Inuvik Wind Monitoring Update 2016

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Executive Summary

Following encouraging results from previous work (Pinard and Maissan, 2015), the Inuvik High Point site was re-instrumented with a 60 m wind monitoring tower that includes, along with regular sensors, a heated wind speed sensor at 50 m above ground level (AGL). Wind measurements started on December 2nd, 2015. New results from the ice free wind sensor are showing slightly faster wind speeds than previously measured at this site and the economics of wind on High Point are improving. Data collection will continue to confirm these early findings.

Measurements made during the period of December 2015 to March 2016 reveal wind speeds of 6.1 m/s at 50 m AGL. Projected to long-term using correlations with the upper air and Storm Hills measurements, the average wind speed is estimated to be 6.42 m/s at 50 m AGL, and 6.81 m/s at 74 m AGL (turbine hub heights). The previous estimates of winds speed at this site were 6.17 and 6.49 m/s at 50 and 74 metre hub heights, respectively.

The estimated monthly mean wind speeds at the 74 m hub height should range from a low of about 6.2 m/s in April and June to a maximum of 7.9 m/s in January, indicating winds are stronger in the winter when the energy demand is higher.

In a previous study (Pinard and Maissan, 2015) a three-turbine project with Enercon 2.3 MW turbines with 74 m hub height was determined to be an optimum size for the High Point site. The increase from 6.5 to 6.8 m/s represents a 5% increase in wind speed and a 10% increase in wind energy production. A simple RETScreen analysis to compare the impact of a wind speed increase from 6.5 m/s to 6.8 m/s reveals that the cost of the wind energy should drop by about 10%. Referring to the previous study this makes a High Point wind project more competitive compared to Storm Hills.

Because the wind follows the town's space heating load there is an opportunity for using the excess wind energy sales to improve the project economics. A price on carbon emissions or a production incentive on renewable energy would also improve the relative economics of wind generated power.

Introduction

This report provides an update on the wind resource assessment on High Point hill near Inuvik. This work follows up on the previous report of Pinard and Maissan (2015).

The community of Inuvik has about 3,600 people and is located on the East Channel of the Mackenzie River Delta. The community is accessible by air year round, and by road (Dempster Highway) most of the year except during break-up (spring) and freeze-up (fall). The annual energy requirement for the community was estimated to be 30,600 megawatt-hours (MWh) in 2013[1]. The space heating needs are estimated to be 97,200 MWh annually (or roughly 350,000GJ; GNWT, 2012). This is roughly triple the electricity demand in Inuvik and presents a market opportunity for wintertime excess wind energy use. The present marginal costs of producing electricity from diesel and natural gas (fuel and variable maintenance only) were estimated at $0.32/kWh and $0.25/kWh, respectively.

The potential for wind energy in Inuvik has been studied several times in the past but the economics had so far been weak. A study by Pinard (2007) measured wind speeds of 4.3 m/s at a height of 60 m above ground level (AGL) on a communications tower at a site 75 m above sea level (ASL), just east of the town of Inuvik. The winds were also measured at Storm Hills located 60 km north of Inuvik and long-term mean wind speeds of 7.8 and 8.1 m/s at 60 and 78 m ASL, respectively, were estimated (Matangi, 2014). While these result on Storm Hills were positive, the cost of road and power line made the site risky and uneconomical for wind power generation unless government subsidies were used and/or the wind project was scaled up.

Then in 2014, at the request of NTPC, another hill (Inuvik High Point) of comparable height to Storm Hills but much closer to Inuvik was equipped with a 30 m tower and instruments to measure its wind potential. The estimates from this campaign of winds speed were 6.17 and 6.49 m/s at 50 and 74 m hub heights, respectively. The site was re-instrumented with a 60 m wind monitoring tower that included a heated wind speed sensor and started measuring on December 2nd, 2015. This hill is 240 m ASL and is referred to as High Hill or High Point (this study uses High Point).

The purpose of this study is to re-evaluate the long term wind speeds economics of wind energy development for Inuvik based on the recent measurements at High Point.

In this study wind climate data was collected, analysed and used to model the economics for wind energy development and energy output of a selected wind turbine model. For this study the Enercon E-70 2.3 MW, which is used at the Diavik Diamond Mine, NWT, was selected. The economic analysis looks at the costs of building and operating a wind project on High Point and compares it to the cost of a wind project at Storm Hills (for which road access costs have now decreased). This study assumes that the excess wind energy could be used for space heating in Inuvik. An outline of next steps is given regarding the pursuit of wind energy development and integration in Inuvik.

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[1] Obtained through a request for information to the Northwest Territory Power Corporation (NTPC).

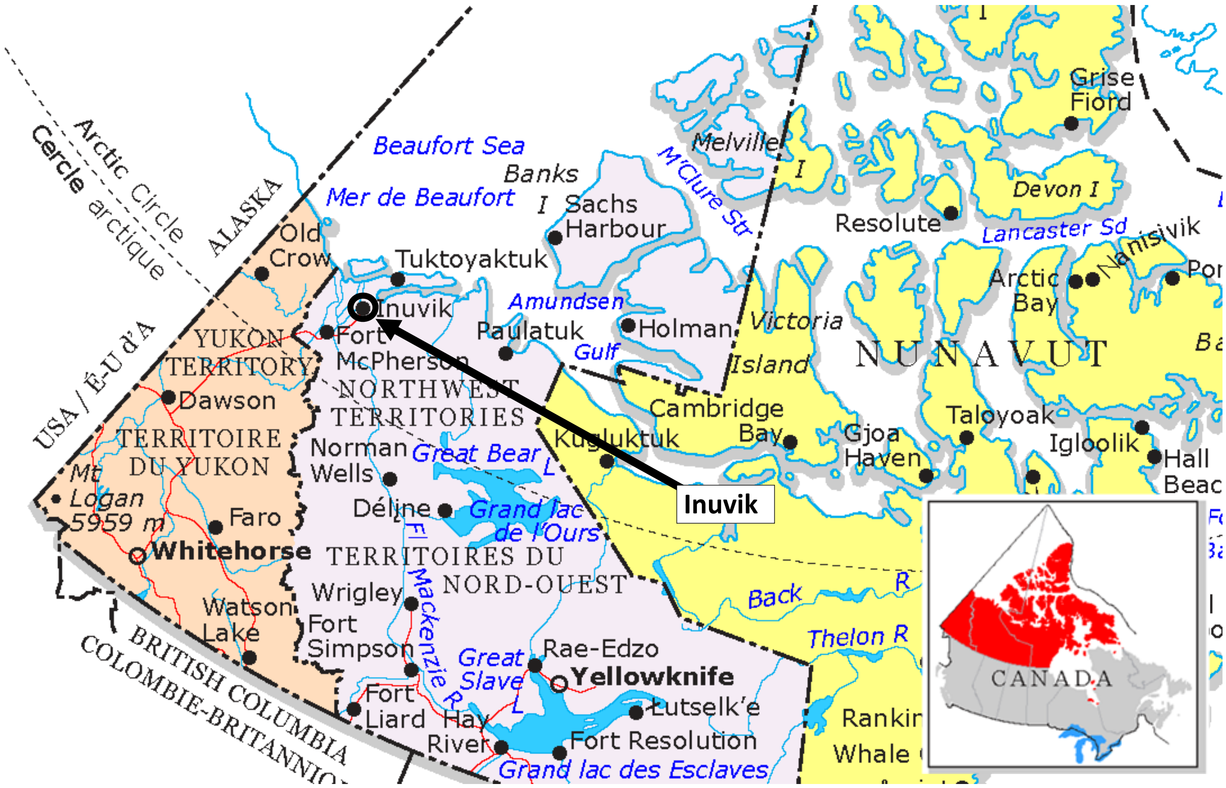

Figure 1: Inuvik is located in the Mackenzie Delta in northwestern NWT, about 1086 km northwest of Yellowknife.

Wind Climate Assessment

The wind data used for this analysis was extracted from the Aurora Research Institute's wind measurements that were made at High Point and at Storm Hills. The monitoring station set up at High Point was located 13 km east of Inuvik and 4.5 km north of the Dempster Highway (see Figure 2). The new wind tower is 60 m tall and collected wind measurements at 10-minute intervals from sensors placed 40, 50 and 60 m above ground level, for a period of about four months from 2nd December 2015 to 31st March, 2016. This new tower replaces a previous 30 m tower, and has a propane-powered generator to run transportation safety lighting and a heated, ice-free wind speed sensor which was placed 50 m up the tower. The other sensors were not heated because the propane generator had only enough power capacity (~300 watts) for one heated sensor (~200 watts) and the tower lights (~20 watts).

Wind measurements were also collected from Environment Canada (EC) weather stations: the upper air (weather balloon) station located near the airport in Inuvik, and the Storm Hills station 60 km north of Inuvik. The data from the Storm Hills station contains hourly measurements of wind speed and direction, temperature, pressure, humidity, and other parameters. The wind measurements at this station are taken at 10 m AGL. The weather balloon data is collected every 12 hours and the measurements used for this study were from 300 m ASL.

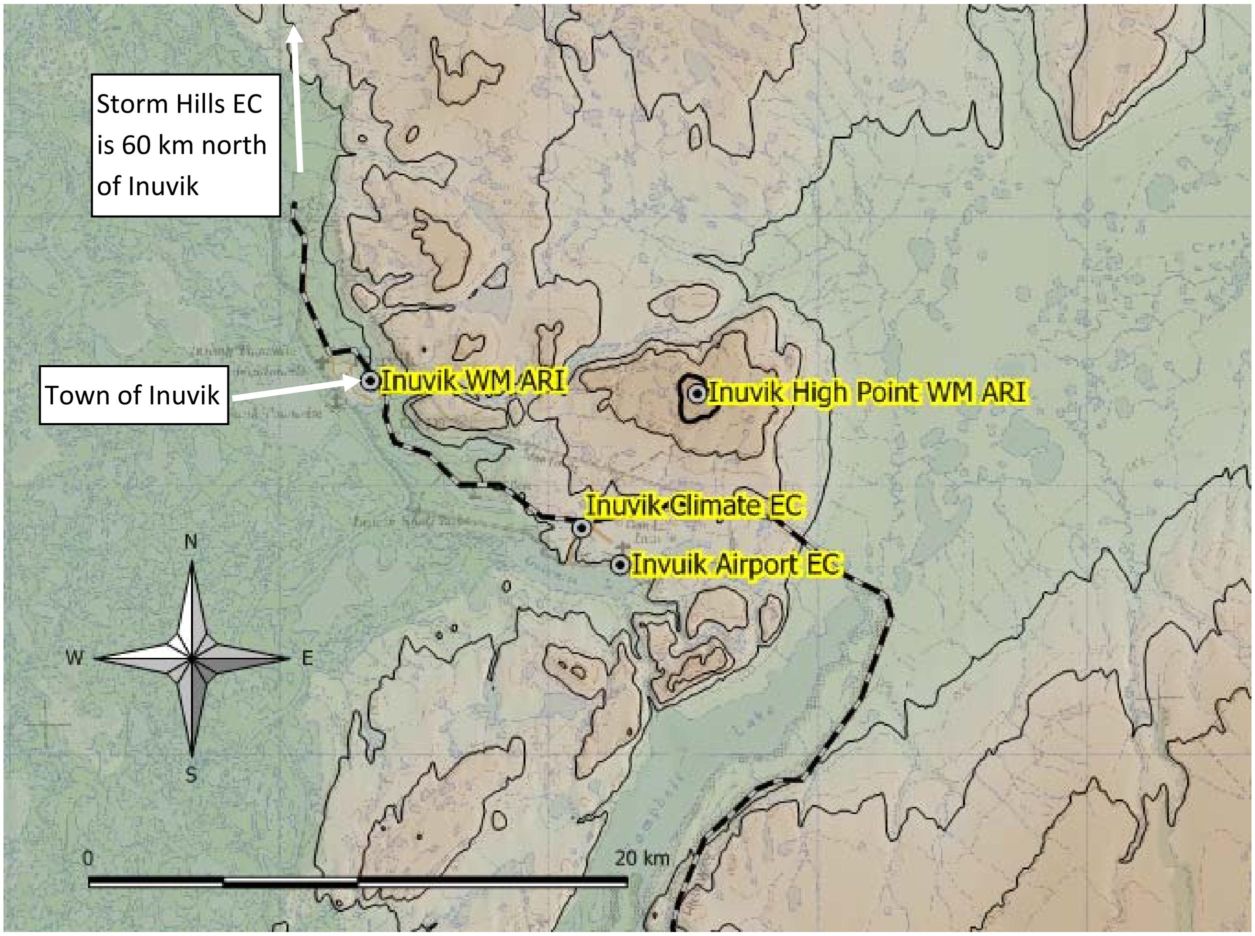

Figure 2: A map of the Inuvik area showing the weather stations (WM: ARI wind monitoring station, EC: Environment Canada weather station) and the topography. The elevation contour lines are at 50 m intervals with the lowest level being at 50 m ASL. The thick line marks 200 m ASL. The dashed line represents the road.

Wind Speed Analysis

The wind speeds at the High Point wind monitoring station (240 m ASL + 60 m tower) were correlated to those of the Inuvik upper air (at 300 m ASL) and the Storm Hills EC station (260 m ASL + 10 m tower) for the same period in which the stations ran concurrently.

The High Point measurements correlate better with the upper air measurements (300 m ASL) than the Storm Hills measurements. The cross correlation coefficient R^2 is 0.619 and 0.339 for the upper air and the Storm Hills measurements, respectively.

The average wind speed for the Inuvik upper air measurements were found to be 6.46 m/s (300 m ASL) over a four-year period from 2012 to 2015. The average wind speed for the Storm Hills station was 6.65 m/s (260 m ASL + 10 m) for an 11-year period (2005 to 2015). The wind speeds that were measured at the High Point tower for the December-March period was 6.09 m/s at 50 m AGL (+ 240 m ASL). During the same monitoring period the upper air measurements were 5.84 m/s (300 m ASL), the 4-year annual mean was 11% faster than this four-month average. During the same monitoring period the Storm Hills measurements were also 5.84 m/s (at 10 m AGL on surface at 260 m ASL), the 11-year annual mean was 14 % faster than this four-month average. A correlation using the upper air wind speeds with a matrix time series (a more reliable correlation method compared to linear least square, both available in the Windographer wind analysis tool) calculated that the four-year mean at the High Point site is estimated to be 6.42 m/s at 50 m AGL. The average wind speed based on the Storm Hills 11-year data set was estimated to be 6.46 m/s. The more conservative value of 6.42 m/s is used for this analysis.

Vertical Projection of Wind Speed

The wind speed measured at 50 m AGL needs to be projected to higher levels to estimate the mean wind speed for wind turbines with taller towers. The heights for the wind turbines used in this analysis are at 57 m and 74 m AGL (Enercon E-70 2.3 MW).

Turbulent air flow over rough surfaces tends to generate a vertical profile of horizontal winds that are fairly predictable. The wind speed profile near the ground is dependent on neutral well mixed air conditions and the roughness of the ground surface. This vertical profile can be defined by the natural log law equation (Stull, 2000):

$$u_2 = u_1 \frac{\ln(z_2/z_o)}{\ln(z_1/z_o)}$$

Where u_1 is the known wind speed at z_1 (typically at 10 m AGL), and is projected to u_2 at the height z_2. The surface roughness is defined by z_o which as a rule of thumb is 1/10 the height of the grass, brush, or ground undulations surrounding the site where the measurements are made. This equation is considered most accurate up to approximately 100 m above the surface. The surface roughness z_o can be categorised by the type and size of vegetation as well as the hilliness of the ground itself.

At the High Point site, the ground is a slight slope but relatively flat with small bushes. At the site the surface roughness was estimated to be z_o = 0.08 m using the tower measurements (at 40, 50 and 60 m AGL in the last half of March 2016 when icing is at a minimum.

The results of the vertical projection model are shown in Table 1 and Figure 3. The annual mean wind speed is expected to be 6.42, 6.55 and 6.81 m/s at heights of 50, 57 and 74 m, respectively. This estimate is based on the heated sensor at 50 m on the tower and will be subject to comparison and calibration against the unheated sensors when no icing is evident (above freezing temperatures). Note that the entire four-month measurement period has been at temperatures below freezing and icing is suspected through much of the measurement period.

Table 1: Details of measurements and their projection to longer term and to higher elevations. Bold values indicate the estimated long-term (four years, 2012 to 2015) mean wind speed at the High Point site.

Location and measurement period	Height	Wind speed	
Inuvik UA, 2nd Dec, 2015 to 31st Mar, 2016:	300 m ASL	5.84	m/s
High Point, 2nd Dec, 2015 to 31st Mar, 2016:	50 m AGL	6.09	m/s
Inuvik UA, 4-year 2012-2015:	300 m AGL	6.46	m/s
Ratio of 2-month to 4-year mean at Inuvik UA:		1.11	
High Point site projected to four years:	10 m AGL	**4.82**	m/s
	20.5 m AGL	**5.53**	m/s
	29.5 m AGL	**5.89**	m/s
	40 m AGL	**6.20**	m/s
	50 m AGL	**6.42**	m/s
	57 m AGL	**6.55**	m/s
	74 m AGL	**6.81**	m/s
	80 m AGL	**6.89**	m/s
	90 m AGL	**7.01**	m/s
	100 m AGL	**7.11**	m/s

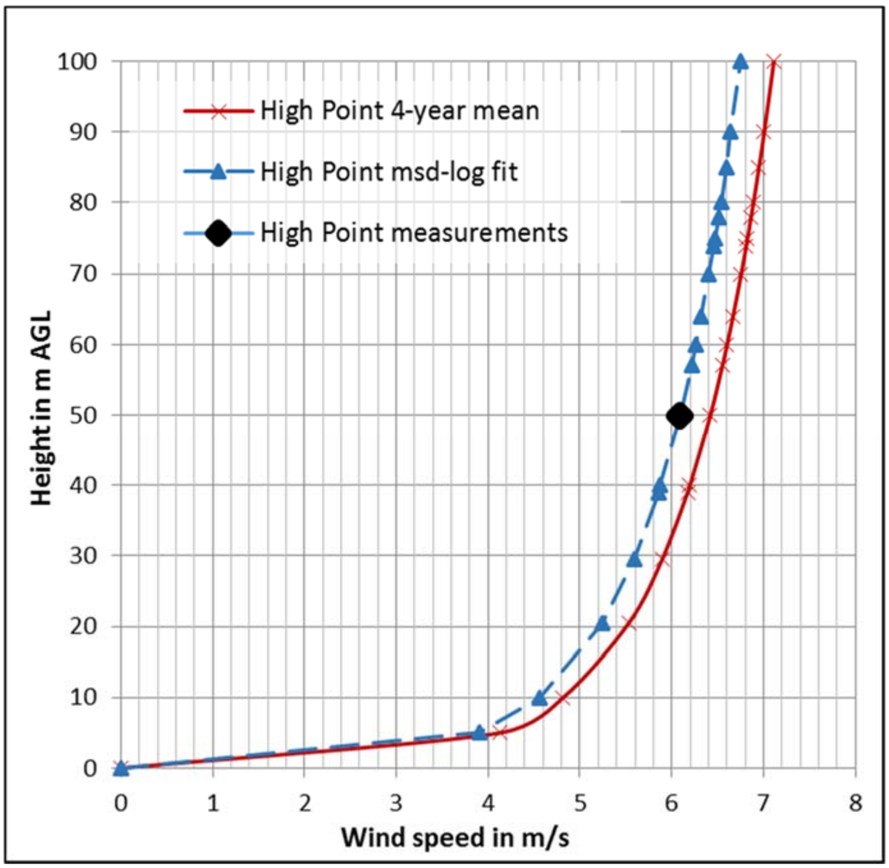

Figure 3: Vertical profile of horizontal wind speed measured and estimated at the High Point ARI station near Inuvik.

Comparison of Monthly Wind Speeds with Weather Balloon Measurements

As noted in Pinard and Maissan (2015) the High Point measurements compare better to the Inuvik upper air measurements than the surface stations located at the nearby airport. The reason for this was that the airport station is lower in elevation (68 m ASL) and more prone to the winter temperature inversions which reduce the wind winters in the low-lying areas compared to the hill tops. The High Point tower is at 240 ASL (240 m ASL + 60 m AGL = 300 m ASL) and the weather balloon measurements compared to are at 300 m ASL. Figure 4 shows that the monthly wind speeds at 74 m AGL should range from 6.1 m/s in May to 8.0 m/s in January. Stronger winter winds compliment the town's increased winter energy demands.

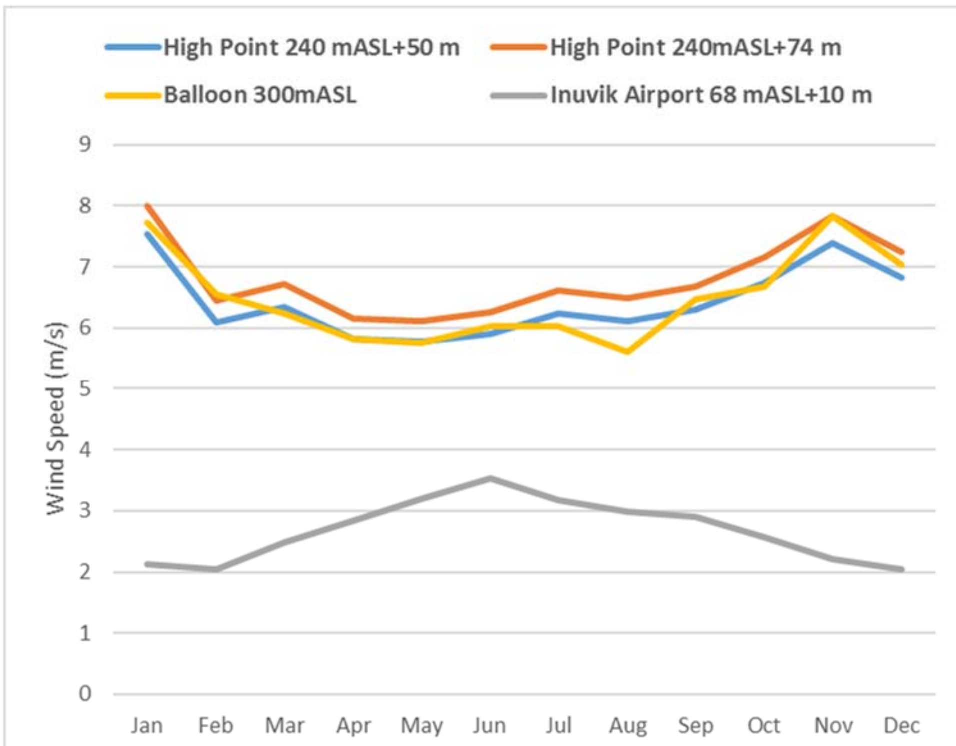

Figure 4: Long term monthly average wind speeds at different stations in the Inuvik area. The balloon measurements are made above the Inuvik EC climate station which is across the Dempster Highway from the airport.

Wind Direction

No wind direction analysis was made as the wind vane was not heated and was subject to icing. Once summer data is available a clearer picture of wind direction will be made. However, it likely that the wind directions will dominantly from the northwest and the south as shown by the weather balloon measurements in Figure 8.

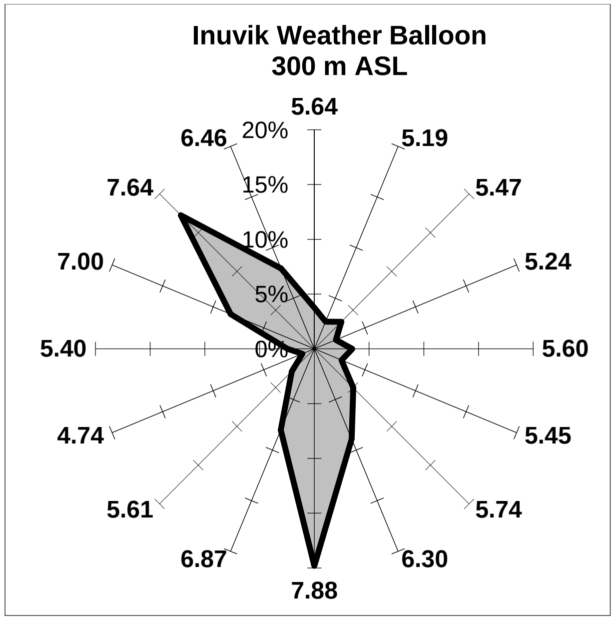

Figure 5: Wind roses showing the wind energy by direction for the Inuvik using data from weather balloons and the High Point wind monitoring station. The areas outlined in grey show the relative wind energy by direction. The mean wind speed by direction is labelled at the end of each axis (m/s). North is towards the top.

A Simple Comparative RETScreen Economic Analysis

To compare the impact of an increase in wind speed from 6.5 to 6.8 m/s (74 m AGL) a RETScreen model analysis was carried out. A scenario of two-Enercon E70 with 4.6 MW of power capacity were used in this case and the assumption is that the wind energy was fully utilized.

In the RETScreen model a 20% loss for the wind project was applied. The following financial parameters were imposed: 2% inflation rate, 25 project life, 60% debt ratio, and 25-year debt term. From the last general rate application, the interest rate on debt was 8.5% and required 0% internal rate of return (IRR) on equity (based on input from David Mahon, manager energy projects at GNWT). The project cost was set to $27.1M and O&M at $575k/year based on the previous study by Pinard and Maissan (2015).

For a wind speed of 6.5 m/s the electricity export rate would be $0.272/kWh to achieve an IRR on the equity of 0%, the equity payback would be 25 years. For a wind speed of 6.8 m/s and keeping the IRR at 0% the new price becomes $0.245/kWh, while the equity payback remains at 25 years. This drop from 27.2¢ to 24.5¢ per kWh represents a reduction of 10% in the cost of the wind energy at High Point.

The cost of the wind energy could be reduced further through frugal project cost management, subsidies, and lower rates on debt. Other measures would include increasing the wind project size and integration energy storage – particularly low cost heat storage – and a smart energy management system to more fully utilize the wind energy for electricity, space heating and transportation opportunities.

Conclusions

1. The projected annual average wind speed at High Point is 6.5 m/s at 57 m AGL and 6.8 m/s at 74 m AGL (turbine hub heights), a 0.3 m/s improvement over the last assessment.
2. The High Point site near Inuvik is appearing to show an improved potential for wind power generation compared to the Storm Hills site.
3. High Point still has a lower wind resource than Storm Hills but road and power line costs for this site would be substantially less than for Storm Hills. This also reduces capital and O&M cost overrun risks for High Point.
4. The High Point site project could produce wind energy at costs competitive with the long term costs of diesel and LNG power generation if three or four turbines are deployed with full utilization of the energy produced.
5. Factors that reduce the cost of wind energy include taller wind turbine towers, lower cost of capital, and increased wind energy utilization.
6. If opportunities are found for the sale of excess wind energy, the economics of the potential wind projects will improve.

Next Steps

1. Data collection should continue with the 60 m monitoring tower to get at least a full year of data to more accurately evaluate the wind resource at the site.
2. Consideration should be given to the possibility of increasing the market for renewable-sourced electricity in Inuvik so as to improve the economics of a wind project through increased size and utilization.
3. Once accurate wind speed data is in hand for High Point, the two potential wind project sites (other site being Storm Hills) could be re-evaluated. At that time a thorough feasibility study that more accurately identifies costs and examines alternative project configurations (including turbine supplier options, tower heights, and technologies to increase displacement of fossil fuel generated power) is probably warranted.

References

Matangi, Adrian, 2014. **Wind Resource Assessment: Storm Hills, NWT**. Report prepared by Sea Breeze for Aurora Research Institute.

Pinard, JP, and John F. Maissan, 2015. **Inuvik Wind Energy Pre-feasibility Analysis: 2015**. Prepared for Aurora Research Institute.

Pinard, JP, and editors: Pippa Seccombe-Hett and John F. Maissan, 2007. **Executive Progress Report for Wind Energy Monitoring in Six communities in the NWT**. Prepared for Aurora Research Institute.

Stull, R.B., 2000. **Meteorology for Scientists and Engineers**, Second Edition. Published by Brooks/Cole.

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