Clean Sustainable Energy Authority

North Dakota Industrial Commission

Application

Project Title: Green Hydrogen Generation and Storage System

Applicant: BWR Innovations LLC

Date of Application: February 28, 2022

Amount of Request
Grant: $5,764,000
Loan: $0

Total Amount of Proposed Project: $16,400,000

Duration of Project: 36 months

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ABSTRACT

Background:

During the next 20 years, North Dakota and the United States will be going through a significant transition in our energy sector. This has been documented in multiple studies and is widely accepted. Our electrical grid will move to a higher percentage of clean energy, while at the same time the demand sector will be increasing significantly.

North Dakota stands at the center of this change. A July 2021 study by the American Petroleum Institute reinforced that North Dakota's economic outlook is brighter when it leads the world in energy production. North Dakota contains the largest deposit of lignite in the world. North Dakota has also used coal to produce synthetic natural gas for export. The state is also blessed by tremendous wind assets that utilize wind turbines to generate about a third of the states' electricity. While the supply of lignite and wind are both local and in great supply there is a need for a better way to utilize these assets. There is also a need to diversify the current energy portfolio with more renewables and a need to store this energy to deploy at the most appropriate time.

Green hydrogen checks off all the boxes. The global green hydrogen market is expected to reach a market size of USD $2,569 Million by 2028. North Dakota has both the distribution infrastructure and energy industry experts in the state to exploit this rapidly growing opportunity. The BWR green hydrogen energy generation and storage system is the "missing link" as the world races towards Net Zero with the electrification of everything. Green hydrogen is the only solution for many industries that cannot adapt to electrification. The transportation sector is a great example as both airlines and long-haul trucking seem to be industries most in need to convert from fossil fuel technologies to green hydrogen. Investing in green hydrogen technology will "future proof" the energy industry in North Dakota.

As we will outline, CSEA could benefit from funding smaller scale less costly hydrogen projects that can be deployed near term. Agriculture is another industry experiencing a sea change of new technology combined with legislative ESG pressures. North Dakota farmers are looking for additional revenue streams, input cost reductions and new ideas around environmentally sustainable practices. Once again green hydrogen checks all the boxes. Farmers can produce and then sell their excess green hydrogen, lower their energy costs and reduce their carbon footprint all with one system. When sized properly, the BWR system would allow for a 100% off grid solution for the farmer or business looking to become energy independent and immune to demand charges and power outages.

A recent study, "INTEGRATING DISTRIBUTED SOLAR AND STORAGE: THE KEYSTONES OF A MODERN GRID" published by the Coalition for Community Solar Access states:

"The United States must transition to an energy sector powered by clean energy as rapidly as possible to meet ambitious state and federal clean energy and climate targets. It must also keep pace with an exponential increase in energy demand resulting from the electrification of the building and transportation sectors. To accelerate the rapid adoption required to meet these combined needs, federal

and state policymakers will need to intentionally reform and make proactive investments in comprehensive system planning and grid modernization, which will significantly improve the process of physically integrating distributed energy resources (DERs) into the electric grid and will lead to significant economic benefits for all Americans" [1]

There is a "missing link" between conventional electrical production (using traditional electric grid sources) and renewable energy sources, resulting in inefficiencies and negative financial implications. Renewable energy sources do not provide the consistent "on-demand" delivery of electricity. Solar panels produce electricity only when the sun is shining, and wind turbines only produce electricity when the wind is blowing. To further complicate the problem, the times of peak renewable electric production does not always correspond with peak electrical demand. Batteries have been viewed as an answer to provide this link between supply/demand needs, but the capabilities are limited and costs (financial and environmental) of batteries are very high.

Objective:

BWR has developed a green hydrogen generator and backup power storage system that uses renewable energy at a local level that would be otherwise lost, creating hydrogen through electrolysis. The PowerHouse hydrogen system provides an alternative for energy storage while providing the use optimization that will produce significant financial benefits.

The captured hydrogen is used on-demand by fuel cells to produce electricity. Put simply, the Powerhouse system "bottles sunlight", storing energy to be used when needed. An estimated 50% of green generated electricity is not used effectively and is either "lost" or not used. Now, excess renewable electricity is best captured at a local level, where use is optimized, and excess energy is stored as hydrogen.

Sites with renewable energy (solar or wind) and PowerHouse generators have three electrical sources available as needed: 1) traditional grid power, 2) solar and/or wind, 3) hydrogen fuel cell. Cloud-based telemetry available as part of PowerHouse provides "real time" analysis of energy costs of the three electrical sources. When the sun is shining and electricity from the solar panel is essentially free (variable cost only), the PowerHouse generator provides electricity to the site from the solar panels. If solar power is not available and grid power is at a low price point, grid power is delivered to the site. If the prices of grid power rises (or if there is an electrical outage), electricity produced from the stored hydrogen is delivered.

1. "Integrating Distributed Solar and Storage: The Keystones to a Modern Grid", Coalition for Community Solar Access, Washington DC USA, February 2022

PowerHouse generators are a critical missing piece to the large-scale movement to “zero-carbon” proclaimed by thousands of international companies and nearly every national government. BWR’s design is a scalable and modular design that will demonstrate the production and storage of energy efficiently, with zero carbon emissions, minimal maintenance, and virtually no operating expenses. The generator has multiple applications, and BWR Innovations has identified immediate market opportunities across various industries including agriculture, oil production, manufacturing, retail and microgrid powered electric vehicle recharging stations.

There are multiple benefits of the PowerHouse for the industrial customers. These include 1) Cost benefits where power is expensive, 2) Reliability and storage of energy for long term needs, 3) environmental considerations (ESG) 4) instant backup power. Each of these alone are a priority, and where two or more are a priority, the PowerHouse could be a viable solution.

PowerHouse is a synergistic tool designed for localized energy production and control that will optimize the creation, use and value of the electricity from renewables (solar and wind), traditional grid and the hydrogen fuel cell. The addition of hydrogen as an energy storage option will capture all of the excess and previously lost solar energy, storing it until it is optimally needed (grid costs are above the optimal threshold). The commercial industrial customer that we have identified is one that would traditionally use between 50-150 kW of power.

At the conclusion of the project, BWR Innovations will deploy 20 pilot programs for 70kW clean energy hydrogen generators and demonstrate the performance, near term and long-term value of the hydrogen system. Pilot programs will target end use customers that will best validate the benefits, with North Dakota opportunities being a priority. We have initially identified agricultural installations and oil/gas production installations. We have had discussions with companies that see the value and potential of the PowerHouse.

These generators will facilitate improved green energy management at agricultural production facilities, industrial facilities or retail/industrial facilities and provide the economic validation to replicate this model across North Dakota and the nation. The project will store excess energy by producing hydrogen and storing it in a local tank. Above the standby hydrogen level, excess energy (electricity or hydrogen) can be sold back to utility companies or third parties, creating a new market of income for North Dakota farmers.

This project will validate the scope of BWR Innovations’ PowerHouse clean energy systems to provide the electricity used in multiple agricultural applications, or oil field applications at near zero variable cost. These units will potentially replace conventional standby generators by creating hydrogen as a portable energy source in a cost effective, environmentally sound and economically viable method.

The success of this project will lead to manufacturing of fuel cell systems in North Dakota, economic diversification within North Dakota, commercialization of intellectual property developed in North Dakota, creation of new science in mechanical engineering, electrical engineering, and finance, and the capability for North Dakota individuals and businesses to generate, store, and sell energy in new and reliable ways.

The commercialization of this hydrogen fuel cell microgrid is substantial. The 8-year potential for this is in excess of five thousand (5,000) individual installations, working with specialized industry specific distributors and with individual companies. There are also domestic and international opportunities where unique issues provide restrictive obstacles for secure localized electrification.

BWR is integrating the PowerHouse with established components from proven and established companies, including the fuel cell, electrolyzer, compressors, inverters and tanks. These will be assembled with the patented BWR telemetry and optimizer in Fargo ND. BWR has been successfully integrating the Intelligent Energy fuel cells into producing generators since 2019.

To support the growth, BWR has the manufacturing commitments to quickly ramp up production with contract manufacturers in North Dakota. Since we are assembling proven components, production can be quickly increased to meet the market needs.

Duration:
BWR Innovation proposes this project to be completed in thirty-six (36) months.

Total Project Cost:

The total pilot project cost is estimated to be $16,400,000 and we are requesting a grant of $5,764,000 with the remaining funds provided by purchase orders for the 20 pilot projects and BWR contributions. With the successful demonstration of these projects, the demand for the PowerHouse generator system will grow quickly in multiple industries, in North Dakota and across the country.

Participants: Companies participating with BWR for the assembly of the PowerHouse Green Hydrogen Generating System include (but are not limited to):

Intelligent Energy: (Loungborough, England, UK) is BWR Innovations' partner for the individual fuel cell modules. BWR Innovations and Intelligent Energy have been collaborating since 2019, creating fuel cell generators with the combination of Intelligent Energy air-cooled proton exchange membrane fuel cell modules and BWR Innovations integration of modules, inverters, telemetry, and controls. Intelligent Energy best-in-class fuel cell modules are used in multiple applications, from automotive to unmanned aircraft to the stationary power systems proposed in the document.

Enapter: (Saerbeck, Germany) is BWR Innovations partner for individual electrolyzer modules. Enapter is a 2021 award winner for the prestigious international Earthshot Prize award for their Anion Exchange Membrane technology. BWR Innovations is integrating Enapter's electrolyzers in our design for the Renewable Energy Council, and has completed Enapter training and courses to qualify as a certified Enapter integrator.

Assembly Systems: (West Fargo, ND) is BWR Innovations partner for production assembly of fuel cell generators. Assembly Systems is a certified ISO 9001:2015 manufacturer, with direct input to the BWR Innovations design process for design-for-manufacture, design-for-test, and design-for-reliability. Assembly Systems is an operating division of Interstate Companies Inc. (Minneapolis, MN), a group of fifty business units throughout the United States for manufacturing and assembly support. Assembly

Systems is a critical component of the proposed work, as successful outcomes will add uniquely to the North Dakota manufacturing base and the North Dakota energy economy.

Artemis AG-Solutions is a global agricultural solutions company that is closely tied with major food production companies such as Cargill and Tyson.

Master-Flo is a leading manufacturer and distributor of valves and pipeline components that are used throughout the oil industry. Both Artemis AG-Solutions and Master-Flo have identified specific use cases for the BWR Innovations' PowerHouse generator for this proposed research.

Other local and regional partners participating in the proposed development include (but are not limited to):

- **Grand Farm** is providing test site access as well as assists in creating the use models for a sustainable agriculturally based electrical system. **Newava** supplies electrical harnesses and electrical sub-assemblies. **Digikey** is a key supplier of components. **Network Center** provides services for web-based data analysis used in the telemetry.

PROJECT DESCRIPTION

Objectives:

This project has the following objectives:

- Demonstrate the value and performance specifics of North America's largest localized "green hydrogen generation and storage system"
- Leverage North Dakota's considerable lignite, oil/gas and renewable assets to exploit and capitalize on the rapidly growing green hydrogen market
- "Future Proof" North Dakota's status as a world leader in energy production with the creation of a new localized Green Hydrogen manufacturing & distribution facilities.
- Eliminate power outage disruptions with the instantaneous delivery of backup electricity.
- Optimize the dispatch of grid generation (fossil fuel and wind), local renewables & stored power.
- Provide for significant power cost deductions in both Ag and Commercial sectors though the reduction of monthly peak demand load charges from the local utility.
- Local grid resiliency improvements that will positively impact Utility sub-station load stresses.
- Improved understanding of peak load times via the use of telemetry to gather real-time data.
- The creation of additional revenue streams for farmers in the Ag sector with hydrogen sales.
- The capture and storage of "curtailed" or wasted renewable energy for back up use or resale.
- Validate a localized link for distributed energy resources that can be expanded across North Dakota and the nation.

Methodology:

BWR Innovations is a partner in the Southern California Gas Home Hydrogen demonstration, a novel approach for creating and storing renewable energy in hydrogen tanks. This H2 Hydrogen Home demonstration uses solar panels only (no wind energy) as its renewable energy source, with the stored hydrogen feeding fuel cell systems provided by BWR Innovations to provide electricity during evening and nighttime hours. Fast Company magazine has recognized the Home Hydrogen demonstration as a "World-Changing Idea".

In addition, BWR Innovations and Grand Farm are partners in the development and deployment of a clean energy electrical system for their Grand Farm Research and Education Initiative site. This design couples 40kW of solar panels, 10kW of wind turbines, and 20kW of fuel cell generation to produce continuous power for the Grand Farm site without carbon emissions, maintenance, noise, or operating costs. This unique electrical system provides an opportunity for the site to sell energy as either electricity or hydrogen, enabling energy as a "cash crop."

This project builds on the design of the "World-Changing Idea" and the Grand Farm design, by increasing the scale for agricultural scales. The efficiencies of renewable energy systems have increased dramatically over the years, and subsequent costs have decreased as economies of scale develop.

While the production of electricity is well known, there is to date an inability to effectively store excess energy. While batteries are often proposed, using batteries for electrical storage is not practical, due to the cost, size requirements, and availability of the number of batteries needed for large scale energy storage.

BWR Innovations proposes a unique energy storage methodology, using compressed hydrogen as a means to efficiently and cost-effectively store energy. The compressed hydrogen is created by an electrolyzer, which is powered by the excess electricity from the renewable energy sources. The electrolyzer takes inlet potable water and splits the hydrogen-oxygen mixture into hydrogen gas and oxygen. The hydrogen is then compressed and stored, in tanks similar to propane tanks found throughout North Dakota.

When the sun stops shining and the wind stops blowing, the compressed hydrogen is used to create electricity through the use of fuel cells. The fuel cells create electricity from compressed hydrogen, and the electricity produced can power the installation. Excess energy from the fuel cells can be sold back to utility companies on demand, as a form of distributed electrical generation to supply electricity to the grid in times of excess demand. Figure 1 shows the operation of the renewable energy production and storage.

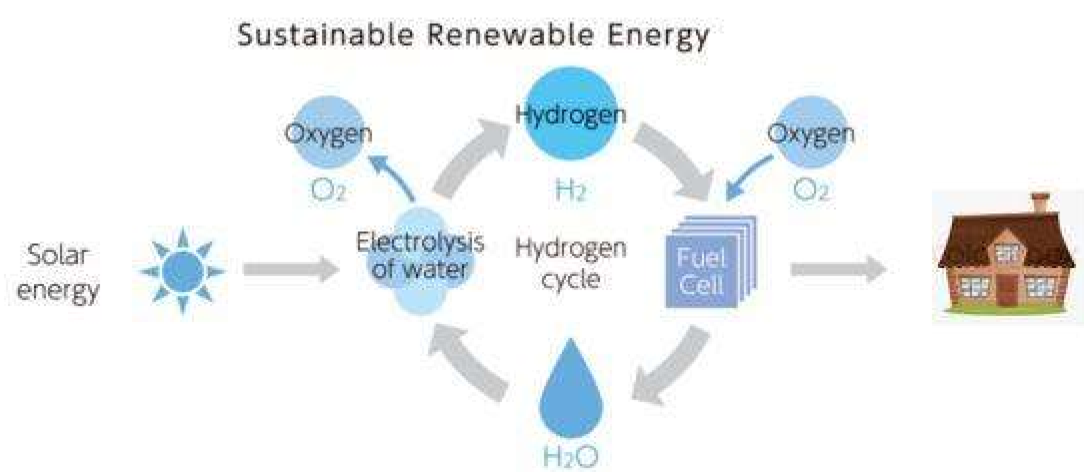


Figure 1. Renewable energy cycle. Solar energy produces hydrogen, which is used to produce electricity when the sun stops shining.

Another option is to sell any excess hydrogen into a rapidly growing market as a portable energy source. This can be sold in a pressurized container or potentially commingled in a natural gas pipeline.

The proposed installation will be the largest demonstration of a complete green hydrogen system in North America and is a model that can be implemented throughout North Dakota, the United States, and worldwide. The only inputs to the system are sun, wind, and water, and the output is clean energy (electricity and compressed hydrogen). Figure 2 shows the installation and the major components.

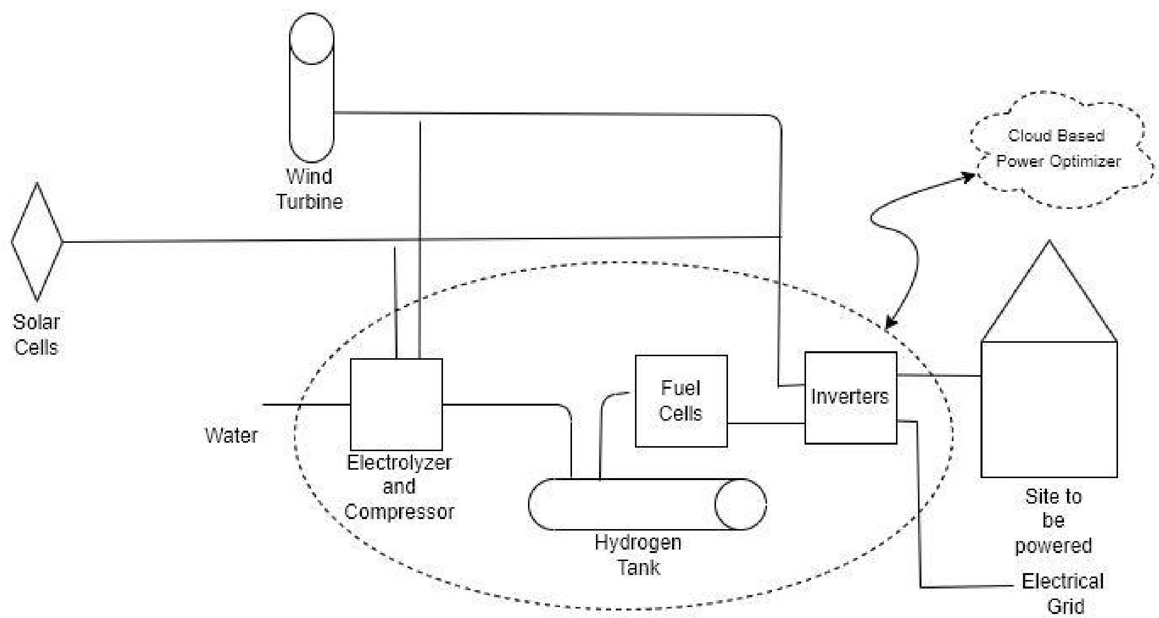


Figure 2. Block Diagram of the Clean Energy Generator System

As shown in Figure 1, real-time data from the PowerHouse generator is uploaded to Amazon Web Services for cloud-based services. Data from the PowerHouse generator includes, but is not limited to, the amount of power demanded by the site, the power created by renewable energy sources, the power created by the PowerHouse generator, and the run time available by the PowerHouse generator. This data is used to create a powerful Cost Optimizing Application.

The Cost Optimizing Application compares the power demand to the energy creation by renewable sources. If the power created by renewable energy is greater than the demand, the Cost Optimizing Application recommends using 100% of the renewable power. If the user accepts the recommendation, renewable energy is provided to the site at a near zero cost.

If the power created by the renewable energy source cannot meet the demand, the Cost Optimizing Application will compare the costs of grid power to the costs of power created from hydrogen in the PowerHouse generator. Additionally, the Cost Optimizing Application will review the available run time of the PowerHouse generator, based on the real-time measurement of the stored hydrogen tanks. The Cost Optimizer will recommend the lowest cost source of electricity to the user.

Once the user accepts a recommendation from the Cost Optimizer Application, the cloud-based telemetry downloads commands to the PowerHouse generator to select the appropriate source (grid power, renewable power, or hydrogen produced power.) After making a recommendation, the Cost Optimizer Application continually monitors the energy demand by the site, the power created by the renewable sources, the run time of the PowerHouse generator, and the current cost of grid power. If any of the factors change significantly, the Cost Optimizer Application will re-evaluate and determine if a new recommendation needs to be provided. All data will be gathered in the AWS files for evaluation and analysis.

Project Management

BWR Innovations uses design methodologies similar to those created for mission-critical electronics, specifically DO-254 design methods. The first major subtask is Design Capture, where the requirements, design environment, test plan, and preliminary vendor list is documented. These documents are critical, to accurately capture all of the performance, size, weight, cost, and environmental constraints of the microgrid design. Once all of the documents are complete, a review for all stakeholders occurs where the requirements are refined and ultimately approved. The approved requirements serve as a template for the conceptual and physical design reviews that will follow.

After the design requirements are documented, the conceptual design tasks follow. These tasks are using computer aided design to create computer-based models to implement the microgrid requirements. For electrical engineers, the conceptual design tasks are harness designs and printed circuit board designs. Software engineers will create software code, and mechanical engineers will make layouts of chassis, enclosures, and fasteners. At the completion of the conceptual design, a complete set of drawings are available for review. The review verifies that the concept drawings will meet the requirements from the Design Capture phase, but also that the concept drawings have considerations for manufacturing, test, field support, procurement, and marketing.

The third stage is the physical design. The items from the conceptual design are prototyped and combined with procured items for the first integrated working model of the system. With all the pieces assembled and integrated, the working prototype is debugged, tuned, and performance tested against the Design Requirements from the first stage. The physical design may also then be stress tested, to verify reliability and stability, as well as to create procedures for installation, field use, troubleshooting, and customer service support.

The last stage is the design assurance. During this stage, the field-tested design is operated for extended durations to fully understand the issues that would be seen by end customers. Does the microgrid have long startup times, and does the startup time vary from winter to summer? Does humidity affect the energy capture of renewables? Is the pressure level of hydrogen affected by temperature? This stage uses the comprehensive telemetry expertise of BWR Innovations to accumulate the data available from the microgrid system, analyze for changes over time, and then start predictive analysis to be able to treat changes in performance or reliability before the system performance degrades or failures occur. A natural outcome of the design assurance stage is cost modeling and analysis. The cost analysis, combined with the performance data, sets the stage for future recommendations and proposed installations. This stage is data and computation extensive, and BWR Innovations is uniquely poised for a successful design assurance completion.

Anticipated Results:
BWR expects to demonstrate an electrical system capable of providing the entire electrical demands for a site, store sufficient energy to provide a buffer during periods of time when the sun isn't shining and the wind isn't blowing, and the capability for providing energy as a revenue source.

The demonstration of the renewable energy storage system will provide energy independence and resiliency, ensuring electricity to the site independent of rolling blackouts or weather-related electrical gird interruptions. In addition, the ability to store and sell electricity to the electrical grid at any point in time, not limited to only when the renewable energy source is producing electricity, allows the site owner to sell electricity as a commodity, garnering the best prices instead of at spot prices when demand is lowest.

Facilities:
BWR Innovations has facilities for design, test, integration, and design validation at our office in Fargo, ND. Additional resources is available to BWR Innovations through Dr. Jorgenson's affiliation at North Dakota State University Electrical and Computer Engineering in his role as Adjunct Professor of Computer Engineering.

Further facilities are available to BWR Innovations through our membership in the United States Department of Energy sponsored REACH Accelerator cohort (https://reachenergyaccelerator.org/). Through our membership of the Reach cohort, BWR Innovations will be doing product testing and design validation at the National Renewable Energy Laboratory (nrel.gov) in Golden, Colorado.

Resources:
No unique or rare resources will be needed for this project. All of the energy is developed from solar and wind, and a small amount of potable water would be needed (not to exceed 0.5 gallons per hour.)

Techniques to Be Used, Their Availability and Capability:
The solar energy is captured by stationary solar cells, using photovoltaic cells to create DC voltage that powers the site through inverters (converting DC voltages to AC voltages). The excess energy from the solar cells powers the electrolyzer and compressor, converting solar energy to compressed hydrogen. Similarly, the renewable energy from wind is captured by a wind turbine, also powering the site through the inverters and powering the electrolyzer and compressor.

The electrolyzer is a rack mounted unit that may be stacked in a modular design, to create the required amount of hydrogen production. The system is modular and scalable with the potential hydrogen production as high as 120 kg of hydrogen per day.

The compressor and storage tank are common gaseous components, similar to tanks used to store propane. The valves, regulators, lines, and fittings are all commercially available at gas suppliers such as Airgas or Praxair.

The fuel cell modules are available from Intelligent Energy. The fuel cell modules, models FCM804s, are units that BWR Innovations has used for years in various products and are scalable in units for 4kW per module. For this installation, BWR innovations is proposing an installation of a single 70kW fuel cell module (model # IE-70).

The inverters proposed in this installation are modular components that provide AC power from DC inputs. These units are capable of providing the complete needs of the site, whether the source of the energy is wind, solar, fuel cells, or any combination of the three sources. A single inverter produces single phase power, two inverters produce split phase power, and three inverters produce three phase power.

All of the components of the system are connected to BWR Innovations telemetry system. The power produced by the solar cells and the wind turbine are recorded. The hydrogen production from the electrolyzer is monitored, as are other parameters within the design. The hydrogen level in the storage tank is monitored, and the fuel cells are controlled by the BWR telemetry system.

All of the components are commercially available. BWR Innovations has partnership with the suppliers for the compressors, storage tanks, fuel cells, inverters, and the site for a target installation. The telemetry system is available from BWR Innovations, and is similar to the telemetry system that BWR offers throughout the United States and Canada via distribution.

This combined system will be the largest planned installation in North America. BWR Innovations is a partner in the Home Hydrogen Demonstration of Southern California Gas, which is based on a 4kW fuel cell installation. BWR innovation is providing the turnkey fuel cell system, inverters, and telemetry control for Southern California Gas.

Environmental and Economic Impacts while Project is Underway:
Once operational, the site will produce all of the energy needed, capturing renewable energy from wind and solar sources. The unique aspect of the project is to capture excess energy and store it in the form of compressed hydrogen gas. Hydrogen gas is the most abundant element in the world and is an extremely clean, safe, and efficient form of storing energy.

When the hydrogen is consumed by fuel cells to produce electricity when the solar energy and wind energy is not available, the fuel cells convert compressed hydrogen to electricity. The byproduct of the fuel cells is water vapor, which has zero environmental impact. At no point of the operation is any carbon produced or any harmful emission present.

Regarding the economic impact, the site will be able to produce all of the electricity needed with zero operational costs, virtually zero maintenance, minimal noise, and may be able to sell excess energy. Excess electricity may be sold to the electrical grid with an optional synchronizer, and excess hydrogen may be sold using portable storage tanks that are filled from the compressor and the hydrogen storage tank on the site. The electricity is likely to be sold at wholesale prices, and compressed hydrogen of 99.9% purity may be sold at a commercial price of $16 per kg.

Ultimate Technological and Economic Impacts:
BWR Innovations is proposing an installation that is scalable, modular, and reconfigurable in creating

electricity and storing energy with zero carbon footprint. The system has telemetry monitoring that allows anywhere, anytime, any platform access of authorized users, and has the ability for utility company control. The ultimate goal of the system is to replicate to any site that desires to have energy as a revenue stream for their operation, where the excess is available as a shared resource in distributed generation.

Having the controls available at the utility level produces a robust distribution network. As the future moves towards microgrids and distributed generation of energy, BWR Innovations' concept is a solid basis that can be replicated anywhere in North Dakota, the United States, or the world.

With the transformation in the US electrical grid as the nation moves from large power plants to distributed clean energy sources, there is a gap that BWR is addressing. In the near term, BWR expects demand for medium sized (~70kW) fuel cells to exceed 5,000 units over the next 8 years. BWR is working with distributors and key industrial partners to purchase and install these units.

Why the Project is Needed:

Carbon minimization and climate change will be accomplished by the localized changes and results by thousands of organizations along with personal choices. Hydrogen is a clean energy source that is believed to be a widely used fuel for many applications. The PowerHouse is a new concept that is using proven technologies combined with telemetry and programming that will allow for the most efficient use of solar, energy storage and traditional grid power.

This project will provide the "third leg" of the energy stool, allowing for the most efficient use and storage of electricity at a localized level. This demonstration will prove the effectiveness of the PowerHouse and assist in further evaluation of the link between solar/grid and long-term energy storage (via Hydrogen) and as a clear path for organizations to achieve the "net zero carbon" goals.

The project is needed to demonstrate the capability of energy storage via compressed hydrogen, to demonstrate the green energy approach of using renewable energy to produce compressed hydrogen, and to demonstrate a standalone microgrid capable of meeting its own energy demand and providing the excess energy as a revenue stream. North Dakota has immense potential with wind and solar energy but finding the most economical method of utilizing this energy is not a clear path. The storage of energy via compressed hydrogen and then the sale of this compressed hydrogen into the rapidly growing market for hydrogen could be significant for existing and new wind/solar production capacity.

The enclosed micro grid that this will demonstrate could also be a prototype for energy savings/production in existing agricultural facilities, industrial and retail facilities. The compact footprint and sizable energy production could be a model for use across the state and as a replacement for the many "stand by" power generation assets.

This capability will produce a whole new market for North Dakota farmers and industries with the sale of energy through electricity and hydrogen.

STANDARDS OF SUCCESS

The standards by which the success of the project is to be measured. This may include:

- *Emissions reduction.*
- *Reduced environmental impacts.*
- *Increased energy sustainability.*
- *Value to North Dakota.*
- *Explanation of how the public and private sector will make use of the project's results, and when and in what way.*
- *The potential commercialization of the project's results.*
- *How the project will enhance the research, development and technologies that reduce environmental impacts and increase sustainability of energy production and delivery of North Dakota's energy resources.*
- *How it will preserve existing jobs and create new ones.*
- *How it will otherwise satisfy the purposes established in the mission of the Program.*

The standards of success are straightforward, based on the objectives proposed by BWR Innovations:

- The demonstration of a site producing sufficient electricity via renewable energy to completely meets its own electricity needs, with excess energy creating stored energy,
- A robust, reliable microgrid that is demonstrated to operate year-round, being impervious to temperature and wind conditions of the North Dakota weather,
- The capability to sell excess energy, either through the sale of electricity to utility companies or the sale of compressed hydrogen gas, ultimately in tanks or diverted to a natural gas pipeline.
- The demonstration of a reasonable return on investment, where future installations can expect to generate revenue and create cost savings to offset any investments for their microgrid system.

If these standards are satisfied, North Dakota would see a new era of energy, energy production, and the sales of systems that would make North Dakota the world's leader in energy systems:

- Fuel cell systems, provided by Intelligent Energy and assembled at Assembly Systems,
- Telemetry systems, designed by BWR Innovations, assembled at Trison, with components from Newava and Digikey,
- Cloud based monitoring, developed by BWR Innovations and the Network Center,
- A new market for energy, which North Dakota can utilize in state or to sell/distribute to customers throughout North America.

BACKGROUND/QUALIFICATIONS

Please provide a summary of prior work related to the project conducted by the applicant and other participants as well as by other organizations. ***This should also include summary of the experience and qualifications pertinent to the project of the applicant, key personnel, and other participants in the project.***

BWR Innovations is uniquely capable for this project due to our products, partnerships, and intellectual property. Our module fuel cell system, scalable from 4kW to 70kW, is unique in the fuel cell marketplace. Currently, most fuel cells are either targeting mobility and material handling (greater than 100kW) or drones (less than 1200 Watts.) The collaborative partnership between BWR Innovations and Intelligent Energy (see attached letter of support) outlines BWR's role as Intelligent Energy integration partner for turnkey fuel cell systems in the United States. Finally, our issued patent in distributed electrical generation (US 11,08,508) along with patents pending in distributed hydrogen generation and utility level control of fuel cell systems is a barrier to entry to any other entity considering this space.

The technical components of this project are led by Dr. Joel Jorgenson, CEO and President of BWR Innovations. Dr. Jorgenson has earned electrical engineering degrees from North Dakota State University (BSEE, 1987), the University of Iowa (MSEE, 1993), and Iowa State University (Ph.D., 1998), and is currently completing his Master of Business Administration degree at the University of Illinois. Dr. Jorgenson holds patents in fuel cell systems, power management, and telemetry, and is an adjunct professor at North Dakota State University's Electrical and Computer Engineering Department. Dr. Jorgenson has been awarded Entrepreneur of the Year by the Fargo-Moorhead Chamber of Commerce, the Architect of Defense by the Minnesota Defense Alliance, and has numerous accolades, publications, and positions.

The program management components of this project are led by Thomas Nelson, Fuel Cell Systems Program Manager of BWR Innovations. Mr. Nelson is a serial entrepreneur and successful business owner, with decades of experience in small and medium businesses throughout Minnesota. Mr. Nelson is leading the business development and advanced partnership at BWR Innovations, and holds a Bachelors and a Masters of Business Administration from the Carlson School of Business at the University of Minnesota.

The consumer outreach and feedback monitoring components will be led by Mr. Douglas Goaley, Director Sales & Strategy for BWR. Mr. Goaley is a 25+ year small business CEO & Strategist. He is a renewable energy generation and storage subject matter expert. He has specific project manager expertise related to Utility Demand Side Management & Energy Efficiency Programs, Residential & Commercial Real-Time Electricity Monitoring and The Monetizing of Environmental Benefits related to Eco-System improvements and Carbon Sequestration on Ag land in the Midwest.

BWR Innovations was founded in 2018 by Dr. Jorgenson as a *Blue-Water* innovator for telemetry and fuel cell systems. The concept of the Blue Water innovation is based on the business concept by Mauborgne and Kim (*Blue Ocean Strategy, https://www.blueoceanstrategy.com/what-is-blue-ocean-strategy/)*where companies produce novel, unique value-added designs that are not commodity and are not directly available from competition. BWR Innovations was founded on this premise and has been developing unique designs in fuel cell systems and telemetry that meet an unmet need and are creating new markets. The acronym *BWR* stands for Blue Water Resolute, which means that as we are creating new markets in Blue Oceans, the problems we are tackling are challenging and require resolute focus.

MANAGEMENT

A description of ***how*** *the applicant will manage and oversee the project to ensure it is being carried out on schedule and in a manner that best ensures its objectives will be met,* ***and a description of the evaluation points to be used*** *during the course of the project.*

Project Management

Projects managed at BWR Innovations use a combination of time-tested project management tools coupled with new technology for a distributed workforce. The online capability of the project management tools allows all users (and project stakeholders) to access project information, view status and progress, and to provide feedback and input.

The overall methodology of the program management is based on DO-254, a set of standards developed for the design of systems used in airborne systems. The Federal Aviation Administration has mandated the adoption of design assurances to be used in the design of electronics and mechanical systems that are integrated into aircraft systems, to assure that structured design methods are created, followed, and documented.

The first step of the project is the Design Capture phase for the 70kWe generator, where each critical part of the design is documented and the interfaces between all parts are defined. For example, in this phase, the complete characteristics of the major components are defined, such as the solar cells, the wind turbine, the electrolyzer and compressor, the hydrogen storage tanks, the fuel cell modules, the inverters, and the telemetry system. Each system will have its performance characteristics established, and a defined means to test, troubleshoot, and repair each component.

The second step of the project is the Conceptual Design phase for the 70kWe generator. During this phase, the architectures of the software, electronics, and mechanical components are defined. Software will be developed using Python, C, and Powervision; Electronic components will be designed using schematic capture, wire harness design, and printed circuit board design software; and mechanical design will use Solidworks for design and manufacturing. At the end of this phase, the projected performance of each component will be compared against the requirements of the first phase.

The third step of the project is the Physical Design for the 70kWe generator, where components are purchased, assembled, integrated, and tested. At the completion of this stage, the 70 kWe generator will be operational, and the performance metrics will be compared against the predicted performance of the Conceptual Design. The completion of the 70 kWe generator design starts the market-specific installations.

BWR Innovations and Artemis AG-Solutions will review the design, performance, cost, and form factors of the 70kWe generator and then architect the specific design for agricultural applications. An initial application under consideration is poultry production, where energy is the second largest cost of the operation. The deployment of the 70kWe renewable energy generator may significantly reduce the cost of the poultry operation, while reducing the carbon footprint of the facility.

BWR Innovations and Master-Flo will similarly review the design, performance, cost, and form factors of the 70kWe generator and then architect the specific design for oil production applications. An initial concept is the electrification of oil production sites. Master-Flo has requested assistance in the creation of electricity at the wellhead site, as future regulatory requirements may favor electrification of oil production sites.

Dr. Jorgenson has used methods of DO-254 for decades. He was first introduced to this methodology while employed at Rockwell Collins (Cedar Rapids, IA) as a design engineer, and taught methods from DO-254 to engineering students at North Dakota State University. This methodology is robust and easy to learn and understand. To track progress, Gantt charts and Trello software are available to all team members and stakeholders.

TIMETABLES

Please provide a project schedule setting forth the starting and completion dates, dates for completing major project tasks/activities, and proposed dates upon which the interim reports will be submitted.

BWR Innovations has developed a detailed project plan, based on a thirty-six month schedule. Multiple Gantt charts are shown to display the critical steps, milestones, and deliverables.

The first three charts outline the design tasks of the 70kWe fuel cell generator with integrated electrolyzers, compressors, hydrogen tanks, embedded controls, and telemetry. Once the 70kWe fuel cell generator is completed (as shown on the critical design review milestone in Figure 4), the specific designs for agriculture, oil production, and other potential applications will be completed.

The first Gantt chart shows the critical steps of the design capture phase. During this phase, the development of the PowerHouse is examined from multiple perspectives, from specific engineering disciplines to manufacturing to vendor capabilities and logistics. Figure 2 illustrates the detailed project plan and timetable of the design capture phase.

Figure 2. Design Capture Gantt Chart

After the design capture phase, BWR Innovations will conduct the conceptual design phase. Detailed design decisions and analysis will be completed, creating the conceptual design to meet the design requirements from the design capture. The milestone marks the completion of the conceptual design, where the design decisions and analysis are reviewed, and to determine if any changes need to be made to the requirements. Figure 3 illustrates the detailed project plan and timetable of the conceptual design phase.

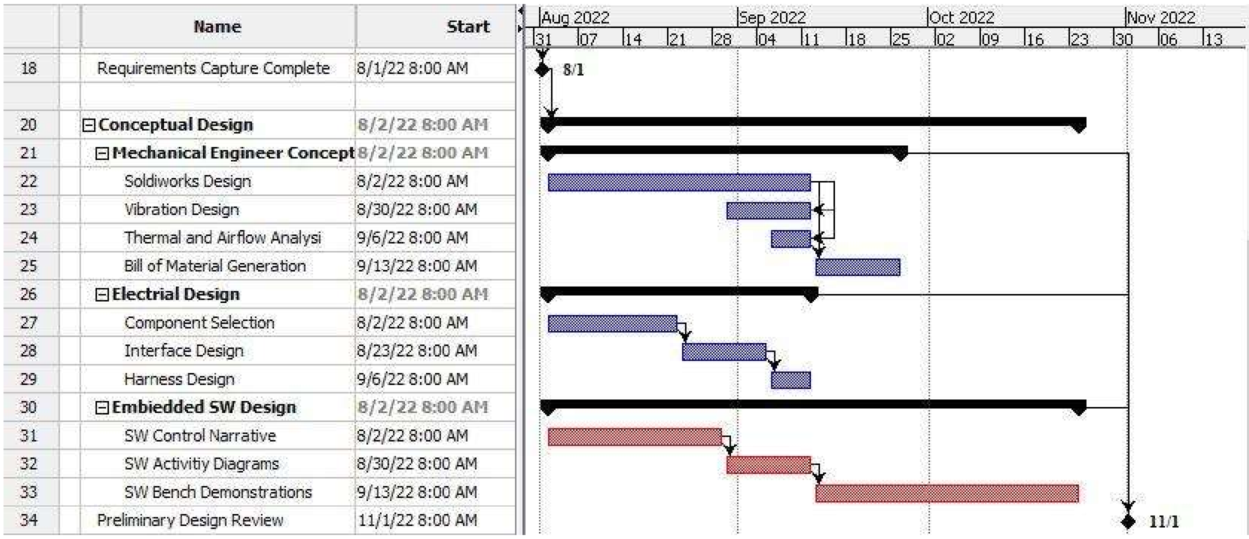


Figure 3. Conceptual design Gantt chart

The physical design phase takes the outcomes of the conceptual design phase and builds the first actual system. All of the requirements of the manufacturing, regulatory, and compliance reviews from the design capture are also added to the physical design. The first system is meant for deployment, performance testing, and transition from BWR Innovations to our manufacturing partners. The critical design review marks the completion of the physical design phase, where all stakeholders of the project examine the first prototype. Figure 4 shows the timetable and tasks for the physical design stage.

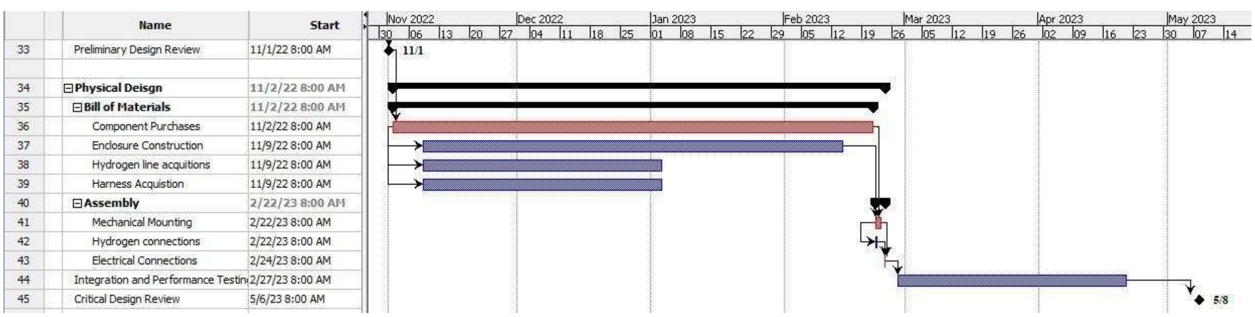


Figure 4. Physical design Gantt chart

The completion of the physical design phase starts the implementation phases for the agricultural locations and the oil production locations. Implementing the BWR Innovations generator at agricultural sites and oil production sites occurs in parallel operations. Artemis AG-Solutions is the partner for the agricultural installations. Artemis will select the sites and assist with installation, testing, and evaluating the impact to agriculture. Master-Flo is the partner for the oil production applications. Master-Flo will select the sites, and will assist with installation, testing, and evaluating the impact to oil production. Figure 5 shows the timetable and plan for installation of the PowerHouse generator with Artemis at agricultural facilities. This phase continues until the completion of the project.

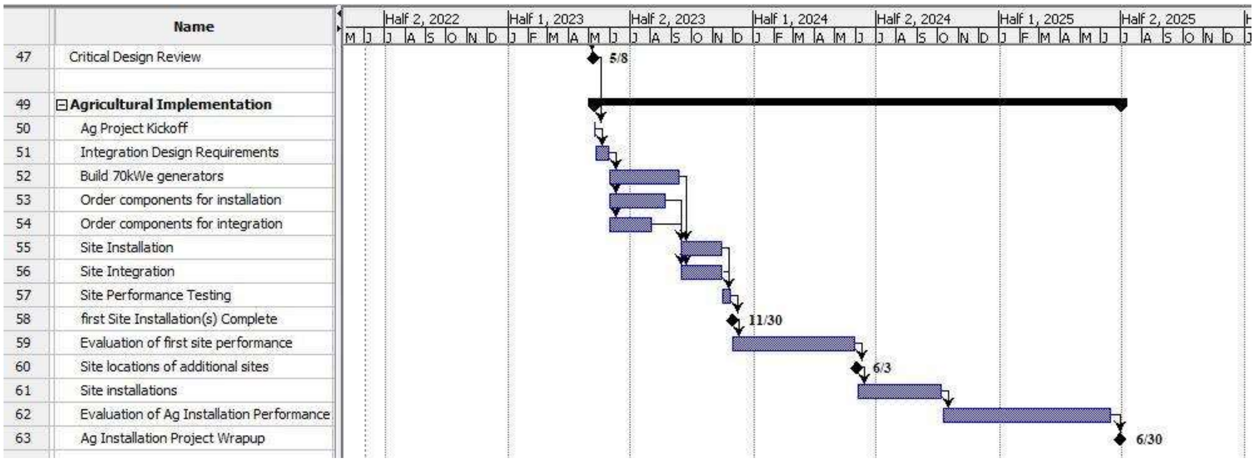
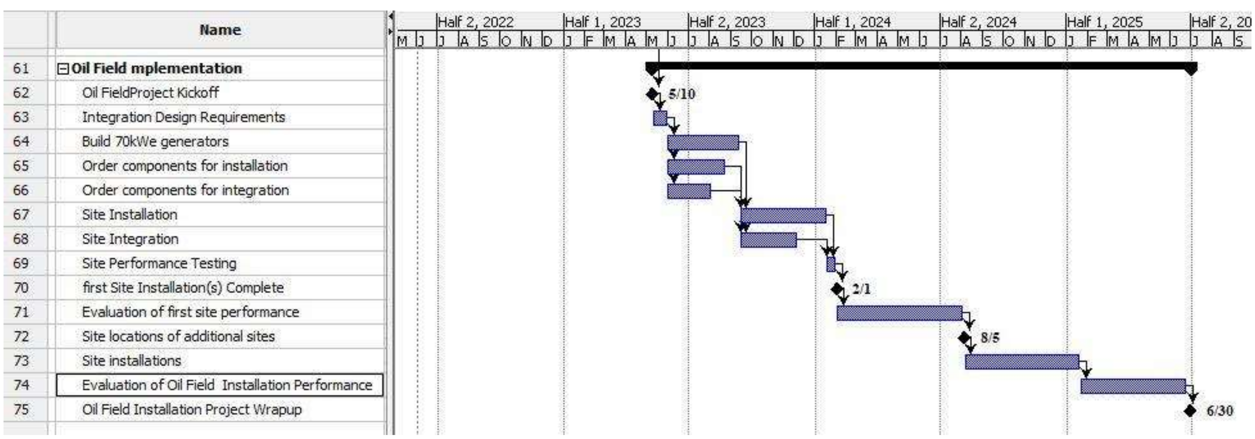


Figure 5. Agricultural installation Gantt chart

At the same time BWR Innovations is working with Artemis AG-Solutions for agricultural applications, and with Master-Flo on electricity generation at oil production sites with our 70kWe generator. From a project planning perspective, the Gantt Charts for agricultural applications and oil field applications are similar, although the planned installation and integration efforts at oil fields are projected to be longer in duration due to additional regulatory requirements and corporate governance. Figure 6 shows the Gantt chart for working with Master-Flo on an oil field installation of a BWR Innovations 70kWe generator.



At the completion of the project, BWR Innovations will have substantial data to prove the success of the project, the cost savings to the users, and the potential for uniquely contributing to the North Dakota economy with new jobs in hydrogen generator design and production.

BUDGET

*Please use the table below to provide an **itemized list** of the project's capital costs; direct operating costs, including salaries; and indirect costs; and an explanation of which of these costs will be supported by the financial assistance and in what amount. The budget should identify all other committed and prospective funding sources and the amount of funding from each source. **Please feel free to add columns and rows as needed.** Higher priority will be given to projects with a high degree of matching private industry investment.*

Current market factors show two major macroeconomic forces that favor the design and implementation of hydrogen based electrical generators, such as the PowerHouse generator. The first macroeconomic factor is the push to Net Zero Carbon by 2050. More than 110 countries have pledged to achieve Net Zero Carbon thresholds[1], and the Paris Agreement has led 39 countries to create hydrogen policies and establish $70bn of funding[2]. While the demand for hydrogen production is increasing, the supply is responding by substantial investments in manufacturing. The investments will result in a cost reduction of the critical components for hydrogen components, such as fuel cells, electrolyzer, compressors, and tanks. Mitsubishi predicts the costs of hydrogen components to follow the same price reduction curve as lithium-ion batteries and solar panels. By 2030, hydrogen components may drop by as much as 90%.

The budget is based on 2022 pricing. Table 1 shows the top-level budget for the proposal.

Table 1. BWR Innovations Proposed Budget for 70kWe PowerHouse Generators

Project Associated Expense	NDIC Grant	NDIC Loan	Applicant's Share (Cash)	Other Project Sponsor's Share	Total
Salary	$178,750	$0	$178,750	$0	$357,500
Fringe	$26,812	$0	$26,813	$0	$53,625
Equipment	$5,559,250	$0	$159,250	$7,562,000	$15,326,500
Materials	$0	$0	$5,000	$0	$5,000
Installation Costs	$0	$0	$0	$875,000	$500,000
Operating Costs	$0	$0	$75,000	$75,000	$150,000
Total	$5,764,812	$0	$444,813	$10,183,000	$16,392,625

The salary line item and fringe line item are based on the development of the PowerHouse 70kWe design as shown in the first three phases (requirements capture, conceptual design, and physical design) efforts within BWR Innovations. Mechanical engineering, electrical engineering, telemetry engineering, prototype manufacturing, and project management salaries and fringe benefits will be invested by BWR Innovations. A 50% match by NDIC is requested on the specified line items. In total the requested grant is projected to be 35% of the project total.

The equipment line item addresses the costs of the first physical design at BWR Innovations, the costs of ten (10) systems created with Artemis-AG for agricultural applications, and the costs of ten (10) systems created with Master-Flo for oil field applications. Table 2 shows a detailed breakdown of equipment costs.

Table 2. Major Component Costs of 70kWe PowerHouse Generator

Item	Cost	
Electrolyzer	$	52,000.00
Compressor (10kgpd)	$	120,000.00
Fuel cell module (70kW)	$	88,500.00
Inverters	$	33,000.00
Enclosure	$	16,000.00
Supercapacitor	$	1,600.00
Hydrogen lines	$	1,400.00
Harnesses, control, and telemetry	$	6,000.00
Manufacturing, Test, G&A Costs	$	221,500.00
Total	$	540,000.00

These are the current component prices that make up the Bill Of Materials (BOM) for the first system created. We expect that prices will decrease as the industry continues to mature with technology improvements and manufacturing scales are achieved with the components.

The equipment costs specific to the agricultural project will be purchased by Artemis AG-Solutions (distributor) and sold to the final agriculturally based customer. The solar panels for renewable energy and hydrogen storage tanks are likely to be site-specific and will be the contribution of Artemis AG-Solutions and the final customer. The additional costs beyond the initial generator will be borne by the end customer. Table 3 shows the budget created for installations for agricultural sites.

Table 3. Equipment Costs for Agricultural Installations of Ten 70kWe generators

Item	Unit Cost		Total Cost	
Electrical generator, transfer switch, and electrical system	$	540,000.00	$	5,400,000.00
Solar Panels	$	130,800.00	$	1,308,000.00
Hydrogen Tanks, Hydrogen Lines, Manifolds	$	40,000.00	$	400,000.00
Total	$	710,800.00	$	7,108,000.00

The equipment costs specific to the oil production project will be purchased by Master-Flo(distributor) and sold to the final oil/gas-based customer. Where possible, existing infrastructure will be used. No budget line item is reserved for hydrogen storage tanks, as above ground and below ground gas storage capability is available to Master-Flo. The additional costs beyond the initial generator will be borne by the end customer. Table 4 shows the budget created for installation of oil production sites.

Table 4. Equipment Costs for Oil Production Installations of Ten 70kWe generators

Item	Unit Cost		Total Cost	
Electrical generator, transfer switch, and electrical system	$	540,000.00	$	5,400,000.00
Renewable Energy Components	$	250,000.00	$	2,500,000.00
Total	$	790,000.00	$	7,900,000.00

For both the agricultural and oil production installations, 50% of the electrical generator, transfer switch, and electrical system costs are requested from NDIC. The equipment total request for NDIC support is 50% of the first 70kWe system produced at BWR Innovations and installed equipment in deployments for a total of $5,559,250.

Installation costs for both agricultural and oil production applications are budgeted at $25,000 per site, which will be funded by the end use customer.

A budget line item of $5,000 for materials is listed for BWR Innovations during the first three phases of the project, during the design and development of the first 70kWe generator.

During the evaluation phases of the project, BWR Innovations will have two new hires for support and telemetry management. One of the BWR support personnel will bill Artemis AG-Solutions for support ($37,500 billed to Artemis AG-Solutions, or 50% of the personnel costs.) Similarly, the second of the BWR support personnel will bill Master-Flo for support ($37,500 billed to Master-Flo, or 50% of the personnel costs.) The total support costs will be two 50% full time employees for BWR Innovations totaling $75,000, and $37,500 from both Artemis AG-Solutions and Master-Flo.

All components are commercially available, either at BWR Innovations or through our partnership with key suppliers. If less funding is available than requested, BWR is able to scale the size of the project to demonstrate the unique capabilities of the project, albeit at a lower electrical and hydrogen production level.

Salaries listed in the proposal are for BWR Innovations personnel to design, document, debug, install, and monitor the microgrid system over the period of the design project. Fringe benefits are calculated at 15% of the salaries. Site lease costs are in-kind support from Grand Farm for the installation of the microgrid on their facility.

Installation costs include, but are not limited to, permitting, excavation at site for concrete footings and pads, trenching for underground wiring from external mechanical cabinets to buildings, electrical work by master electricians to connect microgrid controller to buildings and facilities, and outside services for the permitting and verification of federal, state, and county regulatory requirements.

1. Mitsubishi Power, "A Decarbonized Future", https://www.changeinpower.com/path-to-net-zero/?utm_source=linkedIn&utm_medium=sponsored&utm_campaign=blueprint&utm_content=bp_5&hsa_acc=507780708&hsa_cam=603189156&hsa_grp=194737003&hsa_ad=171600993&hsa_net=linkedin&hsa_ver=3
2. HydrogenOne Capital, "The Bluffer's Guide to Hydrogen"

CONFIDENTIAL INFORMATION

A person or entity may file a request with the Commission to have material(s) designated as confidential. By law, the request is confidential. The request for confidentiality should be strictly limited to information that meets the criteria to be identified as trade secrets or commercial, financial, or proprietary information. The Commission shall examine the request and determine whether the information meets the criteria. Until such time as the Commission meets and reviews the request for confidentiality, the portions of the application for which confidentiality is being requested shall be held, on a provisional basis, as confidential.

If the confidentiality request is denied, the Commission shall notify the requester and the requester may ask for the return of the information and the request within 10 days of the notice. If no return is sought, the information and request are public record.

Note: Information wished to be considered as confidential should be placed in separate appendices along with the confidentiality request. The appendices must be clearly labeled as confidential. If you plan to request confidentiality for **reports** if the proposal is successful, a request must still be provided.

To request confidentiality, please use the template available at http://www.nd.gov/ndic/CSEA-app-doc-infopage.htm.

At this time, BWR Innovations is not aware of any data or project information that must be kept confidential. Key attributes for this project have already been protected by BWR Innovations, through patent applications, trade secrets, copyrights, trademarks, and an issued United States patent. If future research creates new intellectual property that BWR requests to protect, BWR Innovations will work with the Renewable Energy Program for considerations.

PATENTS/RIGHTS TO TECHNICAL DATA

Any patents or rights that the applicant wishes to reserve must be identified in the application. If this does not apply to your proposal, please note that below.

In May 2021, BWR Innovations was issued US Patent 11,018,508 *Electrical Power Generating System,* describing the invention of a fuel cell generator with telemetry and synchronization. BWR Innovations has filed patent applications on fuel cell systems, including (but not limited to):

- A Means to Control Distributed Generation Through Telemetry
- A Software Means to Select Protocols,
- Distributed Generation and Storage of Renewable Energy, and
- A Fuel Cell Based Auxiliary Power Unit.

The listed intellectual property will remain in the ownership of BWR Innovations.

STATE PROGRAMS AND INCENTIVES

Any programs or incentives from the State that the applicant has participated in within the last five years should be listed below, along with the timeframe and value.

In October 2021, BWR Innovations was awarded $332,159 from the North Dakota Renewable Energy Council for the deployment of a 20kW fuel cell generator with connections to solar and wind renewable energy sources.