Project Report

25 April 2017

Government of Northwest Territories
Yellowknife, NWT

Distribution List :

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Sachs Harbour Wind Scoping Study

– EXECUTIVE SUMMARY –

Issued for Use

Rev. 0

Hatch Ltd.

Introduction

This summary presents the main results of the Sachs Harbour Wind Scoping Study report, completed by Hatch and submitted to the Government of Northwest Territories on April 17th 2017, file: *H354025 - Sachs Harbour Wind Scoping Study_Rev0.pdf*. The study investigates the potential sites and turbine options for the integration of wind power generation to the Sachs Harbour electrical network. It also includes a wind resource assessment, an overview of regulatory and environmental constraints and an estimate of project costs.

Wind Resource

The Sachs Harbour site was instrumented with two meteorological ("Met") stations: Met mast 0002 was 30m high and was located 6.5km west of the Sachs Harbour Airport; Met station 0003 was located 300m south of the airport, at the old wind turbine site, and measured the wind at 4.2m from the ground using heated sensors.

The measured datasets were quality controlled and adjusted to reflect long term conditions at turbine height. From these datasets, a wind flow map of the Sachs Harbour area was modeled with the WAsP software. Uncertainty on the wind resource is fairly high given the low data recovery rates and non-standard instrument mounting in the measurement campaign.

Met Station ID	Period of Usable Data	Top Anemometer Height (m)	Measured Annual Average Wind Speed (m/s)	Long Term Wind Speed at a Turbine Hub Height of 38 m (m/s)
0002	3 years	30.0	5.9	5.9
0003	3 years	4.2	6.0	6.3

Project Layout

The wind turbine sites were optimized to maximise energy production with the WindFarmer software. Environmental restrictions and turbine visual impact also contributed to select the potential turbine locations. The proposed turbine sites could change depending on the consultation of the community and their preferences.

The 4 proposed sites for wind development are along the main existing road between the village and the Met tower site. All four sites are between 54 and 60m in elevation and are located from 1 to 6 km west of the Sachs Harbour village.

All locations proposed are within a few hundred meters of existing access roads to minimize construction costs. The electrical collection network is expected to be an overhead line routed along the turbine access roads and the interconnection point is expected to be the closest point on the existing distribution network.

Turbine Selection

The operation of a wind power plant in Sachs Harbour requires technologies with a proven design that is well adapted to arctic conditions, off-grid applications and the wind regime at the site. Product reliability will also be key as servicing costs and downtime can become critical aspects of the project in Sachs Harbour.

The NPS100 95kW wind turbine model by Northern Power Systems was used as the base case turbine for low penetration scenarios. The M-24 model by XANT is also an interesting choice with a similar output and lower costs for transportation and installation, but its performance in arctic conditions is not proven like for NPS. For high-penetration scenarios, the number of 95kW turbines could be scaled up, or a larger turbine like the DW54 by EWT could be considered.

Energy Production

The energy production was estimated at each site using the selected Northern Power NPS100C-24. Similar results were obtained with the Xant M-24. Power and thrust curves were provided by the manufacturers.

Item	Site 1	Site 2	Site 3	Site 4
Wind Turbine Model	**NPS100C-24 Arctic**			
IEC Design Class	IIIA			
WTG Rated Power (kW)	95			
WTG Rotor Diameter (m)	24.4			
WTG Hub Height (m)	37.0			
Number of Wind Turbines	1	1	1	1
Site Capacity (kW)	95	95	95	95
Mean Free Wind Speed (m/s)	6.3	6.1	6.3	6.4
Losses (%)	16.3	16.9	17.1	17.2
Net Energy Production (MWh/year)	**280.3**	**268.5**	**281.2**	**283.1**
Net Capacity Factor (%)	**33.7**	**32.2**	**33.8**	**34.0**

The net production numbers reported reflect the estimated energy available from the wind turbines, including operational and environmental losses, but do not represent the actual amount of energy that would be integrated to the Sachs Harbour grid network. An integration study will evaluate through system modelling the amount of wind energy that would not be integrated and seek to minimize excess power.

Civil and Logistics Overview

Only preliminary information is available at this point. A site visit, a geotechnical survey and a list of available equipment at site will be required in order to establish the best type of foundation to use and the best logistics strategy to implement. estimate the cost of foundations and of road base construction. These two items are important parts of the overall project cost estimate and will require the most refinement in the next development phase of the project.

Project Schedule

At this stage, the project schedule is only to be used in order to establish the overall timeframe of project execution and get an understanding of the critical path. An aggressive schedule would have the investment decision made before the end of 2017 and a project built during the summer of 2018, with commissioning in late 2018. According to the time needed to evaluate the feasibility of the project, to obtain all

permits and environmental studies and the delivery lead times of main components, the project may have to be pushed back to the summer of 2019.

Biological and Regulatory Overview

No environmental restriction preventing wind turbines to be erected at the proposed sites were identified during the overview evaluation, but further study is needed on:

- Migratory birds
- Caribou and muskox
- Banks Island alkali grass

Also, permits and authorizations will need to be obtained from:

- Sachs Harbour community and airport
- Inuvaluit Land Administration
- Government of Northwest Territories
- Transport Canada and NAV Canada

Project Costs

Capital costs have been estimated with respect to each of the four sites identified in this study. Costs of power line extension and road construction were assessed according to the cost estimates given by GNWT. Other costs are based on supplier quotes or similar project costs carried out by Hatch in Northern Canada.

The table below provides a summary of the project capital costs for the design, supply, and construction of one(1) NPS100C-24m wind turbine associated with each of the four site options.

Item Cost	Site 1	Site 2	Site 3	Site 4
Site Preparation				
Power Line Extension (km)	0.77 km	2.07 km	3.25 km	4.31 km
Power Line Extension ($)	$ 154,000	$ 414,000	$ 650,000	$ 862,000
Road Construction & Clearing (km)	0.24 km	0.33 km	0.41 km	0.06 km
Road Construction & Clearing ($)	$ 180,000	$ 247,500	$ 307,500	$ 45,000
Foundations	$60,000	$60,000	$60,000	$60,000
Site & Crane Pad Construction	$15,000	$15,000	$15,000	$15,000
Subtotal	**$ 409,000**	**$ 736,500**	**$ 1,032,500**	**$ 982,000**
Engineering, Project Management, etc.	$ 544,000	$ 544,000	$ 544,000	$ 544,000
Wind Equipment Purchase	$ 578,770	$ 578,770	$ 578,770	$ 578,770
Installation	$ 331,000	$ 331,000	$ 331,000	$ 331,000
Contingency 10%	$ 186,277	$ 219,027	$ 248,627	$ 243,577
TOTAL	**$ 2,049,047**	**$ 2,409,297**	**$ 2,734,897**	**$ 2,679,347**

Based on this result, it is estimated that the total project cost will range between $2M and $2.7M depending on distance between the selected construction site and the interconnection point. With the Xant M-24 turbine model, capital costs are reduced by 5.5% to 7.5% depending on sites, because this model is less costly to install.

Operation and maintenance costs are evaluated at $20,000 per year for all scenarios.

The estimated levelized **cost of energy** (LCOE) is ranging between ¢48.4/kWh and ¢71.6/kWh with the NPS100 depending on site location.

	Site 1	Site 2	Site 3	Site 4
Energy Production (GWh/yr)	0.280	0.269	0.281	0.283
CAPEX (M$)	2.05	2.41	2.73	2.68
OPEX (M$)	0.02	0.02	0.02	0.02
LCOE 20 years (¢/kWh)	**55.61**	**66.95**	**71.60**	**69.82**
LCOE 25 years (¢/kWh)	**48.43**	**58.14**	**62.05**	**60.53**

The marginal cost of diesel generation has been evaluated at ¢46/kWh based on historical diesel cost and efficiency at Sachs Harbour. The only option presenting economic benefits is Site 1 with the Xant turbine for a 25 years investment period. Indeed, a 5% LCOE reduction is achieved using the Xant turbine instead of the NPS, down to ¢45.6/kWh at Site 1.

Other combinations may become viable if grants are available to compensate the cost of the collection line. Conclusions may change once the cost estimates and design are refined in the feasibility phase.

Sensitivity analyses were also performed on road construction costs and economies of scale if more than one turbine is installed.

LCOE can be reduced by up to ¢3/kWh if road construction costs are able to be reduced significantly from initial estimates (at around $200,000/km).

Installing 2 or 3 turbines would increase capital costs, but significantly reduce the cost of energy, because significant costs are associated with project development, mobilization to site and equipment rental, costs that are similar for one, two or three turbines. With the NPS100, the second turbine would bring the cost of energy down 20% to 30% (¢11 to ¢18/kWh) and the third turbine would bring the cost of energy down 30% to 40% (¢15 to ¢24/kWh).

These values show the impact additional turbines may have, however, these LCOE values are based on the assumption that 100% of the wind power can be integrated to the grid. In reality, the more wind power is integrated, the more excess power is generated. And since these scenarios will increase significantly the renewable penetration in the system, they would also need extra controls, power electronics and energy storage. They would also greatly reduce diesel O&M costs and fuel costs; so all these factors need to be addressed and optimized in the integration study.

Recommendations

- In order to reduce the wind project uncertainty regarding the wind resource, it is recommended to install a 30m Met mast in the vicinity of Site 1 or the preferred site location to be determined following public consultations.
- It is assessed that economic benefits can be achieved using Site 1 and the XANT turbine. The NPS 100 turbine would also provide economic benefits if the cost of road construction could be lowered significantly.
- The LCOE of the other sites these sites is consistently higher than the marginal cost of diesel generation. It is assessed that these projects could be

economically profitable if government subsidies could be raised to compensate for the cost of line extensions.

- The size of the selected turbines is based on a low/medium renewable penetration. Additional renewable capacity combined with energy storage would reduce the percentage of fixed project costs and consequently improve the overall economics of the project. Detailed modelling should be performed to confirm the high penetration potential for a diesel - wind - battery alternative at Sachs Harbour. This option leads to significant fuel reduction, reduced O&M costs, extended lifetime of generators and greater environmental benefits.
- In terms of cost uncertainty, installation costs should be reassessed once the geotechnical studies have been performed for the selected site. An integration study should also be carried out to assess the extent of the required modifications on the PLC and diesel plant.