosing only those systems that necessary for the feedstock, but at the same time sufficient to meet the targeted gas composition. For example, arsenate is expected to be a concern for some but not all feedstocks. Likewise, PFAS may be a concern of biosolids and MSW, but not for other biomass feedstocks. Therefore, the recommended treatment system will be optimized for each feedstock to minimize overall cost while still obtaining the required overall removals.

As an example, work has been performed at the Energy and Environmental Research Center (EERC) in conjunction with DOE to develop methods to remove contaminants from syngas to levels suitable for a hydrogen separation membrane. The warm-gas cleanup train is capable of removing sulfur, particulate, chlorine, and trace metals including mercury at temperatures above 400°F. All of the technologies utilized are considered either commercial or near-commercial in development.[1] The warm-gas cleanup train tested at the EERC can provide WGS reactions and/or removal of sulfur, chlorine, and trace metals (including mercury) at temperatures above 204°C (400°F). The basic principle of the warm gas cleanup train is the utilization of solid catalysts and sorbents in fixed beds at elevated temperature to shift composition of the syngas and remove unwanted contaminants. An example configuration tested included Fixed Beds 1 and 2 loaded with Johnson Matthey's KATALCO® K8-11 sour shift catalyst to provide WGS reactions. Fixed Beds 3 and 4 were used for sulfur capture (hydrogen sulfide and carbonyl sulfide) with a regenerable adsorbent (RVS-1, a regenerable zinc oxide-based adsorbent developed by DOE NETL and manufactured by RTI for Süd-Chemie (now Clariant)). In prior testing, RVS-1 has been demonstrated to reduce sulfur to single-digit ppm levels in the syngas. Fixed Bed 5 is a sulfur polishing bed and was loaded with Clariant ActiSorb® S 2. The two-stage sulfur removal process has been demonstrated to produce H_2S levels below our detection limits of 10 ppb.

CO_2 removal is also an important and can be accomplished using a variety of technologies. We propose to evaluate two approaches, conventional CO_2 scrubbing using NETL recommended solvents such as ARG2[2] and newer membrane separation techniques such as the developed by Membrane Technology and Research LLC.[3] The CO_2 captured can be recycled back into the gasifier where it will be thermally reformed, serving to both increase the yield of liquid product from the GTL conversion and to reduce overall CO_2 emissions. This also has the advantage of better control of the temperature allowing the gasifier to operation at optimal temperature.

<u>Near-Zero Emissions</u>: An important goal of the system is near-zero emissions. Testing has determined the feasibility of organic removal from gasifier condensate water using adsorption on chars produced during gasification of biomass feedstock: two types of char produced in the Sandwich gasifier were investigated.[4] Isotherm data verify that the char produced in the Sandwich gasifier is an effective sorbent for phenolics and other organics in gasifier condensate water present at initially relatively high concentration with final effluent levels <3 mg/L. Other organics (cyclic ketones) are also adsorbed, except for some highly volatile components that may be stripped by air sparging. Further sorption kinetics data are needed to determine the size and optimal configuration of the sorbent beds. These studies are planned as part of the proposed effort.

Testing has also demonstrated that the direct injection of char and tars into the gasifier is a viable method to eliminate the need for secondary treatment and/or disposal of these materials. Reinjection of these materials as a part of the overall process eliminates the production of effluents that could potentially be classified as hazardous wastes, with a favorable result of increased hydrogen yield. The Stage 1 process of syngas production can, thus, attain near-zero effluent discharge, an important benefit of this technology.

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[1] Subtask 2.1 – Pathway to Low-Carbon Lignite Utilization, Topical Report for the Period September 15, 2015 through May 31, 2017. Cooperative Agreement Number DE-FE0024233. May 17, 2017

[2] Biomass Cofiring with Precombustion Carbon Capture Baseline Testing at UND EERC, Final Report. December 2021.

[3] Kniep, J.; Bench-Scale Development of a Transformative Membrane Process for Pre-Combustion CO2 Capture; Final Report for DE-FE0031623, July 27, 2022.

[4] Reference tar-water study

Appendix B – Resumes of Key Personnel

Nikhil Patel

Michael Mann

Nichalos Ralston

Ed Olson

SET SINGULARITY ENERGY TECHNOLOGIES, LLC
WASTE TO ENERGY

DR. NIKHIL PATEL
Founder & CEO

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

Principal Area of Expertise

Dr. Patel has 25 years of research and technology development experience in the combustion and gasification of biomass, coal, and unconventional, difficult-to-burn liquid and solid industrial and municipal solid wastes. Dr. Patel currently leads efforts to commercialize mobile truck-mounted and stationary waste conversion technologies. These technologies utilize the patented Sandwich™ gasification process he invented while working at the Energy & Environmental Research Center (EERC).

Dr. Patel joined EERC in 2002 and focused efforts on inventing, developing, and commercializing innovative gasification technologies for distributed energy and Fischer–Tropsch (FT) liquid fuel production. As a research manager and research scientist at the EERC, he led the design, construction, and project management team responsible for implementing gasification-based demonstration and commercialization projects.

Dr. Patel founded Singularity Energy Technologies, LLC, in 2014 to commercialize the Sandwich gasification technology. SET uses the Sandwich gasification technology it owns as a core technology for waste conversion to electricity and FT liquids and chemicals. In 2020 he co-founded and led as CEO of Dakota Green Power Co (DGP), an operating company for manufacturing and deploying SET's Sandwich Gasification technology.

Qualifications

Ph.D. (2001), Aerospace Engineering, Indian Institute of Science, Bangalore,
M.S. (1993) and B.E. (1991), Mechanical Engineering, University of Baroda, Baroda.

Professional Experience

2020–Present: Co-founder & CEO, Dakota Green Power Co (DGP)
2014–Present: Founder & CEO, Singularity Energy Technologies, LLC (SET)
2005–Present: Adjunct Professor, Institute of Energy Studies (IES), Department of Chemical Engineering, UND.
2015–Present: Research Engineer Lead, Distributed Energy Technologies, EERC, UND.
2012–2015: Research Manager, EERC, UND.
2002–2012: Research Scientist, EERC, UND.
2002: Visiting Researcher, EERC, UND.
2000–2002: CSIR Research Associate, Indian Institute of Science, Bangalore, India.
1994–2001: Research Scholar, Indian Institute of Science, Aerospace Engineering Department, Bangalore, India.
1993–1994: Lecturer, University of Baroda, Baroda, India.
1991–1992: Research Assistant, University of Baroda, Baroda, India.
1989: Engineer Trainee, Mukund (Iron and Steel) Ltd., Bombay, India.

Publications and Presentations

Has authored and/or coauthored more than 35 publications and holds four patents, including; IP07-013 – Sandwich Gasification Process for High-Efficiency Conversion of Carbonaceous Fuels to Clean Syngas with Zero Residual Carbon. U.S. Patent No. 10,011,792 (issued 2018), 10,550,343 (issued 2020), US 11,220,641 B2 (Issued 2021), US 17/570,448 (Filed 2021) Canada Patent No. 2808893 (issued 2018), China Patent No. CN103154210, (issued 2015), European Patent Application No. 11818649.3 (Grant fees paid February 2021)

mdm energy consulting, llc

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

MICHAEL D. MANN, Principal

Principal Areas of Interest and Expertise:

Dr. Michael Mann is the founder and Principal of MDM Energy Consulting LLC. His company was founded in 2015 to provide clients with design services, economic assessments and feasibility studies, formulation and execution of research and development projects, and project management support. He has been working in the energy field since 1981 where he has been involved in developing a wide range of technologies, including energy production from combustion and gasification, wind, and geothermal resources along with energy storage options. He has experience with the extraction of rare earth and other critical materials from coal, brines, and spent catalysts, and has explored options to add value biomass, lignite, and other low-grade carbonaceous materials. Much of his activity focuses on system integration and the development of energy strategies coupling thermodynamics with political, social, and economic factors. Dr. Mann has over 215 publications and has secured over $35 million in research funding during his career.

Qualifications:

Mayville State University	Chemistry, Mathematics	B.A., 1979
University of North Dakota	Chemical Engineering	M.S., 1981
University of North Dakota	Business Administration	M.B.A.,
University of North Dakota	Energy Engineering	Ph.D., 1997

Dr. Mann's ability to develop and manage large research projects while juggling a wide range of other activities was recognized when he was awarded UND's highest honor, the Chester Fritz Distinguished Professorship. He has been awarded UND's highest award for Excellence in Research and the UND Foundation Faculty Scholar Award, recognizing his combined excellence and contributions in teaching, research and service to the university. Dr. Mann helped develop major research centers at UND including SUNRISE, a faculty driven sustainable energy center and the Petroleum Research Education and Entrepreneurship Center of Excellence (PREEC). He was recognized for these efforts when he received UND's Interdisciplinary Collaborative Research Award. He was a primary player in the development of the Institute for Energy Studies.

Professional Experience

2015 – Present: Principal, MDM Energy Consulting, LLC:

Provide support in all phases of client's energy and chemical processing projects. Available to support design of pilot and demonstration systems, develop and implement experimental test plans, analyze data to optimize system design and operation, assist in writing proposals to funding agencies, performing techno-economic analysis and life-cycle analysis, and providing project management support. Technical areas of expertise include integration of energy systems, combustion and gasification technologies, geothermal energy, air pollution control, waste-to-energy systems, and chemical processes.

2009 - 2022: College of Engineering (Associate Dean 2013-14; Associate Dean for Research

2009-13; 2018-2022), University of North Dakota (UND):

Provided advice and support to the Dean in issues related research and development within the college and support academic affairs. Responsible for the implementing the college's major research goals, promoting a culture of research in the college, enhancing research opportunities for faculty and students, and providing administrative oversight for proposal submittal and grant accounting.

2014 –2021: Executive Director, Institute for Energy Studies:

Helped realize the Institute's goal of developing UND into a premier "Energy University" that "inspires the creation of new knowledge to enable the development of revolutionary energy technologies, train the next generation of energy experts, and establish advanced industries required to make affordable emissions free energy technologies a reality". Responsibilities included identifying key technical and economic barriers to the development of secure, affordable, and reliable energy production technologies; identifying proposal opportunities and develops new relationships with potential partners; and drawing from resources across campus building teams to deliver the research, education, and outreach required to meet the needs of public and private partners. Highlights include directing over $12 million in research in rare earth elements resulting in the design and construction of a 12 ton/day pilot processing facility and developing the IES into a go-to research support unit for emerging small businesses.

1999 – 2022: UND Department of Chemical Engineering (Professor, 2006-2022; Chair 2005-13; Associate Professor, 1999-2006):

Developed a reputation as an engaging teacher, excellent researcher, and inspirational leader. Awarded UND's highest honor, the Chester Fritz Distinguished Professorship in 2009 in recognition for his accomplishments in research, teaching, and service. Led the Department to UND's top departmental awards for Excellence in Research in 2005 and 2011 and Excellence in Teaching in 2007. Co-founder of the SUstainable eNergy Research, Infrastructure, and Supporting Education (SUNRISE) group in 2004. SUNRISE now has over 30 faculty participants from 12 different departments and 4 North Dakota Universities with over $20 million in research grants. Served as the primary research advisor for over 30 PhD students and 40 Master's students.

1981-99: UND Energy & Environmental Research Center (Sr. Research Mgr, Advanced Processes and Technologies 1994-99; Research Mgr, Combustion Systems 1985-94; Research Engineer 1981-85):

Activities evolved from hands on research to the development and marketing of ideas and technology. Involved in a wide range of technology development, including energy production from combustion and gasification, wind, and geothermal resources. Highlights include management of over $15 million in research projects; design, installation, and operation of a 1 MWth CFBC; design, installation, and operation of a 250 lb/hr gasifier; development of small power systems for Alaskan villages; and the development of a small-modular fluid-bed combustion system (0.5 to 5 MW)

Nicholas V.C. Ralston
Ph.D. Biomedical Research

Environmental Health Emphasis Area:
My team is working to deploy Smart Waste Converters which use the recently patented Sandwich Gasifier technology. Through a growing network of interested individuals, companies, and government agencies, we are promoting development of projects and proposals to support funding and investment in these crucial additions to commercial and community infrastructure.

Public Health Emphasis Area:
I also lead international efforts to update scientific understanding of the effects of maternal consumption of seafood on child health outcomes. This has grown to include consideration of a broader range of exposures which may affect public health.

Current and Former Positions:

2014-Present; Director, Sage Green NRG (See our website at https://www.sagegreennrg.com/)
Our work increasingly involves deployment of Smart Waste Converter Systems. These systems were patented by Dr. Nikhil Patel, Founder and Director of Singularity Energy Technologies (SET). His advanced approach to gasification minimizes problems which prevented previous technologies from profitably converting mixed wastes into electrical power and/or liquid fuels. His Sandwich gasification technology is the least expensive and most efficient option available to diminish pollution of the land, sea, and air. Sage Green NRG has contributed to major proposals in this area and we are developing regional, nation-wide and international relationships in preparation for deployment of these systems.

My group provides Nutrition Research Guidance as well as Natural Resource Guidance (the origin of the "NRG" in the name of our company). Our public health emphasis is on improving reliability of risk assessments by applying biochemical perspectives to more accurately predict the health effects of nutrients present in ocean fish. Increased maternal intakes of these nutrients are responsible for the ~7.7 point increases in the IQ's of their children. We were funded by the US EPA to develop a more reliably accurate seafood safery criterion which is known as the Health Benefit Value (HBV). Consumption of seafoods and fish with positive HBV's will improve maternal and fetal health while those with negative HBV's would be predicted to put it at risk. To continue our work on the EPA, NOAA, and seafood industry funded projects performed to establish the HBV criterion, we are advising the FAO and WHO organization as well as regulatory agencies of various nations on the importance of adopting this criteria.

2015-Present; Adjunct Faculty, Earth Systems Science & Policy, University of North Dakota
I continue to advise on nutrition in health assessments of risks vs. benefits of maternal fish consumption in studies that have been performed in the Seychelles, Hawaii, Saudi Arabia, Peru, and regularly provide invited keynotes at major meetings. I am developing a Toxicology Forum on selenium-mercury issues and recently authored an invited review, 3 book chapters, and am writing a book that contrasts the risks formerly believed to be associated with mercury exposures from eating certain varieties seafood vs. the notable beneficial effects that have instead been observed among children whose mothers eat ocean fish.

2013-2019; Faculty, Masters in Public Health Program, University of North Dakota
I developed the environmental health core curriculum for the MPH program and taught Environmental Health courses. I obtained funding for and led the "Sustainable Cities Initiative" for multidisciplinary studies involving UND students and faculty interacting with city, state, and federal agencies.

2012-Present; Faculty, Undergraduate Nutrition courses at Grand Forks Air Force Base
Along with other work, I provide nutrition courses to members of the military and their families at the Grand Forks Air Force Base. Many students from UND commonly choose attend these courses.

2005–2016; Health Effects Program Leader, EERC, University of North Dakota
I led research health/environment research groups, advised on mercury studies worldwide and served on EPA Science Advisory Boards as a Mercury Review Panel Member and coordinated/chaired a series of "International Symposia on Selenium-Mercury Interactions" conferences.

2002–2016; Biomedical Research Scientist, EERC, University of North Dakota
My training background in the molecular basis of disease enabled me to identify the biochemical causes and fully define the pathophysiology of mercury toxicity. This led to the "Health Benefit Value" (HBV) criterion which reliably indicates neonatal mercury exposure risks vs. nutritional benefits of maternal fish consumption.

1998–2002; GS-12 Biochemist, Grand Forks Human Nutrition Research Center, USDA
I led the methods development group that created research and laboratory protocols to examine boron and selenium biochemistry/physiology and developed novel methods to quantify molecular binding interactions and examine the significance of selenium in brain metabolism, inflammation, and neurodevelopment.

Education and Training:

1974-1978; Biology, Chemistry, & Earth Science, Mayville State University, Mayville, ND.
Graduated with a B.S. composite major in biology with dual minors in chemistry and earth science.

1989–1995; Fellow, Biomedical Research, Mayo Clinic Graduate School, Rochester MN.
I joined the molecular pathology program at the Mayo Medical Center (Rochester, MN) with rotations in hematology, coagulation, molecular biology, and laser fluorescence spectroscopy prior to my research in thoracic disease. I developed novel methods to quantify inflammatory mediators and characterize the molecular etiology and biochemical pathways which result in the pathogenesis of Byssinosis, an acquired pulmonary disorder.

1995–1998; Fellow, Bowman Gray Medical School, Wake Forest University, Winston-Salem NC.
I discovered the biosynthetic pathway of bis(monoacyl-glyerol) phosphate (BMP), a lysosomal phospholipid that avoids degradation due to its unique sn1:sn1' structure. My work provided stereospecifically tritiated substrates for laboratories around the world and identified the crucial reactions of the biosynthetic pathway that forms BMP.

Publications:
My work has resulted in 2 books, 12 book chapters, >12 documentaries, websites, or online interviews, >80 additional publications, (~40 in research journals, the rest as annual and final project reports for government agencies and other sponsors), >100 platform presentations (>50 were invited keynotes) and I have coordinated and chaired 14 international meetings on the updated understanding of the mercury issue. My group recently finished a book titled "Smart Waste Converters" which describes Sandwich gasifier applications in solving public and environmental health issues. This will be used as a marketing tool and provide background for commercial partner organizations as well as in training seminars to support development and commercial expansion efforts.

Achievements:
As Principal Investigator in public and environmental health studies, I performed >$5,000,000 in research for the US EPA, NOAA, DOE, and industry partners in projects that has dramatically changed how US and international regulatory agencies perceive mercury exposures from maternal seafood and freshwater fish consumption.

My group established a new paradigm for the biochemical mechanisms of toxicity of entire classes of toxic agents and created the Health Benefit Value (HBV) criterion which is the most reliable index of the risks associated with exposures to mercury vs. benefits of nutrient intakes from eating typical varieties of seafoods and freshwater fish.

I currently advise international and national health agencies and most recently gave an invited presentation for the Queen of Spain who has been appointed as FAO's special ambassador for Nutrition to the United Nations.

I provided the keynote presentation "Smart Waste Converters: The Sustainable Solution" for >2,000 attendees at the Karnataka Assocham GEM Chapter meeting: "Towards a Technological and Sustainable Built Environment."

DR. EDWIN S. OLSON
Consultant
223 Circle Hills Dr.
Grand Forks, North Dakota 58201
(701) 772-5403, eolson@gra.midco.net

Education B.A., Chemistry, magna cum laude, St. Olaf College, 1959.
Ph.D., Chemistry and Physics, California Institute of Technology, 1964.
Postdoctoral, University of California, Los Angeles, Laboratory of Nuclear Medicine and Radiation Biology.1964.

Professional Experience
2014 to present" Consultant on energy and environmental issues for ME2C (mercury emissions) and SET (gasification effluents).
2013: Part time work at EERC, UND, following retirement. Provided consultation and analytical services.
1994–2012: Senior Research Advisor, EERC, UND. Conducted extensive research programs in the following areas: 1) Developed new models for mercury-carbon-flue gas interactions and mercury sorption on carbon, resulting in a number of patented mercury control methods for power plant emissions. 2) Developed novel methods for carbon dioxide capture with magnesium and amine reagents4. 3) Developed and patented novel levulinate biorefinery, an algae-to-fuels and chemicals biorefinery, a dual fermentation biorefinery, a biomass pyrolysis biorefinery, a method for preparing polyamines from biomass pyrolysis products. In addition to these research activities, Dr. Olson served as in house consultant to engineers in gasification, pyrolysis, and liquefaction projects.
1988–2002: President, Universal Fuel Development Associates, Inc., Grand Forks, North Dakota. Dr. Olson served as Project Manager for Phase I and II Small Business Innovation Research (SBIR) projects involving water purification, nonaqueous enzymatic solubilization of coal materials, fuel oxygenate synthesis from agricultural materials, and fine-particle catalysts for coal liquefaction.. Also he was project manager for a large U.S. DOE contract involving geotechnical and analytical characterizations of many US power utility byproducts (ash and solid wastes).
1983–1994: Research Supervisor, Process Chemistry and Development, EERC, UND. Dr. Olson performed hydrotreating and catalyst research, coal liquefaction, and gasification research, and analytical methods development.
1980–1983: Research Chemist, Grand Forks Energy Technology Center, DOE, Grand Forks, North Dakota. Dr. Olson developed analytical methods for coal gasification and coal liquefaction products and byproducts in air, water, and fly ash by GC, MS, HPLC, and NMR.
1968–1980: Professor of Chemistry, South Dakota State University. Dr. Olson taught graduate and undergraduate courses in organic, biochemistry, and instrumental analysis. Research projects involved catalyst development, synthesis of antimicrobial heterocyclic compounds, amino acids, and fatty acids.
1977: Professor, University of Notre Dame, South Bend, Indiana. Summer faculty appointment.
1972–1976 summers: Visiting Staff Member, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Dr. Olson performed synthesis and biosynthesis of labeled amino acids and heterocyclics.
1964-1968: Assistant Professor, Idaho State University Department of Chemistry.

Synergistic Activities: Dr. Olson is past-chair of the American Chemical Society Division of Fuel Chemistry.

Publications: Dr. Olson has over 250 publications and papers and over 25 patents.

Appendix C – Letters of Commitment and Support

Public Works Department
724 North 47th Street
PO Box 5200
Grand Forks, ND 58206-5200

CITY OF GRAND FORKS NORTH DAKOTA

SHARON LIPSH
PUBLIC WORKS DIRECTOR
(701) 738-8740

April 15, 2024

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

RE: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

The City has entered into a three-year lease agreement with Dakota Green Power for Phase I, which encompasses a 5 ton/day pilot demonstration of your gasification technology, with the potential of a Phase II expansion to 25 ton/day unit. The City recognizes the potential benefits of your project, particularly in mitigating waste going into the city's landfill and fostering the development of new manufacturing ventures within Grand Forks.

The City Council has approved a three-year lease of space at the City of Grand Forks Landfill, utilizing the building that formerly housed our baling facility. The lease agreement grants you access to 10,260 sq. ft. of space, with a nominal annual lease value of $71,820, provided to you at a token lease rate of $1.00.

We are willing to supporting your project by supplying approved solid waste types for conversion upon request, contingent upon your acquisition of an approved Solid Waste Permit from the North Dakota Department of Environmental Quality. Notably, we recognize your interest in utilizing forestry/tree trimming/wood wastes, which are readily available at the City's inert landfill and will be furnished upon your request.

Furthermore, we are prepared to collaborate with you and Nodak Electric, the local electric cooperative serving the City Landfill, to facilitate the establishment of net-metering arrangements for the produced electricity back into the system.

The City of Grand Forks eagerly anticipates the commencement of your demonstration project.

Sincerely,

Sharon Lipsh
Public Works Director

Xcel Energy
RESPONSIBLE BY NATURE

July 29th, 2024

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

Subject: Xcel Energy Letter of Support for the Singularity Energy Technologies LLC (SET) proposal to North Dakota Renewable Energy Council

Dear Dr. Patel,

Thank you for sharing your intentions to submit a proposal for a 5 ton/day pilot-scale system to the North Dakota Renewable Energy Council. The work you are proposing aligns with the proposed R&D project within Xcel Energy's Natural Gas Innovation Act (NGIA) filing, which was filed in December 2023 and is currently going through Commission review and approval. Xcel Energy supports SET's proposal which will enable funding to further research technologies that may be able to help support the energy transition towards carbon free resources such as renewable natural gas, bio-methanol and hydrogen which are also of interest to Xcel Energy.

Xcel Energy is a clean and renewable energy leader and was the first utility to establish a goal to provide its customers with carbon-free electricity by 2050 and Net-Zero emissions in the natural gas local distribution company ("LDC") by 2050. For the reviewers of your proposal, Xcel Energy through the NGIA funding plans to support SET's gasification technology advancements. This R&D project will assess the technical and economic viability of the Sandwich gasifier as a reliable and efficient method for converting Minnesota's diverse biomass resources into high-quality syngas suitable for production of renewable natural gas or hydrogen as well as useful biomaterials such as biochar. Xcel Energy supports the North Dakota Renewable Energy Council funding to help advance SET's technology as having the potential to help Xcel Energy lead the clean energy transition and meet the company's long-term carbon free 2050 goals.

We wish you luck with your submission to the Renewable Energy Council and are looking forward to working with you on the first phase of our NGIA project after commission review and approval.

Sincerely,

Kathryn Valdez
AVP, Corporate Planning & Carbon Free Technology
Xcel Energy

Tristeel Manufacturing Company
3001 N Washington St
Grand Forks, ND 58208
1-800-279-2689
www.tristeelmfg.com

July 29, 2024

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 ND Renewable Energy Program

Dear Dr. Patel,

I am happy to provide support for your proposed project to Singularity Energy Technologies' proposal to North Dakota's Renewable Energy Program. As one of Grand Forks' major farm equipment manufacturers and the owner of the 5-ton/day truck-mounted system, we can assist in all aspects of your project. We will provide labor to help complete your proposed project goals. Based upon your input, we will provide approximately $115,000 in labor towards your project as a mix of engineers, technicians, and operators to best meet the needs of your project. Tri-Steel Manufacturing is committing this amount as an in-kind cost share towards the NDIC cost-share requirements. We will also provide full rent-free access to the 5 TPD truck-mounted system as an in kind cost share equivalent to $108,000.

Sincerely,

Scott Homstad

Tristeel Manufacturing Co.

April 4, 2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

The Grand Forks Region Economic Development Corporation (Grand Forks Region EDC) would like to express its strong interest and support for your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating your Smart Gasifier technology. The Grand Forks Region EDC's mission is to expand economic opportunity through industry growth and diversification. Energy and environment is one of our key targeted sectors when prioritizing business development, along with the programmatic opportunities defined by our partners at the University of North Dakota. In result, our organization actively explores state and local opportunities that can be resourceful for the improvement of waste disposal concerns while simultaneously creating economic opportunities for the community. We are aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated pilot-scale system in operation producing electricity and liquid fuels would provide confidence from key state and local stakeholders to invest in this fascinating technology you have demonstrated with us through your company.

We hope you are successful in obtaining funding for this important demonstration and look forward to continuing to work with you as you fully commercialize your exciting technology.

Sincerely,

Kevin S Hatcher

Kevin Hatcher
Business Development Manager
Grand Forks Region Economic Development Corporation

HydroCarb1

04/14/2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

HydroCarb1would like to express its strong interest in and support for your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating your Smart gasification technology. As you know from our discussions, HydroCarb1 is exploring opportunities that can deal with plastic waste disposal concerns in our area while simultaneously creating economic opportunities for the community. As we discussed, we are considering a facility to process 25-75 tons/day of plastic waste to produce electricity and fuels. The facility would be located in the St Cloud, MN area and operated by HydroCarb1. We are also aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated pilot-scale system in operation producing electricity and liquid fuels would provide us with the confidence needed to invest in your technology.

We hope you are successful in obtaining funding for this important demonstration and look forward to continuing to work with you as you fully commercialize your exciting technology.

Sincerely,

Jeff Grunenwald
CEO HydroCarb1
612-224-1004

ALAKAHI GLOBAL

Date April 3, 2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

Alakahi Globlal Inc would like to express our strong interest in and support for your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating the ability of Smart gasification technology to produce methanol and hydrogen from a wide range of waste materials and biomass. As you know from our discussions, *Alakahi Global Inc* is exploring opportunities to deal with waste disposal concerns in our area while simultaneously creating economic opportunities and reducing greenhouse gas emissions. As we discussed, we are considering a facility to process *25* tons/day of *disposable waste* to produce *electricity* and talking with additional parties located in Maui Hawaii, Oahu Hawaii, and Africa that are interested in Smart gasification as a solution to their waste and energy issues. The first facility we are interested in developing would be located in *Kahalui, Maui* and operated by *Alakahi Global Inc.* We are also aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated commercial-scale system producing electricity and liquid fuels from various forms of biomass and waste materials would certainly enhance the confidence of future investors in your technology.

We hope you are successful in obtaining funding for this important demonstration project and look forward to continuing to work with you and your exciting technology.

Sincerely,

Dr. Nate Makaiwi
President and CEO of Alakahi Global Inc.
Las Vegas, NV
drnate@civilityglobal.com

Dr. Stacen Makaiwi
Vice President and COO of Alakahi Global Inc.
Las Vegas, NV
drstacen@civilityglobal.com

CITY OF
Belle
Fourche
SOUTH DAKOTA

April 8, 2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

The City of Belle Fourche would like to express its strong interest in and support for your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating your Smart gasification technology. As you know from our discussions, The City of Belle Fourche is exploring opportunities that can deal with waste disposal concerns in our area while simultaneously creating economic opportunities for the community. As we discussed, we are considering a facility to process 125 tons/day of sorted municipal solid waste to produce heat, electricity, and sustainable methanol. The facility would be located in Belle Fourche, South Dakota and operated by the City. We are also aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated pilot-scale system in operation producing electricity and liquid fuels would provide us with the confidence needed to invest in your technology.

We hope you are successful in obtaining funding for this important demonstration and look forward to continuing to work with you as you fully commercialize your exciting technology.

Sincerely

Ryan Reeves
Landfill Superintendent
SWANA Certified MOLO
City of Belle Fourche

03 April 2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

Envira Smart Energy would like to express our strong interest in and support for your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating the ability of Smart gasification technology to produce methanol and hydrogen from a wide range of waste materials and biomass.

As you know from our discussions, Envira Smart Energy is exploring opportunities to deal with waste disposal concerns in our area while simultaneously creating economic opportunities and reducing greenhouse gas emissions. As we discussed, we are considering a facility to process 50 tons/day of Municipal Solid Waste to produce Electricity/Methanol. Meanwhile we are talking with parties located in New Mexico and Antigua and Barbuda that are interested in Smart gasification as a solution to their waste and energy issues. The first facility we are interested in developing would be in The City of Rio Communities, NM.

We are also aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated commercial-scale system producing electricity and liquid fuels from various forms of biomass and waste materials would certainly enhance the confidence of future investors in your technology.

We hope you are successful in obtaining funding for this important demonstration project and look forward to continuing to work with you and your exciting technology.

Sincerely,

Hafiz Hassan
Co-founder
ENVIRA SMART ENERGY
Hafiz@EnviraSmart.com
www.EnviraSmart.com

THE CITY OF
Fargo
FAR MORE

Division of Solid Waste

2301 8th Avenue North
Fargo, North Dakota 58102
Phone: 701-241-1449
Fax: 701-241-8109

April 5, 2024

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

Subject: Letter of Support for the Singularity Energy Technologies proposal to the U.S. Department of Energy DE-FOA-0003082

Dear Dr. Patel,

The City of Fargo, North Dakota Solid Waste Department would like to express its strong interest and support in your proposal to the U.S. Department of Energy to build a 25 ton/day pilot facility demonstrating your Smart gasification technology. As you know from our previous discussions, The City is exploring opportunities that can assist with waste disposal concerns in our area while simultaneously creating economic opportunities for the community. As we discussed, we are considering a facility to process 700 tons/day of sorted municipal solid waste to produce a beneficial byproduct such as process heat, electricity, or other sustainable fuels. The facility would be located in Fargo, North Dakota and operated by the City. We are also aware of the potential tax credits that may be generated using your technology. The ability to see a fully integrated pilot-scale system in operation producing electricity and liquid fuels would assist in building the confidence needed to potentially invest in your technology.

We hope you are successful in obtaining funding for this important demonstration and look forward to continuing to work with you as you fully commercialize your exciting technology.

Sincerely

Scott Olson, PE
Solid Waste Utility Director
City of Fargo

POLK COUNTY

Solid Waste Facilities

Incinerator
708 8th Street NW
PO Box 179
Fosston, Minnesota 56542
(218) 435-6501 Telephone
(218) 435-6619 Fax
ESA: jon.steiner@co.polk.mn.us
Facility Mgr: ron.larson@co.polk.mn.us

Landfill
Located: Gentilly, Minnesota
PO Box 179
Fosston, Minnesota 56542
(218) 281-5419
Accountant: julie.mathison@co.polk.mn.us
Secretary: debbie.kappedal@co.polk.mn.us

April 4, 2024

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

Subject:: Singularity Energy Technologies
DoE Proposal - DE-FOA-0003082
Letter of Support

Dear Dr. Patel,

The Polk County (MN) Resource Recovery Facility (Polk RRF) located in Fosston, MN strongly supports your proposal to the U.S. Department of Energy (DoE) to build a 25 ton/day pilot facility demonstrating your Smart gasification technology. As you may be aware, the MN legislature – and various activist groups – are currently attempting to force the pre-mature closure of the Hennepin Energy Recovery Center (HERC) in Minneapolis, MN. The HERC is the largest MSW waste-to-energy (WTE) facility in MN. This development has all WTE facilities in the state, including Polk RRF, closely monitoring the outcome of that initiative and any ramifications to other WTE's. As a result, all WTE's are evaluating possible alternatives should that effort expand.

Polk RRF currently utilizes an advanced Material Recovery Facility (MRF) which processes both MSW and Single Stream Recyclables from the region. The MRF processes the MSW to provide a clean fuel for the WTE portion of the Plant. Polk RRF has had numerous conversations with you regarding the MRF and its potential impact upon your system. The continued evaluation of both a MRF on your system and demonstration of your system's potential to be incorporated into a system such as Polk RRF's provides benefits to both interests. As a result, we have a keen interest in furthering that evaluation process.

Polk RRF hopes that your effort to attain the DoE support will be realized as it would be of benefit to Polk and other MN-based WTE's in determining if a system such as yours would be a viable alternative to our current integrated waste management systems. Please keep us informed as your project moves forward.

Sincerely

Jon D. Steiner
Env. Svs. Admin.
Polk County, MN

John Deere Intelligent Solutions Group
4101 19th Avenue North
Fargo, ND 58102

Brij N. Singh, Ph.D., IEEE Fellow
John Deere Technical Fellow - Power Electronics Engineeirng
John Deere Region 4 Manager External Relationships
SinghBrijN@JohnDeere.com

June 15, 2023

Dr. Nikhil Patel
President, Singularity Energy Technologies, LLC
Suite 201, 4200 James Ray Dr, Grand Forks, ND 58202

RE: Letter of Interest - Integration of John Deere Technology with Sandwich Gasifier for Biofuel and Biomaterial Production in North Dakota's Farming Community

Dear Dr. Patel,
We sincerely appreciate your introduction of Dakota Green Power and Singularity Energy Technologies, LLC's Sandwich gasification technology. After carefully reviewing your technology and considering its potential application to our customer base in the agriculture sector, we recognize the strong synergy between your gasification technology and our mission. Specifically, we acknowledge its capability to effectively process a wide range of agricultural waste, including manure, and harvesting residues. Moreover, the generation of gaseous and liquid fuels from these waste streams, which can be used to fuel generator sets, aligns with end-use requirements for equipment manufactured by the John Deere. Additionally, your technology offers an attractive pathway for our customers to reduce their carbon footprint, granting us a significant marketing advantage over existing commonly used alternatives.

John Deere would like to express keen interest in the commercial implementation of Sandwich Gasification technology. We fully support your application to the Bioscience Innovation Grant Program (BIG) administered by the North Dakota Department of Agriculture, as this project will facilitate client demonstrations of the technology. Establishing a demonstration facility in Grand Forks would provide us with an ideal platform to develop and test our engine technology using fuels derived from actual waste products at a commercial scale. As part of the project team in capacity of advisory role, which amounts to in-kind support with no cost and resource commitments, we intend to provide engineering know-how for assessment of quality of the biofuels and their suitability for internal combustion engines. Our expertise can guide the process optimization of your system, maximizing the benefits in terms of output fuel quality. Subject to budgetary constraints and resource availability, we may consider donating an engine to the project for direct integration with your system. Furthermore, we envision utilizing your facility as a host site for future research endeavors.

Please do not hesitate to contact me at 701-552-8516 or SinghBrijN@JohnDeere.com if you have any questions or require further information. We look forward to continuing our support to your project.

Yours sincerely,

Brij N. Singh, Ph.D., IEEE Fellow
John Deere Technical Fellow - Power Electronics Engineeirng
Region 4 Manager External Relationships

October 1, 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 ND Renewable Energy Program

Dear Dr. Patel,

I am happy to provide support for your proposed project to Singularity Energy Technologies' proposal to North Dakota's Renewable Energy Program. I will use my connections and expertise to procure the required biomass for the proposed work, provide support in developing analytical protocols, analyzing data and report writing, and in using my connections to help develop long-term relationships with customers and identifying potential buyers of your technology.

I am committing 100 hours of my time at a fee of $150 per hour ($15,000 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,

Nicholas Ralston
Director, Sage Green NRG

mdm energy consulting, llc

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

October 1, 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 ND Renewable Energy Program

Dear Dr. Patel,

I am happy to provide support for your proposed project to Singularity Energy Technologies' proposal to North Dakota's Renewable Energy Program. 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 input into your final design, providing oversight for the construction of your system, and developing and executing your testing campaign.

I am committing 133 hours of me time at a fee of $150 per hour ($20,000 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

Michael D. Mann

Michael D. Mann
Principal
MDM Energy Consulting LLC

Dr. Edwin S. Olson
Principal Scientific Advisor

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

October 1, 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 ND Renewable Energy Program

Dear Dr. Patel,

I am happy to provide support for your proposed project to Singularity Energy Technologies' proposal to North Dakota's Renewable Energy Program. 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 133 hours of my time at a fee of $150 per hour ($20,000 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

Edwin Olson

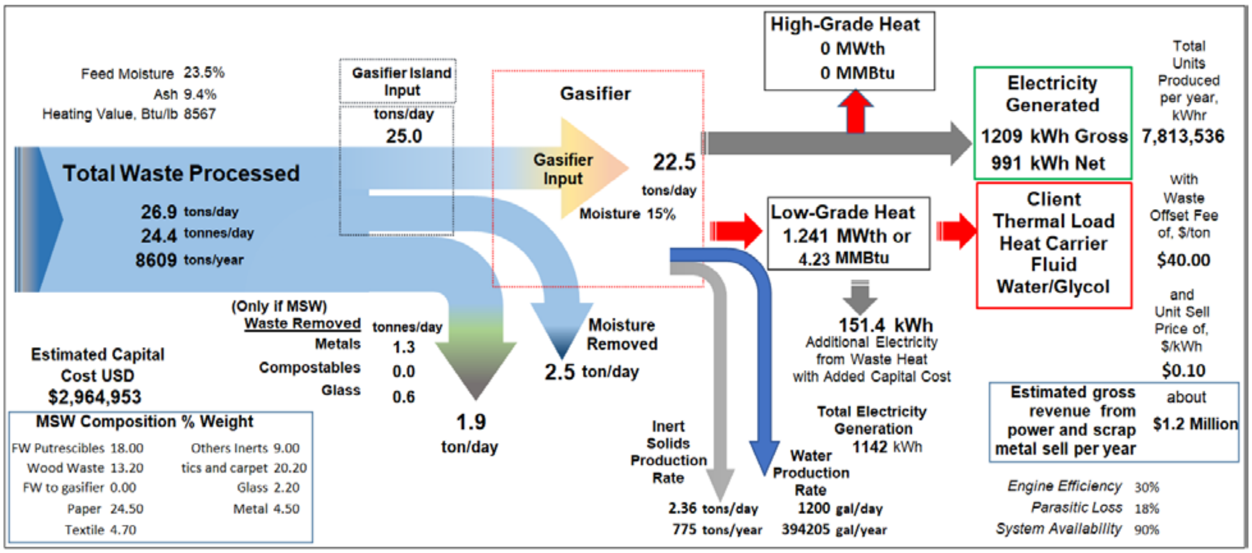
Edwin S. Olson
Principal Scientific Advisor
Singularity Energy Technologies, LLC

Appendix – Projected Economic Performance of Sandwich Gasification Technology on Various Feedstocks: Customer Acceptance

SET and DGP have developed a set of models to estimate the economic performance of the Sandwich Gasifier for various fuels and end-use applications. The model allows projections to be made based upon the characteristics of the fuel and economic factors including tipping fees, electricity and fuel prices, and other major cost/revenue streams. The examples are provided here to show that the Sandwich gasifier has good economic potential and hence the ability to generate a client base.

The Sankey Chart below is an example prepared for an interested client.

Sankey Chart Showing Various Throughputs of a 25 tons/day MSW to Electricity and Heat Convertor

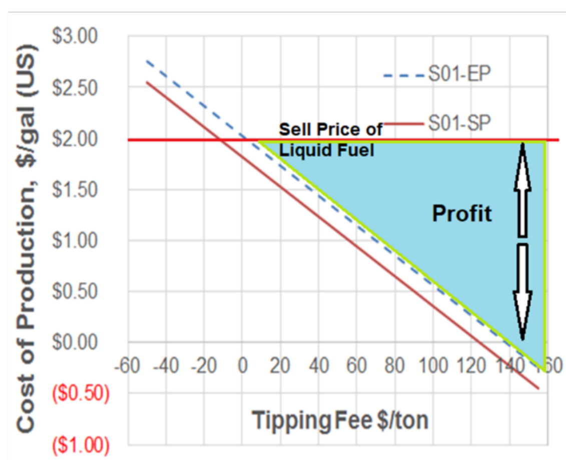


SET also shows clients the potential areas of profit based upon the primary variables of interest. In the example below, the profitable region for production of crude diesel fuel versus tipping fee, and including the benefit of generating electricity on-site is shown.

Capital Cost and Revenue Generation Opportunity

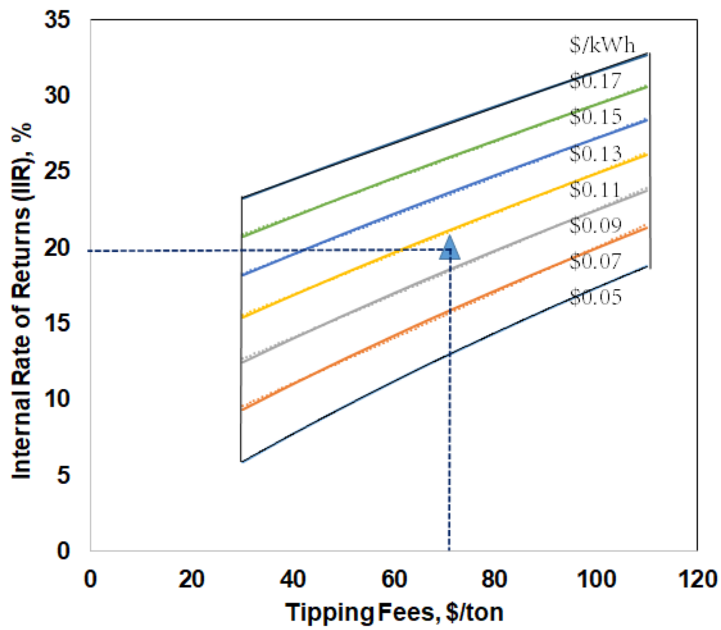
Stationary System 20 tons/day MSW-to-Crude Diesel Fuel
(an example for discussion purposes only)

SET Technology Model	S01-EP	S01-SP
	Electricity Purchased	Self-Sustained Operation
System Capital Cost, $	$3,194,165	$3,549,519
Direct Operating, $/year	$413,016	$277,971
Cost of Debt		
Interest Rate for Borrowing Capital	6.50%	6.50%
Debt Loading (10 yr), $/year	$444,323	$493,755
Revenue from Tipping Fees		
Tipping Fee Rate ($/ton)	35	35
Tipping Fee Revenue , $/year	$217,175	$217,175
Production, gal/year		
Crude Diesel Production	424,422	424,422
Production Cost, $		
Zero Debt	$0.97	$0.65
Gallon Debt-Loaded (first 10yr)	$2.02	$1.82
Debt Loaded With Tipping Fee	$1.51	$1.31



SET SINGULARITY ENERGY TECHNOLOGIES, LLC
WASTE TO ENERGY

SET also provides an indication of the potential return on investment for its clients. As an example, the plot below shows a positive internal return on investment even at tipping fees as low as $20/ton at an electricity selling price of $0.05/kWh. This particular customer was receiving a $70/ton tipping fee with an electricity selling price of $0.10/kWh, showing a potential IRR of 20%.



The table below shows potential gross revenues for a variety of different feedstocks of interest to potential clients.

Feedstock Type	MSW # 2	MSW # 1	RR Ties #3	RR Ties #2	Turkey Litter # 1
Gasifier Island Input tons/day	25.0	25.0	25.0	25.0	25.0
Total Waste Processed, tons/day	29.5	26.9	25.0	25.0	25.0
Feed Composition and Energy Content					
Feed Moisture	34%	23%	17%	32%	33%
Ash	6%	9%	2%	2%	17%
Heating Value, Btu/lb	8171	8567	7786	6790	4114
Pre-Gasification Product Removed					
Metals, tons/day	1.1	1.3	0.0	0.0	0.0
Glass, tons/day	3.4	0.6	0.0	0.0	0.0
Post-Gasification Inert Solids and Water Production					
Inert Solids, tons/day	1.45	2.36	0.46	0.44	4.32
Water Production Rate, gal/day	1069	1200	1458	1186	887
Energy Production					
Gross Electricity, kWh	1153	1209	1098	958	580
Net Electricity, kWh	945	991	901	786	476
Low Grade Heat, MMBtu	4.04	4.23	3.85	3.36	2.03
Estimated Annual Gross Revenue from Sell of Electricity and Byproducts					
$/annum	$ 1,188,322	$ 1,196,282	$ 1,038,633	$ 947,792	$ 845,800
Earning Rate: Electricity = $ 0.1/kWh, Tipping Fees= $40/ton, Metal = $150/ton, Fertilizer = $100/ton					

Also of importance is the quality of the liquid that can be produced from the syngas. The table below presents a fuel specification for a fuel generated from syngas using the technology provided by BGTL, Inc. Based upon the syngas compositions generated from testing on the EERC pilot-scale system and on testing performed at Tri-Steel on the 5-ton/day system we expect a fuel of similar quality will be produced.

Sample ID	FISCHER TROPSH REACTOR
Sample Type	Fuel
Report Date	2/6/2018

U.S. OilChek®
Fuel Oil Report

US Lubricants

179946-0001

Labcode	Sample Date	Receipt Date	Oil Type	Vis @ 40 / 100C	Degrees F: VI	Degrees F: Cloud	Percent: Water	Percent: Sulfur	Particulate	Microbe	Color	API	Distillation Data Degrees F: IBP	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	EP	BTU/gal
					Flash	Pour	Solids	Ash	Halogens	Stability	AF	Lb/gal														Cetane
				2.4		-12						35.4														
2048315	1/30/2018	2/5/2018			135							7.059	267	364	397	433	459	479	499	518	539	565	598	627	646	46.0

Sample Date	Wear Metals (ppm): Iron	Aluminum	Chrome	Copper	Lead	Tin	Cadmium	Silver	Nickel	Titanium	Contaminant Metals (ppm): Silicon	Sodium	Boron	Potassium	Additive Metals (ppm): Barium	Calcium	Magnesium	Molybdenum	Phosphorus	Zinc
1/30/2018																				

Comment:

Specific Gravity 0.8478
Copper Corrosion 1a
Fuel tested within expected ranges for parameters analyzed.

Report To:

ZHIJUN JIA
COMPREX LLC
1740 EISENHOWER DR
DE PERE, WI 54115

Results may now be viewed electronically on our website
www.usoilchek.com
Or sent via email

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U.S. OilChek
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Kimberly, Wi. 54136
Phone 920-831-8839 / 800-490-4903 Fax 920-788-0102

Appendix E – Example Life Cycle Assessment

The Singularity Energy Technology (SET) Sandwich Gasification Process for Manure-to-Energy Conversion:

A Comparative Understanding of CO2e Equivalent Emissions

One of the main features of the Sandwich gasifier is the gas-solid distribution that creates a larger and more uniform high-temperature zone in the gasifier (see Figure 1). This feature ensures a higher level of in situ tar and carbon conversion, thereby eliminating the need for secondary carbon/char converters, large syngas scrubbers and waste disposal systems, and extensive syngas processing. When used to process waste materials into energy, the Sandwich gasifier provides a substantial CO_{2e} reduction/credit as compared to competing technologies. This report provides data showing net CO_{2e} emissions of negative (-) 768 kg CO_2 per ton of manure gasified. Analysis of other potential feedstocks shows net CO_{2e} emission reductions in a similar range.

1. A typical Sandwich configuration consists of at least one **endothermic reduction zone** sandwiched between two high-temperature **oxidation zones.**
2. The reduction zone in the gasifier produces and extracts the syngas. This is an endothermic reaction zone requiring heat transfer from the higher-temperature zones of the gasifier.
3. The patented configuration ensures near-complete waste conversion and augments reduction zone temperature to promote clean syngas production with high efficiency.

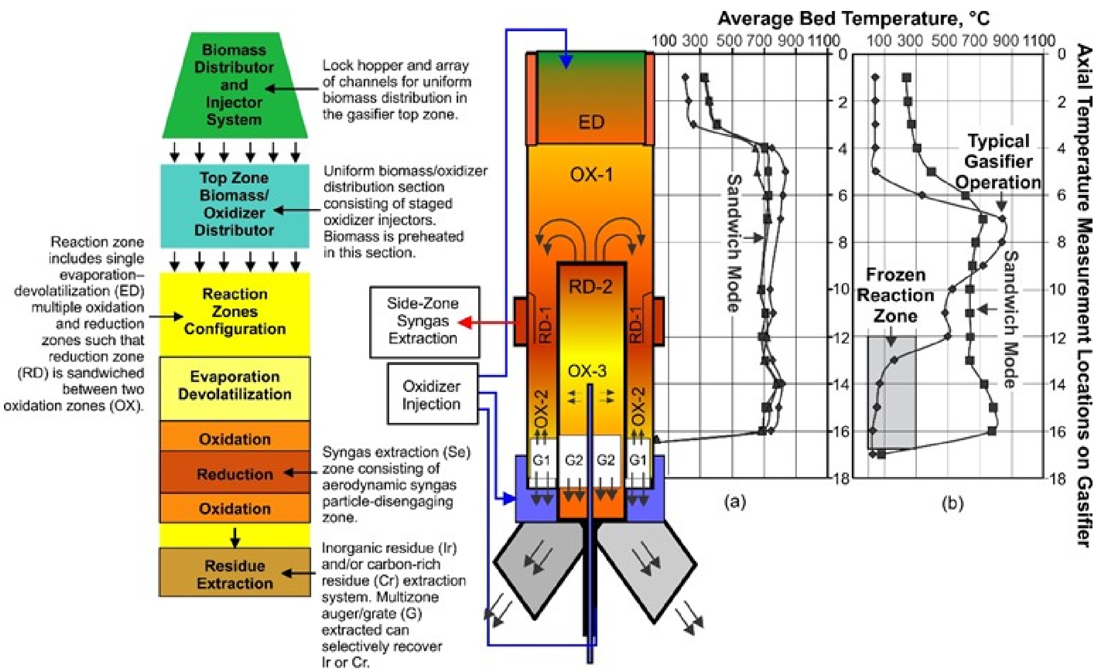

Figure 1. Sandwich gasifier, showing oxidation and reduction zones and the advantage of a uniform axial temperature profile versus the low-conversion "frozen reaction zone" present in typical downdraft gasifiers (oxidation is shown as OX and reduction as RD).

Innovation and Impacts

Current State of the Art – Gasification Processes

For processing residues such as wet manure, competitors of the Sandwich gasifier take two forms: biological methods, such as composting facilities and waste digesters that currently use manure to generate methane as a direct-use fuel or for electricity generation, and thermal methods, such as gasifiers that convert manure to a synthesis gas fuel.[1] Composting facilities and digesters are commercially available and familiar; however, each has significant challenges. Digesters are biological systems that can be negatively impacted by environmental conditions such as cold weather. Additionally, they achieve relatively poor conversion efficiencies compared to gasification, and the waste biosolids generated from digesters add to their overall cost and life cycle impacts.[2] Composting and land application are simple processes, but face limitations to their widespread use due to excessive nutrient runoff and negative impacts on water quality. In the Mid-Atlantic region, such water quality issues have resulted in prohibiting land application of animal waste. Gasifiers represent an emerging technology for power generation from manure that—when compared to biological methods—more quickly treat waste; are more compact; reduce odors, biological oxygen demand, remove pharmaceutical compounds; and eliminate sludge.[3] Several companies claim to market gasifiers that process manure for energy production, such as Ecoremedy® for heat and steam generation[4]; Mavitec Green Energy, which advertises a gasifier to produce steam, electricity, hot water, or hot air but appears to currently demonstrate only heating and drying applications[5]; and BGP International, which also claims heat, steam, or electricity generation but does not disclose any commercial application on its website.[6] As explained earlier, the advanced-design Sandwich gasifier confers performance advantages in manure-to-power applications when compared with other gasifier designs.

A schematic of the Sandwich gasifier and two variations of typical downdraft gasifiers depicting the location of reaction zones with respect to the fuel feed (from the top) and syngas discharge (from the bottom) are illustrated in Figure 2. These gasifiers—Imbert, stratified downdraft gasifier, and Sandwich gasifier – are differentiated based on the distinct temperature profiles achieved as a result of their respective design and operating features. In all three, the pyrolysis zone is located upstream of the oxidation zone, and the reduction zone is located downstream of the oxidation zone. The devolatilized products leaving the pyrolysis zone pass through a high-temperature zone

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1 eXtension. Treatment Technologies for Livestock and Poultry Manure, 2015. http://articles.extension.org/pages/8855/treatment-technologies-for-livestock-and-poultry-manure (accessed June 2018).

2 Gonzaga, J.A.; Biona, J.B.M.M. Application of Energy Return on Investment (EROI) Analysis to Biogas Production. Presented at the DLSU Research Congress, De La Salle University, Manila, Philippines, Mar. 6–8, 2014.

3 Cantrell, K.; Ro, K.; Mahajan, D.; Anjom, M.; Hunt, P.G. Role of Thermochemical Conversion in Livestock Waste-to-Energy Treatments: Obstacles and Opportunities. *Ind. Eng. Chem. Res*. **2007**, *46*, 8918–8927.

4 Ecoremedy, LLC. Agricultural Waste to Energy, Biochar, and Nutrients, 2017. http://ecoremedyllc.com/agricultural-waste-to-energy-biochar-and-nutrients/ (accessed June 2018).

5 Mavitec Green Energy. Gasification. www.mavitecgreenenergy.com/gasifications/ (accessed June 2018).

6 BGP International. About BGP International. www.bgpint.com/about.1/ (accessed June 2018).

formed by the partial oxidation of devolatilized products and char. The products of combustion and unconverted devolatilized hydrocarbons leaving the oxidation zone react with unconverted char in the reduction zone located downstream of the oxidation zone.

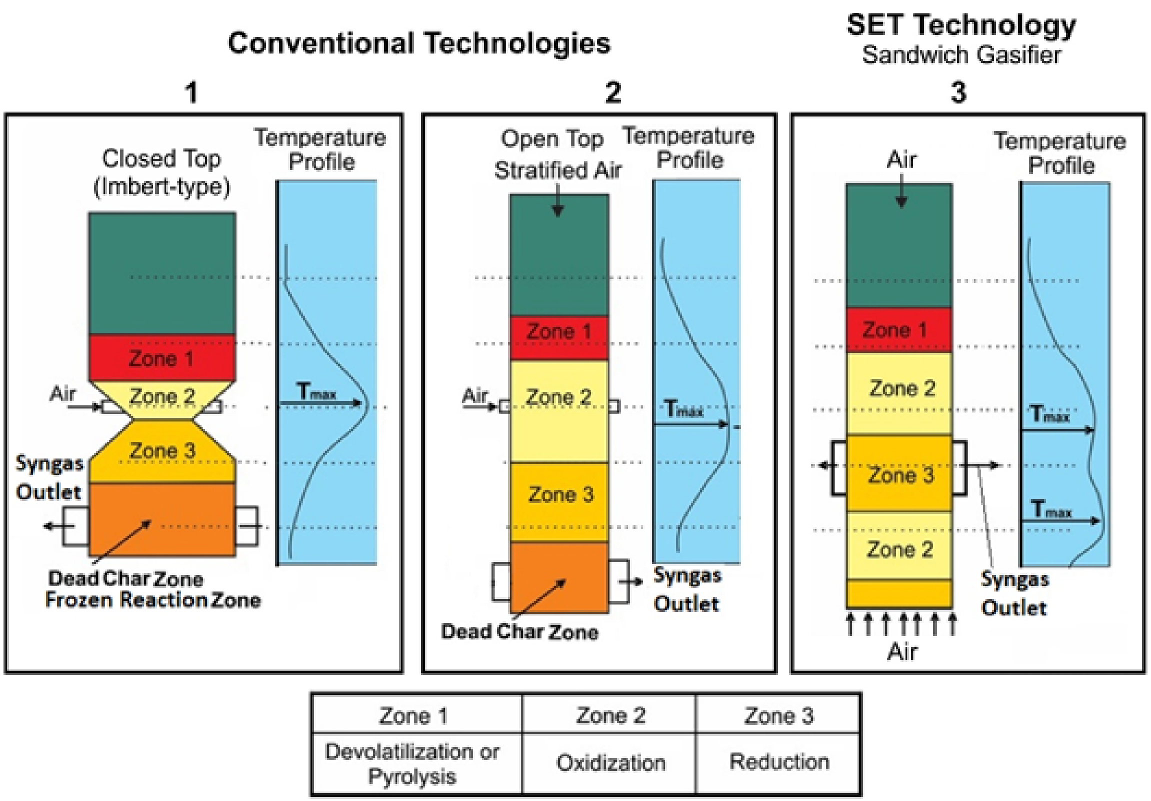

Figure 2. Schematic of downdraft gasifier: 1) Imbert-type, 2) classical stratified, and 3) Sandwich gasifier.

The Imbert downdraft gasifier (Figure 2) has a characteristic constriction near the oxidation zone which limits particle size and fuel ash content. High-ash feedstock, such as railroad ties, tested by the EERC in a commercially purchased downdraft gasifier of this type, failed in operation due to clinker formation near the constriction[7]. This constriction provides the oxidation zone stability and prevents movement. This is a World War II-era technology that was commonly used for powering automobiles during that time. It was therefore designed to utilize quality dry wood, which was affordable at the time. The stratified downdraft has no constriction; however, zone stability is established by maintaining specific oxidizer (air) and fuel throughput. The single oxidation zone achieves a narrow peak temperature, resulting in smaller but similar challenges with high-ash feedstock as was demonstrated in the Imbert-type gasifier.

Competitive Advantage of Sandwich Gasifier

As shown in Figure 2, the conventional downdraft gasifiers are unable to maintain adequate heat transfer to the reduction zone, particularly if the moisture content of the feedstock increases. This causes the temperatures in conventional systems to diminish and waste conversion ceases. In contrast, the reduction zone temperature in the Sandwich gasifier is maintained by heat transfer from the additional oxidation zone located after the reduction zone and before the residue extraction zone. This configuration promotes complete waste conversion, produces clean syngas with an improved composition, and tolerates variations in moisture and energy content of the waste feedstocks, including nonreactive or poorly-reactive feedstocks that can be problematic in conventional gasifiers.

Air, oxygen-enriched air, pure oxygen, or steam mixed with air or oxygen are potential oxidizers that can be used in all downdraft gasifiers to achieve self-sustained gasification. However, if the exothermic heat profile is not achieved because of insufficient exothermic oxidation, possibly due to high moisture or a high fraction of inert material in the fuel, the reduction zone temperature can drop, reducing the carbon conversion rate and adversely impacting syngas composition and flow rate. The additional oxidation zone in the Sandwich gasifier depicted in Figure 5, and the direct heat transfer from both the top and bottom of the reduction zone augments the reduction zone temperature, thus improving syngas composition, flow rate, carbon conversion, and overall efficiency of the gasifier.

In a Sandwich gasifier, as shown in Figure 2, with solids moving from top to bottom, the characteristic second oxidation zone located near the bottom converts energy-dense dry solids (char) into additional heat for the reduction zone. This is the reason the sandwiched reduction zone achieves higher temperature and is less prone to variations in feed moisture that cause conversion challenges in conventional gasifiers. Figure 3 is a comparison of published heating value and tar concentration data from clean, low-ash wood in a conventional downdraft gasifier vs. results from a more difficult manure gasification test in a Sandwich gasifier. These graphs show that a much-higher-heating-value syngas was produced with low tar concentration (sampled prior to performing any tar scrubbing unit operations), compared to the conventional downdraft gasifier concentrations after their syngas had been processed through a scrubber system. The tar concentrations observed in the Sandwich gasifier were not as severely impacted by the higher moisture in the manure feedstock.

Sandwich Gasifier as GHG Emission Mitigation Technology

The main greenhouse gases which absorb heat and contribute to climate change and are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Biomass CO_2 emissions are considered climate-neutral, so the gasification of any compostable biomass (which might otherwise have released CH_4) into syngas or liquid fuels which release CO_2 would accomplish net reductions in greenhouse gases.

The high nitrogen (N), phosphorous (P), and potassium (K) contents of poultry litter make it desirable for fertilizer as the production of these nutrients is energy-intensive and consumes considerable resources. However, the traditional disposal pathway of direct land application of poultry litter has large environmental footprint due to issues such as eutrophication, spreading of pathogens, antibiotic residue accumulation, and greenhouse gas (GHG) emissions among others.

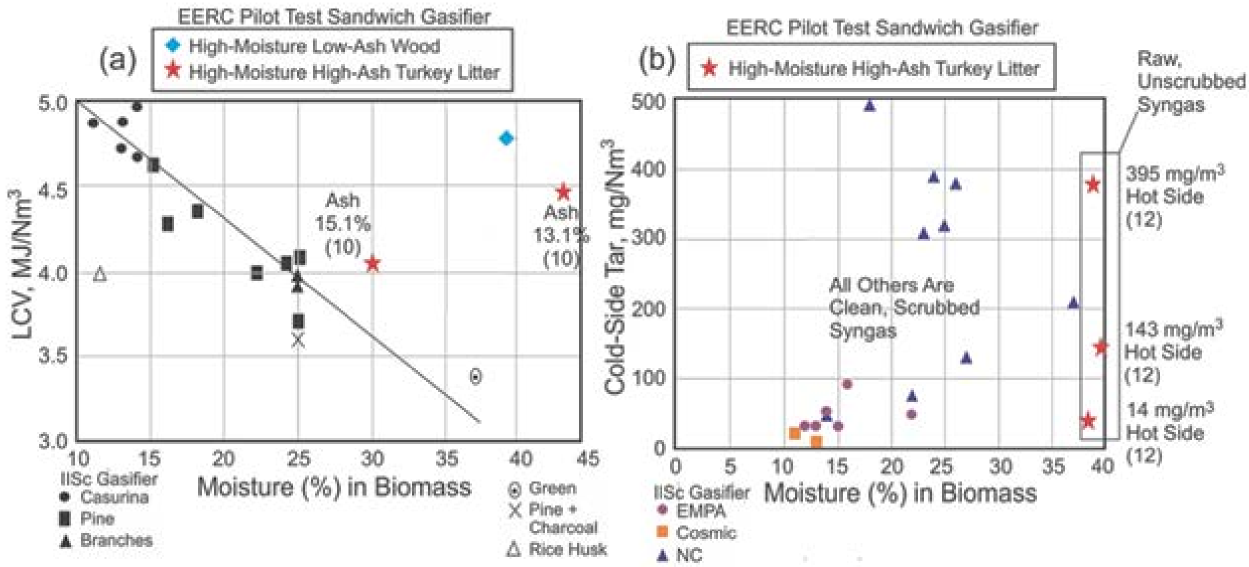

Figure 3. Comparison of Sandwich gasifier syngas heating value (a) and sampled outlet tar concentrations (b) to other commercially available downdraft gasifiers (figure modified from the Indian Institute of Science [IISc] LCV [lower caloric value]; EMPA, cosmic, and NC are other gasifier companies.)[7,8,9,10,11]

Production of N_2O during manure storage and treatment requires nitrification-denitrification of ammonia nitrogen that forms or is present in the wastes. For N_2O to be produced, it must be in an aerobic system where ammonia is converted to nitrites (nitrification). If these nitrites enter an anaerobic decomposition period (become saturated or deeply buried), they can be converted to N_2O (denitrification). This occurs in dry manure management systems which will initially provide aerobic conditions that can be followed by saturation to create the anaerobic conditions necessary

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[7] Patel, N.M. *Advances in Gasification for DH Production: Year 3 – Activity 1.6 –Development of a National Center for Hydrogen Technology®*; Topical Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No.DE-FC26-05NT42465; Energy & Environmental Research Center: Grand Forks, ND, May 2011.

[8] Patel, N.M. *Pilot-Scale Demonstration of Heat and Power Production from High-Moisture Biomass*; Final Report U.S. Army Construction Engineering Research Laboratories (CERL) under Cooperative Agreement W9132T-08-2-0014, Phase III, Task 2.3 Development of Modular Systems for Distributed Fuels and Energy, Jan 2012.

[9] Uniqueness of IISc Biomass Gasification Technology. http://cgpl.iisc.ac.in/site/Portals/0/Main%20Page/UniquenessOfIIScGasificationTechnology.pdf (accessed May 10, 2019).

[10] Dasappa1, S.; Paul, P.J.; Mukunda, H.S.; Rajan, N.K.S.; Sridhar, G.; Sridhar, H.V. Biomass gasification technology – a route to meet energy needs, Special Section: Application of S&T to Rural Areas Current Science, vol. 87, no. 7, 10 Oct. 2004.

[11] Zygarlicke, C.J.; Hurley, J.P.; Aulich, T.R.; Folkedahl, B.C.; Strege, J.R.; Patel, N.M.; Swanson, M.L.; Martin, C.L.; Olson, E.S.; Oster, B.G.; Stanislowski, J.J.; Nyberg, C.M.; Wocken, C.A.; Pansegrau, P.D. *EERC Center for Biomass Utilization® 2008–2010: Phases I–III*; Final Technical Report for U.S. Department of Energy Cooperative Agreement No. DE-FG36-08GO88054; EERC Publication 2015-EERC-08-02; Energy & Environmental Research Center: Grand Forks, ND, Aug 2015.

for N_2O production and emissions to occur. The amounts of N_2O released will depend on the duration of exposure to aerobic and anaerobic conditions in the system used, whether wet-dry cycling occurs, and how long each aerobic/anaerobic encounters last. In the case of a Sandwich gasifier, the manure can be converted without requiring an extended period of storage thus preventing uncontrolled and undesired decomposition of organic matter. Both CH_4 and N_2O releases to the environment can be significantly reduced or prevented using a Sandwich gasifier. The temperature-controlled conversion of manure into clean syngas and high-efficiency removal of ammonia in the wet scrubber prevents nitrogen emission. The captured ammonia is converted as sellable liquid fertilizer such as ammonium sulfate in an integrated process. Other valuable inorganics such as phosphorous and potassium can also be reacquired from the process for their reuse as recovered fertilizer. The clean syngas is devoid of any sulfur and other trace gases after the syngas is passed through the sorbent beds. When the syngas is used in an internal combustion engine generator, the NOx is reduced by an order of magnitude as compared to when fed with hydrocarbon fuels. This extends the duration of catalytic NOx converters used to treat the engine exhaust. Since the syngas engine exhaust is relatively clean, there is an opportunity to utilize low-cost CO_2 capture technology. The small-scale CO_2 production can support its local use. Thus, the process can become a sink for GHG emissions.

For a comparative understanding of GHG emissions from the Sandwich gasifier with competing processes utilizing manure, a side-by-side comparison of their GHG emissions is provided in Figure 4. Table 1 provides the calculated emission numbers based on previously observed test data and manure composition used in the Sandwich gasifier. As shown in Table 1, the net CO_2 emission is negative (-) 786 kg/ton of manure processed using gasification. The dry matter (DM) including combustible organics and inorganics or ash is 0.735. Since the data for the competing methods reported in reference 12 considered manure with a DM of 0.6, the Sandwich gasifier emission data was recalculated for a DM value of 0.6 for presentation in the plot.

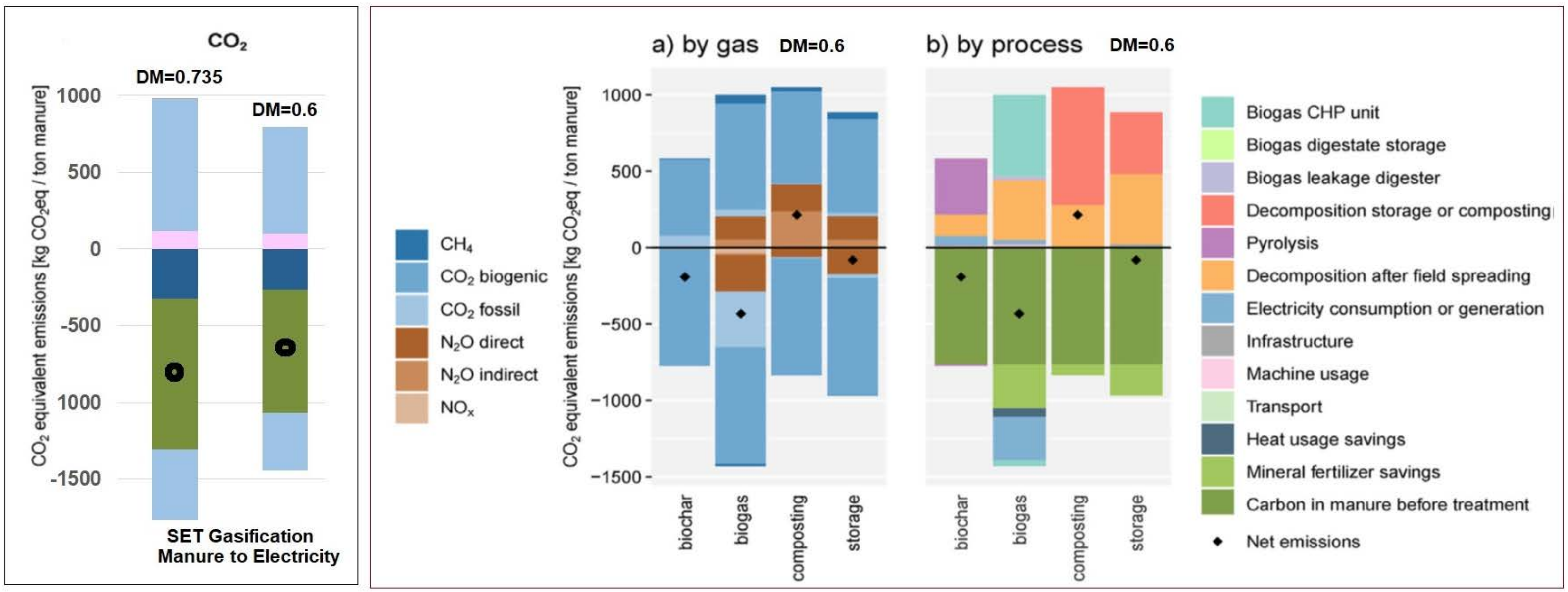
The main assumptions in the SET gasifier emission data calculations are.

1. The category “Carbon in Manure before Gasification” accounts for the organic carbon bound in the manure, which has previously been removed from the atmosphere through plant photosynthesis as in reference 12.
2. The nitrogen in the manure is converted to NH_3 and is removed in the high-efficiency wet scrubber. Therefore, the contribution of the fuel N_2O is neglected in the calculation. The data however includes thermal NOx equivalent CO_2 is included in the data based on previous engine generator NOx emission.
3. The emission from the closed manure storage bin is diverted to the wet scrubber and is fully captured. The holding period is short and therefore fugitive N emission is negligibly small.
4. The net electricity produced offsets the CO_2 equivalent and is considered to have a negative contribution.

5. The low-grade heat is used in the farm which offsets the use of propane and thus equivalent CO_2 emission reductions are accounted.
6. The emission offset accomplished due to the recovered fertilizer is not considered for lack of data. However, the effect on emissions would be negative and contribute to the GHG sink.
7. The embedded energy in steel usage in the 25 tons/day system is estimated to be 2.66 kWe for stainless steel usage of 50 tons. The CO_2e is estimated to be 2 kg/ton of manure.
8. The composition of the manure in reference 12 is similar at an equivalent DM.
9. The CH_4 emission is not considered since organic matter decomposition is prevented by the Sandwich gasification process.
10. Pre-combustion and/or post-combustion CO_2 capture are plausible options using Sandwich gasifiers and CO_2e would be greatly reduced by the implementation of CO_2 capture technology.

Table 1: GHG Emissions from SET Gasification Process

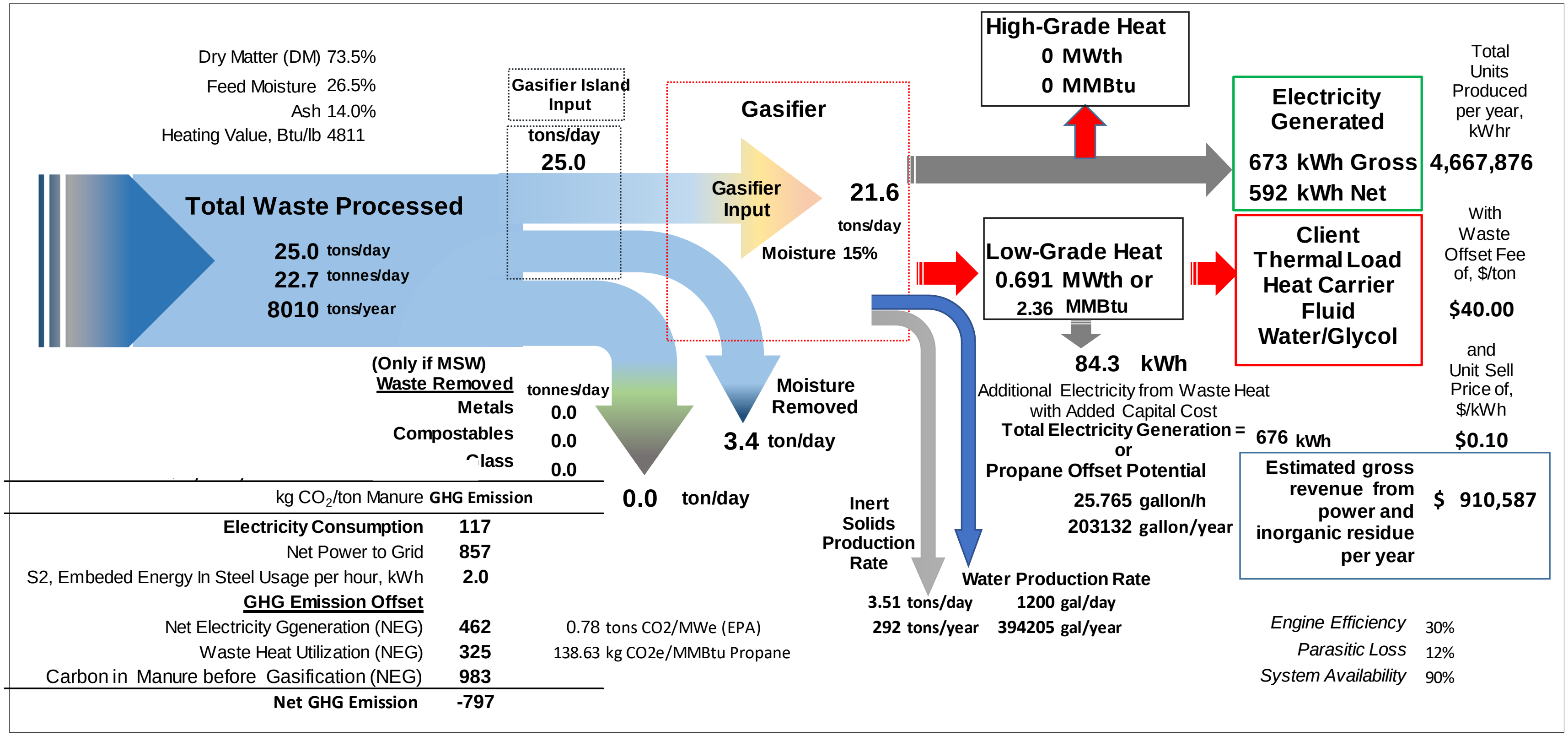
kg CO_2/ton Manure	GHG Emission	
Electricity Consumption	**117**	
Net Power to Grid	**857**	
S2, Embeded Energy In Steel Usage per hour, kWh	**2.0**	
Thermal Nox -engine exhaust with catalytic convertor	**8.8**	
GHG Emission Offset		
Net Electricity Ggeneration (NEG)	**462**	0.78 tons CO2/MWe (EPA)
Waste Heat Utilization (NEG)	**325**	138.63 kg CO2e/MMBtu Propane
Carbon in Manure before Gasification (NEG)	**983**	
Net GHG Emission	**-786**	



12. Kreidenweis, U,; Breier, J.; Herrmann, C,; Libra J,; Prochnow, A. *Greenhouse gas emissions from broiler manure treatment options are lowest in well-managed biogas production*, Journal of Cleaner Production 280. p. 124969, 2021.

Figure 4: Emissions for the SET poultry manure gasification process and the four competing treatment options differentiated according to the process causing the emissions provided Kreidenweis et. al.

Sankey Chart Showing
Various Throughputs of a 25 tons/day Turkey Manure to Electricity and Heat Convertor



Approximate weight of steel used in the system =	**50** tonnes
S2, Embeded Energy In Steel Usage per hour =	**2.66** kWh
(DOE requirement of EORI is 5) EROI (Q/(S1+S2)) =	8.068
S1 = 673 EROI (Q1/(S1+S2)) =	9.078
GHG - gCO2 e /kWh Gross =	1508 g/kWe
GHG - gCO2 e/kWh Net =	1714 g/kWe
GHG - gCO2 e /kWh Gross MAX =	1340 g/kWe
GHG - gCO2 e/kWh Net MAX =	1500 g/kWe

Unconverted Carbon (Char)	**0.92%**
% Carbon in Residue	1.90%
% Carbon as per Analysis,	1.89%

Mineral Fertilizer kg/h	132.7		
K	**27.8**	**Total Nitrogen, kg/h**	**33.2**
P	**30.7**	**NH3 (Max) kg/h**	**40.3614**
Mg	12.1	**(NH4)2SO4, kg/h**	156.578
Ca	49.0	**K2SO4, kg/h**	61.9849

$2NH_3 + H_2SO_4 = (NH_4)_2SO_4$
$2K + H_2SO_4 = K_2SO_4 + H_2$

Energy Return on Investment (EROI)

The EROI value exceeds DOE's requirements of a minimum value of 5. The scalable feature of the system allows the sizing of the Sandwich gasification technology such that it can be located at the feedstock source requiring zero to near-zero transportation cost. This is a big advantage over larger systems where biomass transportation costs negatively impact project economics. The system is capable of converting waste on an "as-received" basis, without requiring feed densification. Also. the ability of the system to tolerate moisture variation besides heat integration capability minimizes completely any energy-intensive feed preparation. The embodied energy cost for the system (S2) therefore, is minimal for the system and is assumed to be restricted only to the energy expenditure considered for the stainless steel (or steel) used in the technology. For the scaled 25-tpd Sandwich gasifier, S2, is conservatively estimated to be 2.66 kWh. (see Table 2) This value was derived by using embedded energy values for steel extracted from Argonne National Lab's GREET model, an estimate of 50 tonnes of steel in a commercial gasification system, and the calculation methodology described by the University of Michigan[13] The electricity consumption in the process is estimated to be less than 12% of the gross electricity production. These preliminary EROI values based on high-level information are already greater than 5, with values ranging from 8.1 to 9.1 (See Table 3)

Table: 2: Embedded Energy in Steel Usage in 25 TPD system

S2, Embedded Energy In Steel Usage per hour, kWh	**2.66**
Embeded Energy in Stainless Steel Used in the Commercial System	
Approximate Weight of Steel Used in the System, tonnes	50
*Energy Consumption in New Stainless Steel, MJ/tonne	35309
*Energy Consumption in Stainless Steel Conversion, MJ/tonne	30187
Total Energy Consumption, MJ/tones	65496
Energy Offset End Life Recovery (Same as New Steel), MJ/tonnes	35309
Net Consumption of Energy in Steel, MJ/tonnes	30187
Total Embeded Energy in the Steel of the Commercial System, MJ	**1509350**
Total Duration of System Operation	
Useful Life of the System, years	20
Operation per Year (Availability), %	90%
Total Duration of Operation, h	157680

Table 3: Energy Return on Investment for 25-TPD high- moisture and high-ash feedstock (manure) conversion System

Energy Return On Investment (EROI)	
Q Gross Electricity Output, kWh e	672.8
Q1 Gross Electricity from Waste heat	757.1
S1 conversion energy input into the process, kWh e	80.74
S2, Embodied Energy, KWh e	2.66
EROI (Q/(S1+S2) =	**8.1**
EROI (Q1/(S1+S2) =	**9.1**

Definitions

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

(e.g., less than or equal to five dry tons of feedstock/day). Applicants must develop technologies that reduce the levelized cost of energy (LCOE) by at least 25% and provide a justified benchmark for the state-of-the-art as part of their application.

Helpful Equations:

LCOE:

$$LCOE = \frac{Total\ Life\ Cycle\ Costs}{\sum_{t=1}^{N} \frac{System\ Energy\ Output}{(1+i)^t}} = \frac{\sum_{t=1}^{N} \frac{After\ Tax\ Cash\ Flow}{(1+i)^t}}{\sum_{t=1}^{N} \frac{System\ Energy\ Output}{(1+i)^t}} = \frac{\$}{kWh\ \ or\ MMBtu}$$

In addition, by the end of the project, technologies must be capable of exceeding an Energy Return on Investment (EROI) of 5.

EROI:

$$EROI = \frac{Energy\ Output}{Energy\ Input} = \frac{Q}{S_1 + S_2}$$

Where:

Q = rate of energy output (kWh/analysis period) for the entire energy production system

S_1 = the conversion energy input into the process (kWh/analysis period)

S_2 = is the embodied energy in the various items the energy production system uses (kWh/analysis period)

i = the discount rate

t = the year

N = the system lifetime in years

Appendix F – Detailed Budget

Instructions and Summary

OMB Control Number: 1910-5162
Expiration Date: 04/30/2025

Award Number:
Award Recipient: Singularity Energy Technologies
Date of Submission: 1-Aug-24
Form submitted by: Singularity Energy Technologies
(May be award recipient or sub-recipient)

Please read the instructions on each worksheet tab before starting. If you have any questions, please ask your EERE contact!
Do not modify this template or any cells or formulas!

1. If using this form for award application, negotiation, or budget revision, fill out the blank white cells in workbook tabs a. through j. with total project costs.
2. Blue colored cells contain instructions, headers, or summary calculations and should not be modified. Only blank white cells should be populated.
3. Enter detailed support for the project costs identified for each Category line item within each worksheet tab to autopopulate the summary tab.
4. The total budget presented on tabs a. through i. must include both Federal (DOE) and Non-Federal (cost share) portions.
5. All costs incurred by the preparer's sub-recipients, contractors, and Federal Research and Development Centers (FFRDCs), should be entered only in section f. Contractual. All other sections are for the costs of the preparer only.
6. Ensure all entered costs are allowable, allocable, and reasonable in accordance with the administrative requirements prescribed in 2 CFR 200, and the applicable cost principles for each entity type: FAR Part 31 for For-Profit entities; and 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.
7. Add rows as needed throughout tabs a. through j. If rows are added, formulas/calculations may need to be adjusted by the preparer. Do not add rows to the Instructions and Summary tab. If your project contains more than three budget periods, consult your EERE contact before adding additional budget period rows or columns.
8. ALL budget period cost categories are rounded to the nearest dollar.

SUMMARY OF BUDGET CATEGORY COSTS PROPOSED

The values in this summary table are from entries made in subsequent tabs, only blank white cells require data entry

Section A - Budget Summary

	Federal	Cost Share	Total Costs	Cost Share %	Proposed Budget Period Dates
Budget Period 1	$313,000	$321,000	$634,000	50.63%	1/01/2025-12/31/2025
Budget Period 2	$173,950	$171,000	$344,950	49.57%	01/01/2026-12/31/2026
Budget Period 3	$0	$0	$0	0.00%	
Total	$486,950	$492,000	$978,950	50.26%	

Section B - Budget Categories

CATEGORY	Budget Period 1	Budget Period 2	Budget Period 3	Total Costs	% of Project	Comments (as needed)
a. Personnel	$308,000	$216,650	$0	$524,650	53.59%	
b. Fringe Benefits	$0	$0	$0	$0	0.00%	
c. Travel	$0	$0	$0	$0	0.00%	
d. Equipment	$220,000	$0	$0	$220,000	22.47%	
e. Supplies	$42,500	$24,250	$0	$66,750	6.82%	
f. Contractual						
Sub-recipient	$0	$0	$0	$0	0.00%	
Contractor	$27,500	$22,500	$0	$50,000	5.11%	
FFRDC	$0	$0	$0	$0	0.00%	
Total Contractual	$27,500	$22,500	$0	$50,000	5.11%	
g. Construction	$0	$0	$0	$0	0.00%	
h. Other Direct Costs	$36,000	$81,550	$0	$117,550	12.01%	
Total Direct Costs	$634,000	$344,950	$0	$978,950	100.00%	
i. Indirect Charges	$0	$0	$0	$0	0.00%	
Total Costs	$634,000	$344,950	$0	$978,950	100.00%	

Additional Explanation (as needed):

a. Personnel

INSTRUCTIONS - PLEASE READ!!!

1. List project costs solely for employees of the entity completing this form. All personnel costs for subrecipients and contractors must be included under f. Contractual.

2. All personnel should be identified by position title and not employee name. Enter the amount of time (e.g., hours or % of time) and the base hourly rate and the total direct personnel compensation will automatically calculate. Rate basis (e.g., rate negotiated for each hour worked on the project, labor distribution report, state civil service rates, etc.) must also be identified.

3. If loaded labor rates are utilized, a description of the costs the loaded rate is comprised of must be included in the Additional Explanation section below. DOE must review all components of the loaded labor rate for reasonableness and unallowable costs (e.g. fee or profit).

4. If a position and hours are attributed to multiple employees (e.g. Technician working 4000 hours) the number of employees for that position title must be identified.

5. Each budget period is rounded to the nearest dollar.

SOPO Task #	Position Title	Budget Period 1			Budget Period 2			Budget Period 3			Project Total Hours	Project Total Dollars	Rate Basis
		Time (Hrs)	Hourly Rate ($/Hr)	Total Budget Period 1	Time (Hrs)	Hourly Rate ($/Hr)	Total Budget Period 2	Time (Hrs)	Hourly Rate ($/Hr)	Total Budget Period 3			
1	Sr. Engineer **(EXAMPLE!!!)**	2000	$85.00	$170,000	200	$50.00	$10,000	200	$50.00	$10,000	2400	$190,000	
2	Technicians (2)	4000	$20.00	$80,000	0	$0.00	$0	0	$0.00	$0	4000	$80,000	
				$0			$0			$0	0	$0	
1	Patel	80	$200.00	$16,000			$0			$0	80	$16,000	Standard conuslting rate
	Engineer	0	$57.50	$0			$0			$0	0	$0	Standard conuslting rate
	Technicians/Operators	120	$50.00	$6,000			$0			$0	120	$6,000	Standard conuslting rate
				$0			$0			$0	0	$0	
2	Patel	160	$200.00	$32,000			$0			$0	160	$32,000	Standard conuslting rate
	Engineer	600	$57.50	$34,500			$0			$0	600	$34,500	Standard conuslting rate
	Technicians/Operators	600	$50.00	$30,000			$0			$0	600	$30,000	Standard conuslting rate
				$0			$0			$0	0	$0	
3	Patel	160	$200.00	$32,000	80	$200.00	$16,000			$0	240	$48,000	Standard conuslting rate
	Engineer	1000	$57.50	$57,500	400	$57.50	$23,000			$0	1400	$80,500	Standard conuslting rate
	Technicians/Operators	2000	$50.00	$100,000	800	$50.00	$40,000			$0	2800	$140,000	Standard conuslting rate
				$0			$0			$0	0	$0	
4	Patel			$0	160	$200.00	$32,000			$0	160	$32,000	Standard conuslting rate
	Engineer			$0	500	$57.50	$28,750			$0	500	$28,750	Standard conuslting rate
	Technicians/Operators			$0	1000	$50.00	$50,000			$0	1000	$50,000	Standard conuslting rate
				$0			$0			$0	0	$0	
5	Patel			$0	100	$200.00	$20,000			$0	100	$20,000	Standard conuslting rate
	Engineer			$0	120	$57.50	$6,900			$0	120	$6,900	Standard conuslting rate
	Technicians/Operators			$0	0	$50.00	$0			$0	0	$0	Standard conuslting rate
				$0			$0			$0	0	$0	
				$0			$0			$0	0	$0	
				$0			$0			$0	0	$0	
				$0			$0			$0	0	$0	
	TOTAL PERSONNEL	**4720**		**$308,000**	**3160**		**$216,650**	**0**		**$0**	**7880**	**$524,650**	

Additional Explanation (as needed): The labor rates include fringe benefits. Personnel used for the project will be a combination of SET and Tri-Steel Manufacturing employees.

b. Fringe Benefits

INSTRUCTIONS - PLEASE READ!!!
1. Fill out the table below by position title. If all employees receive the same fringe benefits, you can show "Total Personnel" in the Labor Type column instead of listing out all position titles.
2. The rates and how they are applied should not be averaged to get one fringe cost percentage. Complex calculations should be described/provided in the Additional Explanation section below.
3. The fringe benefit rates should be applied to all positions, regardless of whether those funds will be supported by Federal Share or Recipient Cost Share.
4. Each budget period is rounded to the nearest dollar.

Labor Type	Budget Period 1			Budget Period 2			Budget Period 3			Total Project
	Personnel Costs	Rate	Total	Personnel Costs	Rate	Total	Personnel Costs	Rate	Total	
EXAMPLE!!! Sr. Engineer	$170,000	20%	$34,000	$10,000	20%	$2,000	$10,000	20%	$2,000	$38,000
			$0			$0			$0	$0
			$0			$0			$0	$0
			$0			$0			$0	$0
			$0			$0			$0	$0
			$0			$0			$0	$0
TOTAL FRINGE	**$0**		**$0**	**$0**		**$0**	**$0**		**$0**	**$0**

A federally approved fringe benefit rate agreement, or a proposed rate supported and agreed upon by DOE for estimating purposes is required at the time of award negotiation if reimbursement for fringe benefits is requested. Please check (X) one of the options below and provide the requested information if not previously submitted.

______ A fringe benefit rate has been negotiated with, or approved by, a federal government agency. A copy of the latest rate agreement is/was included with the project application.*

___X___ There is not a current federally approved rate agreement negotiated and available.**

*Unless the organization has submitted an indirect rate proposal which encompasses the fringe pool of costs, please provide the organization's benefit package and/or a list of the components/elements that comprise the fringe pool and the cost or percentage of each component/element allocated to the labor costs identified in the Budget Justification.

**When this option is checked, the entity preparing this form shall submit an indirect rate proposal in the format provided in the Sample Rate Proposal at https://www.energy.gov/eere/funding/downloads/sample-indirect-rate-proposal-and-profit-compliance-audit, or a format that provides the same level of information and which will support the rates being proposed for use in the performance of the proposed project.

Additional Explanation (as necessary): Please use this box (or an attachment) to list the elements that comprise your fringe benefits and how they are applied to your base (e.g. Personnel) to arrive at your fringe benefit rate. SET does not have an approved fringe benefit rate. Fringe benefits are therefore not included as a cost item.

c. Travel

INSTRUCTIONS - PLEASE READ!!!

1. Identify Foreign and Domestic Travel as separate items. Examples of Purpose of Travel are subrecipient site visits, DOE meetings, project mgmt. meetings, etc. Examples of Basis for Estimating Costs are past trips, travel quotes, GSA rates, etc.
2. All listed travel must be necessary for performance of the Statement of Project Objectives.
3. Only travel that is directly associated with this award should be included as a direct travel cost to the award.
4. Federal travel regulations are contained within the applicable cost principles for all entity types.
5. Travel costs should remain consistent with travel costs incurred by an organization during normal business operations as a result of the organizations written travel policy. In absence of a written travel policy, organizations must follow the regulations prescribed by the General Services Administration.
6. **Columns G, H, I, J, and K are total per trip per traveler.**
7. The number of days is inclusive of day of departure and day of return.
8. Recipients should enter City and State (or City and Country for International travel) in the Depart from and Destination fields.
9. Each budget period is rounded to the nearest dollar.

SOPO Task #	Purpose of Travel	Depart From	Destination	No. of Days	No. of Travelers	Lodging per Traveler	Flight per Traveler	Vehicle per Traveler	Per Diem Per Traveler	Cost per Trip	Basis for Estimating Costs
	Domestic Travel	**Budget Period 1**									
1	**EXAMPLE!!!** Visit to PV manufacturer			2	2	$250	$500	$100	$80	$1,860	Current GSA rates
										$0	
										$0	
										$0	
										$0	
	International Travel										
										$0	
	Budget Period 1 Total									**$0**	
	Domestic Travel	**Budget Period 2**									
										$0	
										$0	
										$0	
										$0	
	International Travel										
										$0	
	Budget Period 2 Total									**$0**	
	Domestic Travel	**Budget Period 3**									
										$0	
										$0	
										$0	
										$0	
	International Travel										
										$0	
	Budget Period 3 Total									**$0**	
	TOTAL TRAVEL									**$0**	

Additional Explanation (as needed): The gasification component of this work is an important piece to the overall success of the project. It is unique from the other components and would require personnel from SET to fully discuss the applicaiton of the gasification component to windmill blades and to answer any substantive questions regarding the technology.

d. Equipment

INSTRUCTIONS - PLEASE READ!!!

1. Equipment means tangible personal property (including information technology systems) having a useful life of more than one year and a per-unit acquisition cost which equals or exceeds the lesser of the capitalization level established by the non-Federal entity for financial statement purposes, or $5,000. Please refer to the applicable Federal regulations in 2 CFR 200 for specific equipment definitions and treatment.

2. List all equipment below, providing a basis of cost (e.g. contractor quotes, catalog prices, prior invoices, etc.). Briefly justify items as they apply to the Statement of Project Objectives. If it is existing equipment, provide logical support for the estimated value shown.

3. During award negotiations, provide a contractor quote for all equipment items over $50,000 in price. If the contractor quote is not an exact price match, provide an explanation in the additional explanation section below. If a contractor quote is not practical, such as for a piece of equipment that is purpose-built, first of its kind, or otherwise not available off the shelf, provide a detailed engineering estimate for how the cost estimate was derived.

4. Each budget period is rounded to the nearest dollar.

SOPO Task #	Equipment Item	Qty	Unit Cost	Total Cost	Basis of Cost	Justification of need
			Budget Period 1			
3,4,5	**EXAMPLE!!!** Thermal shock chamber	2	$70,000	$140,000	Contractor Quote - Attached	Reliability testing of PV modules- Task 4.3
2	Compressor and tank	1	$50,000	$50,000		Compressed gas storage during system operation
2	Shift reactor and catalyst	1	$65,000	$65,000		
2	CO2 system and solvent	1	$60,000	$60,000		
2	Heat exchangers	3	$5,000	$15,000		
2	Pumps	4	$2,500	$10,000		
2	Misc parts and shipping	1	$20,000	$20,000		
	Budget Period 1 Total			$220,000		
			Budget Period 2			
				$0		
				$0		
				$0		
				$0		
				$0		
				$0		
	Budget Period 2 Total			$0		
			Budget Period 3			
				$0		
				$0		
				$0		
				$0		
				$0		
				$0		
	Budget Period 3 Total			$0		
	TOTAL EQUIPMENT			**$220,000**		

Additional Explanation (as needed):

e. Supplies

INSTRUCTIONS - PLEASE READ!!!

1. Supplies are generally defined as an item with an acquisition cost of $5,000 or less and a useful life expectancy of less than one year. Supplies are generally consumed during the project performance. Please refer to the applicable Federal regulations in 2 CFR 200 for specific supplies definitions and treatment. A computing device is a supply if the acquisition cost is less than the lesser of the capitalization level established by the non-Federal entity for financial statement purposes or $5,000, regardless of the length of its useful life.

2. List all proposed supplies below, providing a basis of costs (e.g. contractor quotes, catalog prices, prior invoices, etc.). Briefly justify the need for the Supplies as they apply to the Statement of Project Objectives. Note that Supply items must be direct costs to the project at this budget category, and not duplicative of supply costs included in the indirect pool that is the basis of the indirect rate applied for this project.

3. Multiple supply items valued at $5,000 or less used to assemble an equipment item with a value greater than $5,000 with a useful life of more than one year should be included on the equipment tab. If supply items and costs are ambiguous in nature, contact your DOE representative for proper categorization.

4. Add rows as needed. If rows are added, formulas/calculations may need to be adjusted by the preparer.

5. Each budget period is rounded to the nearest dollar.

SOPO Task #	General Category of Supplies	Qty	Unit Cost	Total Cost	Basis of Cost	Justification of need
				Budget Period 1		
4,6	**EXAMPLE!!!** Wireless DAS components	10	$360.00	$3,600	Catalog price	For Alpha prototype - Task 2.4
				$0		
3	Feedstock procurement and transport	1	$2,500.00	$2,500	Past experience and verbal quotes	Provides the required feedstock for testing as proposed
2,3	Piping, fittings, electrical, misc supplies to prepare site and to make modifications to the 5 TPD system	1	$14,000.00	$14,000	Past experience, catalog prices	Modificaitons are required to the current 5 TPD system to allow the addition and installation of the various gas cleeanup systems including rerouting piping, electrical and controls
2,3	Piping, tubing, fittings, electrical, insulation, heat tape, misc supplies to install syngas balance equipment and gas analyzers	1	$20,000.00	$20,000	Past experience, catalog prices	This includes all materials required to install the CO2 solvent system and shift reactor.
3	Hand held gas analyzers	4	$250.00	$1,000	Catalog price	Safety
3	Initial charges of solvents/sorbents/catalysts	1	$5,000.00	$5,000	Estimated based upon current price and quantities required	Provides the initial charge of materials for the syngas cleanup train, shirt reactor, and CO2 removal system.
				$0		
	Budget Period 1 Total			**$42,500**		
				Budget Period 2		
4	Feedstock procurement and transport	2	$2,500.00	$5,000	Past experience and verbal quotes	Provides the required feedstock for testing as proposed
3,4	Consumable supplies(glassware, solvents, sorbents, fittings, etc.) and repair/replacement parts	1	$10,000.00	$10,000	Experience / Catalog	Materials consumed during the testing are replaced. It is expected that minor repairs and replacment will be needed.
				$0		
3,4	Calibration and purge gases	4	$750.00	$3,000	Calibration and purge gases	Required for calibrating on-line gas analyzers
3,4	55 gallon drums	10	$250.00	$2,500	Estimate	Intermediate storage of various products and wastes
3,4	Charcoal	1	$2,500.00	$2,500	Estimate	Required for cold startup
3,4	Bottled gases	1	$1,250.00	$1,250	Estimate	Required for purge, calibration, and batch tests
3,4	Rental / Truck Mounted System11	0	$5,000.00	$0		
	Budget Period 2 Total			$24,250		
				Budget Period 3		
				$0		
				$0		
				$0		
				$0		
				$0		
				$0		
				$0		
				$0		
	Budget Period 3 Total			$0		
	TOTAL SUPPLIES			**$66,750**		

Additional Explanation (as needed):

f. Contractual

INSTRUCTIONS - PLEASE READ!!!

1. The entity completing this form must provide all costs related to subrecipients, contractors, and FFRDC partners in the applicable boxes below.

2. Subrecipients (partners, sub-awardees): Subrecipients shall submit a Budget Justification describing all project costs and calculations when their total proposed budget exceeds either (1) $250,000 or (2) 25% of total award costs. These subrecipient forms may be completed by either the subrecipients themselves or by the preparer of this form. The budget totals on the subrecipient's forms must match the subrecipient entries below. A subrecipient is a legal entity to which a subaward is made, who has performance measured against whether the objectives of the Federal program are met, is responsible for programmatic decision making, must adhere to applicable Federal program compliance requirements, and uses the Federal funds to carry out a program of the organization. All characteristics may not be present and judgment must be used to determine subrecipient vs. contractor status.

3. Contractors: List all contractors supplying commercial supplies or services used to support the project. For each Contractor cost with total project costs of $250,000 or more, a Contractor quote must be provided. A contractor is a legal entity contracted to provide goods and services within normal business operations, provides similar goods or services to many different purchasers, operates in a competitive environment, provides goods or services that are ancillary to the operation of the Federal program, and is not subject to compliance requirements of the Federal program. All characteristics may not be present and judgment must be used to determine subrecipient vs. contractor status.

4. Federal Funded Research and Development Centers (FFRDCs): FFRDCs must submit a signed Field Work Proposal during award application. The award recipient may allow the FFRDC to provide this information directly to DOE, however project costs must also be provided below.

5. Each budget period is rounded to the nearest dollar.

SOPO Task #	Subrecipient Name/Organization	Subrecipient Unique Entity Identifier (UEI)	Purpose and Basis of Cost	Budget Period 1	Budget Period 2	Budget Period 3	Project Total
2,4	**EXAMPLE!!!** XYZ Corp.		Partner to develop optimal lens for Gen 2 product. Cost estimate based on personnel hours.	$48,000	$32,000	$16,000	**$96,000**
							$0
							$0
							$0
							$0
							$0
							$0
			Sub-total	**$0**	**$0**	**$0**	**$0**

SOPO Task #	Contractor Name/Organization	Purpose and Basis of Cost	Budget Period 1	Budget Period 2	Budget Period 3	Project Total
6	**EXAMPLE!!!** ABC Corp.	Contractor for developing robotics to perform lens inspection. Estimate provided by contractor.	$32,900	$86,500	$0	**$119,400**
1-5	Sage Green LLC	Feedstock procurement, support in developing analytical protocols, analyzing data and report writing	$7,500	$7,500		**$15,000**
1-5	MDM Energy Consulting LLC	Support in developing test plans, interpreting data, and report writing	$10,000	$10,000		**$20,000**
2,3,4	Electrical Contractor	Grid connection, wiring equiment	$10,000	$5,000		**$15,000**
						$0
						$0
		Sub-total	**$27,500**	**$22,500**	**$0**	**$50,000**

SOPO Task #	FFRDC Name/Organization	Purpose and Basis of Cost	Budget Period 1	Budget Period 2	Budget Period 3	Project Total
						$0
						$0
		Sub-total	**$0**	**$0**	**$0**	**$0**

TOTAL CONTRACTUAL	**$27,500**	**$22,500**	**$0**	**$50,000**

Additional Explanation (as needed): SET does not have a dedicated engineering staff. Tri-Steel Manufacturing will provide eningeering support on an as-needed basis at a loaded rate of $80/hr. It is estimated that SET will require 300 hours of engineergin time for Task 1 to support operation of the bench-scale system; 700 hours for Task 2 to for operation of the bench-scale system and to support the shakedown and commissioning of the truck-mounted system; and 1750

g. Construction

PLEASE READ!!!
1. Construction, for the purpose of budgeting, is defined as all types of work done on a particular building, including erecting, altering, or remodeling. Construction conducted by the award recipient is entered on this page. Any construction work that is performed by a contractor or subrecipient should be entered under f. Contractual.
2. List all proposed construction below, providing a basis of cost such as engineering estimates, prior construction, etc., and briefly justify its need as it applies to the Statement of Project Objectives.
3. Each budget period is rounded to the nearest dollar.

Overall description of construction activities: Example Only!!! - Build wind turbine platform

SOPO Task #	General Description	Cost	Basis of Cost	Justification of need
		Budget Period 1		
3	EXAMPLE ONLY!!! Three days of excavation for platform site	$28,000	Engineering estimate	Site must be prepared for construction of platform.
	Budget Period 1 Total	**$0**		
		Budget Period 2		
	Budget Period 2 Total	$0		
		Budget Period 3		
	Budget Period 3 Total	$0		
	TOTAL CONSTRUCTION	**$0**		

Additional Explanation (as needed):

h. Other Direct Costs

INSTRUCTIONS - PLEASE READ!!!
1. Other direct costs are direct cost items required for the project which do not fit clearly into other categories. These direct costs must not be included in the indirect costs (for which the indirect rate is being applied for this project). Examples are: tuition, printing costs, etc. which can be directly charged to the project and are not duplicated in indirect costs (overhead costs).
2. Basis of cost are items such as contractor quotes, prior purchases of similar or like items, published price list, etc.
3. Each budget period is rounded to the nearest dollar.

SOPO Task #	General Description and SOPO Task #	Cost	Basis of Cost	Justification of need
		Budget Period 1		
5	**EXAMPLE!!!** Grad student tuition - tasks 1-3	$16,000	Established UCD costs	Support of graduate students working on project
3	Rental charge for 5 TPD truck-mounted system	$36,000	6 months rent at $6,000/month (30% of the nominal rental rate)	SET will require the use of the truck-mounted system to perform the propsed work. It is estimated that SET will use the system for approximately 30% of its availability, and therefore the rate charged is 30% of the normal rate of $20,000/month.
	Budget Period 1 Total	$36,000		
		Budget Period 2		
3,4	Rental charge for 5 TPD truck-mounted system	$72,000	12 months rent at $6,000/month (30% of the nominal rental rate)	SET will require the use of the truck-mounted system to perform the propsed work. It is estimated that SET will use the system for approximately 30% of its availability, and therefore the rate charged is 30% of the normal rate of $20,000/month.
3,4	Ultimate, proxiimate, ash analysis	$1,000	4 samples at $250	Analysis of feedstock
3,4	Fuel, Tar, and Residual Anlaysis	$1,500	10 samples at $150/sample	Determine concentrations for baseline tests / assist with process optimization
3,4	Certifed Analysis of Process Streams	$2,000	10 samples at $200/sample	Determine concentrations for baseline tests / assist with process optimization / support permitting requirements
3,4	TCLP analysis	$2,000	2 samples at $1000 each	Verify solid wastes are non-hazardous
3,4	RCRA metals analysis	$2,000	2 samples at $1000 each	Verify solid wastes are non-hazardous
3,4	Wastewater analysis	$1,050	3 samples at $350 each	Generate data for wastewater disposal
	Budget Period 2 Total	$81,550		
		Budget Period 3		
	Budget Period 3 Total	$0		
	TOTAL OTHER DIRECT COSTS	**$117,550**		

Additional Explanation (as needed):

i. Indirect Costs

INSTRUCTIONS - PLEASE READ!!!
1. Fill out the table below to indicate how your indirect costs are calculated. Use the box below to provide additional explanation regarding your indirect rate calculation.
2. The rates and how they are applied should not be averaged to get one indirect cost percentage. Complex calculations or rates that do not do not correspond to the below categories should be described/provided in the Additional Explanation section below. If questions exist, consult with your DOE contact before filling out this section.
3. The indirect rate should be applied to both the Federal Share and Recipient Cost Share.
4. NOTE: A Recipient who elects to employ the 10% de minimis Indirect Cost rate **cannot claim resulting costs as a Cost Share contribution, nor can the Recipient claim "unrecovered indirect costs" as a Cost Share contribution.** Neither of these costs can be reflected as actual indirect cost rates realized by the organization, and therefore are not verifiable in the Recipient records as required by Federal Regulation (§200.306(b)(1)).
5. Each budget period is rounded to the nearest dollar.

	Budget Period 1	Budget Period 2	Budget Period 3	Total	Explanation of BASE
Provide ONLY Applicable Rates:					
Overhead Rate	0.00%	0.00%	0.00%		*Example: Labor + Fringe*
General & Administrative (G&A)	0.00%	0.00%	0.00%		*MTDC*
FCCM Rate, if applicable	0.00%	0.00%	0.00%		
OTHER Indirect Rate	0.00%	0.00%	0.00%		
Indirect Costs (As Applicable):					
Overhead Costs				**$0**	
G&A Costs	$0	$0	$0	**$0**	
FCCM Costs, if applicable				**$0**	
OTHER Indirect Costs				**$0**	
Total Indirect Costs Requested:	**$0**	**$0**	**$0**	**$0**	

	BP1	BP2	BP3
Personel	308000	216650	0
Fringe	0	0	0
Travel	0	0	0
Supplies	42500	24250	0
Contract1	7500	7500	0
Contract2	10000	10000	0
Contract3	10000	5000	0
Contract4	0	0	0
SubRecip1	0	0	0
Other	36000	81550	0
MTDC	414000	344950	0

A federally approved indirect rate agreement, or rate proposed (supported and agreed upon by DOE for estimating purposes) is required if reimbursement of indirect costs is requested. Please check (X) one of the options below and provide the requested information if it has not already been provided as requested, or has changed.

______ An indirect rate has been approved or negotiated with a federal government agency. A copy of the latest rate agreement is included with this application and will be provided electronically to the Contracting Officer for this project.
______ The organization does not have a current, federally approved indirect cost rate agreement and has provided an indirect rate proposal in support of the proposed costs.
__X____ This organization has elected to apply a 10% de minimis rate in accordance with 2 CFR 200.414(f).

Provide an explanation of how your indirect cost rate was applied.

*Additional Explanation (as needed): *IMPORTANT: Please use this box (or an attachment) to further explain how your total indirect costs were calculated. If the total indirect costs are a cumulative amount of more than one calculation or rate application, the explanation and calculations should identify all rates used, along with the base they were applied to (and how the base was derived), and a total for each (along with grand total).*

Cost Share

PLEASE READ!!!

1. A detailed presentation of the cash or cash value of all cost share proposed must be provided in the table below. All items in the chart below must be identified within the applicable cost category tabs a. through i. in addition to the detailed presentation of the cash or cash value of all cost share proposed provided in the table below. Identify the source organization & amount of each cost share item proposed in the award.

2. Cash Cost Share - encompasses all contributions to the project made by the recipient, subrecipient, or third party (an entity that does not have a role in performing the scope of work) for costs incurred and paid for during the project. This includes when an organization pays for personnel, supplies, equipment, etc. for their own company with organizational resources. If the item or service is reimbursed for, it is cash cost share. All cost share items must be necessary to the performance of the project. **Contractors may not provide cost share.** Any partial donation of goods or services is considered a discount and is not allowable.

3. In Kind Cost Share - encompasses all contributions to the project made by the recipient, subrecipient, or third party (an entity that does not have a role in performing the scope of work) where a value of the contribution can be readily determined, verified and justified but where no actual cash is transacted in securing the good or service comprising the contribution. In Kind cost share items include volunteer personnel hours, the donation of space or use of equipment, etc. The cash value and calculations thereof for all In Kind cost share items must be justified and explained in the Cost Share Item section below. All cost share items must be necessary to the performance of the project. If questions exist, consult your DOE contact before filling out In Kind cost share in this section. Contractors may not provide cost share. Any partial donation of goods or services is considered a discount and is not allowable.

4. Funds from other Federal sources MAY NOT be counted as cost share. This prohibition includes FFRDC sub-recipients. Non-Federal sources include any source not originally derived from Federal funds. Cost sharing commitment letters from subrecipients and third parties must be provided with the original application.

5. Fee or profit, including foregone fee or profit, **are not allowable** as project costs (including cost share) under any resulting award. The project may only incur those costs that are allowable and allocable to the project (including cost share) as determined in accordance with the applicable cost principles prescribed in FAR Part 31 for For-Profit entities and 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.

6. NOTE: A Recipient who elects to employ the 10% de minimis Indirect Cost rate **cannot claim the resulting indirect costs as a Cost Share contribution.**

7. NOTE: A Recipient **cannot claim "unrecovered indirect costs"** as a Cost Share contribution, **without prior approval.**

8. Each budget period is rounded to the nearest dollar.

Organization/Source	Type (Cash or In Kind)	Cost Share Item	Budget Period 1	Budget Period 2	Budget Period 3	Total Project Cost Share
ABC Company **EXAMPLE!!!**	Cash	Project partner ABC Company will provide 20 PV modules for product development at the price of $680 per module	$13,600			**$13,600**
						$0
						$0
Tri-Steel Manufacturing	In-Kind	Rental for 5-ton/day truck mounted system	$36,000	$72,000		**$108,000**
Xcel Energy	Cash	Support provided through Xcel Energy's Natural Gas Innovation Act (NGIA) filing,	$195,000	$0	$0	**$195,000**
SET	Cash	Salary	$40,000	$34,000		**$74,000**
Tri-Steel Manufacturing	Cash	Salary	$50,000	$65,000		**$115,000**
						$0
						$0
						$0
						$0
		TOTAL COST SHARE	**$321,000**	**$171,000**	**$0**	**$492,000**
		Cost Share Percentage per Budget Period	**50.6%**	**49.6%**	**0.0%**	

Total Project Cost: $978,950

Total Project Cost Share Percent: 50.3%

Additional Explanation (as needed):