Outreach Report – Water Wall Turbine Inc.

Project: **443 MH - WWT Dent Island Tidal Power Generation Project**

March 2017

I. Executive Summary

The Water Wall Turbine (WWT) project has produced the world's first ever deployment of a tidal energy system feeding into a remote microgrid with a sophisticated energy storage system to displace diesel. While not without challenges, this project has achieved the original overall objective of constructing a cost competitive tidal energy device for remote, west coast ocean and river environments.

Dent Island Lodge offered to be our first customer based on an agreement to displace expensive diesel generation. Their cost of barge-delievered diesel power was approximately 65 cents per kWh. The WWT project installed a 1MW turbine driving a 500 kW power plant for Dent Island Lodge.

The project began in early 2014 after competition of an initial front end engineering and design (FEED) study supported by the ecoENERGY Innovation Program. The majority of year one was dedicated to detailed construction design and establishment of the supply chain. WWTurbine 1 was launch ready for deployment in July 2016.

WWTubine 1

Microgrid & Energy Storage

As construction proceeded through 2015, WWT was invited to submit a proposal for an add-on project to develop a microgrid and energy storage system. WWT was successful in receiving NRCan Clean Energy Fund support that matched a contribution from Dent Island Lodge. This funding allowed WWT to develop the first proprietary tidal energy driven microgrid with Tesla's Power Pack systems providing 500 kWh of cost effective energy storage. The Dent Island project was Tesla's first installation of their energy storage technology operating in a remote, off-grid system. As a result of this coordinated development, WWT signed a master agreement with Tesla Energy for valued-added sales with our proprietary microgrid system.

The precision deployment of the 550-tonne vessel required new technologies in anchoring and mooring, with forces exceeding 100 tonnes, currents over 10 knots and slack tides under 30 minutes.

WWT will continue ongoing testing to optimize the total system. The initial deployment resulted in the generation of net energy that exceeded expectations.

WWT woud like to sincerely thank NRCan and its staff for their strong support thoughout this project. Without their assistance, this success achieved in this project would not have been possible.

II. Introduction

The project consists of the development and demonstration of a 500 kW tidal energy power plant, connected to WWT's proprietary microgrid system with Tesla's 500 kWh energy storage system located at Dent Island Lodge in the remote west coast of BC. The project is a collaboration with Dent Island Lodge, the NRCan's Clean Energy Fund, and Headwaters Foundation. Dent Island Lodge is a remote fishing lodge in the Campbell River archipelago.

WWT has developed an innovative technical solution to efficiently harvest tidal and river stream energy. The technology consists of an anchored floating structure that houses a large turbine that rotates at low speed. This patented technology provides high efficiency energy extraction; almost double that of conventional propeller-driven devices. Test trials at scales of 1:100, 1:75, 1:25, 1:10 and 1:6 indicated a high energy extraction efficiency of well over 50% compared to windmill-type devices at less than 30%. The technology is easily scalable from half a megawatt (MW) up to 5 MW per unit. These units may also be linked in series across wider channels or strung out along tidal or river channels to larger multiples of power. The flexibility of the technology allows for a large market potential nationally and internationally.

III. Background

WWT began this project in early 2014, after successful completion of a front end engineering design study funded by the ecoENERGY Innovation Initiative (ecoEII). WWT completed the construction, deployment and initial testing phase on October 31, 2016.

During the microgrid test and installation phases, real time performance data was collected. The initial results obtained after deployment exceeded expectations. WWT will continue testing and optimization of the current prototype annually beginning in May 2017. The data will be used to improve subsequent design iterations.

WWT's device extracts a greater percentage of available power than alternative systems, which target only the kinetic energy in currents. WWT also extracts the latent potential energy of currents by operating on the surface where currents are strongest. It is the only technology able to extract energy from very fast moving currents in tidal systems with speeds that can vary between zero and 14 metres per second. In addition to high-yield energy extraction, WWT's technology features low production & installation costs, eco and bio-friendliness, and simplicity of construction and installation.

In addition, the project provided WWT the opportunity to develop a prototype microgrid management system to integrate the turbine with an advanced energy storage system. The integrated system greatly enhanced tidal energy production and increased diesel displacement. WWT's proprietary integrated microgrid and energy storage system is unique within the global ocean energy industry.

IV. Objectives

This Project successfully achieved the three main objectives – 1) to prove out a new, cost-effective technology for tidal and river stream resources; 2) to provide a show case to launch a national and international product sales and service mode for this technology; and 3) to provide the initial development of a microgrid management system with an advanced energy storage system for remote and distributed generation.

WWT's turbine technology has initially proven its capabilities and cost effectiveness operating in shallow narrow channels – the most abundant source of tidal and river stream energy globally. Further testing and optimization over the next full season of operation will provide an opportunity to enhance this technology for broader application across the marine energy industry. A good example is the newly developed advanced mooring and anchoring techniques for work in fast moving bi-directional currents.

The microgrid and energy storage system integrates multiple generation sources to maximize the displacement of diesel. This proprietary technology is critical to satisfy remote (off-grid) communities power requirements from the optimum mixture of renewable energy sources. This will enhance the markets for many original equipment manufacturer's (OEM's) renewable energy products and establish Canada among the global leaders in renewable energy. The ongoing annual testing period for full operation will be from May through September. Once fully proven, this technology will put Canada in the forefront for tidal and river current power generation.

V. Project Evolution

The Dent Island project began in the fall of 2012 with the award of an ecoEnergy Innovation Initiative FEED.

The ojectives included:

- Detailed design of the proposed turbine,
- Permits and applications,
- First Nation consultation,
- 1:100 scale model for flume testing,
- A 1:6 scale model to be ocean tested,
- Report and presentation of results possibly leading to further ecoEII funding of the demonstration component.

The next step was the construction phase , supported in part by the Clean Energy Fund.

This included:

- Development of the detailed construction design of the 550-tonne vessel
- Design and Procurement of the 77-tonne 1 MW Turbine
- The Design and Procurement of the 500 kWh power plant and drive chain
- The assembly and testing of the major components
- The launch, deployment, installation and testing of the tidal system

The final step was the addition of the microgrid and energy storage project, in part made possible by a call by NRCan's Clean Enery Fund for innovative add-on projects.

This phase included:

- Conceptual Design of WWT's remote "islanded" microgrid system for Dent Island to manage tidal generation, energy storage and emergency back-up diesel.
- The construction, build and deployment of a self-contained enery management system.
- The procurement of the 500 kWh energy storage system from Tesla.
- The design and development of the custom interface between the proprietary WWT Microgrid Management System and Tesla's Energy Storage Management System.
- The intuitive, secure web-based control system for remote monitoring and software updates.

VI. Description of System and its Application

WWT's Tidal Energy System combines 3 major sub-systems – the floating tidal turbine, the proprietary microgrid management system and the energy storage system.

The WWT tidal energy system can be sold as a total turnkey installation, or the microgrid and energy storage system can be sold separately for use with other renewable energy systems.

The tidal energy system is scalable from 0.5 MW to 2 MW. Multiple generator units can also be installed in parallel to serve larger power demand. The microgrid and energy storage can scale from 0. 5 MWh to large industrial storage farms.

The key advantage of WWT's Microgrid system offers the ability to manage and synchronize multiple energy sources in a remote (off-grid) environment to provide firm, load following power.

This key feature will be required for any remote community to displace diesel with renewable energy sources. No one renewable power source – with intermittent and variable power production – can provide firm, year round power without an energy management and storage system such as that provided by WWT.

This first system at Dent Island manages power sources from tidal, energy storage and diesel. The 500 kWh Energy storage system allows firm power during slack tidal periods. It also integrates multiple sources of power to provide for peak periods.

WWT is currently adding solar and wind interfaces to provide secure, year-round power to remote communities.

The following schematic outlines these systems.

WWT System Schematic

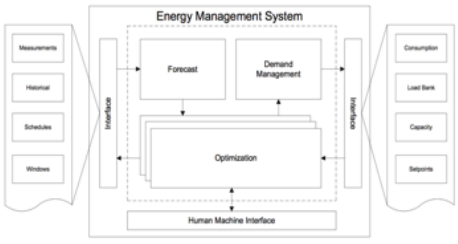
WWTURBINE #1

WET Energy

Energy Management System

Microgrid Management System
- Tidal energy power plant
- Battery energy storage system
- Diesel generator sets (3)
- E-house
- Inverters
- Voltage transformers

EMS
- Unit black start and priority
- Load pickup ability
- Load following capability
- Frequency regulation
- Web-based Communication
- Total operation control
- Synchronizing process



Energy Storage System
- Provides firm power from intermittent sources
- Scalable
- Fast charge/discharge
- Remote Monitoring

VII. Results

This project met all its original objectives:

1. To prove out a new, cost-effective technology for tidal and river stream resources,
2. To provide a show case to launch a national and international product sales and service model for this technology, and
3. To develop a microgrid management system with advanced energy storage for remote and distributed generation. Once established, this technology could put Canada in the forefront of tidal and river current power generation.

While all these major objectives were met, there were several deviations from the work plan. These deviations were caused by:

1. An extension of the project schedule due to three main factors: delays in vessel construction, rework of key components supplied by sub-contractors.
2. A budgetary increase due to major overages in the building costs and the unplanned decline of the Canadian dollar for payments to American component suppliers.
3. Delays were experienced in the coordination of the various sub-contractors at the remote site (only accessible by boat or float plane).

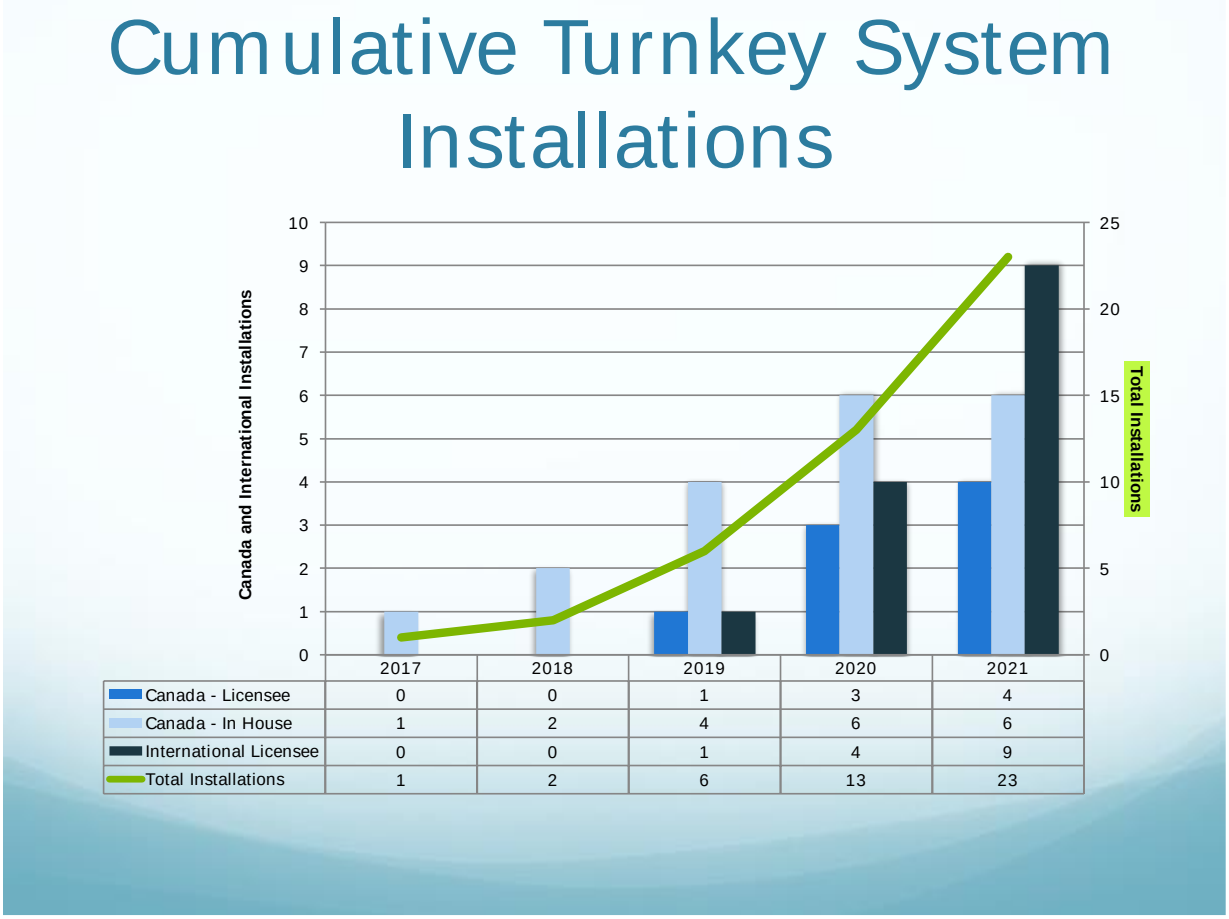
Additional major achievements are:

During the initial testing, net power production was delivered and the full testing period will take place in May to September 2017 during the Dent Island Lodge's operating season.

The design and installation of the unique mooring and anchoring system to keep the turbine at station under the tremendous bi-directional currents was a major success. The installation required special improvised techniques to secure the anchor points during very short windows between tidal currents exceeding 10 knots.

Off-grid control of frequency synchronization and load-following firm power from renewable generation devices that are both variable and intermittent were achieved.

Annual projects for the turnkey system installations are presented in the following chart.



VIII. Lessons Learned

- WWT overcame significant challenges related to the commissioning of a novel microgrid management and energy storage system in a severe tidal environment. WWT was able to design a secure anchoring system, lay the cable and connect the system in a remote location involving many subcontractors and partners and learned many valuable lessons along the way.
- WWT was able to develop methodologies to moor and anchor the vessel, able to withstand over 100 tonnes of force in alternating directions 4 times a day. There were no known precedents.
- Working with our contractors, WWT was able to plan the deployment with precision placement of the anchors and the 900-meter submarine cable in depths over 20 meters.
- This methodology will be of value to the placement other technologies that may also be prospects for our microgrid and energy storage technologies.

IX. Benefits

The new tidal turbine, complete with microgrid and energy storage, provides a showcase for the commercial development of tidal energy, both on- and off-grid. The technologies developed will advance the use of tidal energy in combination with other clean renewables by providing cost competitive, emission free power generation, particularly for the large segment of the world without large power utility suppliers. The demonstration project has already provided much interest for its technologies both locally, across Canada and internationally. During the project's development, WWT has had many interested visitors requesting a tour.

The major benefits from this demonstration project are:

Benefit 1

The energy efficiency of the WWTurbine exceeds most other windmill or turbine fan style tidal devices for deployment in shallow, narrow tidal currents in BC and internationally. The WWT design captures energy from both the current speed (kinetic) and the differential head from the blades barrage (potential).

Benefit 2

The WWTurbine has minimal effect on marine environments. It's slow moving (>10 RPM) horizontal turbine is isolated from large fish and mammals by protective grids, and any smaller marine life will pass through the system unharmed. Noise, particularly underwater, is minimal, similar to nearby washes, and overlaid by the sound of the moving current,.

Benefit 3

The WWTurbine was designed to deliver commercial scale power at the most competitive price possible, estimated to be an equivalent to a fraction of diesel costs for remote sites.

Benefit 4

The displacement of diesel provides two major advantages – reduced greenhouse gas and noxious emissions, and diesel spill risk mitigation.

Benefit 5

Many of the new technologies developed in this project could benefit other Canadian clean energy suppliers, particularly within the marine energy industry for mooring, microgrid management and energy storage.

X. Future Potential/Next Steps

Optimization and year-long monitoring and data gathering will continue., The results acquired to date provide a high level of confidence for future growth in both the tidal generation and the microgrid management integrated with energy storage systems. During the installation period over the summer months at Dent Island Lodge, there were several requests fortours from potential customers. The interest generated 3 new prospects awaiting the results of our first full season of testing.

- In years 3 to 5, WWT will expand our national footprint
- In years 5 to 10, WWT will look to expanding our international markets through licensed agents.

XI. Conclusions

The key results from this project are:

The development of a commercially viable tidal energy system suitable for narrow, shallow channels and river streams.

The development of a microgrid and energy storage system to manage multiple generation sources in a remote off-grid environment.

These two technologies allow the maximum displacement of diesel with multiple renewable sources. As all renewables are intermittent and variable sources; no one renewable source can provide firm, year-round power for off grid locations.

These new technologies provide the opportunity for a clean power option to many locations around the world. The multiple sources of power generation operating through a microgrid and energy storage system are key to supplying reliable, firm power to remote communites, partlculary in remote northern communities with extreme seasonal variation.