ecoENERGY Innovation Initiative
Demonstration Component
Public Report

Project: GC 128296

Glencore RAGLAN Mine Renewable Electricity Smart-Grid Pilot Demonstration

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1 Executive Summary

This Project aimed to set a new landmark in renewable energy penetration of diesel autonomous grids, by coupling leading-edge storage technologies and an advanced controller to an Arctic-grade wind turbine, at a Canadian Arctic mine location. The Project was successful in demonstrating a high-impact pathway towards full energy diversification north of the 60th parallel.

Overreliance on a single fossil fuel exposes northern mines and communities to significant volatility in energy prices, impacting negatively on investment and employment levels, while presenting higher environmental risks, reducing social acceptance of mining activities, increasing exposure to regulatory carbon taxes, and lowering the quality of life of communities. Tragically, overreliance on diesel in the North leaves unexploited one of the best wind resources, available in close proximity to significant industrial activity, in one of the most fragile ecosystems experiencing twice the South's rate in global warming.

The Project installed and operated a wind hydrogen smart grid system at Glencore's RAGLAN Mine, demonstrating in severe arctic climate conditions that industrial / community scale renewable energy with storage can significantly reduce the cost of energy and the diesel consumption, compared to diesel only or to wind-diesel alternatives. In particular, the Project demonstrated how essential energy storage is towards achieving higher levels of penetration in renewable energy.

As of this reporting, we successfully deployed and operated the wind turbine, achieving 97.3% availability during the inaugural period, displacing 3.4 million liters of diesel and 9,110 tons of GHG Green House Gas (equivalent to removing 2,400 cars from Canadian roads). Each storage technology has been commissioned and activated, with positive control from Hatch's HµGRID controller. Experimental optimization is taking place to achieve higher than 40% renewables penetration contained to the subset island of Mine 2 and 3, within RAGLAN's broader micro-grid.

Importantly, the System paves the way towards further regional deployments, community energy, mining transport electrification, and lowered underground emissions at the flagship RAGLAN site. The Project's financials will aptly sustain operations for the next 5 years at RAGLAN, but further regional projects remain economically challenged without continued governmental support given that, over the course of this project, nickel price eroded to the lowest level in 12 years, and oil prices plunged from $120 to less than $30 / barrel in the span of 10 months.

2 Introduction

The Project demonstrated, among other elements, how a hybrid system can integrate high-penetration renewable power with fossil fuel generation in such a way as to maintain grid stability (voltage and frequency) in spite of the intermittent nature of wind power.

The Project minimized the loss of wind energy due to wind curtailment (blade-feathering, or load shedding, or blade ice formation) incurred in conventional wind-diesel hybrid installations, in order to maintain grid stability and when wind power generation is greater than the load. Importantly, it eliminated the need for wasteful diesel powered spinning reserves running at partial loads, and gainfully captured the waste from wind curtailment occurring during excess wind conditions.

The Pilot showed how to meet the above storage requirements and how such a sophisticated system could be delivered in a remote location (Glencore's RAGLAN Mine: 61.66°N; 73.62°W), and how the system could be seamlessly operated as part of complex mine operations subjected to harsh climate conditions.

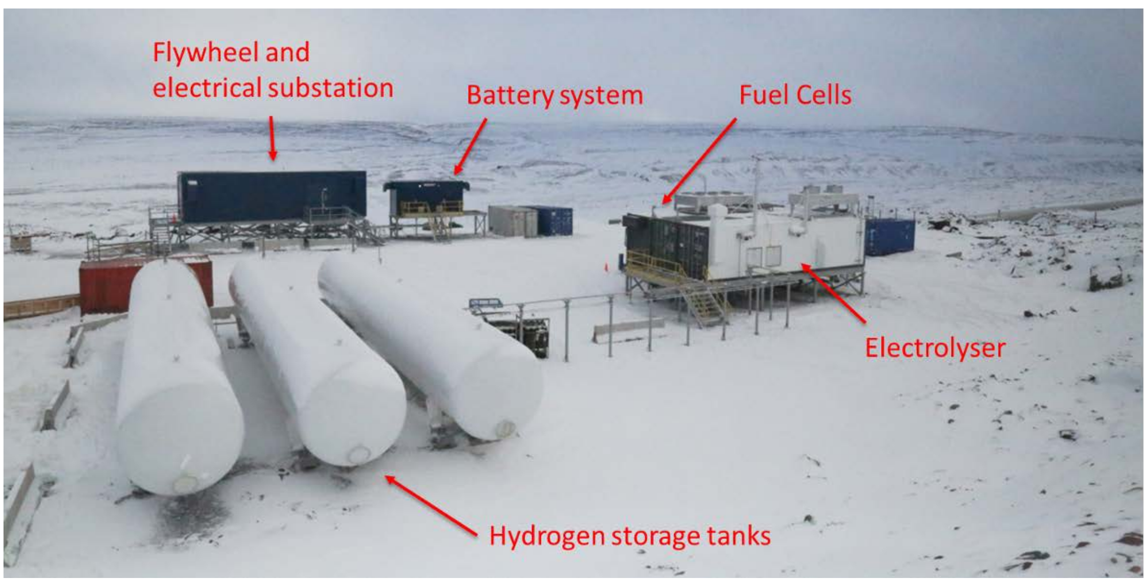


Figure 1 - Layout of Renewable Energy Storage at RAGLAN Mine

During the FEED Front-End Engineering and Design, the site originally selected for deployment (i.e. the port at Deception Bay), was subsequently changed to Mine 2, east of RAGLAN's main complex (Katinniq), because of Inuit reservations expressed about the Deception Bay location (stroboscopic impact on fishing and wildlife, raptor's nesting in proximity). Mine 2 proved a better location to demonstrate autonomous islanded grid operations, as its own 1.6MW diesel genset with 1.4MW average local load matched well to the 3MW wind turbine's 32% capacity factor and to the 600kW storage systems' production.

All long lead-time items were ordered in December 2013 and January 2014, and were shipped in time to the site. Turbine foundation work started in Spring and Summer 2014, and the foundation was ready for turbine erection in August 2014. Storage plant and electrical collector grid works were completed by September 2015, and complete project start-up was achieved on December 17th, 2015, with the first 16 kWh of hydrogen electricity produced on that day.

Collaboration with Glencore's RAGLAN Mine was excellent, along with multiple strategic partners: Hatch Ltd., BBA Inc., Enercon G.m.b.H., Hydrogenics Corp., KTSI Kinetics Traction Systems Inc., Groupe Ohmega Inc., Gas Metro Renewable Energies, Morneau Construction Inc., NEAS Shipping Co., Katinniq Transport Ltd., and a range of other suppliers and partners involved in this $20M effort.

3 Background

To date, virtually all energy (electricity, transport, and heating) needs in the North are met by diesel, and no substantial deployment of renewable energy existed among the North's largest emitters until recently (Diavik 2012, RAGLAN 2014), in spite of some of the best wind resource available and in spite of oil prices' volatility in recent years.

As a result, Canada continues to consume **1 billion liters of diesel** annually north of the 48th parallel[1] (60th parallel west of Ontario), expected to grow to **1.5 billion liters annually** by 2035 if unabated, in one of the most fragile eco-systems (incurring global warming at twice the rate of that experienced in the South).

The challenge faced by mining companies pursuing operations in the North is similar to that faced by northern communities pursuing economic development– having access to sufficient low-cost reliable electricity and energy. Due to their extreme northern location, and to the sparse population spread out over great distances, it is not feasible to provide hydroelectricity or tie-in to the national grid without significant subsidies from government. As a result, mining companies have had to rely on their own resources to generate power using diesel generators.

[1] Source: KPMG-Secor Report "*Assessment of Potential Diesel Demand in Mines and Remote Communities in Northern Canada*", commissioned and sponsored by TransCanada, TUGLIQ Energy Co., NRCan, and Quebec's Ministère de l'énergie et des ressources naturelles, Montréal, 4 April 2013.

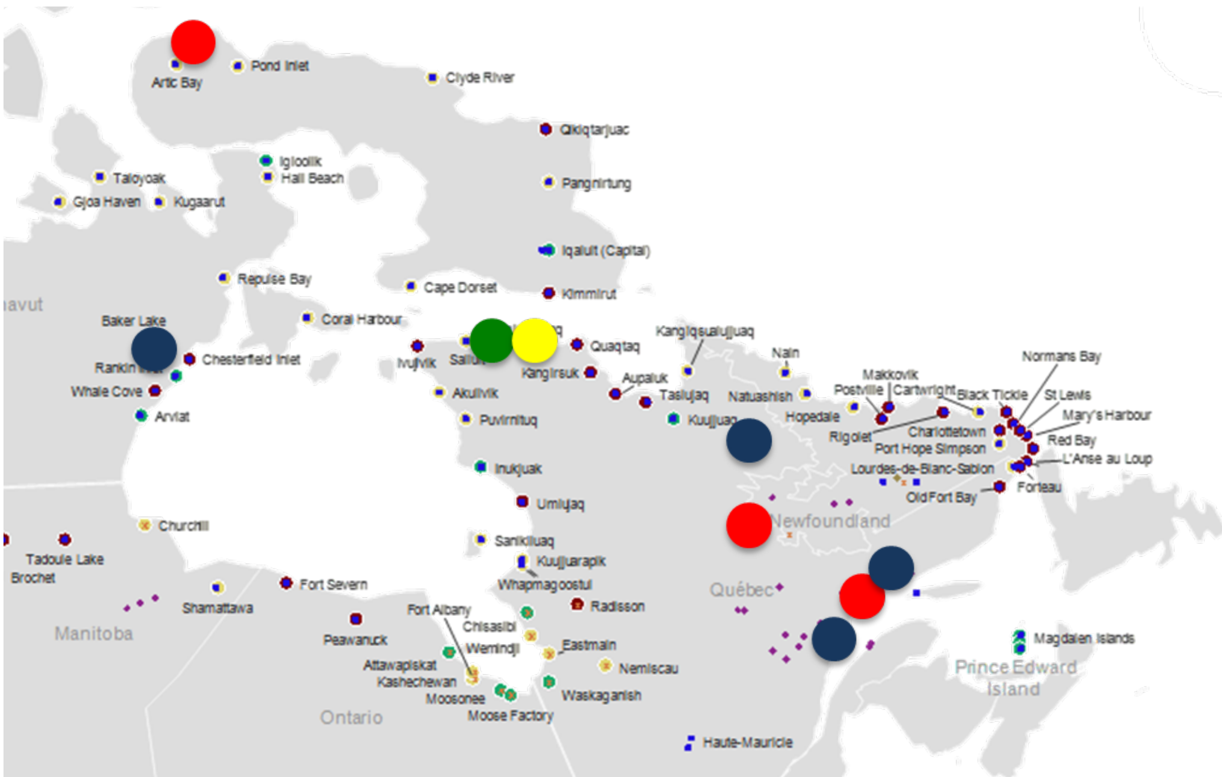


Figure 2 - Map of Main Diesel Consumption Points in North-Eastern Canada

The exclusive use of diesel fuel for electricity generation has left mining companies exposed to volatility that has caused oil prices to more than double in a span of 5 years, and to triple in 10 years, before plunging back to 25% of its peak value within 10 months. Electricity rates in the north range from a high of $1.20 / kWh, to a low of $0.20 / kWh, with average industrial self-generators achieving $0.25 to $0.60 / kWh, in spite of grouped purchasing power.

Much of the overdependence on diesel in the North is due to the fact that northern operators deem renewable energy to be too variable to be reliable at high penetration and at industrial scale, and that such condition can lead to micro-grid collapse with dire consequences on operations and on human life (failing ventilation underground, with emergency egress with prolonged exposure to -40°C for the miners). Also, many deem wind energy impossible in the Arctic, after failed deployments in the past 30 years in the Region.

Therefore, this Project aimed to demonstrate that high-penetration renewable energy at industrial / community scale in the Arctic is not only possible, but also reliable, and that the risks associated with an overdependence on fossil fuels can be reduced and ultimately eliminated.

To that end, the Project installed a 3 megawatts (MW) wind turbine with a hydrogen based storage system on a diesel microgrid at a mining location in Northern Quebec, to decrease reliance on diesel fuel electricity and to pave the way towards electrification of transport (with renewable hydrogen range extenders onboard). Other complementary storage technologies included a flywheel and a Li-Ion battery system.

As shown in the Front End and Engineering Design (FEED) study funded by the ecoENERGY for Innovation Initiative, wind energy at the Project site was found to be persistent, abundant and of world class quality. Utilizing such wind energy enhances the robustness of the mining industry and northern development, since wind energy can be the lowest cost of energy that is available locally, and is the cleanest and the most socially acceptable current option at the scale required.

Combined with an efficient storage system, renewable energy proved to significantly reduce operating costs, green house gas emissions, and dependence on diesel fuel, in mining operations and communities of the Canadian North. Furthermore, experience indicated that energy storage is a necessary enabler towards persistent penetration higher than 40% of diesel micro-grid capacity. Documented field deployments of MW-class hybrid-diesel grids report persistent penetration of less than 20% without storage, and 60%-70% with storage on a sporadic / intermittent basis, but none with persistent long-term displacement of 30% - 60% of diesel, year over year. Therefore, this Project aims to conclusively break through the barrier of 30% - 50% penetration in renewables, at the largest micro-grid and largest emitter in the Arctic, Glencore’s RAGLAN Mine.

4 Objectives

This Project’s objective was to install and operate a wind hydrogen / energy storage smart grid system at a remote northern mining location in order to establish a new state-of-the-art in high penetration renewable power and storage technology. The system was to be installed at a remote mine in severe arctic climate conditions, to demonstrate at an industrial scale that such configuration can operate reliably and achieve significant reductions in the cost of energy and in diesel consumption compared to diesel only or to wind-diesel alternatives.

To achieve high penetration of more than 40 per cent renewable energy on the diesel plant, the Project included a three-tiered storage architecture composed of a fast transient energy storage flywheel to filter out large wind power variations in short durations, a short term battery storage to start up backup diesel generators or fuel cells as required, and a longer term hydrogen fuel cell storage to minimize the loss of wind energy over longer time periods and capture energy that would otherwise be wasted. The three-tier architecture also aimed to minimize the wear and tear on backup diesel gensets by frequent on-off resulting from low storage of bridging renewable energy; it also aimed to substantially reduce the diesel spinning reserves required to maintain micro-grid responsiveness and stability.

To that end, the Project deployed an arctic-rated 3 MW ENERCON E-82 E4 wind turbine generator, coupled to leading-edge storage technologies configured in a three-tiered smartgrid: a 200 kilowatt (kW) 1.5 kilowatt-hour (kWh) KTSI GTR-200 flywheel for fast transients, a 200 kilowatt (kW) 250 kilowatt-hour (kWh) Electrovaya SuperPolymer 2.0™ Li-Ion battery for transition backup, and a HYDROGENICS 200 kW/ 1 MWh system (HySTAT 60™ Electrolyser 315 kW coupled to HyPM-XR.TM 198 kW PEMl fuel cell).

Figure 3 - Energy Storage in Arctic Environment at Mine RAGLAN

Over the 20-year life of the wind turbine, the Pilot aims to achieve savings estimated at $41M in fuel and operation and maintenance, making RAGLAN more economically robust through nickel's commodity pricing cycles. The Pilot aims to act as a regional flagship and reference site for further industrial-grade renewable energy deployments, paving the way towards two more industrial-scale wind farms in the region within 3 years of a successful demonstration project launch. The scale of the Pilot is deemed to readily apply to the scale required by many northern communities currently operating on diesel.

5 Results

5.1 Project Achievements

The Project accomplished many landmark achievements and demonstrated strategically-important results, fulfilling its mandate of regional flagship and reference site for future deployments.

In terms of differences between the initial project description and the finalized project, there was the upgrading of the originally-planned 2.3MW to a 3MW wind turbine, and the supply of a KTSI flywheel instead of a Temporal one (the latter not commercialized yet at the project launchtime). There were no other significant differences from the original project description.

Figure 4 - Electrical Room, Flywheel, and Battery Container

5.1.1 Storage Energy Successfully Integrated into Diesel Micro-Grid Integration

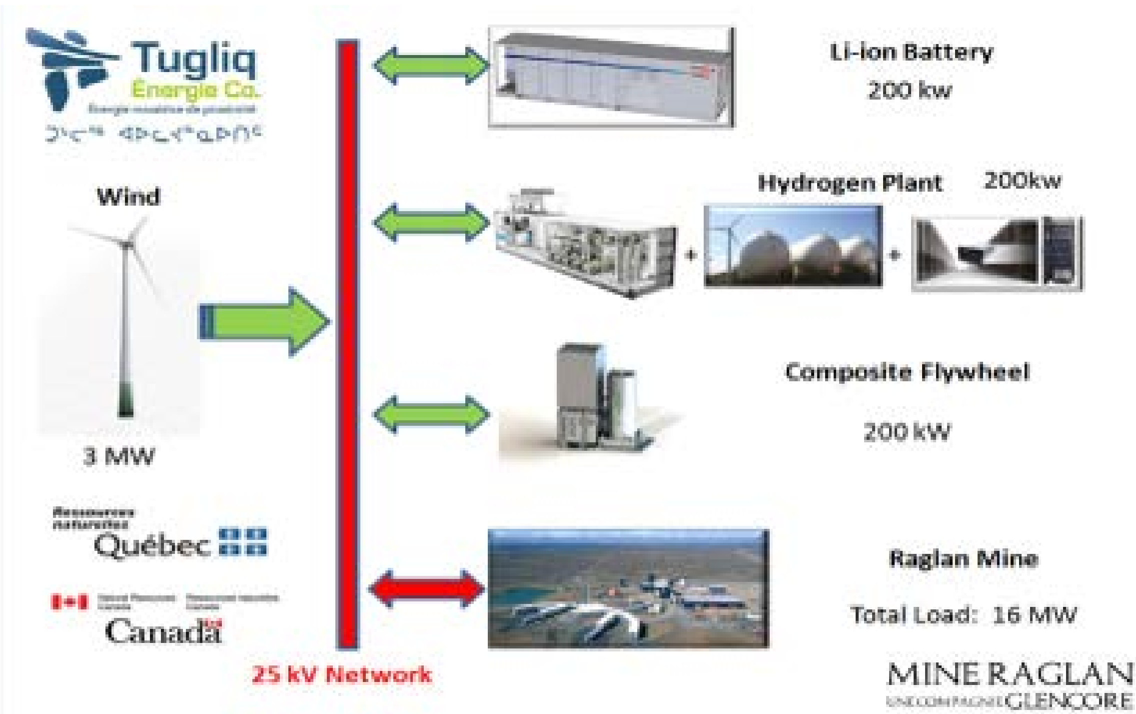


Figure 5 - Demonstration Conceptual Diagram

- Demonstrated interplay of multiple storage technologies in smoothing of sudden loss of wind energy, adapting to drops and dips in wind power:

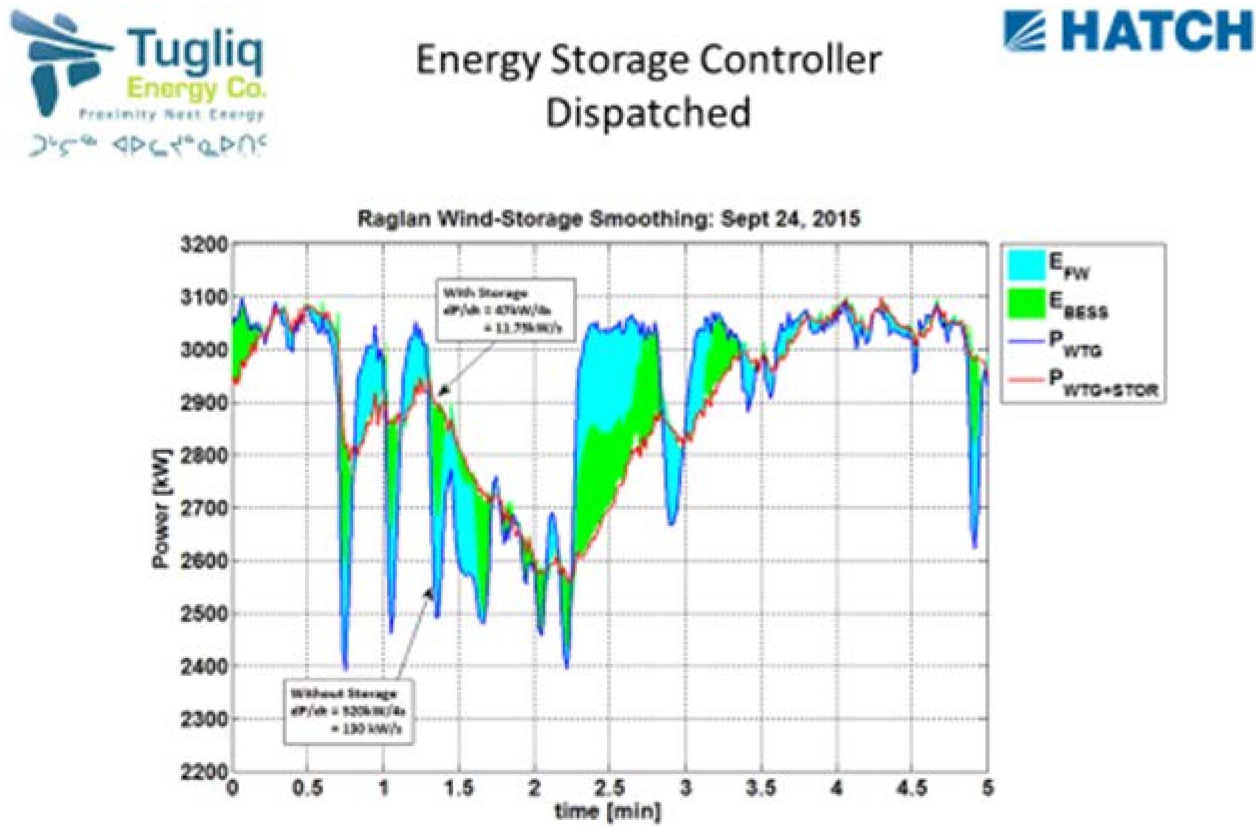


Figure 6 - Smoothing Function of Energy Storage

For instance, in “Figure 6 - Smoothing Function of Energy Storage”, compare the blue line (pure wind power) to the red line (wind power + energy storage) of a 5-minute sample of electrical generation: at timemark 1.3, one can see that the rate of power drop of the pure wind energy (blue line) minute was 130 kW / s, but that the battery and flywheel combination was able to dampen such drop to a smoother 11 kW / s (red line).

Generally, the red line (wind+storage) presents a less challenging absorption load on the microgrid than the blue line (wind turbine only), ensuring better stability and reduced stress on the diesel assets, both key enablers of high penetration of renewables within diesel microgrids. The green surface below the blue line illustrates the contribution of the BESS Battery Energy System to the smoothing, whereas the light blue surface illustrates the contribution of the FESS Flywheel Energy System.

- Demonstrated capacity of riding through momentary wind power dips and drops:

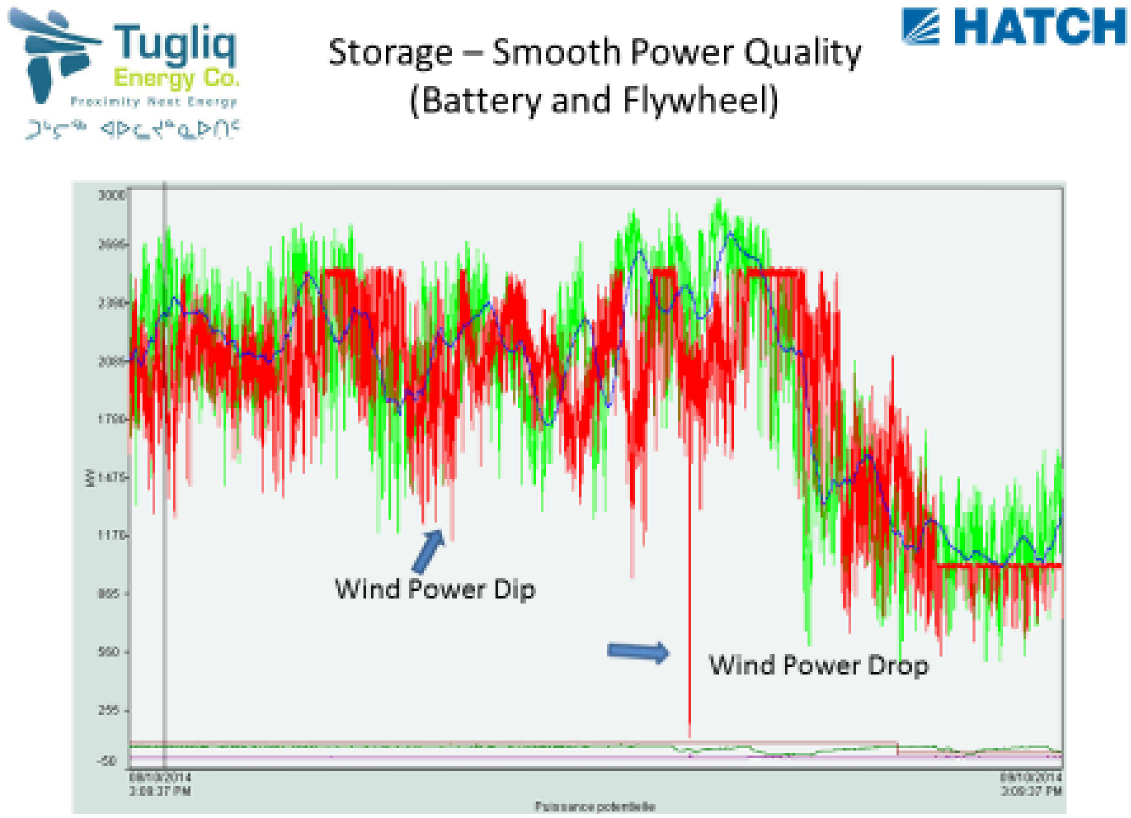


Figure 7 - Ride-Through Function of Energy Storage

In “Figure 7 – Ride-Through Function of Energy Storage”, one can see that the battery and flywheel combination can ride through wind power dips and drops without prejudice to the system. In this graph, the red line represents the wind power available from the wind turbine at any given time (wind produced), whereas the green line represents the actual load requiring service from the grid, and the blue line represents the Wind + Storage net power production. A wind power drop is defined as a sudden loss in wind power that drops to 0 kW produced, whereas a dip is a sudden loss to a value higher than 0 kW. Wind power dips are frequent, whereas complete wind power drops are rare. Note that a “plateau-ed” red line indicates that the wind turbine is in curtailment mode (high plateau being curtailed due to strong winds, and low plateaus being curtailed due to temperatures dripping below 40°C). In the graph, the blue line superimposed to the red (raw windpower) and to the green (raw load) show that the storage system is able to accommodate both dip and drop events, over a one-hour period of observation.

- Demonstrated capacity of stopping one genset spinning reserve with sufficient time for restart using battery power:

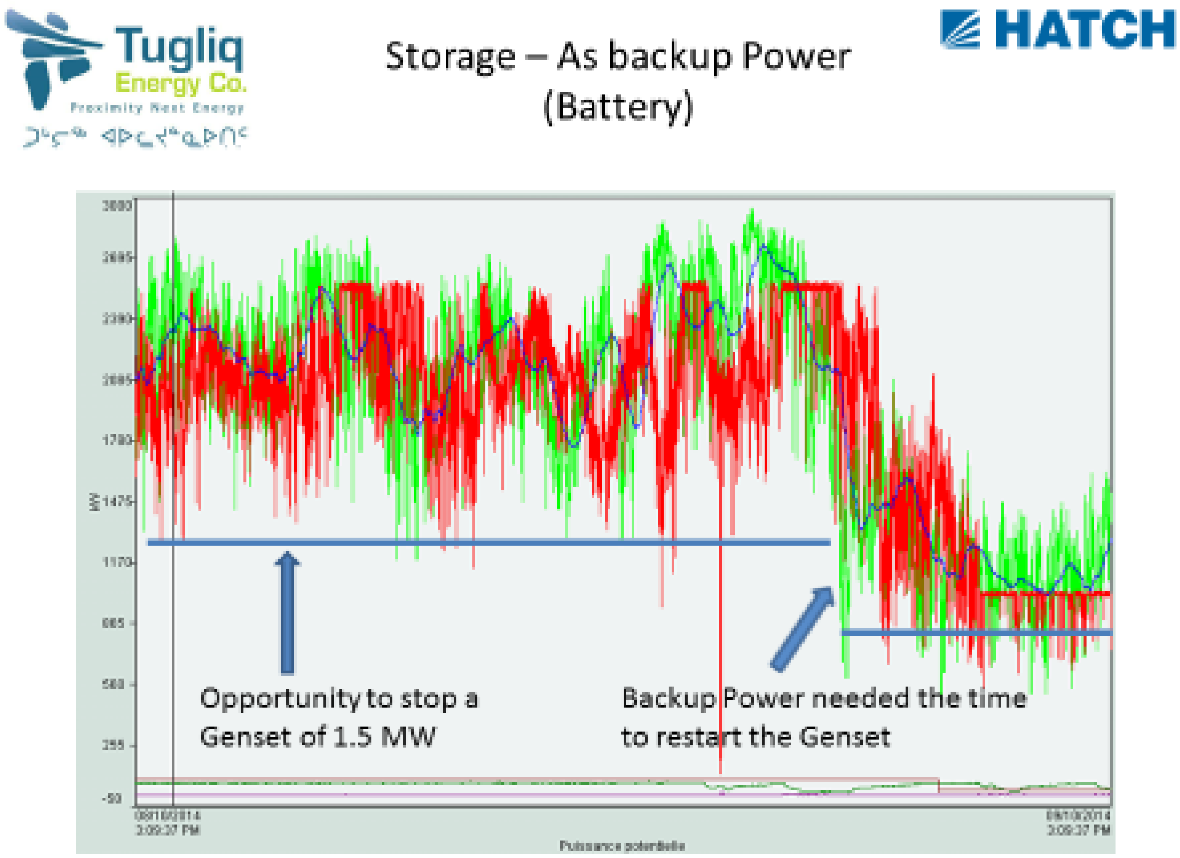


Figure 8 - Spinning Reserve Function of Energy Storage

In this graph, the red line represents the wind power available from the wind turbine at any given time (wind produced), whereas the green line represents the actual load requiring service from the grid, and the blue line represents the Wind + Storage net power production.

On the left half of the graph, one can observe that the wind energy is sufficiently in synchronicity with the load in the 1.5 to 3 MW band that a full 1.5MW diesel genset spinning reserve could have been shut down for the first half of the observed period without impacting the microgrid - the blue line (combined Wind + Storage) never dipped below 1.6MW in that first half.

Conversely, on the right-hand side of the graph, one can observe that the matching band between load and wind power is still in synch, but that the 1.5MW genset spinning reserve that would have been turned off in the first half would have needed to be restarted in order to prevent the blue line from dipping too far below the load green line. At the critical transition of regimes (mid-section), the storage would have provided dampening time sufficient to start a diesel genset and ensure that the grid would be supplemented adequately (blue line not dipping too far below the green one).

- Developed HMI[2] and response protocols, as well as embedded programming and technicians' training, to minimize impact of wind variability and to maximize response / adaptability to fluctuating conditions
- Future steps: setting subset of Mine 2 and Mine 3 loads and gensets as high-penetration micro-grid within Glencore's larger micro-grid, optimizing use of storage to achieve reliable penetration surpassing 40% from renewable energy.

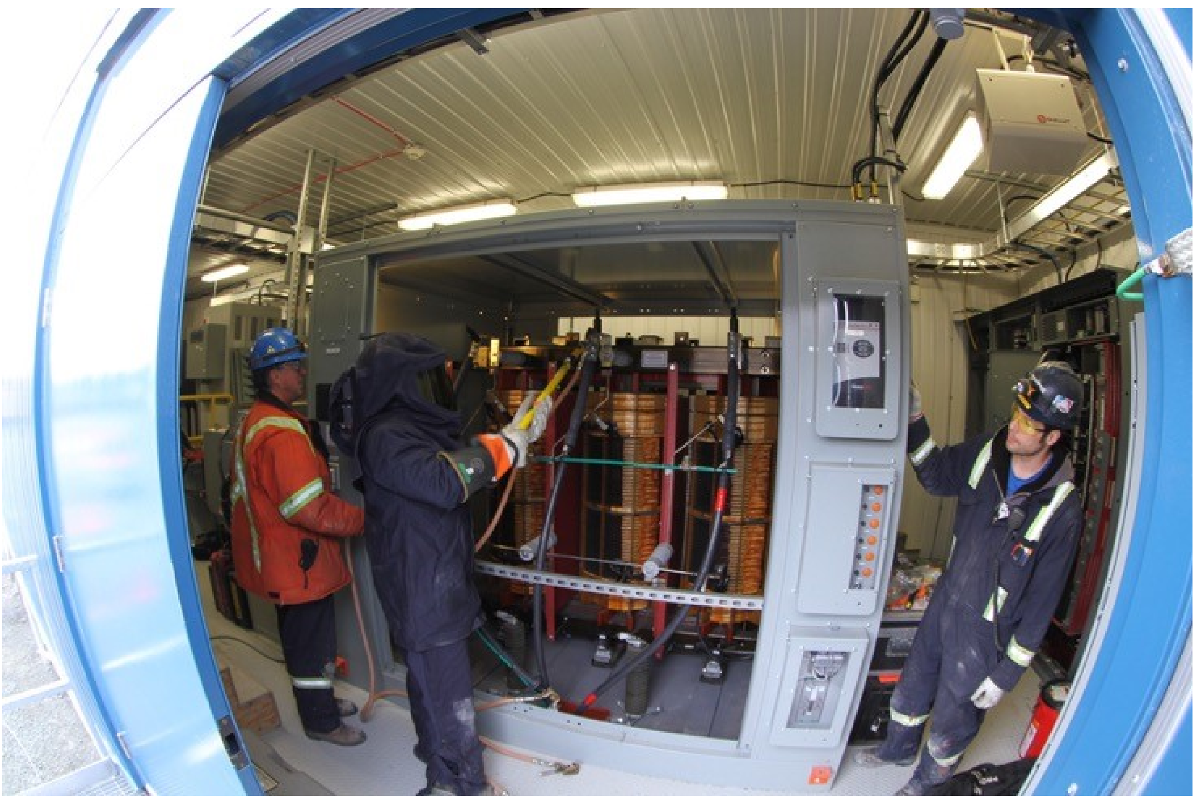


Figure 9 - Switchgear and Power Electronics Installation

[2] HMI: Human Machine Interface

5.1.2 Predictive Algorithms of Variable Wind for Diesel Micro-Grid Integration

- Represents a feature essential in enabling high-penetration of variable renewable energy
- Enables decisions in SOC State of Charge setpoints for each energy storage technology, that smooth out the variability of the wind input to the maximum extent possible by the three-tiered architecture, and that minimizes the loss of excess wind
- To that end, proponents established partnership with a weather prediction company (wPRED, see http://www.wpred.com/) who worked with TUGLIQ to develop the HMI described herein, now used daily by Glencore Control Room operators and by TUGLIQ's operations team;
- TUGLIQ developed further algorithms and methodology in cooperation with Glencore RAGLAN control room operators, Hatch Ltd, Groupe Ohmega, BBA, and wPRED
- TUGLIQ automated daily emails at 8am each day to provide operators and decision-makers with a detailed medium-term (7-day) and long-term (14-day) forecast, both in graphical and tabular (color-coded) format, specific to the E-82 wind turbine and to its location (61.66°N; 73.62°W)
- Impacts:
    - Substantially increased the level of grid integration of the available wind resource by (Glencore's) Control Room operators
    - Reduces level of wasted excess wind in high-penetration conditions
    - Increased grid reliability through better anticipation of freezing conditions, of inadvertent shutdowns, of blizzard / gusts / lull conditions, and of spinning reserve requirements
    - Increased confidence and predictability among Glencore's Control Room operators to accept higher levels of penetration

The following illustrates the predictive information generated by the system and communicated daily to the Glencore Control Room:

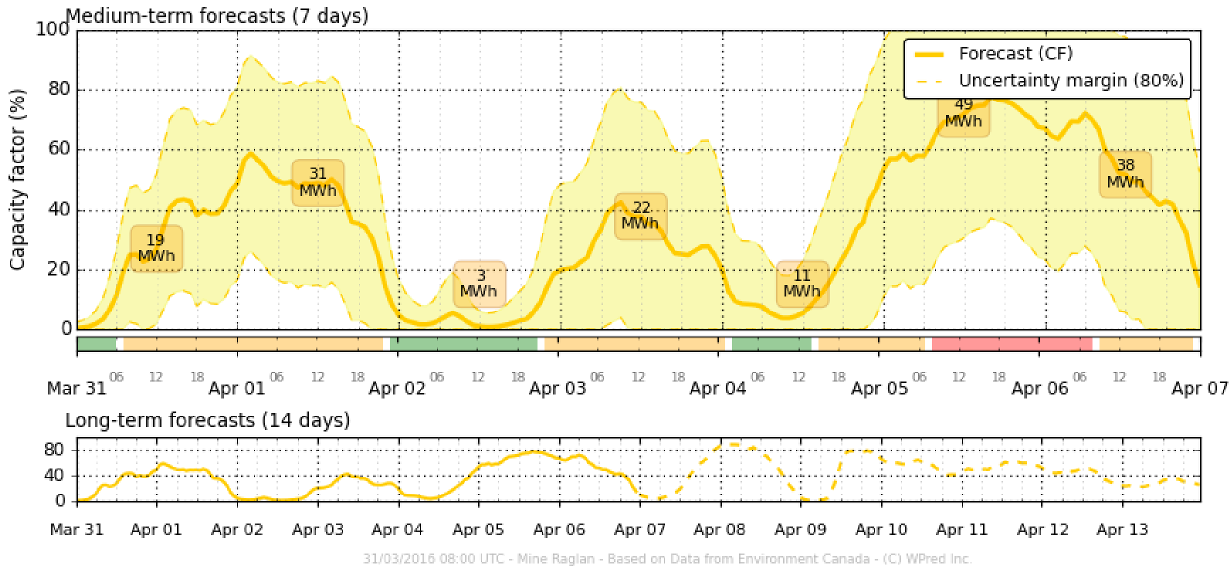


Figure 10 - Predictive Algorithm Output for RAGLAN Operations

"Figure 10 - Predictive Algorithm Output for RAGLAN Operations" indicates for an ensuing 7 days the capacity factor (% of the 3MW capacity) and the energy anticipated daily (central tendency within an 80% uncertainty band), specific to the E82 operated at RAGLAN. This information has proven useful to schedule the start up or shutdown of individual diesel spinning reserves, as well as the State-of-Charge setpoints for the energy storage.

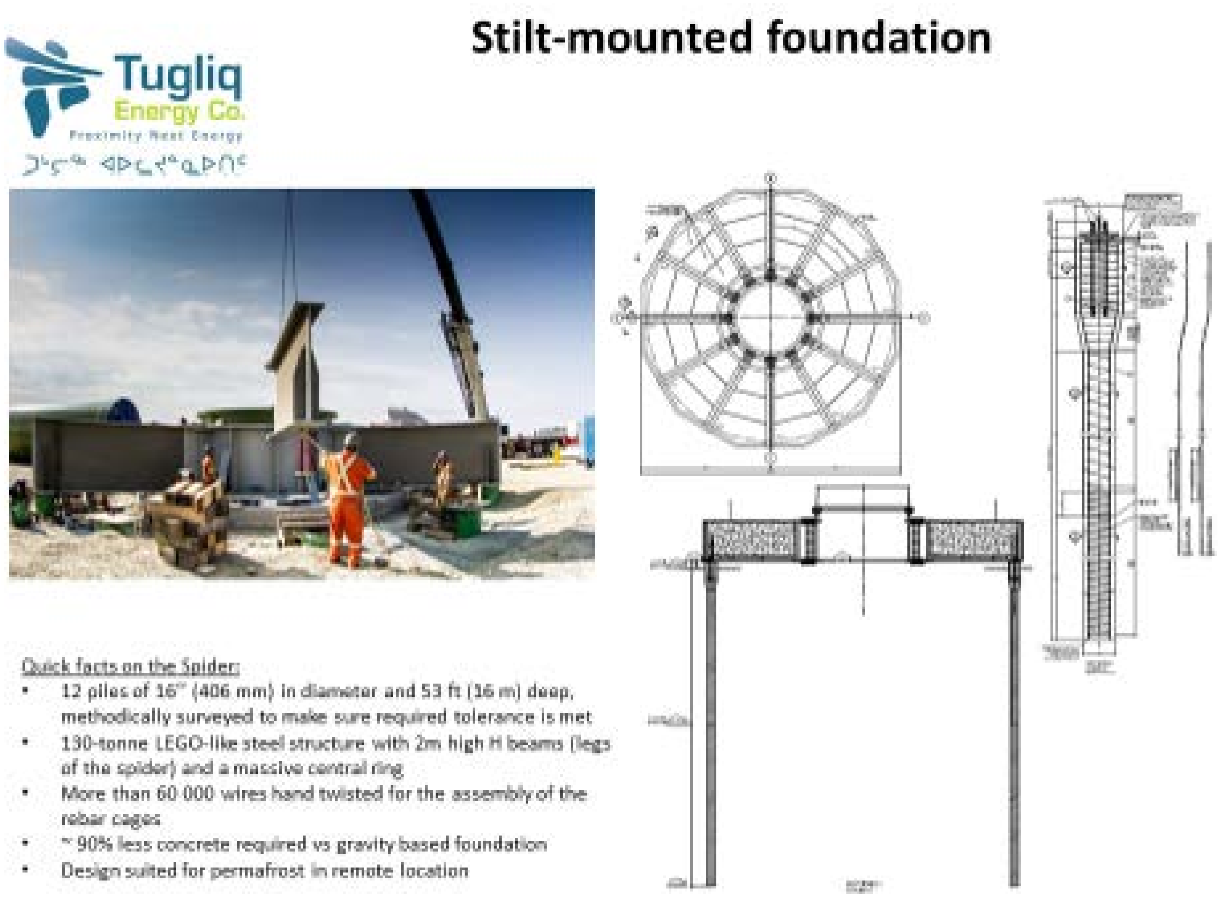
Other graphs, too numerous to portray in this completion report, for instance forecasting temperature vs precipitation, would be used to predict the formation of ice on the blades (and hence a reduction in real Capacity Factor), or the loss of power due to -40°C curtailment.

5.1.3 Innovative Wind turbine Foundation Adapted to the Arctic

- Elevated above ground, on piles, using a "spider-like" structure with steel ring
- Makes the foundation impervious to melting of Arctic ice lenses in permafrost (Arctic's global warming accelerating over the 20-year lifetime of the wind turbine may melt ancient ice lenses)
  - "Spider-legs" resting on deeply-anchored piles will guard against eventual tilting of the wind turbine
  - Strengthening against 160 km/h wind gusts during Arctic blizzards
- Reduces by 90% the amount of concrete required

- o Concrete costs are prohibitive in the Arctic (four times more expensive, at $1,200 / m3 versus $300 / m3 in the South)
- o Also, the limited capacity of portable cement plants impaired the continuous pouring required by the civil engineering specifications for mooring strength
- o Maximizes local sources of aggregates, minimizes imported sources of aggregates, reducing transport GHG

- Impacts:
  - o a new benchmark of how future wind turbine foundations may be built, in the Arctic and in the South
  - o reduced GHG carbon footprint due to the elimination of transport of heavy aggregates
  - o stronger, more universally applicable design regardless of soil composition



5.2 Benefits

5.2.1 Financial

- $ / kWh LCOE[3] reduced by double-digit percentage at Glencore Mine Raglan
 (actual value is available to financial sponsors upon request, but remains confidential to Glencore / TUGLIQ, for competitive reasons)
- Increased robustness to Glencore's business model at RAGLAN, whereby the second largest cost element (after manpower) – energy - in now partially "fixed" for the next 20 years, more diversified and less tightly correlated to fossil fuels' price volatility
- Partnered with TD Bank, Canada's largest bank on an asset-basis, to commit to its first wind energy investment, bringing to contribution conventional banking sources of a larger scale for future energy diversification investments in the North

5.2.2 Validation

- De-risked future major energy procurement decisions in Canada's northern communities and remote mining operations
- Established a flagship reference site validating
    - Technical feasibility
    - Year-round operation under extreme conditions
    - Associated economics and business case; and,
    - Modularizing and right-sizing future applications based on real operational experience

5.2.3 Environmental

- Displaced 3.4 million liters of diesel and 10,200 tons of GHG within first 18 months of operation
- Displacement of 2.2 million liters of diesel per year at RAGLAN for the next 20 years now appears achievable and likely
- Environmentally equivalent to removing 2,400 cars from Canadian roads
- High impact results from one the Arctic's largest emitter, in a fragile eco-system where global warming rate is twice that of in the South
- Took advantage more fully of Canada's richest wind resource (availability of cold/dense arctic winds), in close proximity to where it is most needed and most impactful
- Achieved better alignment of Northern resource development with traditional Inuit landholder values

[3] LCOE Levelized Cost of Energy

- diesel not transported by road nor by sea reduces risk and severity of oil spills in arctic ice or frozen ground

5.2.4 Industry

- 11 jobs created with ongoing operations, and 60 construction / engineering jobs during deployment, among high-tech start-ups and partners
- 65% Canadian sourcing of technology content, designed, developed, built and delivered in Canada
- Packaging and partnerships replicable / deployable into other export markets
- Substantial improvements implemented across all technologies involved, making them more competitive for global exports
- Substantial reduction in energy cost, helping make Canada one of the most robust and productive mining regions in the world

5.2.5 Regulatory

- Mitigated the economic impact of Cap and Trade and Carbon for Glencore Mine RAGLAN, helping maintain competitiveness of industrial operators in jurisdictions where such measures are applied
- improved knowledge to support regulations ensuring technology uptake and energy diversification
- Validates / opens options in setting energy policies for Nunavut, Nunatsiavut, Nunavik, Northwest Territories, and Yukon
  (e.g. making the filing of an energy diversification plan part of the application process to secure C.A. Certificate of Authorization for the opening of future mines, secure in the knowledge that renewable energy can be made to work in such regions)

5.2.6 Canadian Economy

- Significant transformative contribution to the energy landscape in the Arctic and to Canada's mining sector
- Created a flagship reference site important to the development of export of Canada's cleantech industrial base in a prime Canadian sector (mining), internationally and domestically
- Provided a mechanism to make Canada more economically robust to ride through deep commodity cycles
- Increasing acceptance of mining projects in the far north, providing economic development opportunities to some of the most disadvantaged communities

5.2.7 Caveat

Notwithstanding the above benefits and achievements, the rate of follow-on projects' uptake will hinge upon the evolution of commodities pricing, specially oil. For instance, in the case of Glencore Mine RAGLAN, nickel prices are trading at their lowest in 12 years, and oil prices have plunged to 30% of their value of 10 months ago.

The decreased mining revenues and lower diesel prices make the introduction of new renewable energy more problematic. For this reason, sustained governmental incentive will continue to be necessary beyond the pilot phase, if Canada is to build on the successes accomplished to date in energy diversification for the North.

5.3 Technology Development Objectives

The Demonstration achieved unprecedented landmarks in renewable energy and diesel micro-grids:

- Surpassing 40% in penetration of renewable energy relative to installed diesel generated electricity, the result of which being supported by the other two landmarks below;
- Hybridization of three energy storage systems, each with its own purpose and capabilities, yet working concurrently;
- Controller (Hatch HµGRID), software, algorithms, HMI, human and organisational processes, technical onsite presence and attention, enabling optimization of energy assets beyond levels previously achieved;
- Highest availability among hundreds of Enercon E-82's in Canada
- Above-ground, stilt-mounted foundation, reducing concrete by 90% and eliminating permafrost footprint impact / exposure by 85%

Although the Project was deployed at the Arctic's largest operation and GHG emitter, the pilot was scaled to match a northern community or small mine, so that the benefits and future uptake of the technology could be replicated to multiple sites across northern Canada, while allowing a meaningful scale up at RAGLAN.

For the reasons enumerated under Section 6 "Results, Achievements, and Benefits", the Project will contribute significantly and transformatively to the energy landscape in the Arctic and to Canada's mining sector.

6 Conclusion and Follow-up

This Project was successful and has become an international flagship reference for energy diversification in Arctic regions. It achieved landmark results in renewable energy penetration of diesel autonomous grids, by coupling leading-edge storage technologies and an advanced controller to a built-for-purpose wind turbine and foundation, at a Canadian Arctic mine operating under severe climatic conditions. The Project was particularly successful in demonstrating a pathway towards full energy diversification in Northern Canada, where diesel has remained the unique and pervasive source of energy until now.

A number of barriers and challenges were overcome, and substantial improvements of all technologies involved were achieved. One of the best wind resources in the world can now be brought to contribution in reducing the carbon intensity of northern development, specially for mines and communities.

6.1 Potential for Replication

This Pilot project has excellent replication potential:

- Pilot was scaled and structured specifically for replication at local communities and / or smaller-size mines off-grid
- High non-recurring engineering and design is now a sunk cost, that will not have to be incurred on future deployments
- Potential replication to the billion+ people without electricity in the world

Notably, TUGLIQ anticipates the LCOE from the first deployment to drop by 20% by the second and third, and to drop by more than 35% by the 10th. Half of the LCOE drop would be explainable by learning curve effects (volume discounts), and half by enhanced technology and process improvements. Note that half of Project costs are not compressible, e.g. arctic logistics, transport costs, crane rental, equipment, labour content, etc.

The key areas where costs and barriers to replication have been reduced due to this demonstration are: product improvements (e.g. more than 31 itemized improvements on the wind turbine), skills sets (particularly in energy storage technology and in the HMI, algorithms and processes related to the latter), and financing costs (due to reduced perceived risks following a successful execution).

The replication potential within 3 years is excellent, at one to two deployments, including a RAGLAN Phase II and a sister site at Canadian Royalties (30km away from the RAGLAN windfarm). From 3-to-5 years, the replication potential is at a further 3 sites, based on TUGLIQ’s expressed interest and revenue pipeline. Beyond, from 5 to 10 years, TUGLIQ expects an acceleration of transport electrification and a reduction in the price of storage, which will drive replication of up to 10 units. Beyond that timeframe, replication could double every 5 years, given the large markets that “pixelized grids” based on renewables could penetrate worldwide.

6.2 Project Monitoring

The Project is fully funded and staffed to complete the five-year follow-on period and the monitoring activities that will feed into the annual reports required by NRCan. TUGLIQ, Hatch, Glencore Mine RAGLAN, Enercon, and other partners in the Project wish to leverage and deepen the know-how acquired through the Project and through the follow-on period, to export the technology to other mining clusters in the North and around the world.

The three databases (Glencore's Mine Pi system, Hatch's HµGRID, and TUGLIQ / Ohmega's) will generate a rich, redundant, and accessible set of data that will be mined to optimize the use of storage to increase penetration of renewables in hybrid diesel microgrids.

6.3 Next Steps

The Project is ushering multiple industry-defining next-steps, not the least of which will be the electrification of transport at RAGLAN, especially underground transport, and the integration of electrified vehicles to the micro-grid (V2G, "Vehicle to Grid") as one more storage vector enabling high penetration of renewables. Furthermore, the availability of locally-produced renewable hydrogen will also enable the deployment of range-extenders without which electrification of heavy-duty industrial transport cannot take hold in the Arctic.

Another important next step for Market Penetration will be a local scale up involving another wind turbine and storage system for RAGLAN, and a third delivery of the same at Canadian Royalties (another nickel mine 30 kilometers south-east of RAGLAN). Repeat orders within the domestic market are viewed as critical before any export abroad can be contemplated. Beyond local repeat orders, TUGLIQ is currently entertaining 6 other leads for similar systems in the territories of Nunavut, Nunatsiavut, Nunavik, Northwest Territories, Yukon, and Alaska.

In terms of R&D, Hatch, TUGLIQ, and Glencore RAGLAN's control room, are developing a testing protocol covering the 5-year follow on period required by NRCan, which will include the planned and deliberate isolation of the diesel genset(s) at Mine 2 and 3 with a direct connection to the windturbine and storage already installed there, so that the system can be operated as a self-contained islanded subset (or sub-microgrid) of the larger micro-grid at RAGLAN.

Under such scheme, penetration as high as 100% can be tested and operated for extensive periods, and any surplus generated thereby can be exported to the larger micro-grid. If continuous operation can be demonstrated and operated comfortably, then all future grid developments could be adopting a paradigm of incremental renewables coupled with some energy storage and load-balancing among neighboring nodes of export / import energy ("pixelized grid").

TUGLIQ wishes that the Federal Government, as a force multiplier to other collaborative provincial or territorial governments, continue to be a catalyst for such development, by helping mining companies overcome the hurdles caused by the temporary plunge in oil prices and commodities.

Figure 11 - Arctic Landscape of RAGLAN's Energy Storage