WIND ENERGY

Background Report, Yukon Energy Charrette

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1. Resource capacity

Wind turbine generators convert the kinetic energy of the wind into mechanical energy via the rotating blades and then into electrical energy via the generator. Almost all modern wind turbines consist of a three blade assembly mounted upwind of the turbine tower. The blades are mounted to a horizontal drive shaft which is connected either directly to the generator (direct drive) or indirectly to the generator via a gearbox.

Wind turbines use two types of generators; the most common type in use today is an asynchronous generator that uses a high speed gearbox to up-convert the rotational speed of the turbine blades to a high speed three phase cage wound rotor (3). The second type of wind generator is a low speed synchronous permanent magnet generator in which there is no need for a gearbox. The permanent magnet generator is gaining in popularity due to its simplified design and greater reliability. The German manufacturer Enercon has been a long time supplier of permanent magnet generators.

There are currently two wind turbines in operation in the Yukon. Both are located on Haeckel Hill, approximately 14k west of Whitehorse, and both feed power into the Whitehorse/Aishihik/Faro grid. The larger turbine is a Vestas V47-660KW unit that was installed in 2000. The smaller turbine is a Bonus (now Siemens) 150KW unit that was installed in 1993. The total installed capacity in the Yukon is therefore 810KW. Yukon Energy Corp's current electrical generation capacity from all sources is 116.0MW (1).

The predicted total load for Yukon Energy for 2011 is 404.7 GWh (2). Assuming the existing wind turbines on Haeckel Hill operate at a 20% capacity factor, they will generate 1.4 GWh of electricity. This is 0.3% of the predicted 2011 energy load for Yukon Energy.

Without grid interconnection to surrounding jurisdictions (British Columbia, Alaska, Northwest Territories) it is not possible to import electricity generated by wind power into the Yukon.

2. Potential electricity production

A wind energy modelling study was commissioned by the Yukon Energy Corp in Dec 2010. This study identified areas of interest for wind power development surrounding the transmission corridor in central Yukon extending north from Carmacks to the hydroelectric reservoir at Mayo Lake. Additionally, areas in the vicinity of Carcross, Atlin Lake and Burwash were included in the modelling.

Ten different areas of interest were identified in this study. The study focused on wind speed, proximity to grid (<30km) and general constructability of the sites. A minimum wind speed filter of 6m/s was used in consideration of the economics of the avoided cost of diesel generation (28 cents/KWh). An indicative financial analysis of each site is recommended before they are progressed. The sites are identified in the Natural Power Consultants report titled "Yukon Energy: Regional Mesoscale Modelling" (4).

Natural Power Consultants is not aware of any study that estimates the total available economic wind resource of the Yukon; however, it is likely that the 10 sites identified in the wind modelling study have a total installed capacity over 100MW.

Ultimately, grid stability and load demand forecasts will determine how much wind energy is acceptable for the Yukon. Currently less that 1% of the Yukon's total energy load is supplied by wind energy. For perspective Denmark is already generating 20 percent of its electrical power and Spain and Germany have set their sights on ultimate wind penetration levels in the 25-30 percent range (wind energy "penetration" refers to the percentage of energy produced by wind compared with the total available generation capacity). In a 2008 technical study, the U.S. Department of Energy concluded that 20 percent wind penetration was technically sound and achievable by the year 2030. CANWEA's WindVision 2025 document calls for Canada to meet 20 percent of its total electricity demand from wind energy by 2025. (1)

There are several examples of wind farm installations from around the world. Europe and the USA have been installing industrial scale wind turbines for the past 25 years. Haeckel Hill, just to the west of Whitehorse, was actually near the forefront of wind power installation in Canada. The Vestas turbine sited atop Haeckel hill is of the same general appearance of modern wind turbines.

Figure 1 - Haeckel Hill

The lifespan of a wind turbine is generally considered between 20 and 25 years for financial depreciation purposes. However, with proper maintenance and periodic refitting, the actual operational period may be extended.

Modern utility scale on-shore wind turbines are typically in the 1.5MW to 3.5MW range, with hub heights ranging from 70m to 110m. The rotor diameter of the turbines blade can be up to 120m for some of the largest turbines. Examples of wind farms relatively near to the Yukon include the Dokie Mountain and Bear Mountain projects in northern British Columbia, and the Pillar Mountain project in Alaska.

The Dokie wind farm is located approximately 40km west of Chetwynd in Northern BC. The installation will be completed in 2011 and will consist of 48 Vestas V90 3MW turbines (tower height of 80m and rotor diameter of 90m).

Figure 2 - Dokie Wind Farm

The Bear Mountain wind farm is located approximately 15km southwest of Dawson Creek in Northern BC. It consists of 34 Enercon E-82 2.0MW turbines (tower height of 78m and rotor diameter of 82m).

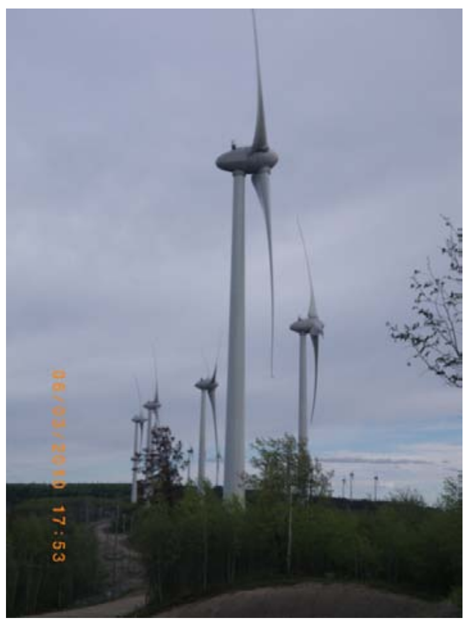

Figure 3 - Bear Mountain Wind Farm

Pillar Mountain wind farm is shown in Figure 4. It is located on Kodiak Island, Alaska, and consists of three GE 1.5MW turbines.


Figure 4 - Pillar Mountain Wind Farm (6)

The Crystal Rig I wind farm in Scotland is shown in Figure 5. Natural Power was responsible for designing, consenting, constructing, and currently manages this wind farm. It won the 2004 Best Renewable Project prize in the UK Green Energy Awards, and shows how large machines can be deployed with minimal visual impact. It consists of 25 Nordex N80 2.5MW wind turbines. The turbines have a hub height of 60m and a rotor diameter of 80m.


Figure 5 - Crystal Rig Wind Farm

Rothes wind farm in Scotland is shown in Figure 7. Natural Power was responsible for designing, consenting, constructing, and currently manages this wind farm. It consists of 22 Bonus B82 2.3MW turbines. The turbines have a hub height of 60m and a rotor diameter of 82m.

Figure 6 - Rothes Wind Farm

Paul's Hill wind farm in Scotland is shown in Figure 7. Natural Power was responsible for designing, consenting, constructing, and currently manages this wind farm. It consists of 28 Bonus B82 2.3MW turbines. The turbines have a hub height of 60m and a rotor diameter of 82m.

Figure 7 - Paul's Hill Wind Farm

A 1.5MW Leitwind turbine was installed atop Grouse Mountain in 2009. The turbine is located 10 km from downtown Vancouver. It has a hub height of 65m and a rotor diameter of 77m.

Figure 8 - Grouse Mountain Turbine (6)

There is more accessible wind energy available in the Yukon than the total 375 GWh consumed in 2009. However, it is not possible to supply a utility grid solely with wind power due to its variable nature.

The maximum possible wind penetration level will require detailed analysis of the Yukon's existing reserve and the reliability of the existing electricity generation system. The success of the integration of wind energy also relies heavily on the ability of other generators on the system to ramp production up and down on very short timescales. In order to follow the changes in load, sufficient primary power reserves that are synchronized to the grid ("spinning reserves") need to be available. The required spinning reserve response timescales for wind are typically in the second or minute range; the variations of wind power output are small compared to the corresponding variations in typically seen in demand. Low penetration wind generation (<20%) on isolated grids is common around the world and the spinning reserve can often be met by running the diesel or other primary generation full time but at reduced output (8). It is more the variation on longer timescales (days, months) that impact the extent to which wind can supplant conventional sources of power (9).

Wind energy is complimentary with both diesel and hydropower generation. As the wind varies the system operator is able to ramp up these flexible generation sources as the wind drops, and ramp them down as the wind increases. As the wind output ramps up, the system operator can reduce hydro or diesel production and either stock water in the reservoir or reduce diesel consumption.

Wind energy penetration can be increased by spreading out wind farms geographically, with each experiencing a different wind climate and therefore reducing overall output variability. Wind forecasting systems can also help to increase wind penetration; accurate forecasts enable the prediction of a wind farm's electricity production ahead of time which gives the utility more time to make the necessary system adjustments. (1)

It is highly recommended that a wind penetration study is carried out in order to determine the maximum recommended penetration level for wind power in the Yukon. Such a study should also explore spinning reserve options that may be able to increase wind energy's penetration rate. There are several examples of wind-diesel hybrid systems in nearby Alaska, including the Kodiak Island wind farm and the Kotzebue wind farm.

For perspective, AWEA mentions that "at wind penetration levels of up to 20% of system peak demand, experience shows that system operating cost increases arising from wind variability and uncertainty amount to about 10% or less of the wholesale value of the wind energy. Detailed power system modeling studies have looked at scenarios in which wind provides 10 to 40% of the electricity in various regions of the country and found that wind integration costs are typically less than $5 per megawatt-hour" (6). These integration costs did not consider isolated grids, but they give a baseline sense of the added cost of wind integration.

3. Electricity cost

The cost of utility scale wind energy generation is dependent on multiple variables, including the wind speed, turbine type, proximity to transmission and the difficulty of construction. In British Columbia, the 2008 BC Hydro Clean Power Call recently wrapped up in 2010 with levelized plant gate prices awarded for six wind projects ranging from $90/MWh to $121.2/MWh (this assumes a power purchase agreement term of 25 years).

The capital cost estimate (2010 dollars) for the Yukon Ferry Hill 21MW wind project, including contingency, was $3.4 million per MW. Capital costs for the 2008 BC Clean Power Call for wind energy are thought to be close to $3.2 million per MW. It should be noted that wind energy has a capacity factor that typically ranges from 20-40% of total installed capacity. Detailed technical and financial analysis is required to estimate the ultimate cost per MWh.

Wind is immune from rising fuel costs and therefore avoids the risks of volatile fuel costs and future carbon charges.

While the costs of generating electricity from conventional hydrocarbon based energy sources are likely to increase in the coming years, it is expected that the costs of wind generation will fall or remain stable as the technology advances.

4. Complementary applications

Electricity generation from wind power can be complementary with pump storage hydro. This combination results in a firming of the variability of wind capacity and the recharging of the pump storage basin when the wind power is not otherwise required by the grid.

5. Time to market

The 2010 Ferry Hill Wind Feasibility Study laid out a timeline for brining the proposed 21MW Ferry Hill project (estimated 55.6 GWh) into production. (3) The study separated the project's timeline into four broad categories: 2011 – Wind monitoring and feasibility studies, 2012 – Environmental assessment and permitting, 2013 – Balance of plant construction, including roads and foundations, and 2014 – Turbine installation, collection system and commissioning.

A 5-6 month construction season was assumed based on the site's winter climate conditions. From Natural Power's experience, the construction season is thought to be too short to enable the complete BOP construction and turbine installation in one season, while accounting for possible delays. For this reason it is recommended that the project balance of plant (roads, foundations, lay down area, control building) be constructed over one season, with the turbines and collection system being delivered and installed the next season. The suggested timeline is largely based on labour resource, and it may be compressed or lengthened by varying the resource intensity applied. It may also be possible to bring the project completion date forward one year if the Environmental Assessment process was brought forward to 2011; however, this comes with the risk of absorbing the cost of the EA process before the project's feasibility has been fully determined.

6. Probability to market

Wind energy conversion is a time tested and proven type of electricity generation. Utility scale wind projects have been constructed throughout most of the world, including several northern latitude sites. Some considerations unique to northern latitude wind farms include a shortened construction season, the uncertainty of energy losses due to blade icing, and servicing delays and additional expense caused by cold climate conditions and the remote nature of the installations. The risks associated with these issues can be identified and accounted for in the pre-planning stages of the project.

7. Regulatory issues

Regulatory approval requirements for a wind energy project in Yukon include assessment approval under the *Yukon Environmental and Socio-Economic Assessment Act* (*YESAA),* permitting approval under territorial and federal legislation applicable to the proposed project, and compliance with applicable federal and territorial legislation and policy with respect to birds and other wildlife.

Assessment approval under *YESSA* must occur before any permits or licenses can be issued; however, the assessment can occur simultaneously with review of permit applications, and this can reduce overall timelines for the regulatory approvals process. An overall regulatory approval schedule must also provide for collection of any baseline or field study information, some of which may be season-specific.

For a wind project in the 20MW range, three main approvals have been identified as required:

1. *Yukon Environmental and Socio-economic Assessment Act* – Designated Office level Evaluation

2. *Yukon Public Utilities Act* – Energy Project and Energy Operating Certificates

3. *Yukon Lands Act* – Land Use Permit

The *Migratory Birds Convention Act* and *Species at Risk Act,* both of which apply in Yukon and are administered by Environment Canada, also apply to the Project.

8. Environmental issues

In order to make relevant comparisons about the environmental impacts of different types or energy generation, we need to do full life-cycle cost accounting. This includes the environmental burden that comes from obtaining the fuel source, building and operating the facility, and decommissioning the facility at the end of its useful life.

The Canadian Wind Energy Association states that in Canada, "the electricity system is responsible for about 17 percent of our greenhouse gas emissions. Wind, hydro and nuclear generation produce no GHG emissions. Natural gas is the next choice from a GHG perspective while coal, diesel and heavy oil trail far behind.

One way to measure environmental performance in the electricity system is to look at the 'energy pay-back ratio' for different generating technologies. Figure 4 tells us how much electricity is produced during a plant's normal lifespan divided by the energy it takes to build, maintain and fuel it. While building hydro dams and generating stations involves huge amounts of energy and construction materials, they also produce huge amounts of electricity for up to 100 years. So, in terms of energy payback, hydro sits in first place with a ratio of 280. Compared to hydro, wind farms involve modest inputs of energy and materials, and produce modest amounts of power. Still, with an energy payback ratio of 34, wind energy takes second place while nuclear, gas and coal generation trail."

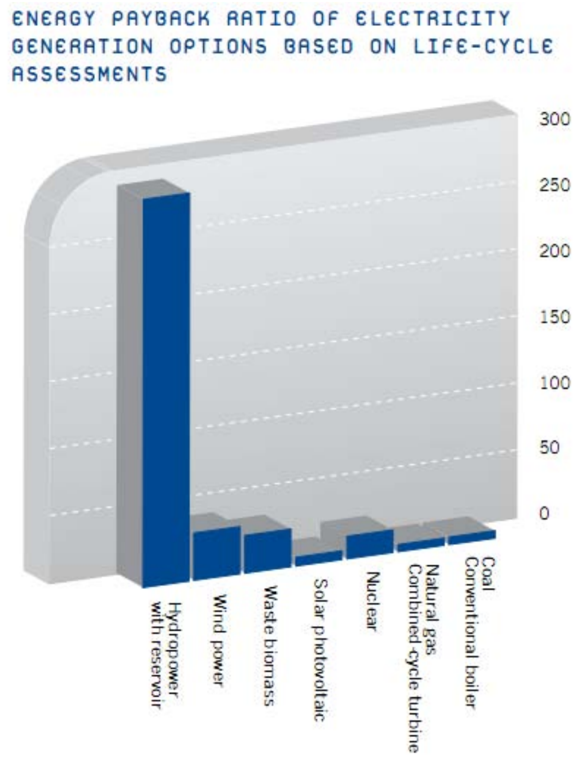

Figure 9 - Energy Payback Ratio (Source: CANWEA WindVision 2025)

There is no active carbon credit market at the federal level in Canada. There are very small carbon markets in BC and Alberta for emission intensive operations in oil and gas, but opportunities to sell credits in these markets are limited at this time.

There may be opportunity to sell carbon credits in the form of "renewable energy certificates" (RECs) to certain states in the USA, including California, that have renewable portfolio standards. As an example, Greengate Power recently sold all of the energy credits associated with 450MW of their wind projects in Alberta to Pacific Gas and Electric in the USA. This was made possible after the California Public Utilities Commission reversed in January 2011 a ban imposed on trading RECs separately from the associated electricity, though utilities can use the credits only to fulfill a quarter of their renewable energy requirements. The renewable energy certificates are granted and verified by third party certification and verification companies. EcoLogo was founded in 1988 by the Government of Canada and is the most established carbon standard and certification mark in Canada.

9. Seasonality

Figure 10 shows that the electricity demand in the Yukon is highest during the winter months (4). The winter months are also the time when wind speeds in the region are at their highest (Figure 11). This should be a complimentary factor. However, it should be noted that higher potential icing losses during the winter may reduce energy production during these months. The energy production and losses will be estimated with greater accuracy once the new mast with heated sensors is installed and gathers winter data. Heated blade technology would reduce winter losses.

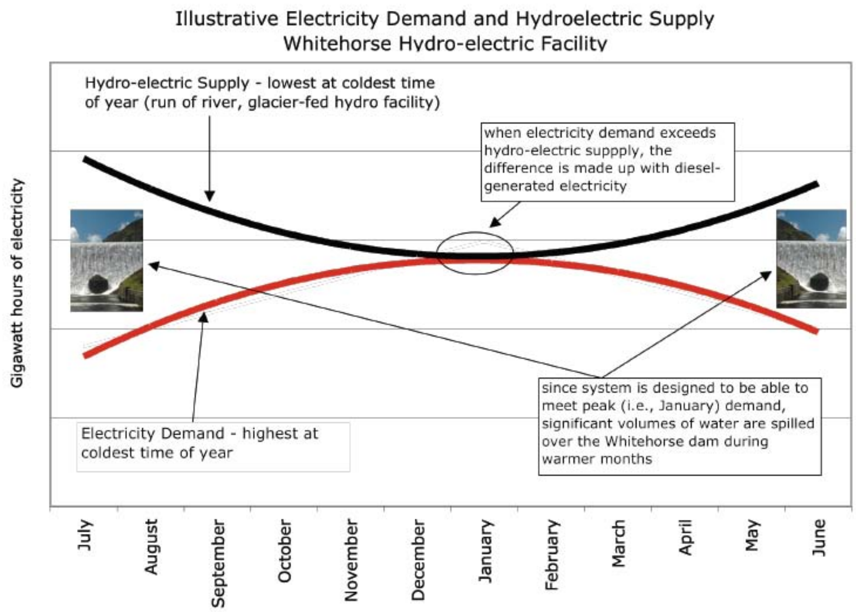

Figure 10 - Whitehorse Electricity Demand (Source: Vector Research (8))

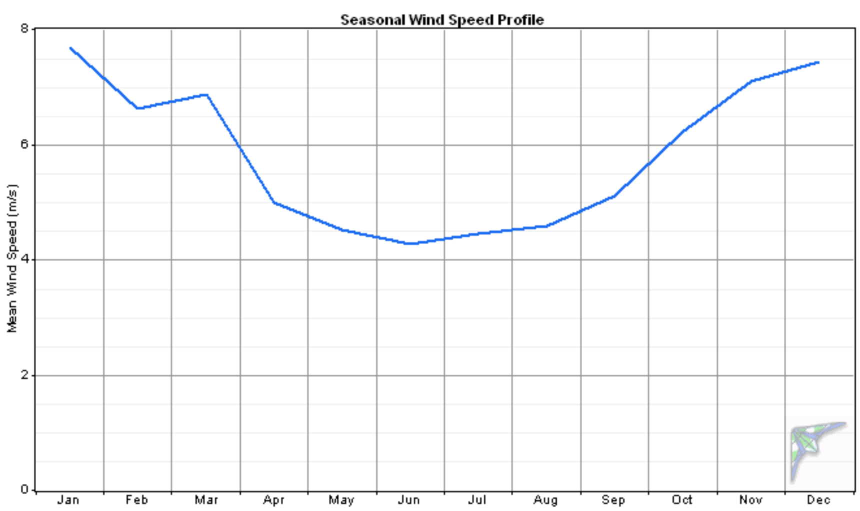

Figure 11 - Vortex Mesoscale Model – Ferry Hill

10. Other considerations

Noise is one factor that is often raised when wind farm proposals go through the environmental assessment process. Noise studies should be performed early in the pre-feasibility phase to ensure that dwellings are not negatively affected by noise generated by wind turbines. The best way to address concerns over sound is proper wind farm siting that ensures sound levels at residences are appropriate and regulations are in place to ensure this.

The visual impact of wind farms can also be of concern for some people. Wind turbines are difficult to hide. To mitigate concerns that wind farms will spoil the view, wind energy project developers must consult with and work with local residents to understand and work to address any concerns.

A final concern about wind farm development is its potential impact on wildlife. It is possible that poorly sited wind turbines could harm bird and bat populations. Environmental assessment processes, however, focus extensively on minimizing any potential impact on avian life. US surveys have concluded that the average wind turbine kills about 2 birds per year and that buildings, house cats, and the impact of climate change on natural habitats represent a much larger threat to birds.