DAKOTA GREEN POWER

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February 25, 2022

Clean Sustainable Energy Authority
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Application for a Clean Sustainable Energy Authority Grant to Support the Commercial Development of the Sandwich Gasifier by Dakota Green Power

NDIC and Clean Sustainable Energy Authority,

Dakota Green Power hereby submits its application entitled "Accelerating the Waste-to-Energy Commercialization Pathway for the Sandwich Gasifier" for consideration for grant funding from the North Dakota Clean Sustainable Energy Authority. Dakota Green Power (DGP), a spin-off of Tri-Steel Manufacturing, is proposing to streamline manufacturing of Singularity Energy Technology's (SET) patented Sandwich gasifier technology as its core business and accelerate the commercialization pathway for drop-in liquid fuels, electricity, and hydrogen production from biomass and waste materials. The proposed work will demonstrate the patented sandwich gasification technology at a commercial scale. The technology will provide North Dakota communities the opportunity to grow their waste-to-energy infrastructure while striving to reach Governor Burgum's goal of reaching carbon neutrality by 2030.

This effort will involve the manufacturing, installation, and testing of a 25 ton/day gasification-based heat, electricity, and biofuels production facility in Grand Forks North Dakota. Access to the operating commercial-scale site in Grand Forks will allow DGP to engage customers and develop a worldwide waste-to-energy business. The ability to show potential customers an operating facility along with the relevant cost, performance, reliability, flexibility and negative carbon emissions is needed to penetrate the market. Once the technology's commercial operation is demonstrated, DGP is projecting manufacturing and selling of 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. Demonstration of our technology is also of importance to the State as it provides communities with a proven option to economically address growing MSW/landfill concerns.

We are requesting $5.5 million in grant funding from the Clean Sustainable Energy Authority. Dakota Green Power commits to match the State's funding with investments from Trilogy Financial Group, Tri-Steel Manufacturing, and other project partners as identified in our proposal budget.

If you have questions regarding the proposal are require additional information, feel free to contact Dakota Green Power's CEO, Dr. Nikhil Patel at 701-739-8720 or npatel@singularity.com.

Sincerely

Scott Homstad
President, Dakota Green Power
Manager/Secretary Treasurer, Tri-Steel Manufacturing

Clean Sustainable Energy Authority

North Dakota Industrial Commission

Application

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

Applicant: Dakota Green Power

Date of Application: March 1, 2022

Amount of Request
Grant: $5,371,457
Loan: $0

Total Amount of Proposed Project:

Duration of Project: 30 months

Point of Contact (POC): Nikhil Patel

POC Telephone: 701-739-8720

POC Email: npatel@singularity.com

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

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ABSTRACT

Objective

Dakota Green Power (DGP), a spin-off of Tri-Steel Manufacturing is proposing to streamline manufacturing of Singularity Energy Technology's (SET) patented Sandwich gasifier technology as its core business and accelerate the commercialization pathway for drop-in liquid fuels, electricity, and hydrogen production from biomass and waste materials. SET's Sandwich gasifier has been proven to operate on a range of complex feedstocks, including municipal solid waste (garbage), railroad ties, biosolids, biodigester waste, high moisture forestry and agricultural wastes including poultry and livestock manure, tires, and other difficult to process waste materials. The proposed work will demonstrate, at a commercial scale, the conversion of domestic waste resources into baseload electricity, heat, drop-in-liquid fuel, or hydrogen using the patented sandwich gasification technology. The technology will provide North Dakota communities the opportunity to control waste disposal by growing their waste-to-energy infrastructure while striving to reach Governor Burgum's goal of reaching carbon neutrality by 2030. This effort will involve the manufacturing, installation, and testing of a 25 ton/day gasification-based heat, electricity, and biofuels production facility in Grand Forks North Dakota.

Expected Results

Access to the operating commercial-scale site in Grand Forks will allow DGP to streamline its manufacturing capabilities to cater to customers need for waste-to-energy technology world-wide. The ability to show potential customers an operating facility along with the relevant cost, performance, reliability, flexibility, and negative carbon emissions is needed to penetrate the market. 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. The 25 ton/day system will continue operation beyond the demonstration serving the City of Grand Forks.

Duration

Thirty months (Suggested: September 1, 2022 – March 31, 2025)

Total Project Cost

$5,371,457 is requested from NDIC of the $10,985,489 total project cost.

Participants

Dakota Green Power (DGP), Singularity Energy Technologies, LLC (SET), Tri-Steel Manufacturing, City of Grand Forks, Sage Green N.R.G. LLC, Barr Engineering Company, MDM Energy Consulting, LLC, and the University of North Dakota.

PROJECT DESCRIPTION

This project proposes to install and operate a 25 ton/day waste-to-energy system in Grand Forks, ND. SET's Sandwich gasifier has been proven to operate on a range of complex feedstocks, including municipal solid waste, biodigester waste, high moisture forestry and agricultural wastes including poultry and livestock manure, railroad ties, tires, and other difficult to process waste materials. The proposed work will demonstrate, at commercial scale, the conversion of domestic waste resources into electricity, heat, drop-in-liquid fuel, or hydrogen using the patented sandwich gasification technology. The schematic in Figure 1 provides an overview of the technology fully implemented at a client's site demonstrating how DGP manufactured systems can be integrated to meet with client's site-specific demands for waste conversion.

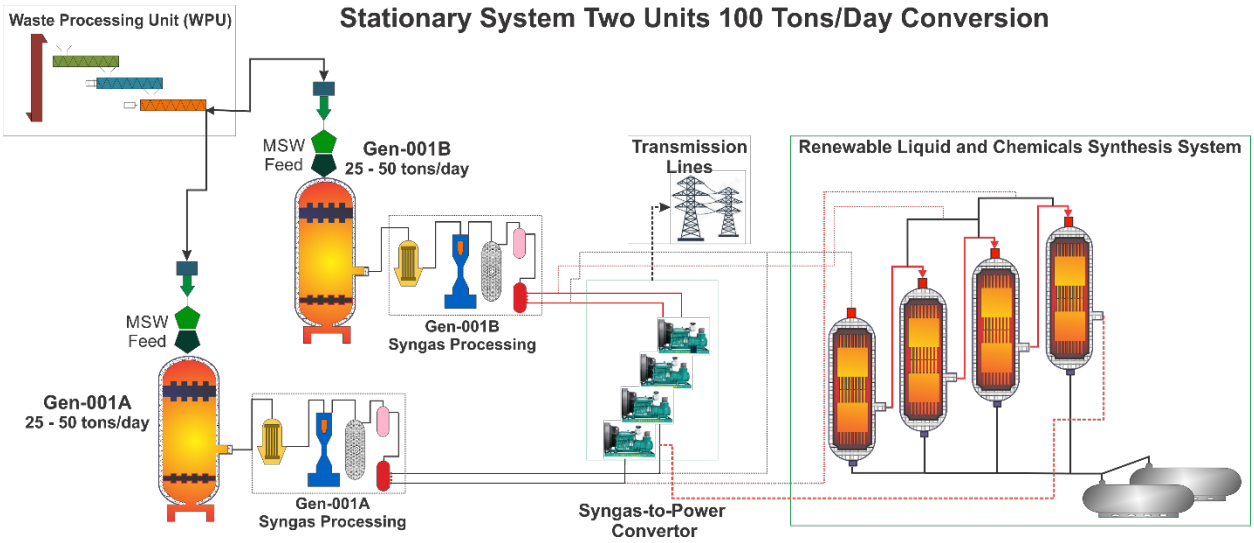

Figure 1: High-Level Process Flow Diagram of a commercial Sandwich gasification system

Objectives

Dakota Green Power (DGP), a spin-off of Tri-Steel Manufacturing, is proposing to streamline manufacturing of Singularity Energy Technology's (SET) patented Sandwich gasifier technology as its core business to support accelerated deployment of commercial technology for production of drop-in liquid fuels, electricity and hydrogen production from biomass and waste materials. The primary objective of this project is to accelerate business growth by demonstrating the technology at a commercial scale using feedstocks of primary interest to potential customer base looking at utilizing Sandwich gasification technology.

As a part of this demonstration, this project will:

- Integrate the SET Sandwich Gasifier with available commercial or near-commercial subsystems including:
    - Syngas cleanup system to remove trace contaminants such as tar and particulate matter.
    - Syngas-to-heat and power production.
    - Syngas composition balance by demonstration of integrated water-gas-shift reactor, CO_2 capture and H_2 separation technologies to optimize the H_2/CO ratio for increasing yield of liquid fuel production.
    - Sorbent-based CO_2 capture system.
    - Gas-to-liquids system to convert clean syngas to drop-in compatible diesel fuel replacement.
- Facilitate market expansion by developing key requirements to cultivate end-use customers by:
    - Providing an operating system for prospective clients to visit that demonstrates the viability of the technology, including its flexibility and ease of operability.
    - Developing the financial data and forecasting tools required to create reliable economic forecasts for potential customers.
    - Obtaining the data required to provide assurance to customers regarding the system's throughputs, outputs, emissions, and related technical/product performance criteria.
- Develop a platform for continued development of technology and end use applications and potential new fuel sources.
- Advance the Manufacturing Readiness Level from a MRL of 6 to a MRL of 8 (a definition of the MRL is provided in Appendix E).
- Identify operating conditions, equipment configuration, and technology upgrades to optimize capital and operating costs.
- Provide a full-demonstrated system that can be duplicated for other clients (either at same scale or at 2x or 4x scale).
- Engage potential long-term partners with supporting technology – such as methanol production, combined heat and power (CHP) applications, H_2 for fuel cells, NH_3 for use as fertilizer and carbon-free fuel of the future and technology for CO_2 conversion.
- Long-term sustainable operation to generate revenue to support technology development.

DGP has customers interested in investing in this technology, contingent upon the success of this project (see letter from Trilogy Financial Group in Appendix D).

Methodology

Dakota Green Power (DGP) has developed a business model to manufacture and sell waste-to-energy-systems that use the patented Sandwich gasifier technology to achieve near complete conversion of waste into renewable heat, electricity, liquid fuels, and hydrogen. During the proposed project, the DGP team will design and construct a 25 ton/day system at its host site, the City of Grand Forks, ND Landfill (see

letter of support in Appendix D). This system will serve as the prototype, i.e., serial number 1, required to demonstrate at full-scale the reported advantages of the system, including its ability to burn a wide variety of feedstocks while avoiding the many issues that typically plague small-scale waste and biomass gasification systems. In addition to providing a site for potential clients to visit, data from the work will be used to refine and fully develop marketing tools that will allow DGP to provide potential customers and community leaders with data driven forecasts of capital and operating expenses and cash flow projections to make informed decisions. The results from proposed testing will also be used to improve the overall design of the system required for cost optimization.

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 2). 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. The system design philosophy adopted is that of achieving zero effluent discharge such that the packaged distributed power system can be seamlessly implemented within any environmentally constrained region of North America. When used to process waste materials to energy, the Sandwich gasifier also provides a substantial CO_2e reduction/credit as compared to competitive technologies as demonstrated by the LCA presented as Appendix B. The main features of the Sandwich gasifier are highlighted below.

- A typical Sandwich configuration consists of at least one **endothermic reduction zone** sandwiched between two high-temperature **oxidation zones.**
- 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.
- The patented configuration ensures near-complete waste conversion and augments reduction zone temperature to promote clean syngas production with high efficiency.

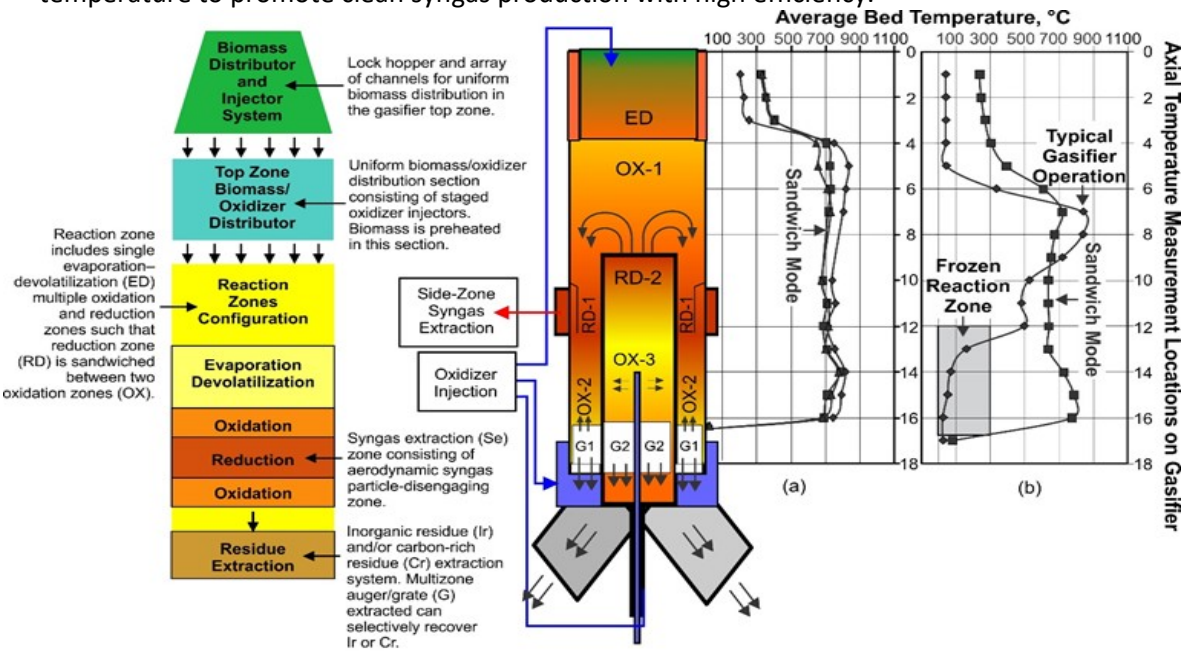

Figure 2. Sandwich gasifier, showing oxidation and reduction zones and the advantage of a uniform axial temperature profile versus the low-conversion "frozen reaction zone" present in typical downdraft gasifiers (oxidation is shown as OX and reduction as RD).

The proposed system has undergone a detailed review by Corval Group on behalf of Trilogy Financial Group and they have endorsed the system as the best option for TFG to meet their need to process large volumes of railroad ties (see attached letter from Corval in Appendix D). A detailed description of the technology is presented in Appendix A.

Detailed Scope of Work

To facilitate accomplishment of the project goals, this project will establish an operational commercial Sandwich gasifier technology near its manufacturing base in Grand Forks for testing a wide range of client-specific feedstocks. The majority of this effort will involve the manufacturing, installation, and testing of a 25 ton/day gasification-based heat, electricity, and biofuels production facility in Grand Forks, North Dakota. Other work will include continued efforts on the development of marketing and commercialization plans for the technology. The work to be performed is outlined in the five tasks that follow.

Task 1.0 – Project Management and Planning

Dakota Green Power (DGP) shall manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule, and budget objectives and requirements. A Project Management Plan is included as Appendix B. DGP shall update the Project Management Plan 30 days after award to account for any developments that may have occurred between the time of this proposal and the start of the project, and then as necessary throughout the project to accurately reflect the current status of the project. Examples of when it may be appropriate to update the Project Management Plan include: (a) project management policy and procedural changes; (b) changes to the technical, cost, and/or schedule baseline for the project; (c) significant changes in scope, methods, or approaches; or (d) as otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives.

Management of project risks will occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor, and mitigate technical uncertainties as well as schedule, budgetary, and environmental risks associated with all aspects of the project. The results and status of the risk management process will be presented during project reviews and in quarterly progress reports with emphasis placed on the medium- and high-risk items.

Task 2.0 – Detailed Design of Full-Scale Commercial Sandwich Gasification System

This task includes the design of the 25 ton/day demonstration plant that will be built in Grand Forks, ND, and will include identifying required site modifications, sizing and planning of all equipment, necessary environmental controls, and staffing requirements of the plant. Sizing will be largely conducted through scale-up parameters associated with the data from the current truck-mounted system. Preliminary design for both a 25 and 50 ton/day system has been completed and was used to estimate the equipment cost and other requirements for this proposal. During this task, detailed system design will be performed.

Barr Engineering has been retained to perform the detailed engineering design. Deliverables from their work will include preparing construction ready diagrams, including detailed energy and mass balance at

design conditions, P&ID diagrams, electrical line diagrams, piping requirements, a process control system diagram, an equipment and instrumentation list, and a preliminary plot plan and elevations. They will also prepare a Class 4 AACE capital cost estimate for the plant. This work will be done in close coordination with the DGP team and will include regular design review meetings with the City of Grand Forks. Barr Engineering will be retained as the engineering firm of choice for the commercialization steps.

This task will also include obtaining construction and environmental permits for the demonstration plant. Planning for logistical concerns associated with the continuous plant operation of the plant, including potential off-take agreements for the electricity and fuels produced will be considered as a part of this task. Wastewater treatment and disposal systems will be developed as per local, state, and federal environmental requirements, along with management with local utilities to ensure effective integration into existing infrastructure.

A HAZOP review will be performed as a part of the design task, and will be reviewed and updated after construction is completed.

Task 3 –Plant Procurement and Construction

The procurement/manufacturing and installation of the required plant components will be completed under this task. Multiple vendors have been contacted related to procurement of off-the-shelf equipment available. Tri-Steel Manufacturing will produce the specialized equipment required for the system. The Tri-Steel/DGP partnership has been developed to facilitate the manufacture of the gasification systems. The team of vendors identified and used for this project will be vetted for potential selection as preferred vendors as a part of the commercialization efforts.

This task will also incorporate multiple aspects of the on-site construction, including any required infrastructure improvements and facility upgrades, fabrication of field-fitted equipment, integration of equipment, development of controls systems including accommodations for net metering of electricity, and individual component testing to ensure adequate performance from vendors.

The HAZOP review performed during the design task will be reviewed and updated as needed.

Shakedown testing of the integrated system for adequate performance and training for operators will verify total system performance.

Task 4 – Testing of Selected Feedstocks

DGP will perform a series of parametric tests on a variety of feedstocks to optimize the design and operation of the system. Particular attention will be paid to integration of the back-end equipment with the gasifier island to ensure syngas quality and quantity from the gasifier are optimized to and meet the specifications of the final conversion technology (i.e. engine specification for electricity generation, optimal CO/H_2 for liquid fuels production, purity requirements for membrane separation of hydrogen, etc.). Parametric testing will also complete the development and testing of several patented recycle strategies focused on improving overall efficiency and minimizing waste production. Effluent monitoring (solid, liquid and gas) will be performed to provide data required for emission guarantees. Long-term testing (i.e., continuous testing of at least one month operation at 90% availability coupled with hot shutdowns) on a variety of feedstocks including railroad ties and MSW will be performed to demonstrate

the long-term stability of operation. Supplies of railroad ties will be obtained from a potential client. MSW will be obtained from then City of Grand Forks (see letter attached commitment letters). DGP will also perform shorter validation testing of other feedstocks to match interests of potential clients. These may include forestry wastes common to the lumber industry in Northern Minnesota, rejected plastic waste common from regional recycling operations, and agriculture-based biomass/wastes. Preliminary pre-screening tests will be performed by the University of North Dakota for new and unfamiliar feedstocks to identify any potential issues prior to testing in the demonstration unit.

The goals of the testing will be several and include

- Define the operational characteristics to portray and optimize ease of operation, including hot and cold-start up, feedstock feeding, byproduct/waste removal and treatment, and sustained long-duration operation.
- Demonstrate a high degree of operating flexibility by verifying the system's ability to process waste with varying composition, time-varying blend of fuels, and high-degree of turndown.
- Provide information on system performance to drive optimization of overall system efficiency, with a goal of maximizing the potential economic returns for customers utilizing the Sandwich gasifier.
- Optimize system controls to improve operational reliability with minimum human intervention.
- Measure and document the emission characteristics. Make system modifications as needed to ensure system emissions will meet requirements of permitting agencies.
- Determine any design and operational considerations that will be required to accommodate changes in feedstock type and end-use applications.
- Establish gas cleanup protocols required to limit downstream process upsets, including catalyst poisoning or corrosion.
- Advance the Technology Readiness Level (TRL) from 6 to 8 and the Manufacturing Readiness Level (MRL) from 6 to 8.
- Prepare operational and training manuals and test their implementation in the field.

Task 5 – Economic Evaluation and Business Plan Development

Subtask 5.1. Business Plan Development and Optimization

DGC will utilize the information gathered during this project to update its Business Plan and its Financial Plan for Manufacturing. The current Business Plan is presented as Confidential Appendix I. At a minimum, the plan will explain the economic feasibility demonstrated by the DGP's current Excel financial spreadsheet model and develop a detailed business plan for continued development and commercial implementation of the Sandwich Gasification technology. Information to be included is an explanation of the hurdles and risks for factors such as: supply of process inputs; process and technology development; capital, operating, and maintenance cost; process operation factors; life-cycle environmental, permitting, and other regulatory factors; market demand and quantity/price points for output products; offtake agreements; downstream supply chain for products; international demand, supply, competition, and other considerations; etc. Cash flow and balance sheet projections will be refined based upon additional

information learned during the proposed work. As a part of this effort, a banker, accounting firm, insurer, and law firms will be vetted and formally retained to support DGP as they move into full commercialization.

The financial plan will consist of a written report with the key assumptions and data used for development being documented in the design basis. The results of the design basis and financial plan will be utilized and refined through subsequent tasks. A final financial plan will be validated using all data and experience gained through execution of the project and will be complete 30 days prior to award completion.

Subtask 5.2. Development of Economic Projection Tools for End User Marketing

DGP has developed a forecasting model that can be used with potential customers using their specific feedstock provides an overall energy and material balance showing flows of material and energy into and out of the system, and to estimate the potential capital and operating costs including return on investment and payback calculations. Examples of output from this pro forma model is presented as Appendix D. This model will be refined based on testing and operation of the demonstration system. The sensitivity of the economics to future market prices for both the feedstocks (including the potential for tipping fees) and product suite will be included. Revenue projections will be itemized for each potential marketable product. Both capital and operating cost factors will be used to estimate the economic viability. The capital cost estimate will indicate the all-in costs for the facility, including infrastructure from the site fence line, interconnection to existing facilities, equipment costs, construction costs, construction indirect costs, and owner's costs.

The forecasting tool will include a design estimate with adequate detail to be classified as an Association for the Advancement of Cost Engineering (AACE) Class 3 or better estimate. This estimate is intended to serve as an estimate for use in the sale of future commercial projects. The design basis, process model (including mass and energy balance and process flow diagram), proposed plant general arrangements, and equipment specifications prepared as a part of Task 2 for both a 25 and a 50 ton/day system will support this task. The forecasting tool will be developed by the DGP project team with input from Barr Engineering, a qualified Architectural and Engineering (A&E) firm with extensive experience in EPC of similar waste-to-energy projects.

DGP will also utilize the University of North Dakota to develop Life-Cycle Analysis (LCA) of various feedstocks and end use applications. The goal of this work is to have both a tool and substantiated data that can be used by DGP's potential clients to quantify the potential CO_2e reduction and assist in their applications for potential CO_2 credits. DGP will work with the University of North Dakota to continue the development of its technology to further enhance the marketability of the Sandwich gasifier and its potential applications.

ANTICIPATED RESULTS

The presence of a commercial scale Sandwich gasifier along with a complement of operational data is expected to provide a number of benefits including:

- Positioning DGP to close the deal on several commercial projects pending demonstration of the Sandwich gasifier including its end use technologies.

- The development of a new manufacturing facility in Grand Forks, ND with potential for annual revenues of $30-40,000,000.
- Adding 35 to 40 new high-paying STEM and skilled-technician jobs to the state, a projection of 24 new jobs in first 4 years is presented in the business plan (Appendix I).
- Providing a proven economical option for cities, counties, ag-businesses, large farming operations and other entities to generate revenue from a current waste disposal issue.
- Contributing to the State's goal of carbon neutrality by 2030 by offering a carbon negative solution for production of liquid fuels, baseload electricity, heat, and hydrogen from low- to negative-value waste feedstocks.
- Providing a facility DGP, the City, UND EERC, and IES and others can leverage for future large-scale federal grants.

FACILITIES AND RESOURCES

The current 5 ton/day truck mounted gasifier (see figure 3) owned by Tri-Steel Manufacturing will be relocated to the proposed test site and will be available to support screening of new feedstocks and testing of new concepts. This system was originally conceived by Dr. Patel while he worked at the EERC. Over $7,500,000 in 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 Singularity Energy Technology (SET) and its owner, Dr. Patel. Tri-Steel Manufacturing purchased the truck mounted system from the EERC and invested approximately $1,000,000 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. In addition, the EERC has a pilot-scale system and the UND IES has a bench-scale system that can be used to support the development efforts as needed.

Tri-Steel Manufacturing will serve as the primary facility to manufacture and assemble specialty, i.e., not off-the-shelf components, and will provide support for on-site fabrication and installation requirements. The City of Grand Forks will provide space for the project in the current Baling Facility located at the Grand Forks City Landfill. Figure 4 shows the existing host building with a 3-D conceptual drawing of the proposed system to be located in the building. Ample room exists should the City decide to invest in additional systems for their use once the demonstration is complete. The key human resources required for the success of the project are committed to the project as presented in the management section.

Figure 3. Teams from Dakota Green Power and the City of Grand Forks shown together with Tri-Steel's 5 ton/day truck-mounted Sandwich Gasifier.

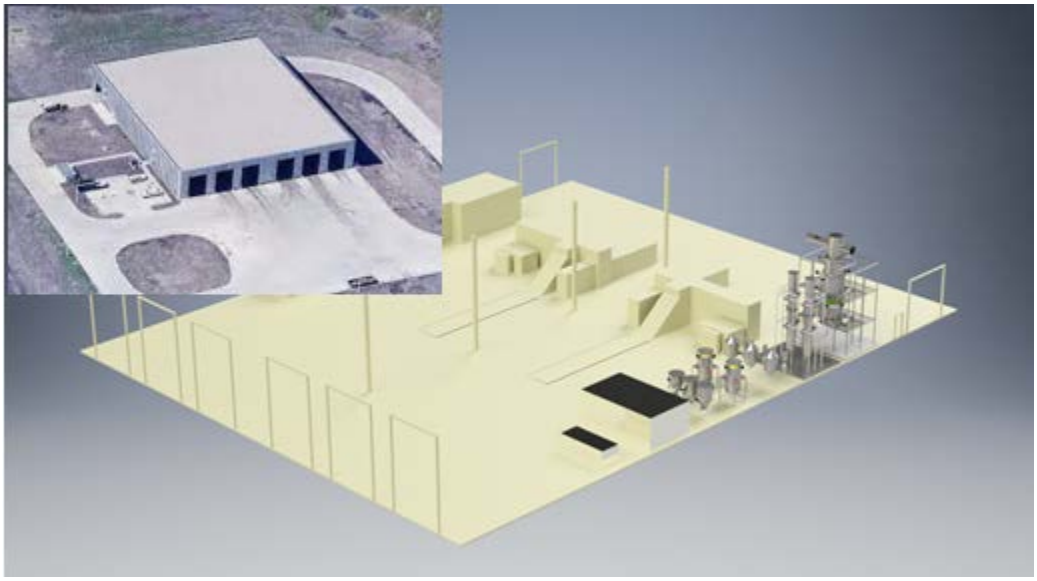

Figure 4. Layout of proposed 25 ton/day located in City of Grand Forks Landfill Baling Facility

ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE PROJECT WHILE IT 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 either be converted into liquid fuels or used for heating or electricity generation while the project is underway. A thermal oxidizer will also be available with the capacity to oxidize the entire gas stream to protect against emergency shutdown or during transitional operating conditions. 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.

Several hundred tons of railroad ties, MSW, and other waste materials 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.

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.[1] This comparison represents an output improvement ranging from 38% to 70%. Details are provided in Appendix A.

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

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

development of up to 35-40 high paying jobs. Manufacturing will occur in Grand Forks, ND. Even during the initial growth phase, as shown in the business plan, DGP will generate 24 jobs in its 4th year.

WHY THE PROJECT IS NEEDED

Many sectors within the State and Country are interested in developing carbon neutral and carbon negative technologies to utilize abundant, zero, or negative-cost feedstocks. These materials vary widely in composition and exhibit low-energy-density and availability. Detrimental effects such as these have significant techno-economic challenges for utilizing the conventional conversion technologies optimized for operation with processed coal. For these feedstocks, an ideal system will be distributed scale and fuel flexible, while accommodating significant compositional variations, overcoming feedstock shortages, and maintaining the consistent production of hydrogen or other valuable fuels. The Sandwich gasifier has these attributes.

There has been significant effort to develop technologies to economically and technically provide the ideal system described in the preceding paragraph. Unfortunately, most systems have been significant failures, and as a result, there is a lack of trust from investors and potential end-users of gasification and pyrolysis-based technologies. This project will build the confidence needed for full commercialization of the Sandwich gasifier by providing an operational commercial scale system for customers to visit and the ability to present real-scale performance and economic data generated from feedstocks with similar characteristics as our end-use customers.

Efficient and low-cost manufacturing of the system is important to the long-term success of DGP. The manufacturing readiness level (MRL) is currently at 6, meaning a majority of manufacturing processes have been defined and characterized and preliminary design of critical components has been completed and producibility assessments of key technologies are complete. A cost analysis has been performed to assess projected manufacturing cost versus target cost objectives and the program has in place appropriate risk reduction to achieve cost requirements or establish a new baseline. This project will take the MRL to 8, where manufacturing and quality processes and procedures will be proven and ready for low-rate production. At a MRL of 8, known producibility risks pose no significant challenges for low-rate production. The engineering cost model is driven by detailed design and has been validated with actual data. The supply chain is established and stable.

STANDARDS OF SUCCESS

The success of this project and the value it adds to the State will be evaluated from two points of view. Of primary interest are the direct benefits afforded by the establishment of Dakota Green Power as a manufacturer and supplier of waste-to-energy systems. Secondary indirect benefits will be obtained by the end users of the DGP systems. The direct measures of success include:

- A marketable waste-to-energy/fuels technology with the ability to process challenging waste streams with negligible solid, liquid, and gaseous emissions and net carbon negative.

- Annual net sales of $30-40,000,000 from the sales of five systems per year
- Development of up to 35-40 high paying jobs. Manufacturing will occur in Grand Forks, ND.
- Data required for end users to meet emissions and environmental permitting requirements
- Advancement of the MRL to 8, providing a pathway for sustainable manufacturing

Indirect measures realized by end-users of the DGP technology include:

- A proven option for the entities within the State to address future waste disposal issues
- Substantial CO_{2e} reduction/credit as compared to competitive technologies. A recent study performed for John Deere provides data showing net CO_2e emissions of negative (-) 768 kg CO_2 per ton of manure gasified (supporting calculations are presented in Appendix G).
- Realize greater than a 10:1 reduction in volume for waste materials processed
- Flexibility to stage feeding allowing the use of variable feedstocks eliminating the need for premixing
- Complete financial data allowing companies, cities, municipalities, and others to assess the economic viability of implementing a waste-to-energy technology as a part of their long-term waste management strategy.
- Generate electricity that can be net metered to demonstrate reduction of the City's electric bill
- Provide EERC and the UND campus with access to a demonstration facility to leverage funding opportunities expected as a result of the Federal Infrastructure bill.

BACKGROUND/QUALIFICATIONS

The core team includes Dakota Green Power (DGP), Tri-Steel Manufacturing, Singularity Energy Technologies (SET), Trilogy Financial Group (TFG), Barr Engineering Co. (Barr), the City of Grand Forks, Sage Green N.R.G., MDM Energy Consulting, John Deere, Steffes, and the University of North Dakota (UND). The roles of each of these core team members is summarized in Table 1. Resumes of key personnel are presented in Appendix F.

Table 1. Project Team and Primary Roles

Team Member	**Role**
Dakota Green Power	Prime contractor and project lead. Manufacturer of Sandwich gasifier systems
Singularity Energy Technologies LLC	Owner of patents. License patent rights to DGP. Input into long-term potential projects.
Tri-Steel Manufacturing	Manufacturer of gasifier components through established relationship with DGP and SET
Barr Engineering Company	Engineering firm of record. Prepare detailed construction drawings. Support development of end-user financial models
City of Grand Forks	Host site for facility, supplier of MSW, cost share partner

Trilogy Financial Group	Cost share partner and potential client of first commercial system
Sage Green N.R.G.	Provide support for permitting, marketing, and communications
MDM Energy Consulting	Provide support for project management, design, and reporting
John Deere	Engineering consulting to assess applicability of renewable fuels in John Deere engines
Steffes Corporation	Manufacture and certify specialized pressurized equipment
University of North Dakota	Provide engineering support including personnel for emission testing and monitoring, LCA, and system operation

Dakota Green Power (DGP) is a Grand Forks company specifically formed to develop and deploy the recently patented Sandwich gasifier in the global waste-to-energy marketplace. Dr. Nikhil Patel, the co-founder and CEO of DGP is the inventor and patent holder for the technology. He has 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. While working at Indian Institute of Science where he completed his PhD and later at the EERC, he invented the next generation gasification technology that his company, Singularity Energy Technologies LLC (SET) is now commercializing. In addition to continued development of his patented gasification technology, his interests are on advancing the technologies needed to fully utilize the gasifier for a wide range of end use applications, including internal combustion engines, micro turbines, fuel cells (SOFC and MCFC), advanced low-pressure, low-temperature, Fischer Tropsch, alcohol and chemical synthesis processes, CO_2 capture/utilization technologies, and syngas applications.

Mr. Scott Homstad is a co-founder and President of Dakota Green Power and the Manager/Secretary Treasurer at Tri-Steel Manufacturing Company. Tri-Steel Manufacturing, 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 the SET who earlier purchased from EERC and has invested into refurbishing and updating the previously mothballed system into a fully operational system with help of Dr. Patel. Mr. Homstad and Dr. Patel founded Dakota Green Power to develop and deploy the Sandwich gasification system. Their goal is to serve as a manufacturer 10, 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 in consultation under a license agreement with the SET technology provider.

Sage Green N.R.G. LLC is a Grand Forks, ND company which provides natural resource guidance to protect and improve public and environmental health. Dr. Nicholas Ralston, director of Sage Green NRG, has over 40 years of experience in applied research and has particular expertise in environmental aspects related to energy production. He provides advice and support in business considerations, marketing, networking, and outreach presentations, publications, and communications, and will be overseeing work performed to comply with environmental permits.

MDM Energy Consulting LLC provides support for the design, installation and operation of energy facilities. Its founder, Dr. Michael Mann 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 which will 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. He was the PI on a $2.27 million Department of Defense funded project on lightweight reliable materials for military systems. Previously while at the Energy & Environmental Research Center, he was responsible for the design and installation of their 1 MW circulating fluid bed combustion facility and their 1-MW transport gasifier and associated hot-gas cleanup unit.

Barr Engineering, headquartered out of Minneapolis, MN has 9 different locations, including an office in Bismarck, ND. Barr provides engineering and environmental consulting services to clients across North America and around the world. Barr works with clients on large, complex—and sometimes controversial—engineering and environmental projects, for which they provide everything from initial permitting and siting assistance through process and facility design to construction management, operations support, and closure planning. Nicole Nguyen, Barr Engineering's lead on this project brings over two decades of process development and deployment experience, including laboratory, pilot, and plant level systems.

MANAGEMENT

The team brings together the expertise required to advance our waste-to-energy technology to commercialization. The project structure is designed to facilitate management of the project by task. A detailed Project Management Plan is included as Appendix B. The task lead and lead individuals are shown in Figure 5. Dr. Nikhil Patel, 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 NDIC and other project participants/sponsors. Dr. Patel will work in close consultation with Mr. Scott Homstad, President of DGP. Mr. Homstad will play a major role in the development of the commercialization strategy and identification of potential customers. 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.

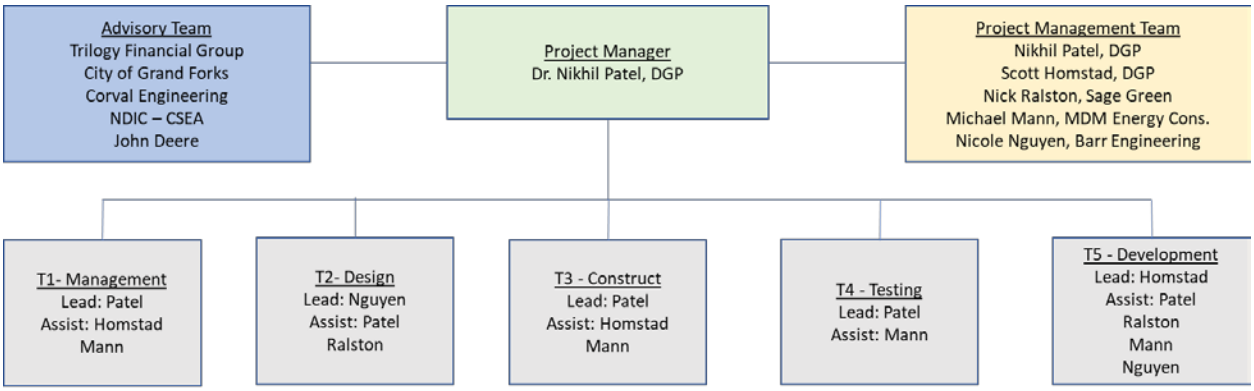

Figure 5. Project Organization and Team Participation

Nicholas Ralston and Michael Mann have been working with SET, the technology licenser since its inception. For this project, Nick Ralston will take the lead on obtaining permits and serve as the logistical interface with the City of Grand Forks (logistics related to site access), Excel Energy and Nodak Electric (potential off-take agreements), and other utility-related agreements required for the project. 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. 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. He 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.

Nicole Nguyen will serve as Barr Engineering's lead for this project. She will work closely with Dr. Patel and the DGC engineering team in Task 2 to deliver the design package required to construct the proposed 25 ton/day plant. She will also provide assistance as needed in the permitting process during Task 2. The work that Ms. Nguyen will do in developing construction drawings and cost estimates will also support Task 5. She has been a part of several waste-to-energy projects of various sizes and brings this expertise to the project.

To help support this project, Dakota Green Power will hire a full-time project supervisor who will be responsible for overseeing the day-to-day management of the construction and operation of the waste-to-energy system. This person will report directly to Dr. Patel and serve as the direct supervisor for operators and technicians working on this project.

Project sponsors representing key energy industry companies in the state and potential commercial project developers will form an advisory team to help guide the project.

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. Project review meetings with sponsors will be held semi-annually 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.

TIMETABLE

The project schedule for proposed project including major milestones is summarized in Table 2. The start date for project is projected as September 1, 2022. The verification methods will include providing data

and reports to the ND CSEA. In addition, meetings with ND CSEA will be conducted at periodic points in the project to provide detailed review of findings and future directions.

Table 2. Project Timing

Task	Timing (months)	Start Date	Planned End Date	Deliverable
Project Management	1 - 30	9/1/2022	3/31/2025	Quarterly reports and semi-annual project review meetings
Detailed Design				
Develop design package	1 – 6	9/1/2022	2/28/2023	Construction ready design package
Obtain required permits	1 – 6	9/1/2022	2/28/2023	All required permits obtained
Obtain off-take agreements	2 - 8	10/1/2022	4/30/2023	Agreement in place to take produced electricity
Procurement/Construction				
Procure major equipment	6 – 11	2/1/2023	7/31/2023	Orders placed for all major equipment
Site preparation	4 – 10	12/1/2022	6/30/2023	All building upgraded completed
Install equipment	9 – 16	5/1/2023	1/31/2024	Facility construction completed
Shakedown system components	17 – 18	2/1/2024	3/31/2024	All systems tested and fully operational
HAZOP Review	14-16	12/1/2023	1/31/2024	HAZOP review completed – design updated
Testing of Selected Feedstocks				
System optimization on railroad ties	19 – 21	4/1/2024	6/30/2024	Gasifier successfully operated for 30 days – 5 days continuous with at least two cold starts and four hot starts
Testing of end use applications	19 – 23	4/1/2024	8/31/2024	
		9/1/2024	11/30/2024	Integrated system operated with engine to generate electricity and with GTL to produce liquid fuels
Alternative feedstock testing	24 – 26	4/1/2024	11/30/2024	Steady-state operation demonstrated for each fuel tested
Emission and performance certified	19 - 26			Emission performance data collected for all feedstocks and end use applications
Economic Evaluation & Business Plan Development				
Develop commercialization plan	1 – 30	9/1/2024	3/31/2025	Fully develop business plan. BAIL identified
Develop end-user marketing tools	9 – 30	5/1/2023	3/31/2025	Marketing material including interactive spreadsheets developed. LCA fully developed and verified
Final Report	29-30	2/1/2025	3/31/2025	Report delivered and accepted by ND CSEA

BUDGET

Tables 3 and 4 present a summary of the required budget for this grant application. Table 3 presents the budget by Task, Table 4 is a breakdown by major cost category. Both budgets indicate the cash

requirements for the project and the in-kind cost share provided by project partners. Table 5 provides a breakdown of the cost share contributions for this project. A detailed breakdown of the budget is presented in Appendix H.

Table 3. Budget breakdown by Task

Project Associated Expense	NDIC Grant	NDIC Loan	Applicant's Share (Cash)	Other Project Sponsor's Share	Total
Project Management	$101,865		$101,865	$0	**$203,730**
Design	$300,865		$26,715	$274,150	**$601,731**
Construction	$4,087,177		$242,575	$4,087,177	**$8,416,928**
Testing	$700,317		$169,765	$530,552	**$1,400,634**
Business Development	$181,233		$101,247	$79,986	**$362,466**
Total	$5,371,457		$642,167	$4,971,865	**$10,985,489**

Table 4. Budget Breakdown by Category

Project Associated Expense	NDIC Grant	NDIC Loan	Applicant's Share (Cash)	Other Project Sponsor's Share	Total
Labor Cost	$1,319,991		$161,138	$1,158,853	**$2,639,983**
Subcontractors	$509,350		$91,650	$417,700	**$1,018,700**
Operation and Supplies	$291,148		$265,000	$168,723	**$724,871**
Travel	$25,631		$24,379	$1,252	**$51,262**
Equipment	$2,936,750		$0	$2,936,750	**$5,873,500**
License	$0		$100,000	$0	**$100,000**
Contingency	$288,587		$0	$288,587	**$577,173**
Total	$5,371,457		$642,167	$4,971,865	**$10,985,489**

Table 5. Funding breakdown by support source

Support Source	Amount	% of Project
NDIC - CSEA	$5,371,457	48.9%
Dakota Green Power	$185,517	1.7%
Trilogy Financial Group	$4,971,865	45.3%
City of Grand Forks*	$240,000	2.2%
Singularity Energy Technologies	$100,000	0.9%
MDM Energy Consulting	$70,200	0.6%
Sage Green N.R.G.	$21,450	0.2%
Client Feedstock	$25,000	0.2%
TOTAL	$10,985,489	

*Estimated value based upon value of commercial rental space

The project team has developed detailed P&ID for the 25 ton/day system envisioned for this project. Budgetary quotes were obtained for the major pieces of equipment. Estimates for the equipment costs for other minor pieces of equipment including the costs of assembly and fabrication were based off of experience from Tri-Steel Manufacturing and their current business model. Labor costs for the construction and fabrication phase were also based upon similar experience from Tri-Steel Manufacturing.

Labor estimates for the testing phase were estimated based upon Dr. Mann's experience in the design and construction of the 12 ton/day rare earth element extraction plant that was built at UND over the past two years under his supervision. The major supply costs for the testing phase were estimated upon the projected raw material input and gas flow rates and composition for the planned feedstock consumption rates. Additional supply costs were estimated based upon Dr. Mann's experience performing similar testing during his time with the EERC and the Institute for Energy Studies.

Bids were obtained from prime contractors and their bids are included in the letters of support included in the appendices.

An intermediary level of detail of the cost estimation for this project are included as Appendix H. An additional level of detail is available upon request by the NDIC CSEA.

In the event that the State does not approve the full amount proposed, the project would look to reduce the overall cost by first reducing the size of the gas-to-liquid unit used as a part of the demonstration, with further reduction in cost being accomplished by using a smaller engine-generator set. These reductions in size would still allow the technology to be demonstrated but would result in the performance data and costs for the full-scale systems proposed to potential customers to be extrapolated from the smaller GTL and engine testing. It would also require a portion of the syngas to be flared rather than being converted to electricity and/or liquids. Dakota Green Power will continue to seek funding from potential client to enhance the work scope and deliverables from the proposed project.

TAX LIABILITY

Dakota Green Power does not have an outstanding tax liability owed to the State of North Dakota or any of its political subdivisions. A Tax Liability form is included as Appendix L

CONFIDENTIAL INFORMATION

Information included in Appendices H, I, J and K is privileged and confidential. Such information shall be used or disclosed only for the review and evaluation purpose. A confidentiality form is included as an introduction to each confidential appendix.

PATENTS AND 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:

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)

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).

BUSINESS PLAN

Dakota Green Power's Business Plan is presented as Appendix I including budgeted projections and it organizational documents. DGP is a new spin-off company formed by Tri-Steel Manufacturing for the purpose of manufacturing and marketing the gasification technology. Therefore, DGP does not have three years of financial history. Three years historical financial information is provided for Tri-Steel Manufacturing (Appendix J).

APPENDICES

Non-Confidential Appendices

Appendix A – Detailed Description of Sandwich Gasifier Technology

Appendix B – Project Management Plan

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

Appendix D – Letters of Support

Appendix E – Manufacturing Readiness Level Definitions

Appendix F – Resumes of Key Personnel

Appendix G – Example Life Cycle Assessment

Confidential Appendices

Confidential Request

Appendix H – Budget Details

Appendix I – Dakota Green Power Business Plan

Appendix J – Tri-Steel 3-Year Financial Statement

Appendix K – Confidential Letters of Support

Appendix L – Tax Liability Statement