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Hydrokinetic Pumped Energy Storage for Microgrids

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Topic - 14 a.

DoE SBIR Grant Title - *Microgrid for Improved Resilience in Remote Communities Through Utilization of Marine Hydrokinetics and Pumped Storage Hydropower.*

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Proprietary Data Legend

1.0 Trade Secrets

Renewable Energy Design Concepts Llc. (REDC) has completed preliminary designs of our hydrokinetic technology. A preliminary patent search was completed and nothing was found to be similar to our invention. A Provisional Patent was applied for with the United States Patent and Trademark Office on August 30, 2017. The patent has since expired.

1.1 Financials

REDC has zero debt. REDC is a brand-new company and has not yet taken on any investors or loans at this point. Our financial situation is that REDC has not over extended itself and we have not pitched the company to any investors (Angel or V.C.). REDC is 100% owned and operated by Kelly C. Fetters. He has paid out of pocket for all of REDC's expenses.

Project Narrative

2.0 Problem

A Microgrid is a small electrical grid that supplies a small community and businesses with electricity. Normally they stand-alone by themselves and are not connected to a larger grid. Usually they are powered by diesel generators and the locations are remote. [1] Some of these remote communities have Microgrids that power up 300 homes and an industry that supports the community. In Alaska the Microgrid Industry helps rural, remote communities survive and industries are kept alive that would normally fail without electricity. Unfortunately these communities are susceptible to the high cost of imported diesel and often it is delivered only twice a year. Some communities are paying over $1.00 per Kilowatt (KW) hour for their diesel microgrid systems.

What about renewable energy, why can't a community use solar and wind for their Microgrid versus expensive diesel fuel? When incorporating solar and wind power for a Hybrid Microgrid (two different technologies powering the Microgrid) or implementing a Microgrid that uses solar or wind alone, they are not reliable. Together they are better suited, when the sun is not shining the theory is, that the wind will blow (not all of the time though). If the electricity is not constant it causes problems with reliability; black outs can be expected. Industries (businesses) relying on the electricity to get work done are brought to a snail's pace when electricity is down. For example a saw mill or fishing village located in a remote Alaska community would need reliable electricity to get work done. Without the electricity the business suffers financial hardship and jobs are lost. Entire communities slow down without electricity and jobs.

Microgrids that use diesel fuel are not healthy for our environment and with the Microgrid industry expanding so rapidly we must be careful not to create a nation or world that uses only diesel fuel for its Microgrids.

2.1 What is being done to solve the problem today?

Companies are developing pumped energy storage systems that use renewable energy to pump water uphill, store the water (energy) at the higher elevation and then released into turbines as needed. The Pumped Hydropower System uses a supply of clean energy technologies such as wind and solar as the energy sources and they average together 12 hours of pumping time daily. These hybrid pumped energy storage systems are fantastic, but still average only 4-5 hours (solar) and 8 hours (wind) of pumping hours daily.

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[1] The Alaska Center for Energy and Power Dec. 2013 https://cf.denali.gov/Data/attachments/Hydrokinetics%20in%Alaska%20FINAL.pdf

Pumped energy storage is the most inexpensive way to store energy. Batteries, fly wheels, compressed air are all ways to store energy. Batteries and pumped storage are the two leading technologies to store energy at the lowest cost. Nothing is more inexpensive per watt than pumped energy storage.

2.2 How can we provide reliable, carbon-free, electricity for Microgrids with little impact on the environment?

Rivers and tides both possess hydrokinetic energy. Rural communities residing close to flowing rivers and tides can use the energy from these natural sources and pump water uphill 24 hours a day (except for slack tides with tidal power). The stored energy will provide Microgrids with reliable, carbon-free electricity that can be used for base load and peak hour electricity.

2.3 Current technology issues for the Marine and Hydrokinetics (MHK).

Most MHK technologies operate in an axial motion or cross flow. (Fig. 1). The chopping motion is not friendly to most aquatic species. Orcas, salmon, and even jelly fish will all have problems if caught in the blades. Some technologies operate like a fan, a grinder, (Fig. 2) or a rolling pin with rotating blades (Fig. 3). Some of the bladed technologies have a problem during winter months in Alaska. Above water and beneath the surface hydrokinetic technologies experience downtime due to floating debris and ice chunks in the river during the Fall and Winter months [3]. Logs rocks, sticks ice chunks and branches get trapped in the MHK system if the system is not well thought out.

Fig. 1.

[2] Electricity Storage and Renewables: Costs and Markets to 2030 https//www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct?IRENA_Electricity_Storage_Costs_2017.pdf
[3] "Potential Maritime Markets for Marine and Hydrokinetic Technologies" (in draft) DoE, 2018 file///media/removable/USB%20Drive/Water%20Power%20Technologies%20Office/Water%20Technology%20Office/Draft_MM_RPT.pdf

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Fig. 2.

Fig. 3.

REDC's MHK invention uses the hydrokinetic energy from flowing rivers and tides to pump water uphill 24 hours a day. Communities that have nearby flowing rivers or tides, along with mountains, possess the ability implement our solution for a low-cost, reliable, commercial Microgrid powered by clean energy. (Fig. 4.)

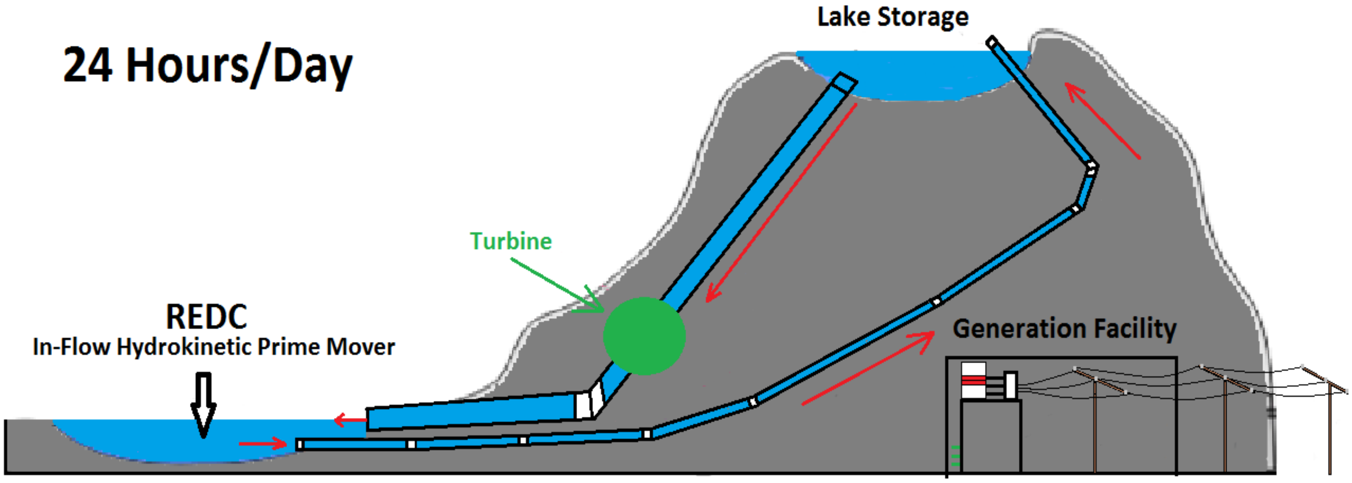

Fig. 4.

Our In-Flow Hydrokinetic Prime Mover converts the hydrokinetic energy from flowing water and turns it into mechanical energy with little to if any impact on the environment. Our slow moving buckets move with the current in a conveyor style motion and do not harm aquatic species or plants. The buckets are debris friendly; rocks, sticks, logs and ice chunks and do not impede the technology from operating. The buckets force a chain to pull large sprockets, and

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turn a set of gears that spin a shaft at high speeds. The shaft provides the mechanical energy needed to operate a pump. The pump pushes water uphill, the water is stored at the higher elevation and then released downhill under pressure to spin Pelton Wheel Turbines (for efficiency), which provide base load and peak load power. Generators are added and reliable carbon-free electricity is created on demand for the Microgrid. (Fig. 5.)

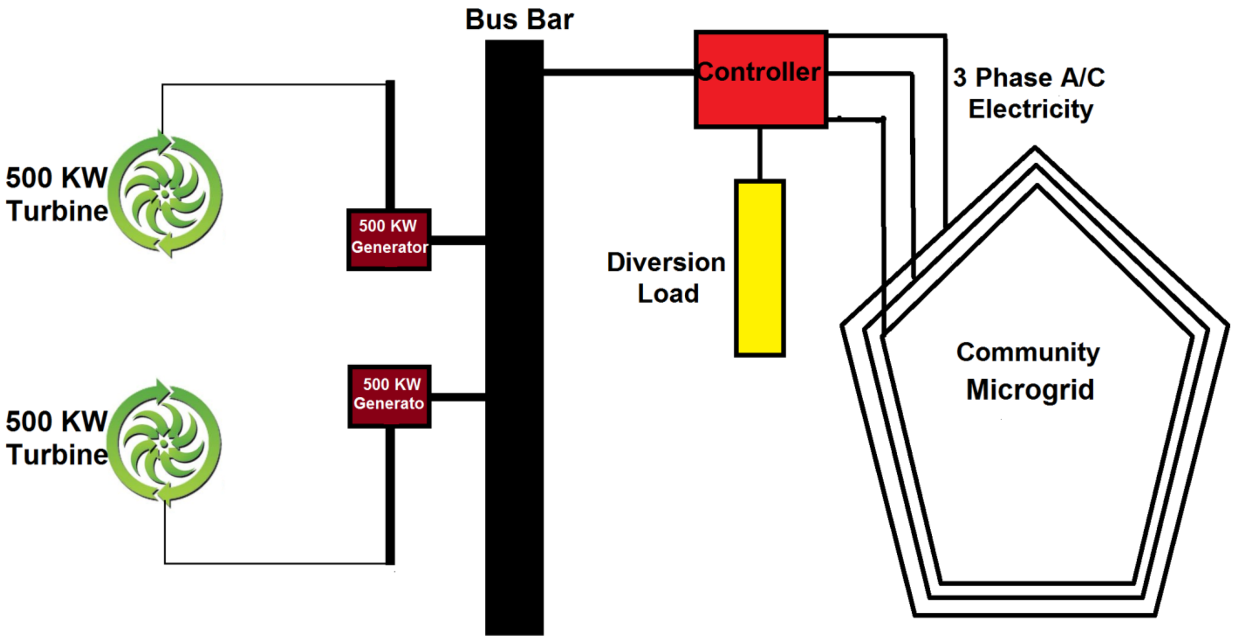

Fig. 5.

2.4 Resiliency of the system

Our MHK invention operates beneath the surface of the river, which helps it become more reliable than other renewable energy technologies. Storms such as hurricanes can devastate a solar renewable energy park or wind farm. Underwater hydrokinetic energy parks or river applications are protected by the water during storms that bring high winds and flooding.

REDC's invention (Fig.6.) is better than other MHK technologies and pumped storage systems. Our clean energy technology has little to if any impact on the environment, it experiences less downtime, our design is simple, it's easy to repair, and our cost is low. Our system pumps water and generates variable amounts electricity 24 hours a day. Diesel, solar, and wind power Microgrid developers will not be able to compete with our technology or its resiliency.

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REDC's river and tidal applications include a fender (Fig. 6.) to deflect water current away from the back of the bucket as it rotates around the sprocket. Without it the current will push against the back of the bucket and briefly stall the system. With it, the current is directed towards the face of the buckets and away from returning buckets, thus increasing efficiency.

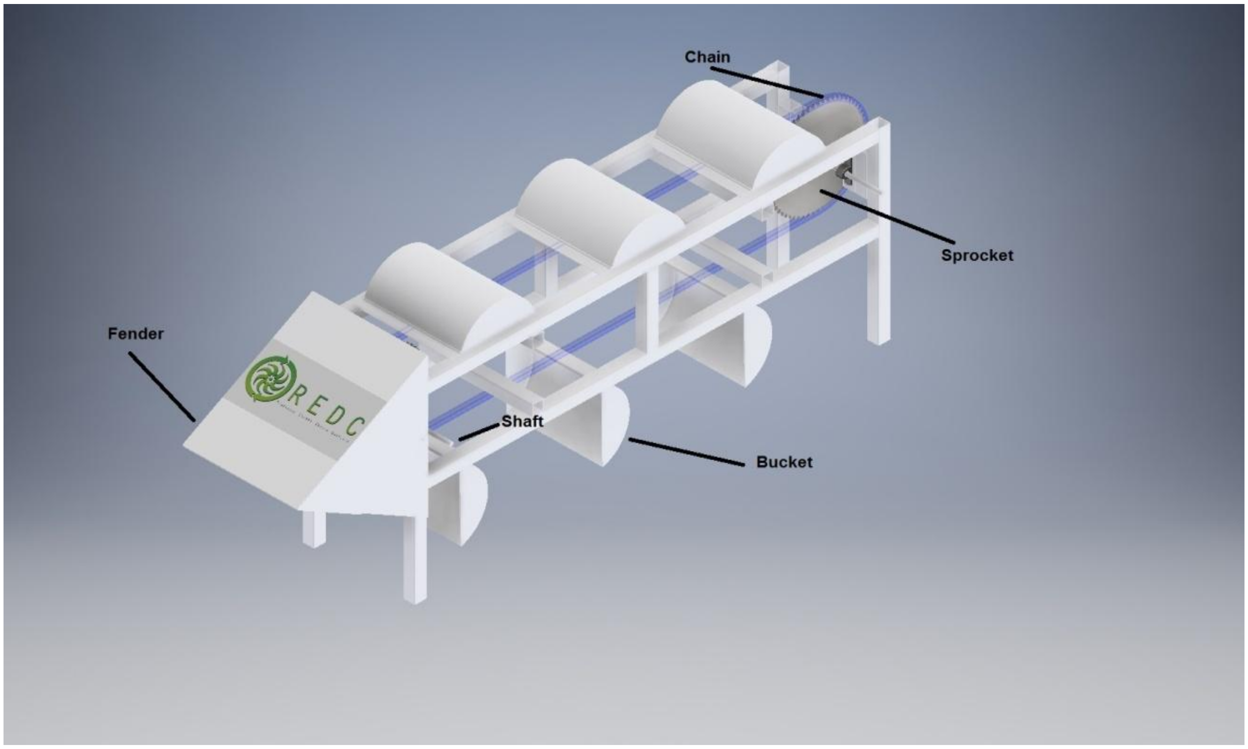

Fig. 6.

2.5 Community, economic and social benefits

Rural and island communities located close to a flowing river and have hills nearby possess the opportunity (depending on water velocity, water depth and river size) to generate dependable carbon free electricity 24 hours a day 365 days a year for their microgrid without impacting our environment (humans, land, aquatic species and plants). Even in Alaska; their rivers have ice chunks mixed with river water during Fall and Winter months. The ice chunks pass our system with ease. Our competitors must remove their technologies before the freezing months due to ice chunks damaging their axial flow turbines. Our technology allows us to provide reliable, carbon-free electricity 24-7, 365 days a year for our customer. The hydrokinetic river system, piping, storage tanks, and the power house can all easily be removed if the habitat needs to be restored to its original path.

Economies benefit from the technology. Electricity at a lower price will benefit the entire community. Residents, businesses and City Government will benefit from the reduced overhead costs. The cost of fuel alone is a great incentive for diesel Microgrid owners to make the change to our technology. New jobs will be created and new industries are formed with our Hydrokinetic Pumped Energy Storage System.

2.6 New opportunities for the industry

We have a marketable product; the market is new and growing leaps & bounds. There are a very small amount of companies creating Microgrids with MHK technologies today, especially in remote communities with rivers and tides. Most hydrokinetic technologies create electricity. Ours pumps water. Creating electricity to pump water is not efficient in comparison to our invention. Energy losses at the motor make our system more energy efficient due to our system not having a motor.

3.0 Explain what you are going to do

REDC does not know how much energy is at the shaft (for pumping) with respect to each bucket size. We need to solve this equation as a business to better understand our equipment costs versus power output.

We will design, fabricate, and test our hydrokinetic technology in the Cowlitz River in Toledo, WA. The system will use a 48”L X 36”W bucket and we will apply a torque wrench at the shaft to measure the energy output. We will also test the system with different size buckets to better understand our pumping capacities versus bucket size.

Once torque values of the buckets are better understood we can properly size our technology and understand costs per watt. We have found that MHK technologies cost approximately $5.00/Watt to develop. If our technology is superior in price we can compete with diesel power generators for remote communities. Some remote communities in Alaska are paying as much as $1.00 per KWh for the diesel power generation. Our technology can compete at this price; we don’t know how well we can compete, at this point. Without collecting the results we cannot project costs for the hydrokinetic aspect of the system for Phase II of this project.

We will model (computer) the 100 KW- 1MW Hydrokinetic Pumped Energy Storage technology. We will use this information to analyze the feasibility of the project, costs per watt, changes that can help the technology reduce costs (such as building molds for buckets), and to provide DoE with Final Report. Modeling will show us how the hydrokinetic system works in a river or tide. Once modeling is complete we will know pump size(s), pumping pressure, head pressure water volumes, piping diameter, turbine sizes and powerhouse outputs to the Microgrid.

Our goal is to provide the Department of Energy with the following technical objectives:

- **Design Of The Complete System**
- **Build Prototype**
- **Build Test Bench**
- **Collect Data & Analyze**
- **Begin Final Report**
- **Model System**
- **Model River Or Tidal Currents And Energy Conversions For Buckets**
- **Figure Cost Per Watt**
- **Is The Project Feasible For Phase II**
- **Finish Final Report**

Grayling, AK is located along the Yukon River in Southeast Alaska. They have mountains nearby (500'). The community uses diesel fuel as their primary energy source for their Microgrid.

Pilot Station, AK resides along the Yukon River. They have nearby mountains that make an excellent area for a Hydrokinetic Pumped Energy Storage System.

We have located 130 rural communities that use diesel fuel for their Microgrids in Alaska.

3.1 Team and Phase II

Putting together a team of experts that can implement our Hydrokinetic Pumped Energy Storage System during the Phase I period would be ideal for Phase II. Up to this point we have three excellent partners to help REDC. Entel-inc will take care of our commercialization, business development. Permitting and regulation (if needed) will be taken care of by our colleagues Hydro Regulation Services Llc., Finally, McLaren Engineering Group will handle all engineering and site development.

Bibliography

1. The Alaska Center for Energy and Power Dec. 2013

   https://cf.denali.gov/Data/attachments/Hydrokinetics%20in%Alaska%20FINAL.pdf

2. Electricity Storage and Renewables: Costs and Markets to 2030

   https//www.irena.org/media/Files/IRENA/Agency/Publication/2017/Oct?IRENA_Electricity_Storage_Costs_2017.pdf

3. “Potential Maritime Markets for Marine and Hydrokinetic Technologies” (in draft) DoE, 2018file///media/removable/USB%20Drive/Water%20Power%20Technologies%20Office/Water%20Technology%20Office/Draft_MM_RPT.pdf

Work Plan

4.0 Explain in detail how you will accomplish your plan

The project will be led by our Principal Investigator Kelly Fetters, who is the founder and 100% owner of Renewable Energy Design Concepts (REDC). We will follow a timeline and meet all of our milestones. There are multiple companies that we will use to complete this project. REDC is a start-up company our finances are quite low. We do not have a workshop with the proper tools to fabricate the equipment needed. We do not have a design team that works for us. What we do have is experience and we understand that we can hire other companies to complete the work at their facilities. To overcome our infancy we have business to business relationships that are already-in-place. We will rent a workspace that has the needed tools for a period of 3 months. We will hire a company that is qualified to handle all modeling and specializes in water hydraulics. We will use CAD or Autodesk Inventor to model each part of the Hydrokinetic Prime Mover. We will hire fabricators to build our specialty items for us like our truck assembly that mounts the bucket to the wheels and chain. We will have fabricators who specialize in aluminum from one company and fabricators that specialize in steel from another company.

Our plan is to build MHK technology that uses a 48” x 36” buckets, mount the technology to a test bench (Aluminum frame heavy duty Pontoon Raft) and test the system. After testing we will better understand the torque of the buckets and how much energy is available at the shaft. We will use the velocity of the water, its density, overall size of the bucket face (surface area) and the torque value to predict the cost of our technology per watt. We will make multiple sizes of the buckets for testing; the largest buckets will be 48”L X 36”W.

This information is vital for bidding purposes and projecting the size of bucket needed for a system that delivers between 100KWh and 1MWh of carbon-free electricity. Projecting the costs of the pumped storage part of the project will also rely upon the analytical data gathered from the testing. Once energy conversions are better understood for our technology, pump sizes can be better understood. This information also helps us determine the size of piping needed, pressure ratings for pipes, turbine sizes and installation costs for Phase II.

We have already-in-place business to business relationships built from our prior testing jobs. We know what venders and people to work with that reside in our local area to get the job completed on time.

REDC will hire Northwest Hydraulic Consultants located at Evergreen Plaza, 711 Capitol Way S #607, Olympia, WA 98501. They will model our technology working in a river or a tidal power application, our pumping system, piping infrastructure, retention system and two Pelton Wheel Turbines that are used for base load and peak load electric generation. REDC will work closely with them and provide as much information and data related to the project as possible. They will be an excellent group to work with for the research side of the hydrokinetic and hydrostatic systems that are used

The 48" x 36" buckets will be made of 3/16" gauge steel. The buckets will be built by REDC. We will rent a space for prototype development from our supplier J & B Log Stackers located at 1010 W. Reynolds Ave Centralia, WA 98531. The space will have welding equipment, tools, an indoor crane or forklift, to lift heavy objects. We will rent this space for 3 months. The rollers will be purchased off-line and a trucking system that the rollers mount to will be fabricated out of steel by our supplier Way Machinery that is located at 1622 Lum Rd. Centraila, WA 98531. Four 2' dia sprockets (we have CAD designs already) will be made by a water jet machine (width to be determined) by our supplier Way Machinery and delivered to our rented space for assembly. The sprockets rest on a 1"- 2" diameter steel shaft that glides on bearings (both purchased from J&B Logstackers), which are connected to the frame. The frame is made of square aluminum tubing and welded together by our supplier Industrial Fabrication, located at 138 Chase Rd. Chehalis WA 98532, who specializes in aluminum welding. They will also fabricate the fender, make it adjustable (slide up and down), build the aluminum track, which prevents the truck and buckets from twisting. All of the above vendors have helped build prototypes in the past and we are very satisfied with their ability to complete the work on time, make perfect, strong welds and produce an end result that we desire.

Once the hydrokinetic system is built, REDC can begin testing. We will use the J & B Logstackers shop truck to lift and transport the technology to our testing site. Once transported to REDC headquarters we will mount the technology to the aluminum frame of our test bench. Once mounted, we will transport the system to the Cowlitz River. A rope is attached to the front of the test bench and is wrapped around a tree to stop the test bench. Once stopped, the water current pushes the roller gliding buckets, the chain that forces sprockets to rotate. The sprocket rests on a shaft. At the shaft (Fig.6) we will measure the torque value by welding a nut to the shaft and connecting a dial wrench, used to measure torque. All testing will be video recorded underwater on the hydrokinetic prime mover.

During Phase II of the project REDC will build a brand-new hydrokinetic turbine to scale that will supply enough water to generate between 100KW-1MW of carbon-free electricity with our Pelton Wheel Turbines and generators. Canyon Hydropower located at 5500 Blue Heron Lane Deming, WA 98244 will build our Pelton Wheel Turbines to our specifications. Our partners McLaren Engineering Group will install our technology in the river or tide. REDC will work closely with every division of McLaren. Together we will produce the final project design and implement the entire system from water to wire. REDC will manage the project by its owner and Principal Investigator Kelly Fetters. Permitting with the Federal Energy Regulatory Commission

(FERC) will be handled by our colleagues Hydropower Regulatory Services Llc (if needed). Commercialization and business development will be taken care of by our partner Entel-Inc.

Our in-flow river systems are coated with an epoxy resin paint to prevent rust. Protecting steel underwater is very important. If REDC wants a 20+ year lifespan for our underwater equipment, we need to protect its surface area. We will transport our technology from our rented space to P&M Paints located at 168 Barns St. Park, Toledo WA 98591 for painting after completion of the build. We will transport the equipment with our shop truck from J&B Logstackers. The shop truck is equipped with a crane that can easily lift our equipment on and off the trailer.

We have taken steps to investigate our hydrokinetic technology with the United States Patent and Trademark Office (USPTO) in Alexandria Virginia. Although not an expert in patent research, Kelly Fetters traveled to the USPTO and researched their files for similar technologies and nothing was found in the industry of marine hydrokinetics. Kelly did file a Provisional Patent with the USPTO under the name of the "Fetters Hydrokinetic Turbine" on August 30, 2017. That provisional patent has now expired.

The project will last 12 months and all milestones will be achieved by the 9th month of the project. A final report will be produced between month 9 and 12.

4.1 Key personnel or companies

Kelly Fetters is the Principal Investigator (PI) of this project. He has experience with rural community microgrid development, marine hydrokinetics (MHK) and hydropower. He is the Founder & Owner of Renewable Energy Design Concepts and the mind behind our Hydrokinetic Pumped Energy Technology. In the past he's led a group of professors and students through a R&D project dealing with MHK technology. He has years of experience in developing renewable energy Microgrids for rural communities. During his final year in college he led the Bamboo Hydropower Project where bamboo is used as a pen-stock pipe, connected together for miles if needed and a centrifugal pump is used as a turbine in a Micro-hydropower application. The inexpensive run-of-the-river system is ideal for rural communities with water traveling downhill in developing nations.

He brings with him a unique set of skills and abilities that help him understand every aspect of this project. Years of entrepreneurial success, education in high voltage transmission and distribution of electricity, power plant operations, business, scientific research and his experience with rural community clean energy development all contribute to his ability to understand and deliver every aspect of the project. Kelly expects to work close to 2000 hours on the project (Phase I).

McLaren Engineering Group brings with it a wide array of engineering services that REDC uses for research and development purposes as well as the development of our sites from water to wire. They provide in house engineering (mechanical, civil, structural and marine).The company has over 15,000 completed projects. McLaren offers REDC the ability to complete this project on time, on budget and it allows REDC to compete with other industrial developers. They are our partners that make the project possible in Phase II and our commercialization plans that Entel-inc has in place for Phase III.

Entel-inc is handling all of REDC's new product commercialization, investor relations, product marketing, and business development. Entel-inc will be a partner for REDC that plays an important role when the project moves onto Phase II and III. Companies like Entel-inc helps REDC reduce its workload during critical times for any new start-up. Planning for commercialization now, helps REDC feel out the market today and gauge the market for widespread implementation during Phase III.

Hydro Regulatory Services Llc. will handle all of REDC's permitting and regulation paperwork that is required when implementing our Hydrokinetic Pumped Energy Storage System in the United States. Even though not used a great extent in Phase I, they will be a key player in Phase II and Phase III of this project.