Appendix 5.9
Wind Site Inventory
(CBER, Envint and V3 Energy 2016)

YUKON Wind Site Inventory

Final Report

RFP 2015-060

Prepared for:

YUKON ENERGY

Prepared by:

CBER

with

envint Consulting *and* V3 Energy, LLC

August 9, 2016

EXECUTIVE SUMMARY

For its new planning cycle, the Yukon Energy Corporation (YEC) is investigating renewable energy sources and several parallel assessments have been commissioned. These assessments are to inform YEC of the potential viability of each power generation resource in Yukon, identify suitable sites, estimate capital and operating costs, and determine the resulting per-kWh power generation cost. These results then feed into a resource option plan that evaluates power generation options according to the financial, technical, socio-economic and environmental attributes of each technology.

This report addresses utility-scale wind power, one of the technologies YEC identified as a potential source of electricity generation for the territory. The study has four major objectives:

- **Wind site inventory** to identify potential wind project sites near existing or planned power infrastructure. This task included reviewing existing wind mapping and selecting preferred sites for detailed analysis;
- **Develop potential wind projects at a conceptual level** to include wind resource assessment, site turbine layout, infrastructure footprints, and modelled gross and net power output;
- **Economic modelling** to create site-specific cost estimates for development, construction, power production, and determining the cost of power and energy;
- **Additional information pertaining to wind farm development** that might affect its viability.

The Yukon has significant wind resources although development of those resources is challenging due to the territory's mountainous nature. Most suitable wind farm sites are located on mountaintops, peaks, ridges or crests while YEC's transmission lines naturally route through valleys. The result is a challenging exercise of identifying sites that are not only windy but also able to be *developed*.

A number of criteria influenced the wind site prospecting task. These include:

- **Wind and atmospheric considerations**, such as high mean wind speed and wind power density;
- **Site development considerations**, such as a reasonable distance to a community or YEC office for maintenance purposes or proximity to existing roads.
- **Environmental and human factor considerations**, including potential harmful effects on wildlife and birds, vicinity to parks, use for recreational purposes and other environmental restrictions.

Another criterion was a desire to represent northern, central and southern Yukon. Part of the intent was to screen as wide an area as possible and represent sites of varying characteristics. Because the

Yukon is a high-latitude region with a mostly sub-arctic-to arctic, often maritime-influenced climate, winter-time icing at higher elevations is operationally challenging. For this reason, the most desirable wind-power sites are at lower elevations where icing conditions do not occur. There are, however, few sites in the territory that are both windy and low elevation. Kluane Lake is an exception.

Out of a longlist of 26 sites we selected five locations for an in-depth review and conceptual design. The selections were based on wind speed, distance to transmission lines, road access, and land ownership. Other factors such as potential conflicts with other land uses or anticipated public opposition were also evaluated to determine a shortlist of seven sites. Of the seven, only Kluane Lake is a low-elevation site.

We developed representative wind turbine arrays of 20, 10 and 6 MW capacity for each of the seven selected sites. The site layout and location are on a conceptual level only but sufficient for estimating the power output and the cost of installing wind farms. The layout of each wind farm accounts for the prevailing wind direction(s) and topographic optimization. To locate an access road to each site, we retained an average gradient and turning radius within the limits of requirements to transport a 45 meter blade and a 70 tonne nacelle to the sites.

In the absence of measured wind data, this report relies on computer models that predict wind direction, wind speed, turbulence and power production from wind turbines at a given site. We chose a 2 MW, 80 meter hub height Vestas V90 model as the generic turbine for modeling purposes.

Apart from the generic turbine used for financial modeling, we also separately compared three alternate turbines for each site based on the AWS Truepower Advanced Reports. The resulting monthly data shows that for most sites a turbine designed for higher wind speeds produced less energy per year, but more during the period from October to April when electricity is most need in the Yukon.

At the site with the highest output, Miller's Ridge near Carmacks, a 20 MW farm would produce 57 GWh of energy a year, equivalent to the annual consumption of 5,800 households in the Yukon. For YEC, the annual net energy production may be less important than generation during the colder period of the year. From May to September there is generally a power surplus from existing hydropower generation facilities. Fortunately, all seven sites show a clear pattern of lower monthly mean power production during the summer months compared to winter, despite the higher percentage of energy loss due to icing during winter. On average, three-fourths of wind energy generated would be during the seven months from October to April.

The mean annual power output is 26% to 28% of the nominal wind farm capacity, i.e. a 10 MW wind farm, for example, would generate on average 2.6 to 2.8 MW over the course of the year, more during the winter, less in summer. Wind power is a variable resource and technically cannot guarantee any minimum output at any time of the year. There may be days when wind speeds are below the start-up wind speed; output will drop to zero during these hours.

Capital costs, including hard and soft costs, such as financing and project development costs, range from $31 million for a 6 MW wind farm to $66 million for a 20 MW project for the average of all seven sites. This equates to mean specific costs of $5.2 million per MW to $3.3 million per MW, respectively. The overall accuracy of these cost estimates is ±30%, commensurate with the project definition of a pre-feasibility or screening level study. Operational costs are approximately $300,000 of fixed cost, and variable cost of around $25 per MWh of net energy produced. These costs are similar for all sites.

The levelized cost of energy at almost all sites and all sizes remains under the current Yukon standard offer price of 21 ¢/kWh but often above the average residential retail price of 12 ¢/kWh, see the table below. Of the seven sites selected, five show above-average performance in terms of the cost of energy produced. These sites are, in the order of performance, Miller's Ridge near Carmacks, Thulsoo Mountain near the Aishihik hydroelectric facility, Kluane Lake, a mountain ridge near Cyprus Mine, close to Faro, and Mt. Sumanik near Whitehorse. The table below provides key economic parameters. There is little difference in energy production cost between these five sites; non-monetary factors may play an important role in selecting the preferred location.

Miller's Ridge near Carmacks and Thulsoo Mountain near the Aishihik hydroelectric facility are the sites with the highest wind resource and a low cost of energy (LCOE). Thulsoo Mountain is near an existing facility, but Miller's Ridge has more expansion potential. Sumanik Mountain is attractive due to its location near Whitehorse. Cyprus Mountain is the furthest from Whitehorse, but appealing due to its brownfield nature next to an abandoned mine. Kluane Lake gets a qualified recommendation because of its low elevation and low energy costs (LCOE), but requires a transmission line to be built first. Tehcho and Sugarloaf are not recommended because the other site options clearly are superior, both in terms of annual energy production and energy cost.

Key Financial Parameter of the Three Wind Farm Sizes at the Seven Sites Evaluated

Site	6 MW		10 MW		20 MW	
	Capital Cost (million $)	Levelized Cost of Energy *	Capital Cost (million $)	Levelized Cost of Energy *	Capital Cost (million $)	Levelized Cost of Energy *
Cyprus Mine	34	17.3¢/kWh	44	13.8¢/kWh	69	11.7¢/kWh
Kluane Lake	26	15.1¢/kWh	36	12.6¢/kWh	62	11.0¢/kWh
Miller's Ridge	39	17.1¢/kWh	49	13.1¢/kWh	73	10.7¢/kWh
Sugarloaf Mountain	28	22.6¢/kWh	38	18.7¢/kWh	62	15.3¢/kWh
Mt. Sumanik	30	17.2¢/kWh	39	14.6¢/kWh	64	12.4¢/kWh
Tehcho (Ferry Hill)	28	21.4¢/kWh	39	16.4¢/kWh	64	15.1¢/kWh
Thulsoo Mountain	36	16.8¢/kWh	46	13.2¢/kWh	72	10.9¢/kWh
Average	**32**	**18.2¢/kWh**	**42**	**14.6¢/kWh**	**67**	**12.5¢/kWh**

** at 3.38% real weighted average cost of capital (WACC)*

Due to fixed costs and economies of scale, larger wind farms have lower energy production costs than smaller ones. The cost of energy at the seven sites averages 13 ¢/kWh for a 20-MW wind farm but increases to 18 ¢/kWh for a 6-MW capacity. Our modelling assumes that all energy produced will be used. Curtailment of the operation during the summer when YEC has a surplus of power would increase the cost of energy produced during the rest of the year by more than a quarter.

A sensitivity analysis of a 10-MW wind farm at Kluane Lake showed that the cost of energy is most sensitive to forecasted energy production. This underlines the importance of monitoring wind speed, rime icing, and temperature at selected sites. These are key parameters that will determine the output of a generator and thereby the financial performance of the wind farm.

Developing a wind farm in the Yukon will likely require four years, including a wind monitoring campaign during the first year. The schedule may be more relaxed or could be condensed to three years for sites with existing and suitable road access.

If the update to YEC's 20-year plan yields that wind power is a viable source of electricity, then further research should be done on the five sites mentioned above. We recommend a full-scale feasibility study for some or all of those sites, and wind and icing monitoring at several sites in parallel to then select the most suitable one for development.

Table of Contents

Notice to Reader

This report was prepared by Cornelius Suchy of Canadian Biomass Energy Research (CBER) Ltd, Martin Tampier of ENVINT Consulting and Douglas Vaught, P.E. of V3 Energy, LLC. The material in it reflects the authors' best judgement in light of the information available to them at the time of preparation.

The sole purpose of this report is to assist Yukon Energy Corporation in its decision of whether to pursue the initiatives discussed herein. The authors and CBER, as the main contractor, accept no responsibility if any party relies on this report for any purpose that Suchy, Tampier and Vaught have not expressly agreed to. Any reliance placed on this report by another party will be at that party's risk and without recourse to Cornelius Suchy or CBER Ltd.

This report involves matters that cannot be precisely determined. Our calculations generally depend on subjective judgements and uncertainties that increase as we forecast further into the future. Much of the information available to us is based on estimates and assumptions provided by third parties. Accordingly, this report does not guarantee a specific result; instead, it is a means of assessing the relative desirability of alternative courses of action, a range of investment requirements, and anticipated income or cash flow, as the case may be.

Cornelius Suchy, Martin Tampier and Douglas Vaught reserve the right (but will be under no obligation) to review all calculations referred to in this report and, if we consider it necessary, to revise them in light of new facts, trends, or changing conditions that become apparent to us after the report is published.

Interested parties are cautioned that decisions of whether to rely on the accuracy and completeness of the information in this report, and whether to invest or provide financing, are theirs alone and neither Cornelius Suchy nor CBER will assume any responsibility for losses resulting from such decisions. Decisions to invest or provide financing will likely require additional information beyond the information in this report.

Opinions expressed in this report are those of the authors and do not necessarily reflect the opinion of the Yukon Energy Corporation.

Inquiries and requests for more information relating to this report should be directed to:

Cornelius Suchy, Tel.: (250) 814-7184, email: cornelius@biomassenergyresearch.ca

Martin Tampier, Tel.: (450) 627-1003, email: martin@envint.ca

Douglas Vaught, P.E. Tel.: (907) 350-5047, email: dvaught@v3energy.com

Conversion of units used in this report

1 kilometer (km)	=	0.62	miles (mi)
1 meter (m)	=	3.28	feet (ft)
1 meter per second (m/s)	=	3.6	kilometre per hour (km/h)
1 kilogram (kg)	=	2.2	pounds (lb)
1 metric tonne (t)	=	2,205	pounds (lb)
1 pound (lb)	=	0.45	kilograms (kg)
1 metric tonne (t)	=	1,000	kilograms (kg)
1 square metre (m^2)	=	10.8	square foot (sft)
1 square foot (sft)	=	0.09	square meter (m^2)
1 cubic metre (m^3)	=	1,000	litres (L)
1 cubic metre (m^3)	=	1.3	cubic yard (cyd)
1 hectare (ha)	=	2.5	acres (ar)
1 hectare (ha)	=	0.01	square kilometers (km^2)
1 acre (ar)	=	0.4	hectare (ha)
1 gigawatt hour (GWh)	=	1,000	megawatt hour (MWh)
1 megawatt hour (MWh)	=	0.001	gigawatt hour (MWh)
1 megawatt hour (MWh)	=	1,000	kilowatt hour (kWh)
1 kilowatt hour (kWh)	=	0.001	megawatt hour (MWh)

Glossary and Acronyms

$	Canadian dollar; all costs in this report are given in CAD
¢	Cent
AACE	Association for the Advancement of Cost Engineering
AB	Alberta
AOI	Area of Interest
AEP	Annual Energy Production
AWS	Company providing wind energy modelling
BC	British Columbia
Capacity factor	Mean annual power output divided by rated power or the total annual power output divided by the capacity and by 8760, the number of hours in a year
CAPEX	Capital cost
DDP	Delivered Duty Paid, an Incoterm for point of delivery
DEM	Digital Elevation Map
ELCC	Effective Load Carrying Capability
ENE	East-Northeast
Enercon	A German wind turbine manufacturer
EPC	Engineer-Procure-Construct, a contract form where the EPC Contractor is responsible for all activities from design, procurement, construction, to commissioning and handover of the project to YEC
FN	First Nation
GE	General Electric, an American wind turbine manufacturer
GeoYukon	Yukon's online geographic information system (GIS)
GIS	Geographic Information System
Hwy	Highway
IEC wind class	A wind speed and turbulence classification of the International Electrotechnical Commission.
IRENA	International Renewable Energy Association
km	Kilometer
kV	Kilovolt
LCOE	Levelized Cost of Energy
LIDAR	Light Detection and Ranging is a method of measuring distance or wind speeds by projecting a laser into the air and detecting the backscatter from random particles in the atmosphere.

Meso-scale	Model with a raster size of 1 x 1 km
MW	Megawatt
N	North
NE	Northeast
NNE	North-Northeast
NNW	North-Northwest
NW	Northwest
O & M	Operation and maintenance
OPEX	Operational cost
PPA	Power Purchase Agreement
RFP	Request for Proposals
SE	Southeast
SW	Southwest
SSW	South-Southwest
TIF	Tagged Image File (Format)
Tx	transmission
U.S.	United States
UTM	Universal Transverse Mercator
Vestas	A Danish wind turbine manufacturer
WACC	Weighted Average Cost of Capital
Wake loss	The loss a wind turbine may experience due to turbulences from the ground or nearby wind turbines.
WAsP	Wind Atlas Analysis and Application Program
WTG	Wind turbine generator
YEC	Yukon Energy Corporation

1 INTRODUCTION

1.1 Background

The Yukon Energy Corporation (YEC) has a winter peak demand of 82 MW[1] and dependable renewable capacity of 72 MW. Thermal generation is used to provide peak power. If consumer loads continue to grow or if a large industrial customer is added then additional sources of energy may be required.

This report is the result of a two-month study of the wind energy potential in the Yukon Territory. This work will support the planning process that aims at identifying potential resource options to meet the long-term load forecast (2016-2035) of the area served by Yukon Energy Corporation (YEC).

YEC has entered a new planning cycle. A five-year update of YEC's Integrated Resource Plan is scheduled for completion at the end of 2016. To this end, YEC has commissioned a series of assessments on several energy technologies. These assessments are to inform YEC about the potential viability of each power generation resource in the Yukon, identify suitable sites, estimate capital and operating costs, and determine the resulting per-kWh power generation cost.

The assessments then feed into a Resource Option Report that evaluates the various options for power generation according to financial, technical, socio-economic an environmental attributes of the individual technology options.

1.2 Scope and Objective

This report is about power generation from wind turbines. The report is of a technical nature and mainly aimed at YEC staff, but also provides information for other parties interested in wind power with a general understanding of the technology.

This study has four major objectives:

1. **Wind site inventory**: Mesoscale wind mapping (1 x 1 km resolution) to identify potential wind project sites near existing and planned power infrastructure. Select sites for detailed analysis of wind farm capacity (Chapter 2);
2. **Develop potential wind projects at a conceptual level**: Detailed analysis of wind farm capacity, including wind resource assessment (200 x 200 m resolution), site turbine layout, infrastructure footprints (Chapter 3), and gross and modelled net power output (Chapter 4);
3. **Economic modelling**: Create site-specific cost estimates for development, construction, power production, and power costs (Chapter 5);
4. **Additional information pertaining to wind farm development**: Technical and other considerations affecting the viability of wind power development, including potential for rime icing and possible mitigation measures, development risks, and typical development schedules (Chapter 6 to 8).

[1] YEC's generation profile for 2015, Excel spreadsheet provided by Yukon Energy Croporation on March 15th, 2016

1.3 Previous Work

The Yukon has numerous potential sites with excellent wind power potential in addition to the operational Haeckel Hill wind turbine project near Whitehorse. YEC recognizes this and commissioned previous wind resource studies to explore YEC's wind power development options. They are:

- Yukon Energy Corporation, Regional Mesoscale Modelling, Natural Power, February, 2011
- Yukon Energy Corporation, Aishihik Area Mesoscale Modelling, MG Renewables Consulting, July 2012

Other reports and papers reviewed include the Ferry Hill (referred to as Tehcho below) wind feasibility study (two parts) by Natural Power, 2010, *Wind Climate of the Whitehorse Area in Arctic*, by JP Pinard, Sept. 2007, *Wind Power Development in Sub-Arctic Conditions with Severe Rime Icing*, by John Maissan, Mar. 2001, and the *Mt Sumanik Wind Feasibility and Icing Study*, by Natural Power Consultants, Sept. 2010.

These reports were very useful for this project analysis and in several cases our site recommendations overlap. The primary difference is that the present study has a stronger bias toward site access and constructability and less toward optimum wind resource as the primary salient criteria. A strong wind resource is highly desirable, of course, but only if it can be developed at reasonable cost and effort.

2 WIND POWER SITE IDENTIFICATION

2.1 Site Identification Criteria

Due to the Yukon's mountainous topography, most suitable wind farm sites are located on mountaintops, peaks, ridges or crests. YEC's transmission lines naturally route through valleys, typically following highway corridors. The result is a challenging exercise of identifying sites that are not only windy, but can also be *developed*. During the initial screening process, potentially suitable wind power sites were identified within 25 km of existing and planned or proposed Yukon power infrastructure (see Appendix A for a map). YEC determined, and the project team concurs, that potential wind sites located beyond 25 km from existing power infrastructure are too costly to develop and operate, regardless of their wind resource merits.

As can be seen in Figure 1, the Yukon has somewhat less wind potential than the NWT and the eastern part of Alaska. There is more wind power potential (green-yellow areas on the map) in the higher elevation western part of the Yukon than in the lower elevation east. All sites identified are therefore situated in the western half of the Territory. This also reflects the concentration of population and infrastructure in the western and especially southwestern Yukon.

A number of criteria were considered for the wind site prospecting task, including:

Wind and atmospheric considerations

- Desirable wind resource, defined as relatively high mean annual wind speed and wind power density, normal or near normal Weibull distribution, low turbulence and acceptable extreme wind behavior
- Atmospheric rime icing environment (high/low probability)
- Ice throw distance to roads/other public use facilities

Site development considerations

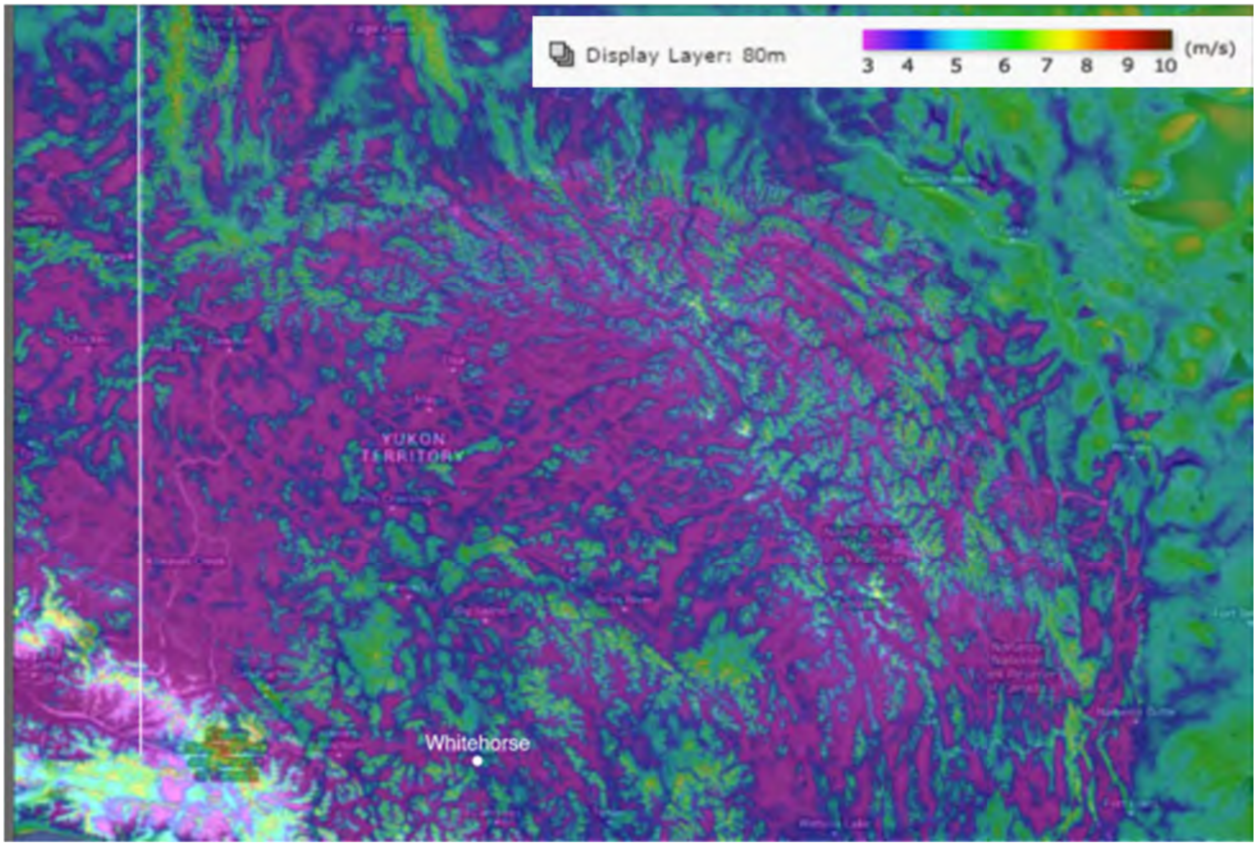
- Reasonable distance to a community, industry, or other electric loads
- Near existing or proposed power transmission infrastructure (<25 km for this project)
- Capacity of existing transmission to accept maximum power output of wind farm
- Suitable geotechnical conditions for foundations and access roads
- Proximity to existing roads; prospective cost to develop access (steepness, river crossings etc.); serviceability
- Airspace restrictions; proximity to airports and/or military airspace use areas
- Land use availability (land ownership, parks, easement restrictions, likely lease rates, nearby cultural sites or natural parks)
- Local geology (based on GeoYukon website)

Environmental and human factor considerations

- Deleterious effect on terrestrial wildlife and avian species (high-level)
- Wetlands, parks and other high-level environmental restrictions
- Noise, and aesthetic considerations; closeness to recreational activities

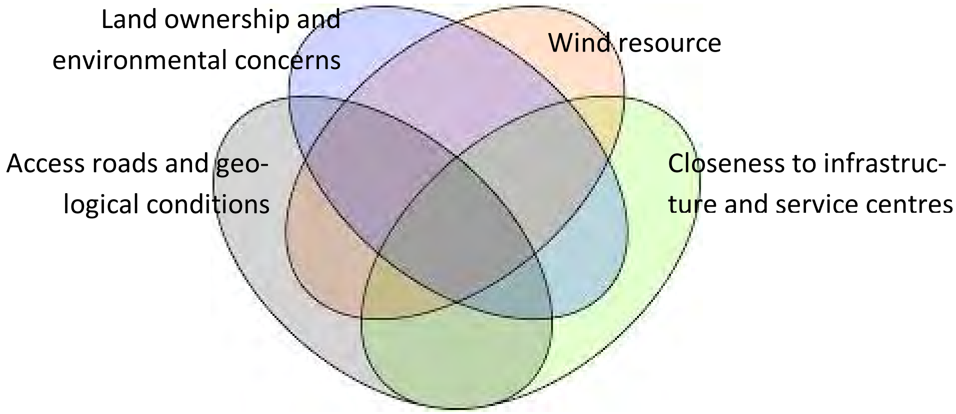
Other criteria were a desire to represent northern, central and southern Yukon and a preference for locations close to cities, larger towns, or existing hydroelectric infrastructure to facilitate wind turbine operations and servicing. Part of the intent was to screen as wide an area as possible and represent sites of varying characteristics.

Figure 1 Yukon Territory AWS Truepower Meso-Scale Wind Resource Map



The authors developed an initial long-list of potential sites that meet all or most of the criteria listed above. The conceptual image of a Venn diagram in Figure 2 below illustrates the process. Each ellipse represents a criterion listed above; the best or most promising solutions lie at the intersection of all criteria.

Figure 2 Conceptual Venn Diagram of Wind Site Criteria and Site Selection



Beginning the site search by reference to the wind resource we selected preliminary options by referencing two data sources, in addition to previously published wind studies noted above:

1. International Renewable Energy Agency (IRENA) 1,000 x 1,000-meter resolution,[2] 100-meter level (representing a typical utility-scale wind turbine hub height), mesoscale wind resource data. Note that IRENA employs Technical University of Denmark (DTU) wind data using their methodology.
2. AWS Truepower Windnavigator 200 x 200-meter resolution, 100-meter and 80-meter level (80 meters also represents a typical utility-scale turbine hub height), microscale wind resource data. AWS data has 25 times higher resolution than IRENA .

Large area AWS Truepower 200 x 200-meter resolution maps of three regional subsets of the territory – northern, central and southern – are presented below. From a broad territory-wide perspective, one can see that high winds are found at higher elevations – mountains, hills, high elevation plateaus – and low winds are found in lower elevation areas, such as valleys.

The Yukon is a high latitude region with a mostly sub-arctic-to arctic, often maritime-influenced climate. The consequence is atmospheric icing at higher elevations that creates wintertime rime ice conditions which are operationally challenging. For this reason, the theoretically most desirable high latitude wind power sites are at lower elevations where rime icing conditions don't occur. But, as one can see in the AWS Truepower Windnavigator wind maps of the Yukon, there are no sites in the territory that are both windy and (relatively) low elevation, with the exception of Kluane Lake, which is a site of interest for this study.

2.2 Initial Site Inventory

Using the Venn diagram model as a conceptual guide, 26 potentially promising sites for wind power development were initially identified and considered before narrowing the list to five sites (later expanded to seven sites with the inclusion of Tehcho and Mt. Sumanik). The 26 sites were evaluated

[2] The resolution refers to the spatial grid resolution of the computational fluid dynamics model. Both IRENA's and AWS's data are based on numerical analysis conducted for a specific land area. The finer the grid the lower the modelling error.

using the criteria mentioned above in a desktop analysis to screen all sites. The results of this exercise are presented in Table 5.

2.2.1 Northern Yukon Sites of Interest

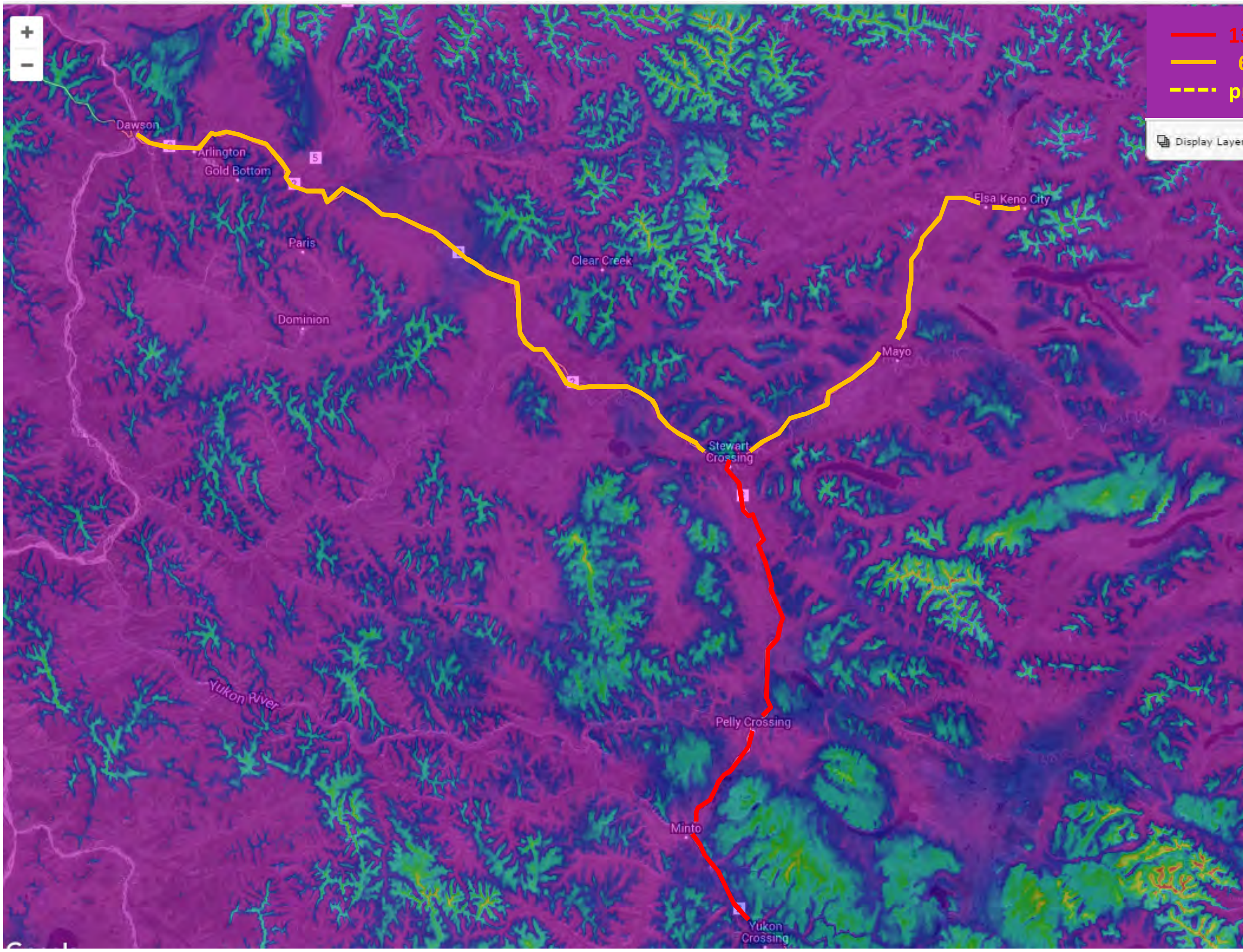
The wind resources in the northern Yukon are fairly sparse compared to the Yukon's central and southern regions. Our analysis did not extend north beyond the developed Dawson-to-Mayo parallel at approximately 64° N latitude. Options are generally limited to particularly high and mostly isolated mountaintops and ridges. The sites listed in Table 1 represent a range of possible wind power development options for this region. Site identification numbers are the same as those used throughout this report on maps and in tables.

The wind resources of the central Yukon that can potentially be developed represent, for the most part, the Carmacks-to-Faro meridian at about 62° N latitude. They are generally quite good but, as noted earlier and true of most of the Yukon, are limited to higher mountain ridges or plateau-like areas.

Table 1 Northern Yukon Wind Sites Considered

#	Site Name	Location	Brief Description
16	Keno City hill	7 km east of Keno City	Hills complex just east of Keno City; access from Keno City
10	Unnamed hill between Wareham and Janet Lakes	11 km northeast of Mayo	Large, plateau-like hill; plenty of space for turbines; near AOI's 9 and 10 identified by Natural Power (2011 report) but easier access
6	Tehcho (Ferry Hill)	Near Stewart Crossing	Hill immediately north of Stewart Crossing; Natural Power study addressed wind power options and icing potential
19	Willow Hills	16 km SSW of Stewart Crossing; 12 km west of Hwy 2	Broad area of hills increasing elevation from east to west; plenty of space for turbines; possible site access from utility easement or due west from Hwy 2

Figure 3 Northern Yukon AWS Truepower Meso-Scale Wind Map



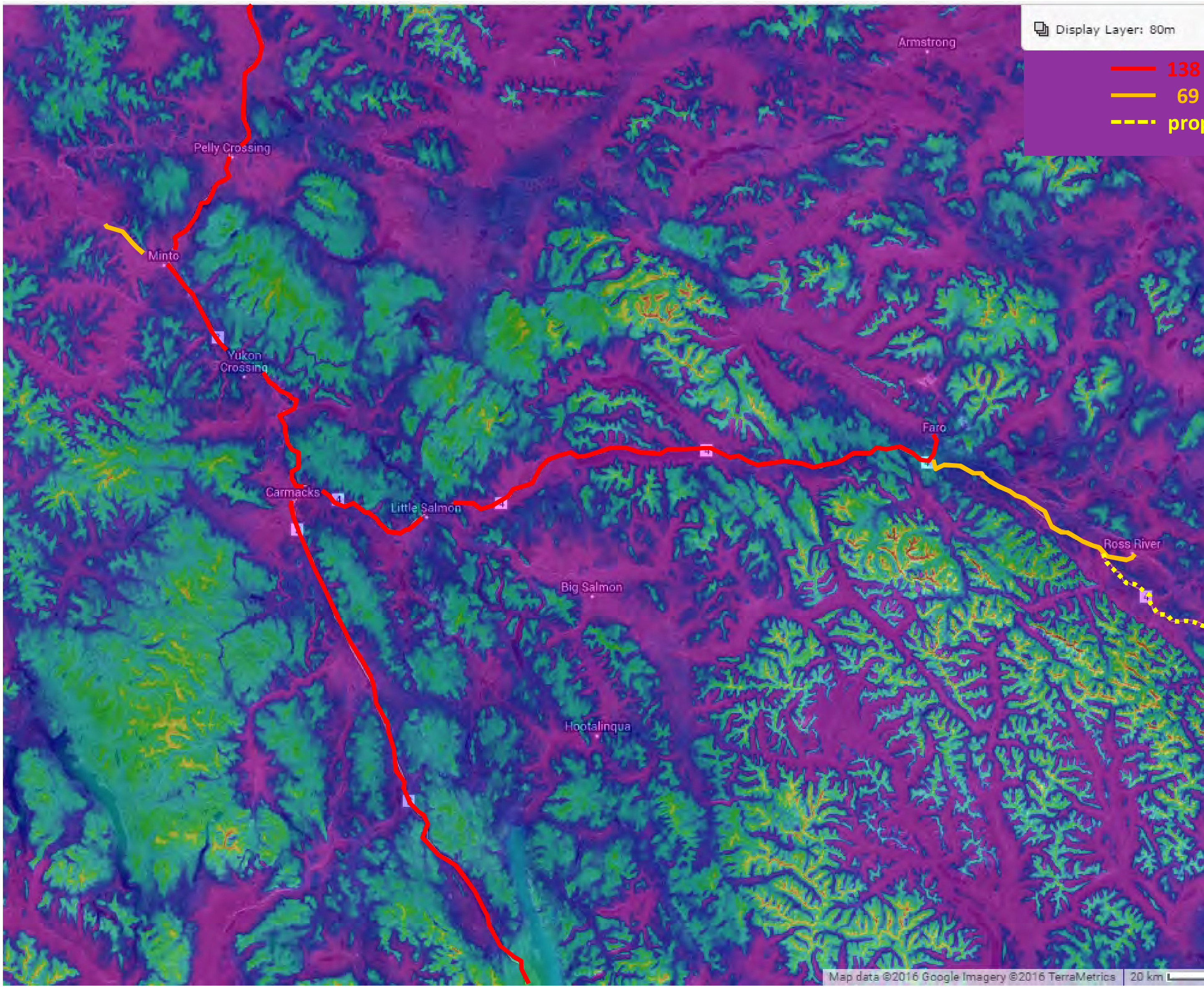
2.2.2 Central Yukon Sites of Interest

The wind resources of the central Yukon, representing for the most part the Carmacks-to-Faro parallel at about 62° N latitude, are generally quite good: They are, however, as noted earlier and true of most of the Yukon, are limited to higher mountain ridges or plateau-like areas. The sites listed in Table 2 represent a range of possible wind power development options for this region.

Table 2 Central Yukon Wind Sites Considered

#	Site Name	Location	Brief Description
3	Miller's Peak/Ridge	15 km west of Carmacks	Large, broad ridge; plenty of space for turbines; identified as AOI 4 by Natural Power (2011 report); near area access via gravel road W of Carmacks; site access from the gravel road
21	Mt. Berdoe	8 km SSE of Carmacks	Large hill near Carmacks with existing road access for a communications tower; site access exists
17	Unnamed hill east of Minto (between Pelly Crossing and Carmacks)	27 km SE of Minto; 18 km from highway	Large hill complex east side of highway near Minto, north of Carmacks
18	Little Salmon hill	39 km east of Carmacks	Very large and broad hill complex north of highway
22	Unnamed hills between Little Salmon and Drury Lakes	85 km E of Carmacks	Two parallel sloping ridges ascending from Little Salmon Lake to NW; plateau-like on top; possible site access from Hwy 4 east side of lake
11	Hill west of Faro, north of highway	27 km west of Faro	North-south trending low ridge just north of highway; access from hwy
12	Hill west of Faro, south of highway	27 km west of Faro	Hill complex south of highway and river access would require river crossing
1	Cyprus Mine hill	20 km N of Faro and 7 km north of the mine	Compact ridgeline immediately north of the mine pit and also a similar hill immediately SE of the mine; possible site access from the mine itself or from mine access roads
26	Hill SE of Ross River	75 km SE of Ross River	Hill group 16 km south of highway; access from the highway

Figure 4 Central Yukon AWS Truepower Meso-Scale Wind Map



2.2.3 Southern Yukon Sites of Interest

The wind power site options identified in the southern Yukon are generally quite good and include the relatively low elevation Kluane Lake. Low elevation has the advantage of low rime icing risk and avoids the considerable operational challenges that icing entails. The southern Yukon includes Whitehorse and hence is the population center of the Territory. That is advantageous from a wind farm operations perspective due to ready proximity to Whitehorse-based utility staff and contractors. The sites listed in Table 3 represent a range of possible wind-power development options for this region.

Table 3 Southern Yukon Wind Sites Considered

#	Site Name	Location	Brief Description
2	Kluane Lake, west shore	8 km SE of Destruction Bay	Midpoint of west shore of Kluane Lake; between Alaska Hwy and the lake
14	East shore of Kluane Lake	12 to 15 km N of Silver City	Two adjacent options: slopes above Grayling Lake, and NE-SW trending ridge just north of Rat Lake. Identified as AOI 4 by MB Renewables (2012 report) and NP (2011 report); gravel road access from Silver City
23	Anticline Mountain and adjacent ridges	75 km NNW of Whitehorse	Two SE-NW trending ridges just east of Little Fox Lakes and Hwy 2; jeep road access on southern ridge from Hwy 2
20	Hard Time Mountain	15 km ENE of Paint Mtn. and 11 km NW of Canyon	Southern end of mountain complex trending N from Hwy 1; site access possible from Hwy 1 west of Canyon
7	Thulsoo Mountain	21 km NNE of Canyon near Aishihik Hydro facility	High, rounded mountain immediately east of Aishihik hydro facility; identified as AOI 1 by MG Renewables (2012 report); site access from Canyon Lake road
15	Flat Mountain ridge	35 km NW of Whitehorse; west of south side of Lake Laberge	Rounded ridge immediately SW of Flat Mountain itself; site access possible from Hwy
4	Mount Sumanik	Immediately west of Whitehorse and existing Haeckel Hill wind turbines	Large, broad hill complex; equipped with Lidar for ongoing wind resource assessment study
9	Grey Mountain	9 km SE of Whitehorse	North-south trending ridgeline; access road to comm. tower on southern end; Whitehorse city recreational parkland
8	Mount Lorne subpeak (Minto Hill)	East of Hwy 2 between Mount Lorne and Carcross, 8 km SE of Mount Lorne	Gentle-top grouping of connected hills just S of more rugged Mount Lorne; no existing access; possible site access from Hwy 2
5	Northeast	7 km SSE of Carcross	Very broad, flat, wide, exposed, above treeline fea-

#	Site Name	Location	Brief Description
	slope of Sugarloaf Mtn.		ture comprising the north slope of Sugarloaf Mtn; plenty of room for turbines; site access via existing gravel road/jeep trail to Montana Mountain from Carcross
25	White Pass	On Canada/ U.S. Border, in B.C.	Open areas of the pass immediately east or west of Hwy 2 on Canada side and AK Hwy 98 on U.S. side; near Klondike Nat'l Historic Park; access from the highway
13	Hayes Peak	10 km S of Johnsons Crossing	Broad shouldered hill just west of northern shore of Teslin Lake

Figure 6 is a map of the 26 sites identified as possibly suitable for wind power production. Sites are colour-coded as red (the preferred seven sites), orange (potential alternate sites) and grey (unlikely to be developed).

Figure 5 Southern Yukon AWS Truepower Meso-Scale Wind Map

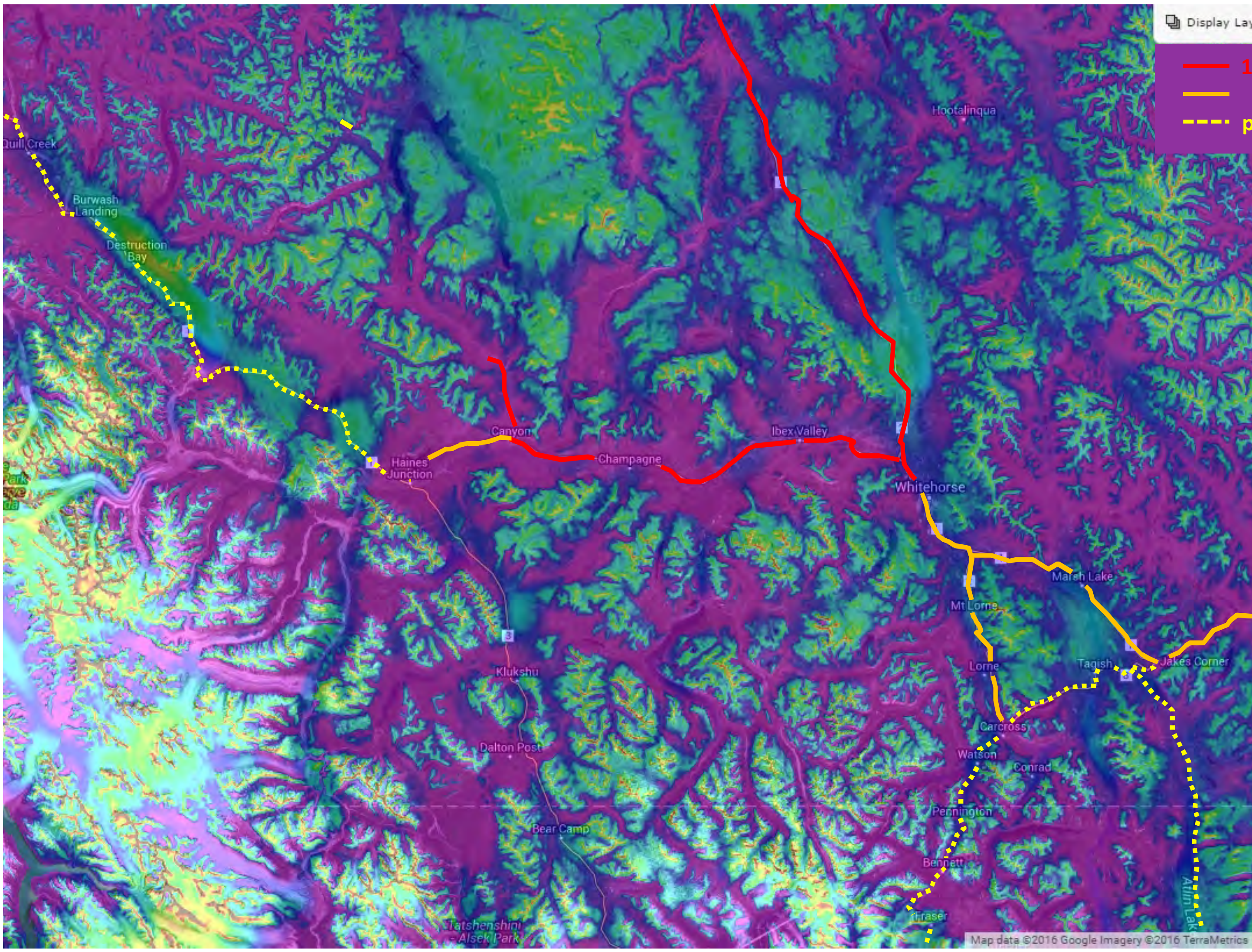
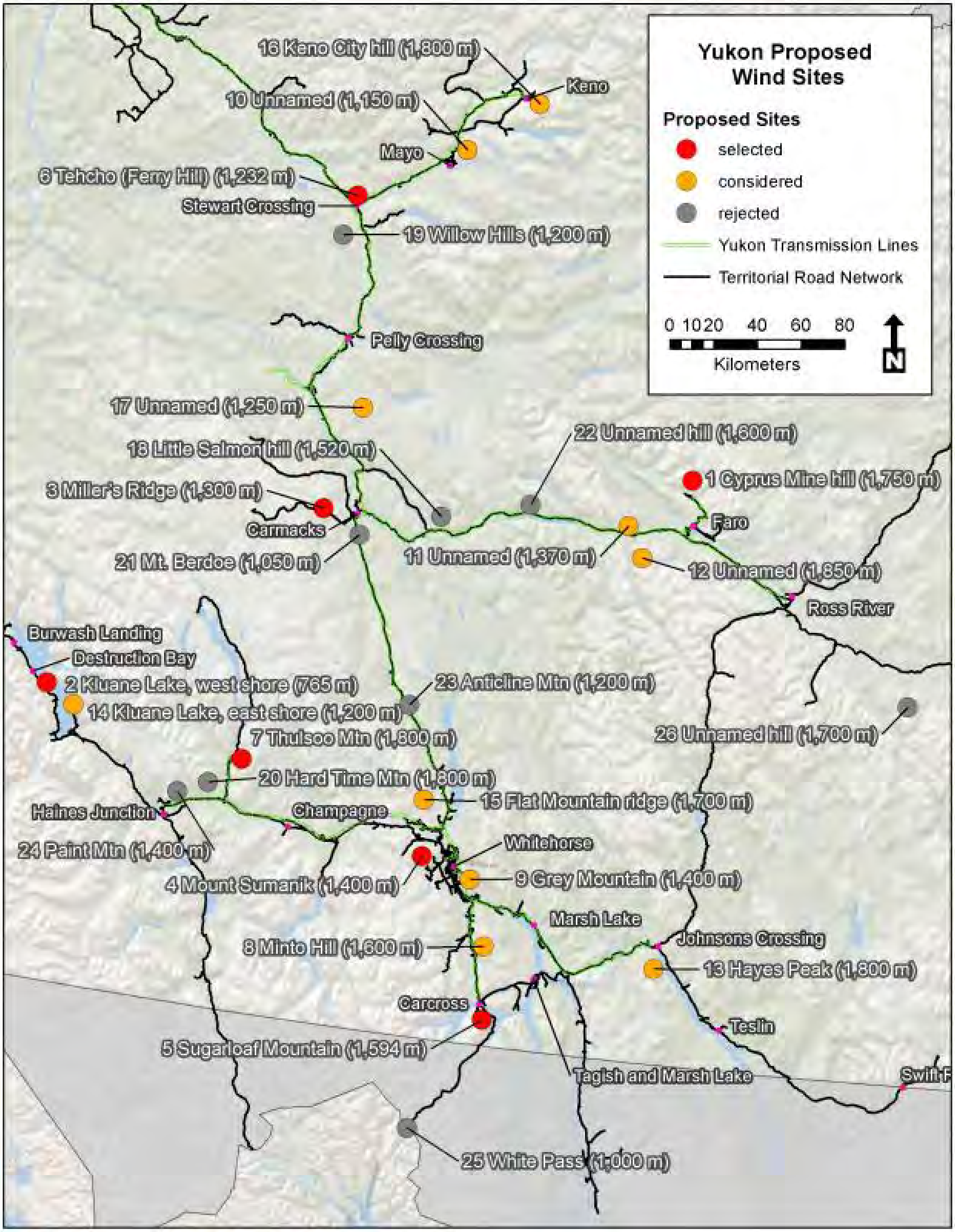


Figure 6 Map of Potential Wind Farm Sites



2.3 Yukon Site Visit

Douglas Vaught, P.E. (Ak) of V3 Energy LLC visited the proposed central and southern Yukon sites by helicopter and/or from roads during a site visit in late April 2016 to confirm the selection of the seven preferred sites, obtain photographs of the sites themselves and possible access routes, and garner a general qualitative assessment of site development potential. A number of photos were taken for documentation and to provide additional information. One photo per site was included in Chapter 3; additional photos can be found in Appendix F.

With reference to Figure 6, sites visited from the air in a broad flight loop from Whitehorse to Carmacks, to Faro, to Johnsons Crossing, to Carcross and then back to Whitehorse. Also visited and/or observed by ground travel were the potential sites in the vicinity of and west of Whitehorse.

Table 4 Observations of Yukon Site Visit

#	Site	Observation
4	Mt. Sumanik	Reasonably good access options, somewhat narrow ridge, near Whitehorse, high potential
15	Flat Mountain	Complex ridgeline, hard to access, low potential
23	Anticline Mountain	Complex ridgelines, access appears difficult, low potential
21	Mt. Berdoe	Heavily forested, small site area, very low potential
3	Miller's Ridge	Reasonably good access option with use of Nansen Mine road, huge site area, great exposure, very high potential
17	Unnamed Minto hill	Too far away from the highway, remote site, low potential
22	Unnamed hills between Little Salmon and Drury Lakes	Complex ridgelines, difficult access, remote site, low potential
1	Cyprus Mine hill plus alternate nearby	Easy access, turbine site options limited to ridge edge, alternate site has good site options, confirmed brownfield nature of site, high potential
11, 12	Unnamed hills west of Faro	Access to hill south of highway difficult, not as promising as Cyprus, low potential
13	Hayes Peak	Difficult access, peak too steep to develop, low potential
5	Sugarloaf Mountain	Good access, large, open site, moderate potential
8	Mt. Lorne subpeak/Minto Hill	Difficult access options, remote, low potential
2	Kluane Lake, west shore	Very easy access, new transmission land route would be difficult, very windy day of visit, moderate potential
14	Kluane Lake, east shore	Observed from across lake, transmission connection easier than west shore, moderate potential
24	Paint Mountain	Difficult access, small area, low potential
20	Hard Time Mountain	Difficult and expensive access, too remote, low potential
7	Thulsoo Mountain	Observed from a distance, site ridge appears promising
9	Grey Mountain	Very windy day of visit, complex ridgeline, high value recreational use, low potential

Information gathered from the site visits primarily reinforced the team's thoughts regarding site suitability developed through reference to mapping, Google Earth, photographs available on-line, previous reports, and other sources. Impressions of the site visit are documented in Table 4 above.

2.4 Site Selection

The 26 sites were assessed according to the following criteria:

1. Mean wind velocity (IRENA and AWS data at 80 and 100-meter hub heights)
2. Distance to transmission line (straight line distance)
3. Road access (straight line distance)
4. Land ownership and usage

Other non-quantifiable factors such as potential conflict with other land uses or public opposition expected for certain sites were then evaluated to determine a shortlist of seven sites. This shortlist includes two sites that had previously been examined, Mt. Sumanik and Tehcho (Ferry Hill), that YEC had requested to be included so they could be compared to the sites identified through the comprehensive territorial wind site assessment conducted for this study.

The result of the selection process can be seen in the Table 5 below. Red shaded rows are sites we shortlisted. Second-tier candidates are marked in yellow, while less desirable sites are shaded grey. The emphasis was to give preference to "low-hanging fruit" sites that seemed easiest to develop. Second tier sites are usually also good candidates and could be considered for replacing shortlisted sites that prove too difficult to develop, e.g. after monitoring revealed excessive periods of rime icing.

The location of these sites is illustrated in Figure 6 above. AWS Truepower wind resource maps for the seven selected sites can be found in Appendix B and AWS Truepower Compass-level site reports of all 26 sites can be found in Appendix E.

Table 5 Assessment of Potential Wind Farm Sites

ID	Name	Elevation above sea level	Mean wind velocity AWS data At 80 m hub	Distance to transmission line	Type	Road access River Crossing Required?	Straight line distance to hwy	Hw pav
1	Cyprus Mine Hill	1,750 m	7.0 m/s	7.2 km	138kV Tx Line	Yes	6.9 km	Un
2	Kluane Lake, west shore	765 m	6.5 m/s	77.9 km	69kV Tx Line	No	1.7 km	P
3	Miller's Peak/Ridge	1,300 m	7.3 m/s	15.5 km	138kV Tx Line	No	2.6 km	Un
4	Mount Sumanik	1,594 m	6.2 m/s	10.2 km	138kV Tx Line	No	5.2 km	Un
5	Northeast slope of Sugarloaf Mtn.	1,400 m	5.7 m/s[3]	9.1 km	69kV Tx Line	No	1.7 km	Un
6	Tehcho (Ferry Hill)	1,232 m	5.8 m/s	3.0 km	69kV Tx Line	No	0.3 km	Un
7	Thulsoo Mtn	1,800 m	7.8 m/s	5.5 km	138kV Tx Line	No	3.8 km	Un
8	Mount Lorne subpeak (Minto Hill)	1,600 m	7.7 m/s	4.6 km	69kV Tx Line	Yes	5.1 km	P
9	Canyon Mountain / Grey Mountain	1,400 m	7.1 m/s	3.6 km	69kV Tx Line	No	1.3 km	Un
10	Mayo, unnamed hill between Wareham and Janet Lakes	1,150 m	4.9 m/s	3.9 km	69kV Tx Line	No	4.0 km	Un
11	Hill west of Faro, north of highway	1,370 m	7.1 m/s	3.6 km	138kV Tx Line	No	3.6 km	P
12	Hill west of Faro, south of highway	1,850 m	8.5 m/s	10.9 km	138kV Tx Line	Yes	10.8 km	P
13	Hayes Peak	1,800 m	7.4 m/s	10.6 km	69kV Tx Line	No	6.2 km	Un
14	East shore of Kluane Lake	1,200 m	6.7 m/s	7.5 km	Proposed	No	0.9 km	Un
15	Flat Mountain Ridge	1,700 m	7.6 m/s	9.4 km	138kV Tx Line	Yes	8.6 km	Un
16	Keno City Hill	1,800 m	6.8 m/s	7.2 km	69kV Tx Line	Yes	4.9 km	Un
17	Hill east of Minto (south of Pelly Crossing)	1,250 m	6.9 m/s	18.0 km	138kV Tx Line	No	18.1 km	Un
18	Little Salmon Hill	1,520 m	7.3 m/s	6.4 km	138kV Tx Line	No	6.5 km	P
19	Willow Hills	1,200 m	6.4 m/s	9.1 km	138kV Tx Line	Yes	9.2 km	P
20	Hard Time Mtn	1,800 m	6.7 m/s	7.7 km	69kV Tx Line	Possibly	7.9 km	P

[3] Reflects average wind speed at proposed turbine sites; AWS Truepower reference wind speed higher on Sugarloaf knob (compass report) and lower at AWS Truepower data reference point between knob and turbine sites.

ID	Name	Elevation	Mean wind velocity	Distance to transmission line		Road access		
		above sea level	AWS data At 80 m hub		Type	River Crossing Required?	Straight line distance to hwy	Hw pav
21	Mt. Berdoe	1,050 m	5.4 m/s	1.4 km	138kV Tx Line	No	0.1 km	
22	Unnamed hills between Little Salmon and Drury Lakes	1,600 m	6.6 m/s	3.7 km	138kV Tx Line	No	3.7 km	Ur
23	Anticline Mtn and adjacent ridges	1,200 m	6.2 m/s	2.7 km	138kV Tx Line	Yes	2.1 km	G
24	Paint Mtn	1,400 m	4.3 m/s	5.2 km	69kV Tx Line	No	5.1 km	P
25	White Pass	1,000 m	5.3 m/s	0.5 km	Proposed	No	0.4 km	P
26	Hill SE of Ross River	1,700 m	9.0 m/s	75.1 km	Proposed	Yes	15.8 km	Ur

3 CONCEPTUAL WIND FARM DEVELOPMENT

We developed representative wind turbine arrays of 20, 10 and 6 MW capacity for each of the seven selected sites. The site layout and location is on a conceptual level only. The level of detail is sufficient for estimating the power output and the cost of installing wind farms of the respective size at these sites. Further and more detailed engineering will be required, though, should YEC decide to move forward any of these proposed installations.

For modelling of the wind farm we employed a wind modelling software called WAsP (Wind Atlas Analysis and Application Program). The WAsP software is a Danish PC-based software for predicting wind climates, wind resources and power production from wind turbines and wind farms and was used to model wind turbine performance. WAsP is the most widely used wind power analysis software in the world. WAsP modelling begins with a digital elevation map (DEM) of the wind farm site and surrounding area and conversion of coordinates to Universal Transverse Mercator (UTM).[4] WAsP modeling results for the seven selected sites can be found in Appendix G.

A wind data reference point (for this project, a purchased AWS Truepower annual data series file for a representative location at the site of interest) is added to the digital elevation map, wind turbine locations identified, and a particular wind turbine (for this project, as noted, a generic 2.0 MW model) selected to perform the calculations. WAsP considers the orographic (terrain) effects on the wind, plus surface roughness and obstacles, and calculates wind velocity increase or decrease at all nodes of the map. The mathematical model has a number of limitations, including the assumption that the overall wind regime of the turbine site is same as the met tower reference site, prevailing weather conditions are stable over time, and surrounding terrain at the wind data reference point and turbine sites is sufficiently gentle and smooth to ensure laminar, attached wind flow. The version of WAsP software used for this study is not capable of modelling turbulent wind flow resulting from sharp terrain features such as mountain ridges, canyons and shear bluffs.

To compare sites, we modelled each site using a generic 90-meter rotor diameter, 2.0 MW capacity, 80-meter hub height wind turbine. Although the modelled turbine is a Vestas V90, it is considered generic for the purpose of this exercise and can be considered representative of other turbines of the same power output class. Note, however, that the generic turbine in this exercise may not be the best choice at every site.

Specific turbine selection is a detailed and significant process of customer and manufacturer consideration and hence appropriate to the detailed design phase of a project. With that in mind, the generic 2.0 MW turbine modelled is a compromise choice. Although it would be suitable for most of the sites, or most turbine locations within a site, for other sites or locations other wind turbine models or manufacturers may be preferable.

[4] UTM is a geographic coordinate system that uses a two-dimensional Cartesian coordinate system to identify locations on the surface of Earth. UTM coordinates reference the meridian of its particular zone (60 longitudinal zones are further subdivided by 20 latitude bands) for the easting coordinate, and distance from the equator for the northing coordinate. Units are meters. Elevations of the DEMs are converted to meters if necessary for import into WAsP software. Digital elevation data was obtained from Natural Resources Canada (http://geogratis.gc.ca/site/eng/extraction) as TIFF format files.

For the representative wind turbine layouts presented in this section, an approximate turbine separation of five rotor diameters, or 450 meters, was consistently used. This is the conservative end of the three-to-five rotor diameter separation range generally recommended in the wind power industry for turbines oriented perpendicular to the prevailing wind. For turbine placement parallel to the prevailing wind, which only applies to the Kluane Lake site, a separation distance of approximately 1,000 meters, or 11 rotor diameters was chosen. This separation distance is also consistent with industry practice.

For actual design of a wind farm, an optimization analysis of turbine separation distance would be accomplished. The optimization of turbine separation and placement recognizes the non-coincident relationship between turbine distance and wake loss. Increased inter-turbine distance decreases wake loss but increases project development costs. This is because of the need for longer access roads, larger land area purchases or lease, longer electrical transmission lines, etc. The opposite, naturally, is also true. There is no one correct answer, other than to reference industry practice and guidelines of approximately five percent aggregate wind farm wake loss as a suitable compromise with respect to site development costs.

The following sections summarize the results of the WAsP model and observations from Google Earth and site visits. Details on annual gross energy production, wake losses and monthly generation profiles for each site can be found in Appendix H.

3.1 Cyprus Mine Hill

The hill complex immediately north of Cyprus Mine near Faro is an excellent wind farm site option due to the 'brownfield'[5] nature of the mine. Additional industrial-type development at a brownfield site, such as a wind farm, generally elicits less public opposition than greenfield development.

3.1.1 Site Description

Being close to a former large mine, significant advantages of Cyprus Mine Hill are the vicinity of a 138 kV transmission and partially developed high quality road access to the site. The ridge has a desirable orientation perpendicular to prevailing wind directions. Figure 7 shows a Google Earth image of the site area, and Figure 8 is a photo taken during the site visit, with the site area shown in the foreground (orange line).

A possible alternative or adjunct to Cyprus Mine Hill as a wind power site are hills of similar elevation immediately east of the connecting road between the northern and southern mine pits. AWS Truepower and WAsP modelling both predict a strong wind resource on the more accessible western slopes and ridges of these hills. Should a wind power project be contemplated for Cyprus Mine area, we recommend that data collection with met towers or LIDARs [6] of both hill groups: the proposed and the alternate.

[5] Term to describe land previously used for industrial purposes and potentially contaminated with hazardous waste or pollution.

[6] LIDAR: Light Detection And Ranging is a method of measuring wind speeds by projecting a laser into the air and detecting the backscatter from random particles in the atmosphere.

Figure 7 Cyprus Mine Prospective Wind Power Site, Google Earth Image

Figure 8 Cyprus Mine Prospective Wind Power Site, Photo (East view)

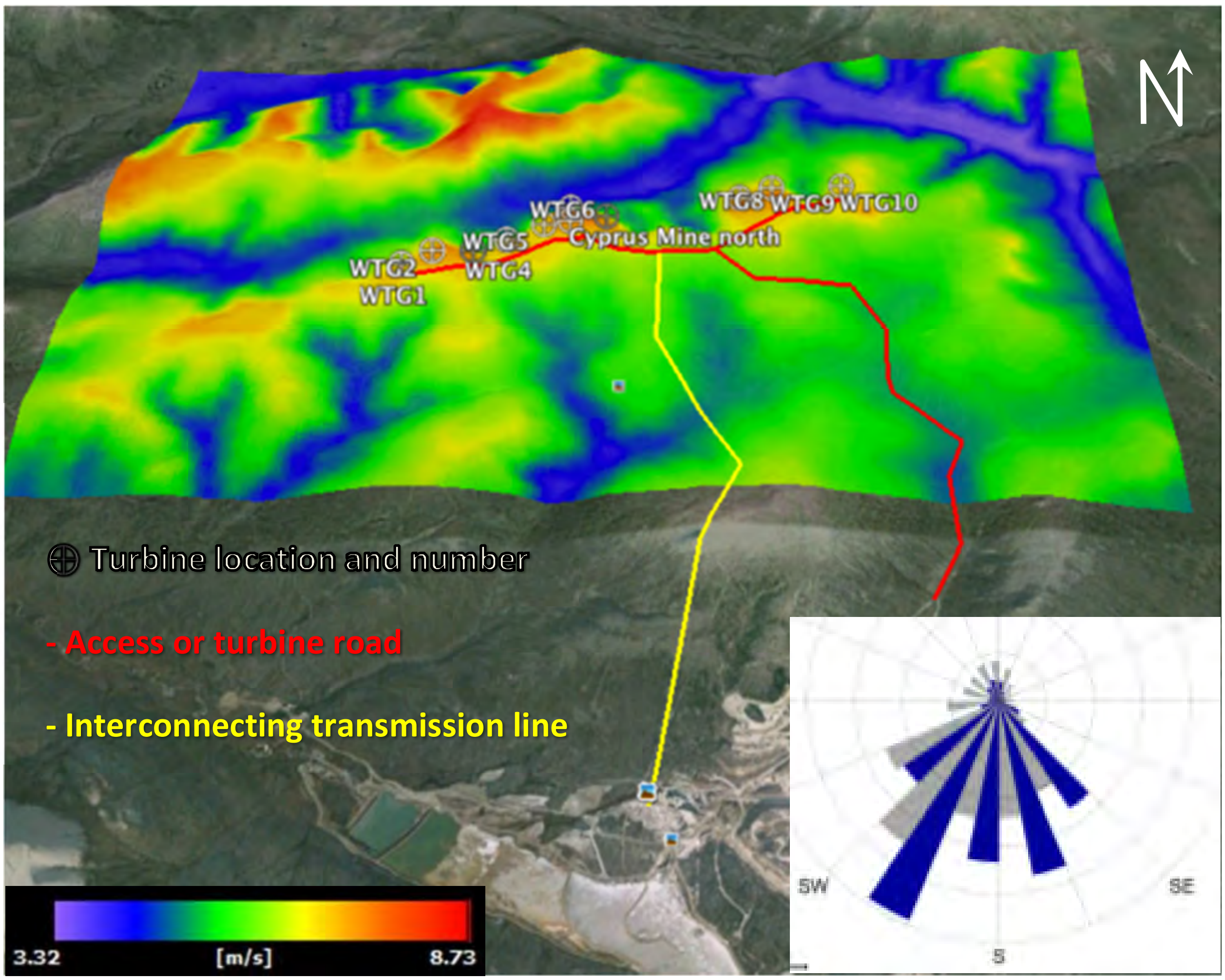
3.1.2 Site Layout

The ridgeline where turbines would be located is quite long and perpendicular to the prevailing wind direction as noted in Figure 9. This is advantageous in that the ridge can support installation of many wind turbine and wake loss would be minimal.

A 20 MW wind farm (ten two-MW wind turbines) would be arrayed at higher elevation points along the ridge as shown in Figure 10 below. Turbines in this figure are identified as "WTG", the AWS Truepower data reference point for the WAsP model is noted by "Cyprus Mine north", recommended turbine access roads are indicated by red lines, and the existing communication tower electrical connection that would be upgraded to support wind turbines is indicated by the yellow line.

Additional turbines to the west of Turbine 1 (WTG1) are possible as are installing turbines on an adjoining parallel ridge to the north. Access to that ridge would be possible via a broad "pass" between the two (visible left center of Figure 8). Beyond this site area, the alternate site option east of the two mine pits could support at least another 20 MW of wind power capacity, if not more.

Figure 10: 20 MW Wind Farm Layout for Cyprus Mine Hill Site, WAsP Wind Speed Overlay



3.2 Kluane Lake (West Shore)

As a prospective wind power site, the west shore of Kluane Lake presents intriguing possibilities. It is the only relatively-low-elevation location in the Yukon with projected high wind speeds. The mountains west and east of the lake concentrate and funnel wind along the long axis of the lake.

Although the highest wind speeds at Kluane are straight down the middle of the lake, as one would expect, the west shore has only a minimally lower wind resource.

3.2.1 Site Description

At 720 meters above sea level, Kluane Lake is much lower elevation than the six other sites profiled in this report. As such, the problematic winter rime icing environments that would be an operational challenge at the higher elevation sites would not exist at Kluane Lake, or at least would be significantly reduced in frequency and severity.

A disadvantage of Kluane Lake is that currently there is no electrical transmission line nearby, although a planned new line would run very closely to the site. Today, YEC's transmission terminates at the Aishihik Generating Station and all communities and load centers to the west operate as isolated grids. The map in Appendix A shows the proposed transmission to possibly as far west as Destruction Bay. If constructed, a Kluane Lake project would be quite viable. The west shore of Kluane Lake as a site recommendation is presented in this report based on a presumption that the proposed transmission is constructed independently of a wind project; in other words, a Kluane Lake wind project would not absorb the cost of transmission to Haines Junction.

A possible site alternative to the west shore of Kluane Lake are sloping hills near Grayling and Rat Lakes, nearly directly across the lake from the west shore site and about 12 to 15 km from Silver City. An advantage of the east shore is a shorter transmission connection to Haines Junction, should an extension of the transmission line to the west shore Kluane Lake communities of Destruction Bay and Burwash Landing not be possible. Disadvantages are higher elevation sites and more complex access and construction requirements.

Figure 11 indicates the proposed Kluane Lake west shore site on a Google Earth image, and Figure 13 shows a photo of the lake shore near the site, which was taken during a site visit in late April 2016.

Figure 11 Kluane Lake Prospective Wind Power Site, Google Earth Image

3.2.2 Site Layout

A ten-turbine, 20 MW wind farm (assuming 2 MW wind turbines) could be arrayed in two rows of five turbines between the Alaska Highway and the Kluane Lake shoreline as shown in Figure 14. The site area is entirely forested and pad areas and access roads would require clearing. The AWS Truepower data reference point for the WAsP model is adjacent to WTG6, recommended access roads (one road for two turbines) are indicated by red lines, the recommended new wind farm electrical sub-transmission connection to existing transmission is indicated by the yellow line (under "WTG3"), and the planned transmission line is indicated as a light blue line.

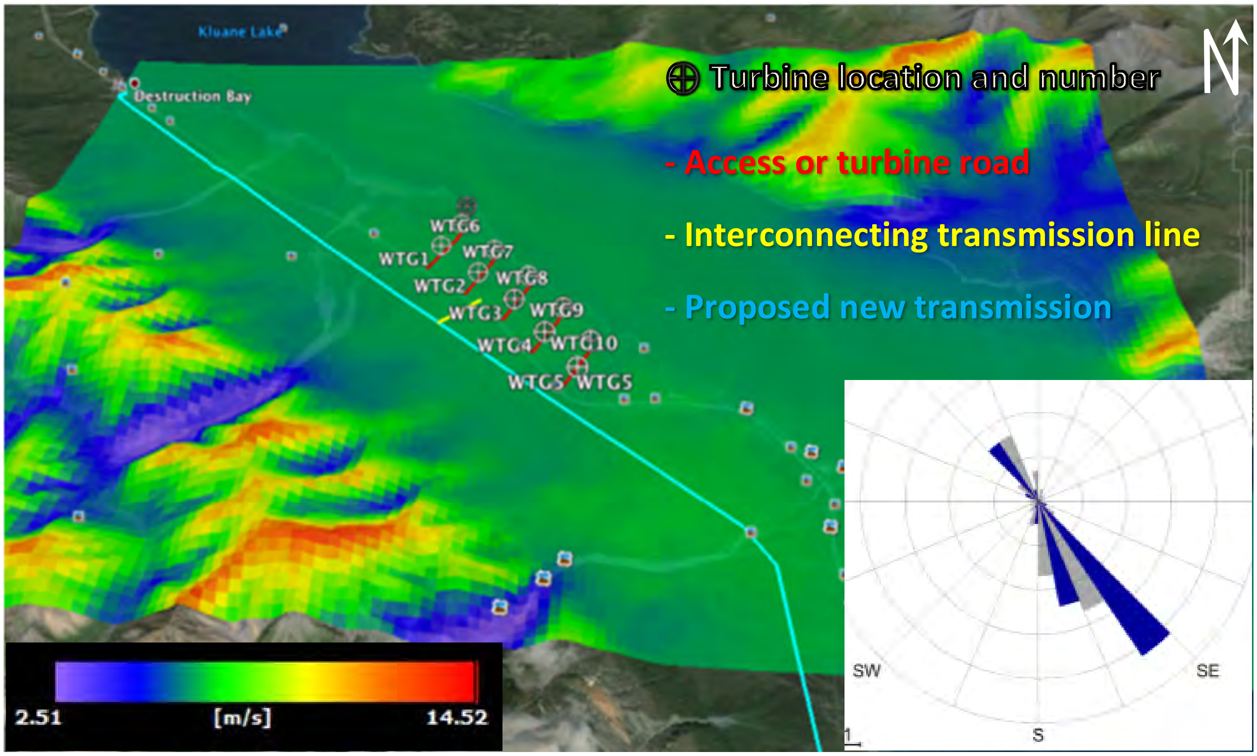
To account for the highly directional nature of the Kluane Lake wind resource (refer to Figure 12) along the axis of the lake and the site constraint that requires turbine alignment along the same axis, inter-turbine distances are higher for the parallel-to-wind turbines than the perpendicular-to-wind turbines, requiring a larger overall site footprint than one might expect for a ten turbine array.

The west shore of Kluane Lake has room for at least twice, if not three times, the number of turbines shown in Figure 14. The proposed access arrangement of one road to serve two turbines could be repeated northwest all the way to Destruction Bay and southeast along the shoreline. The maximum site capacity is estimated to be in the range of 40 to 60 MW rated output.

Figure 13 Kluane Lake Site, Photo of West Shore Site

Note: turbine sites would be in the forested area to the left

Figure 14: 20 MW Wind Farm Layout for Kluane Lake (West Side), WAsP Wind Speed Overlay



3.3 Miller's Ridge

Miller's Ridge near Carmacks has superb potential for wind power production and perhaps is the most preferred site for a large wind farm of 20 MW or more capacity. The ridge is expansive, very wide, fairly flat, well exposed in all directions, and suitably oriented to the prevailing winds.

3.3.1 Site Description

A significant advantage of Miller's Ridge as a wind power site is the existing Nansen Mine Road, which runs immediately under the south side of the ridge. Although further road access to the ridge itself would be required, Nansen Mine Road transforms what otherwise would have been a suitable but rather isolated site into one with considerable development potential.

An electrical transmission connection to Carmacks would be expensive, though, as would an access road to the ridge, so a larger capacity wind farm on Miller's Ridge would be preferable to a smaller one. Figure 15 shows a Google Earth image indicating the site area, and Figure 16 shows a photo taken during site visits, illustrating the openness and flatness of this location.

Figure 15 Miller's Ridge Prospective Wind Power Site, Google Earth Image

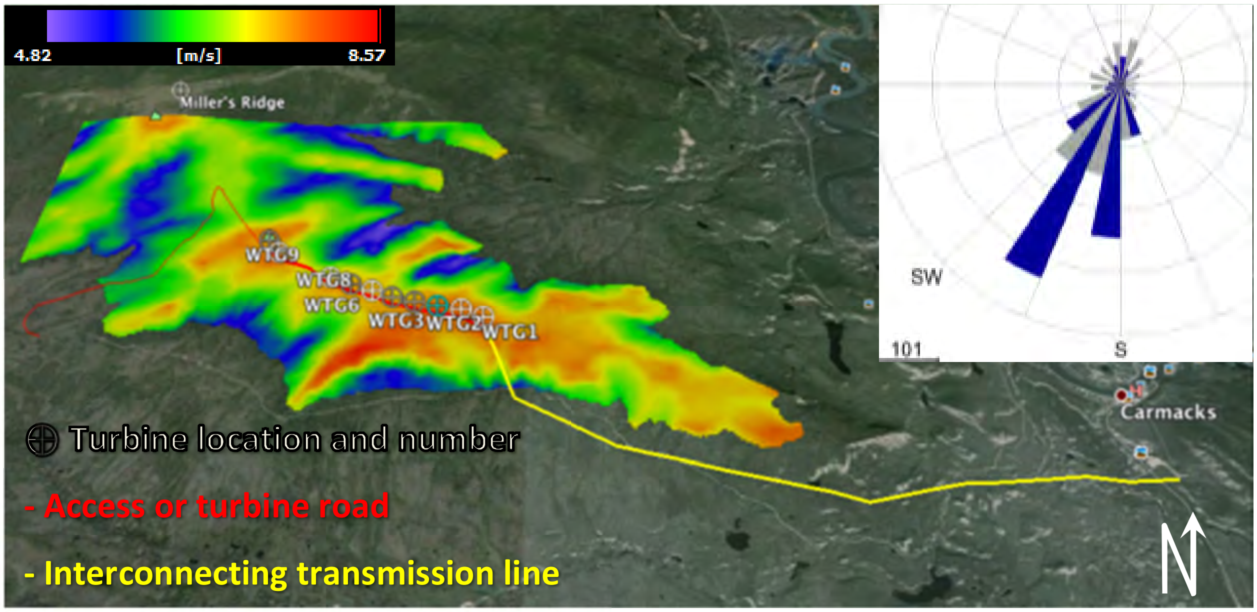
Figure 16 Miller's Ridge Site, Photo of NW View

3.3.2 Site Layout

The mostly east-west orientation of Miller's Ridge is perpendicular to the strongly south-southwest prevailing wind (see Figure 17), which is ideal for a wind farm layout and results in low wake loss.

A 20 MW wind farm (10 turbines each 2 MW) would be arrayed at higher elevation points along the ridge as shown in Figure 18 below. Turbines in this figure are identified as "WTG", the AWS True-power data reference point for the WAsP model is noted by "Miller's Ridge", recommended access roads (to Nansen Mine Road) are indicated by red lines, and the recommended new wind farm electrical sub-transmission connection to existing transmission is indicated by the yellow line.

Figure 18: 20 MW Wind Farm Layout for Miller's Ridge Site, WAsP Wind Speed Overlay



3.4 Sugarloaf Mountain

Sugarloaf Mountain near Carcross, due to its lower wind resource, was perhaps the most difficult prospective wind turbine site recommendation in this report, but site access is very good and it would be easiest site in the southern Yukon to develop for wind power.

3.4.1 Site Description

Site access to Sugarloaf – not the high knob itself but the lower portion of the alpine slope below it to the northeast – is already possible via the Montana Mountain jeep road, and a transmission extension from Carcross to reach the site would be relatively short. But wind speeds at the site appear to be fairly low in comparison to the other profiled sites. Modelled data is not perfect, however, and may underestimate the actual wind resource. With that in mind, obtaining site data from a met tower or Lidar is recommended.

Note that a possible alternative to Sugarloaf Mountain is Mt. Lorne Subpeak just northeast of Carcross. Although higher and windier, the site is more remote than Sugarloaf with no improved road, or even trail, access. Further, due to topography and terrain features, road access options would be somewhat circuitous. The trade-off of development costs versus higher energy production potential for Sugarloaf and Mt. Lorne Subpeak is beyond the scope of this project. Figure 19 shows a Google Earth image identifying the site area, and Figure 20 is a photo taken during the site visits, also showing the existing access road.

Figure 19 Sugarloaf Mtn. Prospective Wind Power Site, Google Earth Image

Figure 20 Sugarloaf Mountain Site, Photo of NW View Showing Access Road

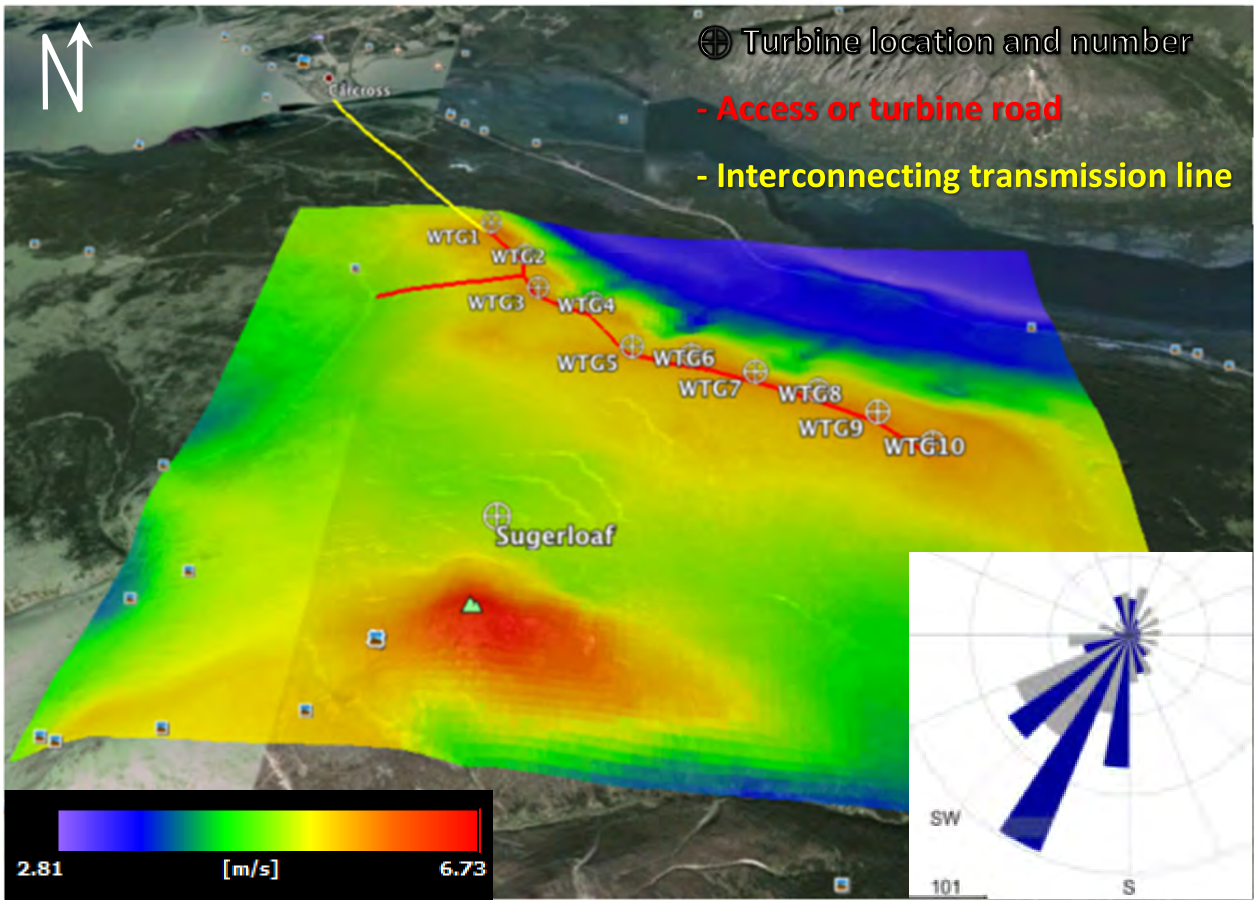
3.4.2 Site Layout

A 20-MW wind farm (ten turbines each 2 MW) would be arrayed at higher elevation points along the ridge as shown in Figure 23. The AWS Truepower data reference point for the WAsP model is noted by "Sugarloaf." The orientation of the prospective wind turbine site area is perpendicular to the southwest prevailing wind (see Figure 21) and hence would result in minimal wake loss.

Also note in Figure 23 below that the wind resource of Sugarloaf suitable for wind power development is limited to the low bench that marks the transition between lower elevation forest and higher elevation tundra. The summit of Sugarloaf itself indicates a very good wind resource but this knob is too small and steep for installation of wind turbines. WAsP modelling indicates that winds between the knob and the bench are low, although interestingly, very well defined wind-blown snow sastrugi was observed during the late April site visit overflight.

Additional wind turbines at Sugarloaf beyond the ten turbine layout of Figure 22 would be possible by closer inter-turbine spacing or use of larger turbines. The modelled array wake loss was very low and a tighter turbine spacing would be acceptable.

Figure 23: 20 MW Wind Farm Layout for Sugarloaf Mountain, WAsP Wind Speed Overlay



3.5 Mount Sumanik

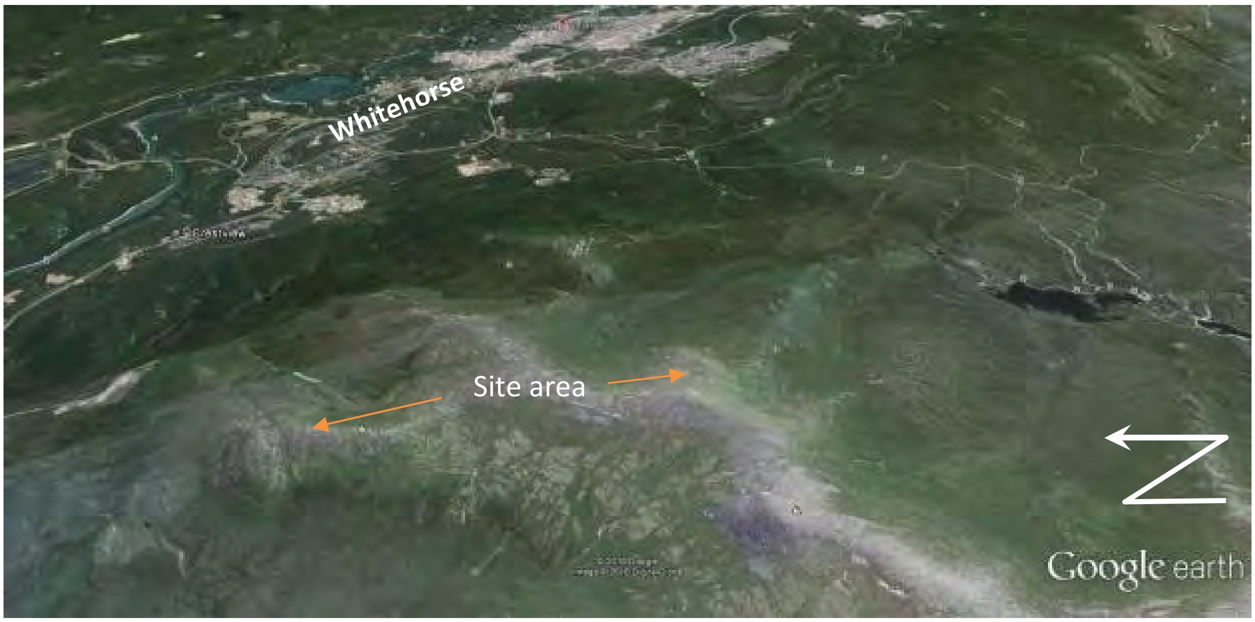
Mount Sumanik was originally excluded from the project analysis by YEC and then added later for comparison to the five sites identified during the site assessment.

3.5.1 Site Description

Mount Sumanik is a natural wind turbine site option due to its immediate proximity to Whitehorse, the presence of two older wind turbines (reportedly, only one is presently operational) on nearby Haeckel Hill, and exhibits a very good wind resource. YEC's interest in Mount Sumanik as a wind turbine project site is extensive and long-standing. At present, the site wind resource is being measured with a Lidar unit located on the summit of the mountain (more accurately described as the high point of a long ridgeline).

Development access to Mount Sumanik might be somewhat challenging though as an extension of the Haeckel Hill access road may not be the ideal access route to the Sumanik ridge itself. It appears that better access may be via a quarry/borrow pit northeast of the mountain. **Error! Reference source not found.** shows a Google Earth image indicating the site location, and Figure 25 is a photo taken during the site visits, also showing the Lidar monitoring device (middle of photo).

Figure 24 Mount Sumanik Prospective Wind Power Site, Google Earth Image

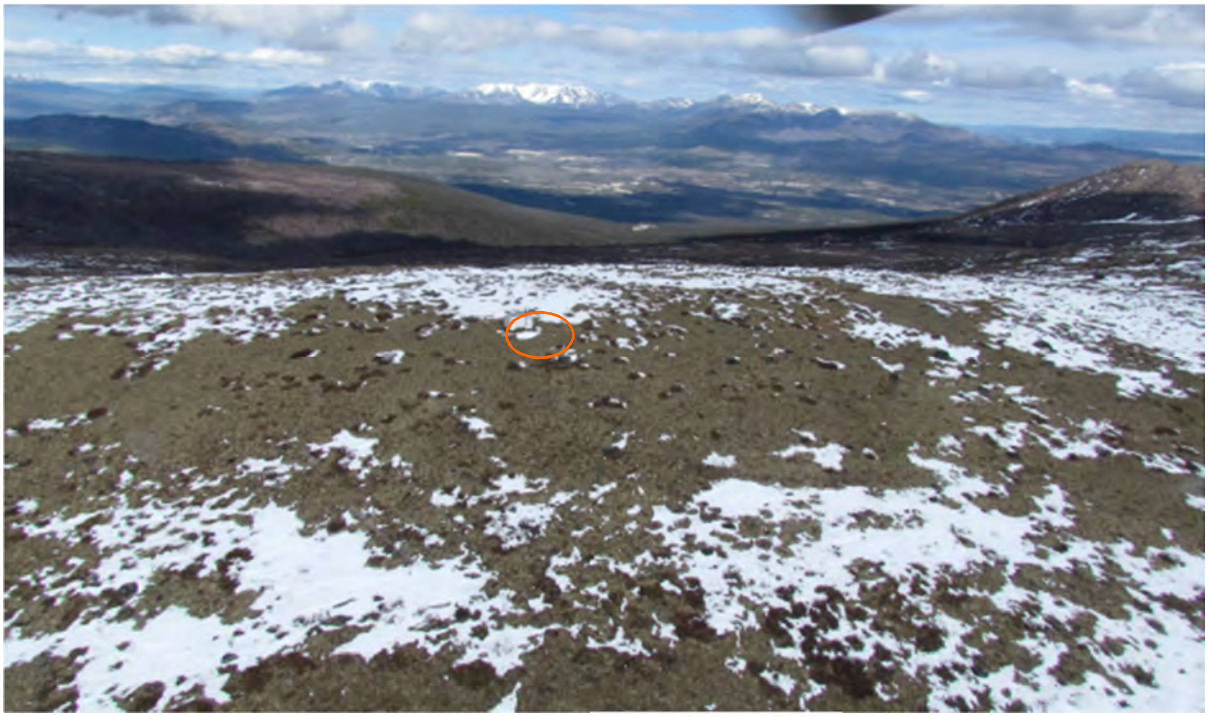


3.5.2 Site Layout

The Mount Sumanik wind resource predicted by AWS Truepower predicts mostly southerly winds with some variability from east-to-west, as seen below in Figure 26. Power production winds, however, appear to be strongly south-southeasterly, which complicates wind turbine layout at the site as the ridge orientation is north-south.

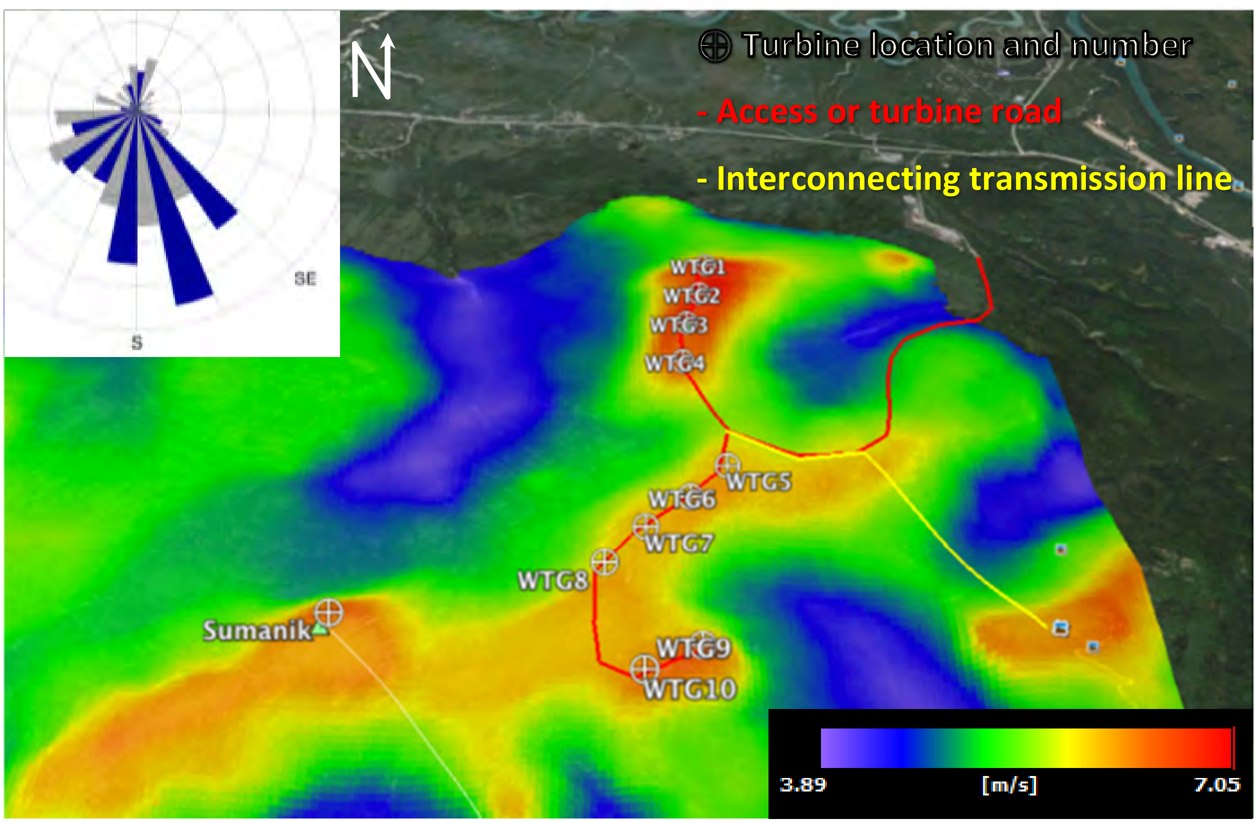
Interestingly, it appears from modelling that a 10 x 2-MW wind farm would be best arrayed along the ridgelines north of the actual summit area as shown in Figure 25, not along the higher elevations of the summit itself. Turbines in this figure are identified as "WTG", the AWS Truepower data reference point for the WAsP model is noted by "Sumanik." Although road access via the north-side borrow pit is recommended, electrical sub-transmission connection to existing transmission at the Haeckel Hill wind turbine site would likely be most efficient and is indicated by the yellow line in Figure 25.

Figure 25 Mount Sumanik Site, Photo Looking East



Note: LIDAR wind monitoring equipment can be seen in the middle of the photo

Figure 26 20 MW Wind Farm Layout for Mount Sumanik, WAsP Wind Speed Overlay



As demonstrated in Figure 27, the proposed turbine site area consists of two separate ridges north of the summit itself. Additional turbines could be installed along the ridge line extending towards the peak, although wind speeds are somewhat lower from south of WTG8 to near the Mt. Sumanik summit where WAsP modelling indicates they would be higher. Sumanik could accommodate a larger wind farm with use of additional or larger capacity wind turbines.

3.6 Tehcho (Ferry Hill)

Tehcho, previously referred to as Ferry Hill, was originally excluded by YEC from the project analysis and then later added for comparison to the 5 originally recommended sites.

3.6.1 Site Description

Tehcho would be relatively straightforward to develop due to an existing road to the summit of the hill and an existing transmission line from Stewart Crossing to the summit to power a communications tower. Although the transmission line would require an upgrade, the existing easement is a significant development advantage. Figure 27 shows the site area on a Google Earth image.

Tehcho has received considerable attention as a possible wind turbine site with installation of two met towers and a 2011 two-part study by Natural Power that assessed the met tower data, icing potential and prospective wind turbine layout. Project history of the met tower study is not entirely clear, but the Natural Power report indicates that data was collected from October 2001 until June 2005. In their study, Natural Power did not analyze the overall measured wind resource *per se*; rather, they concentrated on data loss due to icing, assessment of effects of rime icing on energy production at the site, and a financial analysis of a prospective wind project.

Figure 27 Tehcho Prospective Wind Power Site, Google Earth Image

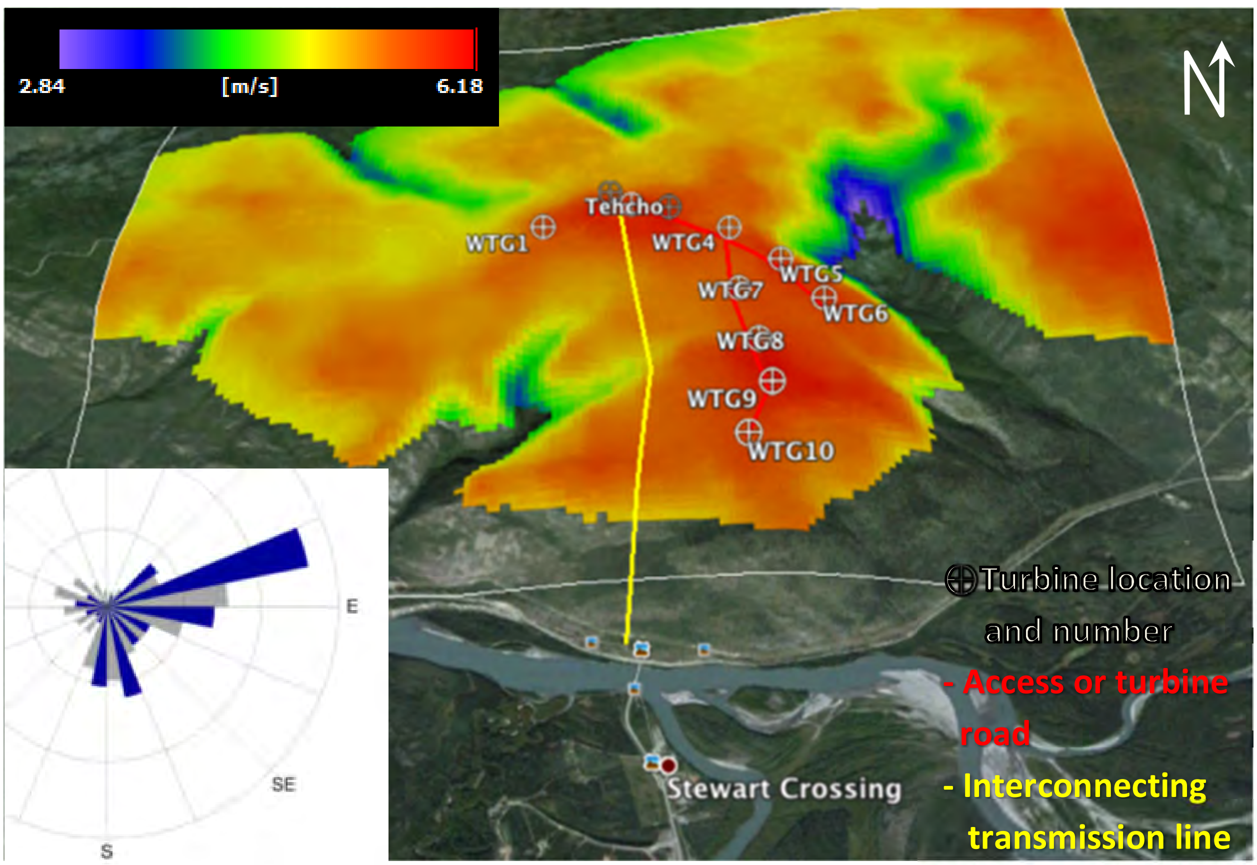
3.6.2 Site Layout

The Tehcho wind rose, as predicted by AWS Truepower, indicates mostly easterly, with some southerly, winds (see Figure 28). For the more frequent easterly winds, this is advantageous as the ridgeline orientation is generally north-south.

A ten-turbine, 20-MW wind farm would be arrayed along the southern shoulder of Tehcho as shown in Figure 28 below. This is slightly different than Natural Power's 2011 site layout, which concentrated wind turbines along the southwest shoulder of the hill. Note that the AWS Truepower data reference point for the WAsP model is indicated by "Tehcho". This is the same site as the larger met tower in the 2001 to 2005 wind study.

Additional wind turbine capacity at Tehcho could be installed on the southwest shoulder of the hill as laid out by Natural Power in 2011.

Figure 28: 20 MW Wind Farm Layout for Tehcho, WAsP Wind Speed Overlay



Note: the connection may have to go to Stewart Crossing south substation, on the south side of the Stewart River (not the north side as shown) as there is probably enough space at the existing substation. This would slightly increase the capital costs for his project.

3.7 Thulsoo Mountain

Thulsoo Mountain near the Aishihik hydroelectric facility (north of Canyon, between Haines Junction and Whitehorse) has superb potential for wind power production and, along with Miller's

Ridge, can be considered the preferred sites for wind power in the Yukon, although Thulsoo has less absolute wind power capacity potential than Miller's Ridge.

3.7.1 Site Description

Although there is no existing access road to the summit of Thulsoo, a new access road would be relatively short. Similarly, transmission to tie to the Aishihik substation would be short distance as well. Figure 29 is a Google Earth image identifying the site, and Figure 30 is a photo taken during the site visit trip in April 2016. Unfortunately, flight scheduling did not enable us to have an over-flight during the site visit and poor weather prevented a close visual examination of the mountain from the Aishihik canyon access road.

Figure 29 Thulsoo Mtn. Prospective Wind Power Site, Google Earth Image

Figure 30 Thulsoo Mtn. Site, Photo taken from Alaska Hwy (view north)

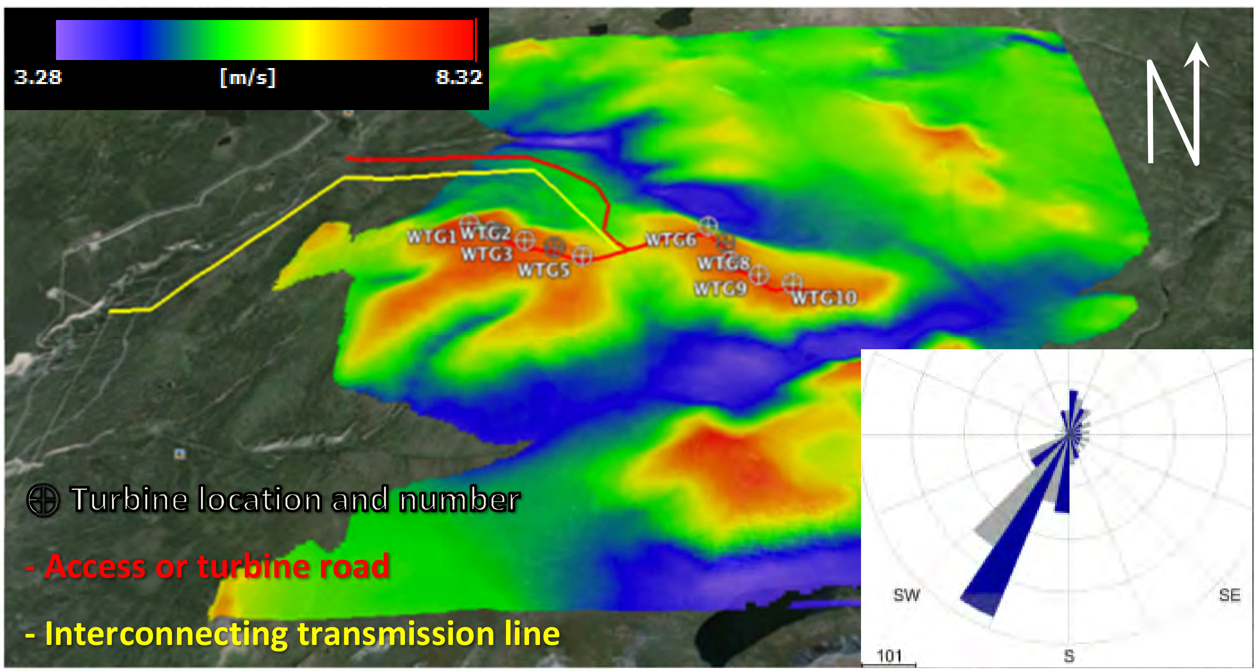
3.7.2 Site Layout

Thulsoo Mountain has an excellent wind resource with strongly prevailing south-southwesterly winds that complement the generally east-west orientation of the mountain (see Figure 31), but the site area that can be developed is somewhat constrained.

For a 10 x 2.0-MW wind farm, half the turbines would be located at an adjacent ridge of Thulsoo Mountain as shown in Figure 31. Turbines in this figure are identified as "WTG", the AWS Truepower data reference point for the WAsP model is adjacent to WTG5.

The site might allow one additional 2.0 MW turbine to the northeast of turbine WTG10 to be installed at the end of the turbine road. The maximum capacity of the site would then be 22 MW (11 x 2 MW). No other additional turbines could be deployed without negatively affecting the performance of the 20-MW array.

Figure 31: 20 MW Wind Farm Layout for Thulsoo Mountain, WAsP Wind Speed Overlay



3.8 Land Use

Wind farms require significant amount of land. For a 20 MW wind farm at each of these seven sites between 70 and 190 hectare of land are required, three to nine hectare per MW of installed capacity. Only about one third of the land is used by the turbines themselves, the rest is for the access road and a connection to YEC's transmission line, including the required easement offset. On average, both, the access road to the site and the interconnecting transmission line are six to seven kilometer long.

Land will be used for the turbines itself, a road connecting the turbine, an access road, unless existing and a power line connecting the turbines to YEC's grid. Along power lines and access roads we assumed an easement of 60 meters. The latter includes the width of the road, typically around seven meters.

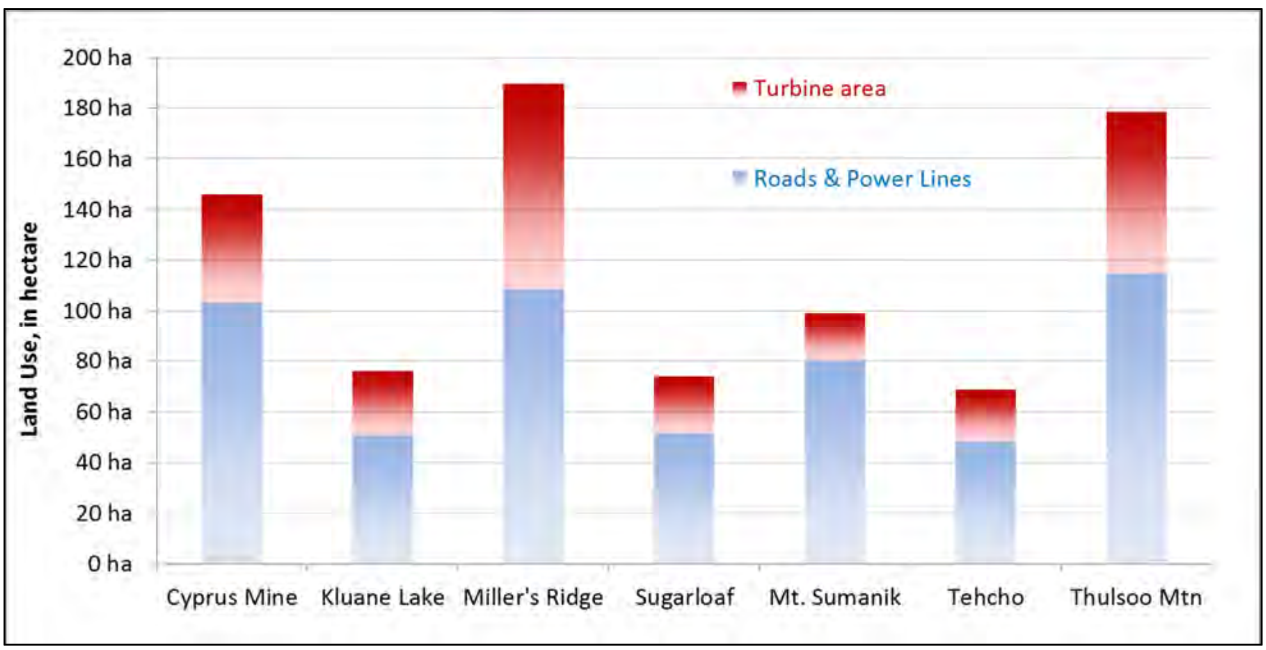
We used a buffer of 45 meters around the turbine. This is the rotor radius for a 2.0-MW turbine. From a bird's eye view the tower can swivel 360°. The downward projection of this area, a circle 90 m in diameter, needs to be purchased from a legal point of view.

The 45-meter buffer would go along the entire array of turbines. The total land to be purchased would be the length of the road connecting the array of turbines (the 'turbine road') plus 45 m x 45 m on either end of the road. An underground collector line between the turbines will run along the turbine road. The 90-meter easement will also be used by turbine transformer and the area for the switch yard. Finally, this easement allows the rotors and turbine to be laid down during construction. Usually the three blades are assembled on the ground and then lifted up onto the erected tower.

As an example: An array of 10 turbines, each placed five rotor diameters apart, are arranged in a line, e.g. along the ridge of a mountain. This array may be 5 km long. There has to be a 45 m buffer on either side of this array. The total width of the buffer is 90 meters. If the array is 5 km long the total area would be 5 km x 90 m = 45 ha.

Trees can create turbulence. Most of the wind-farm sites are on ridgelines above the tree line, though. No cost for land clearing has been assumed for the turbines or the turbine road. Kluane Lake is an exception to this.

Figure 32: Land Use of a 20 MW Wind Farm at the Seven Selected Sites



4 WIND FARM ENERGY PRODUCTION

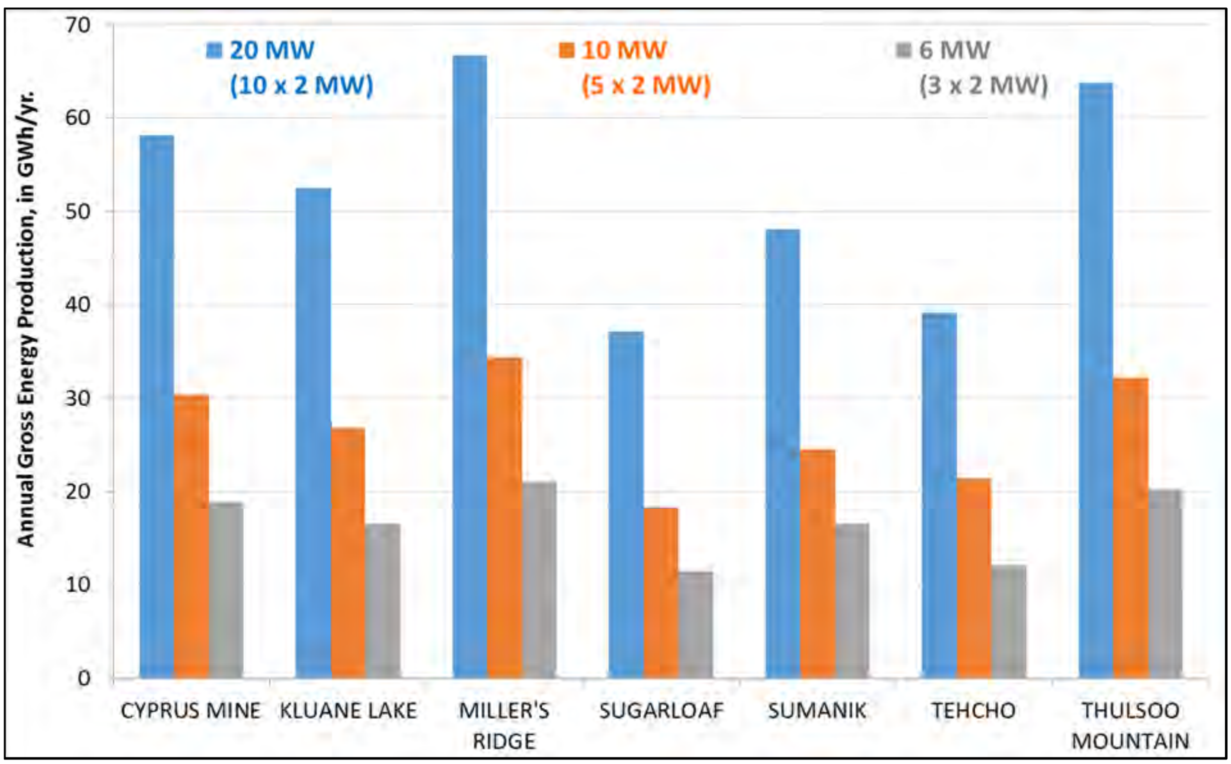
This chapter presents projected energy output of wind farms at the seven selected sites. Modelled energy production is a key input to the financial model in Chapter 5. Details on energy production , losses, and monthly generation profiles for each of the seven sites are given in Appendix H.

4.1 Annual Gross Energy Production

For modelling the energy production of the various sizes of wind farms at the seven sites we employed the wind modelling software called WAsP mentioned in the previous chapter. Based on topography, wind resource and site layout WAsP determines the Annual Energy Production (AEP).

A 20 MW wind farm produces 52 GWh per year on average at the seven sites, equivalent to the annual consumption of 5,300 households in the Yukon.[7] A 6 MW farm will only generate 17 GWh annually. Comparing the three sizes of wind farms, a clear pattern can be recognized: the fewer wind turbines there are on site, the lower the wake losses and the higher the capacity factor. While the annual energy production is obviously higher for larger wind farms, the average capacity factor is lower (generally about 2-4% lower for 10 MW and about 4-7% lower for a 20 MW farm, compared to 6 MW). A wind farm with five turbines produces slightly more than half the energy that the wind farm with ten turbines – see Figure 33 below.

Figure 33 Summary Results of WAsP Wind Farm Modelling: Annual gross energy generation of various wind farm sizes, 2 MW generic turbine



[7] Over the past years, Yukon residential customers consumed an average of 9,801 KWh per year. Source: Yukon Bureau of Statistics, "Yukon Energy Facts 2013", see www.eco.gov.yk.ca/pdf/energy_2013.pdf, accessed on June 7th, 2016

4.2 Energy Losses

The actual energy fed into the grid is lower than the numbers stated above. A wind farm will face the following losses:

- Wake loss due to turbulences and the shadowing effect turbines have on each other;
- Curtailment during extreme temperatures and icing to protect the blades
- Parasitic energy, such as electricity for melting ice on the blades,
- Conversion losses when transforming turbine voltage to grid transmission voltage
- Sub-optimal performance, e.g. due to soiled blades
- Downtime necessary for maintenance;

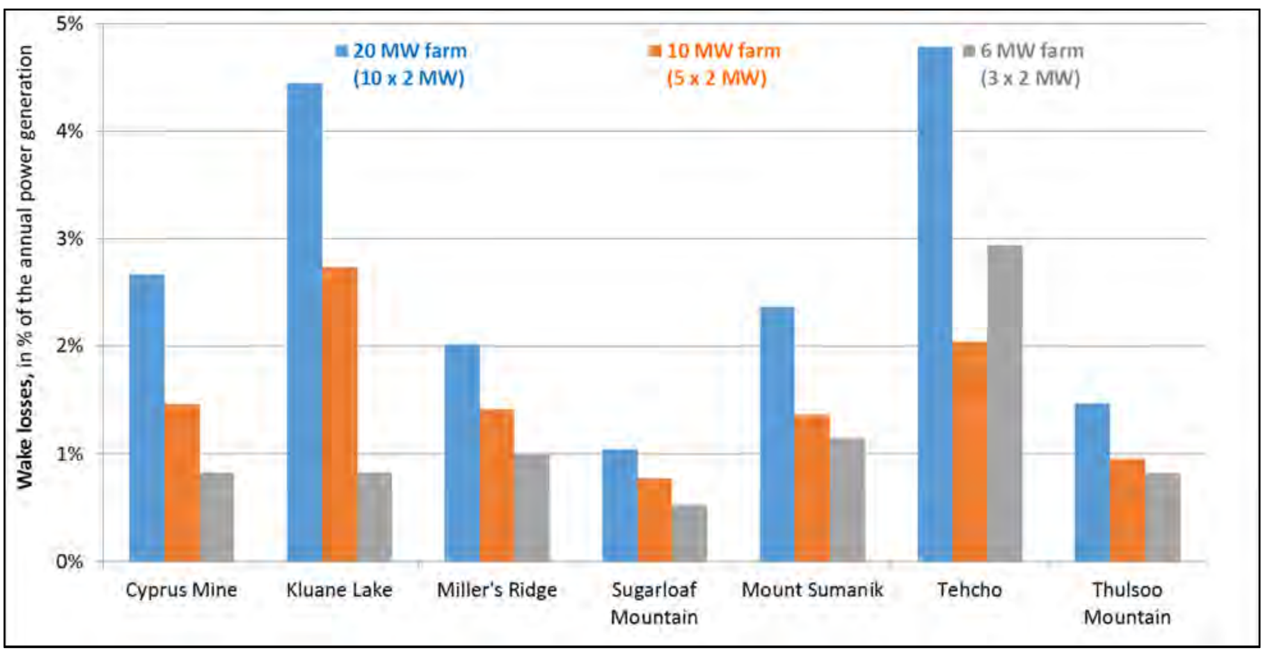
The following chapters quantify these losses.

4.2.1 Wake Losses

Turbine array wake loss is due to the shadowing effect that upwind turbines have on those downwind. This effect is highest very near a turbine and dissipates with distance until the wind-free stream velocity resumes. As one might expect, wake loss is relatively high in large arrays, especially those with multiple rows of wind turbines, and high at sites with complicated or highly variable prevailing winds.

Wake losses for the seven selected site range from 0.5% to close to 5%, depending on the site and the size of the wind farm. This is well within an industry standard range of three to five percent. Of the seven sites studied in this report, wake losses are predicted as highest at Kluane Lake and Tehcho and lower at the other sites. As discussed in Section 3, this is due to the unavoidable parallel-to-the-prevailing wind orientation of turbines at Kluane Lake and the constrained site size at Tehcho.

Figure 34 Wake Losses of the Three Wind Farm Sizes at each of the Seven Sites



Wake loss can be reduced by moving turbines further apart, both parallel and perpendicular to prevailing winds, but there is a cost tradeoff. A larger site footprint is more expensive to develop, hence the industry rule of thumb of three to five percent wake loss as economically optimal.

4.2.2 Extreme Temperature Curtailment

For many wind turbine models, power output automatically curtails (by sensor input, via the turbine control system) at temperatures below -30°C and the turbine shuts down at -40°C. This protective feature reflects metal fatigue and lubricant limitations in severe cold. Whereas temperatures below -40°C are rare, even in the Yukon, the AWS hourly time series data for each site suggests a number of hours below -30°C each year. For Tehcho, near Stewart Crossing, and the coldest site, AWS hourly time series data predicts 241 hours a year with air temperatures below -30°C. At Kluane Lake by comparison -30°C are predicted for only five hours per year. Using these numbers of hours, we determined the curtailment losses due to extreme temperatures, see Table 6 below.

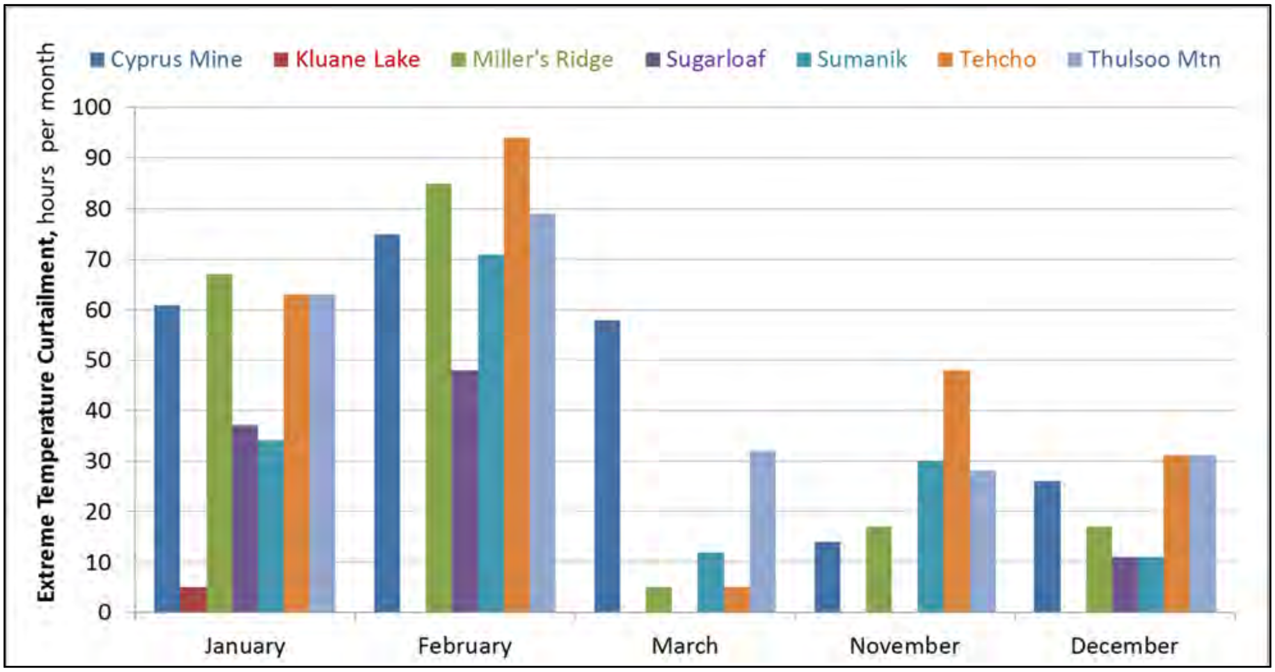
Table 6 Losses Due to Low Temperature Turbine Curtailment

Site	Hours below -30°C	Curtailment losses of a 20 MW wind farm	
Cyprus Mine	234 hours / year	2.7%	-1,552 MWh/yr.
Kluane Lake	5 hours / year	0.1%	-30 MWh/yr.
Miller's Ridge	191 hours / year	2.2%	-1,455 MWh/yr.
Sugarloaf Mountain	96 hours / year	1.1%	-407 MWh/yr.
Sumanik	158 hours / year	1.8%	-868 MWh/yr.
Tehcho	241 hours / year	2.8%	-1,077 MWh/yr.
Thulsoo Mountain	233 hours / year	2.7%	-1,695 MWh/yr.
Average	**165 hours / year**	**1.9%**	**-1,012 MWh/yr.**

Although some manufacturers allow their turbines to operate below -30°C, especially direct drive turbines, we have conservatively assumed that the turbine will stop operating to protect the turbines against extreme cold-weather risk. It is likely that the entire wind farm will stop operating during these hours.

Because these losses occur during winter, they can reduce output during the coldest months by up to 14% in an extreme case (Tehcho in February), although typical cold-temperature curtailment would be much lower. Curtailment due to extremely cold temperatures is presented in Figure 35.

Figure 35 Hours of Curtailment due to Temperatures below -30°C



4.2.3 De-icing Energy and De-icing Downtime

Another factor reducing turbine output is icing. Contrary to cold temperatures, icing may only affect one or some of the turbines at a given time so that the plant can maintain a portion of its power-generation ability. Icing losses have been estimated as 7.8% of total production in the Natural Power's 2010 Tehcho study,[8] and above 25% of production in the study on Mt Sumanik (also referenced in Section 2.1).

For all sites except Kluane Lake, which is not expected to display icing, we assume that 20% icing loss could occur without mitigation. De-icing equipment is expected to largely reduce the downtime from icing but will consume energy. In total, we estimate that the annual loss can be reduced to 5% of annual gross output with de-icing equipment. Half of this – 2.5% – will be downtime due to rime icing, the other half will be energy required for de-icing. Again, this energy loss will be mainly during the winter and could account for ten or more percent of a winter month's energy production.

4.2.4 Transformer Losses

There will be two types of step-up transformers at each wind farm: one from the turbine voltage, around 1,000 V, depending on the model, to 12.47 kV. Each turbine will be equipped with a transformer to achieve the turbine connection bus voltage. A final transformer will be at the end of the collector lines in the switch yard. This transformer will step-up the voltage from 12.47 kV to either 69 kV or 138 kV, depending on the voltage of the transmission line it will connect to.

Both transformers are estimated as 98% efficient. Combined losses are therefore approximately 4% of turbine power output. Line losses are included in this estimate.

[8] Natural Power, *Ferry Hill Wind Feasibility Study, Stages 1 and 2*, 2010

4.2.5 Sub-optimal Performance

A number of factors, such as soiled rotor blades, can lead to sub-optimal performance of a turbine. We have assumed 1% losses due to sub-optimal functioning.

4.2.6 Maintenance Downtime

Each turbine will require preventive maintenance and will also experience some unscheduled downtime. The former may be accomplished in the summer when YEC has a surplus of hydropower and wind turbines can be taken off line with little consequence. We estimate that 2% of the potential annual energy output will be lost due to maintenance; half of this will be unscheduled over the course of the year, the other half during the summer as a regular revision.

4.2.7 Total Losses and Net Output

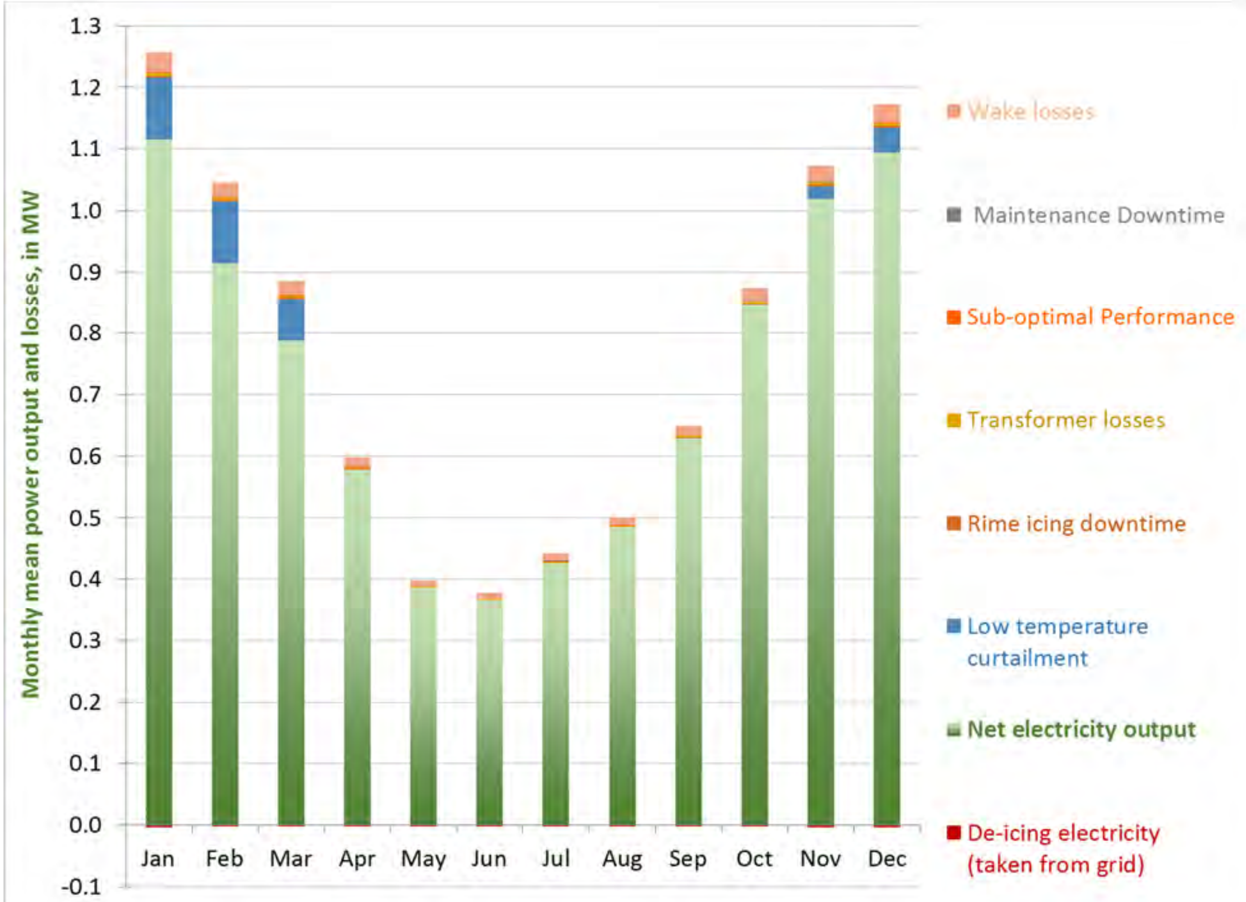
WAsP wind farm analysis software, which was used to create turbine layouts presented in Section 3, calculates wake losses due to shadowing between turbines, are specific to each capacity option per site, and are summarized in the following subsections. All other losses, however, are summarized in Table 7. Wake losses aside, we estimate approximately 9% annual energy loss for Kluane Lake and 14% for the other sites.

Table 7 Wind Farm Energy Production Loss Summary

		Kluane Lake	All other sites
1	Wake losses	0.83% - 4.45%	0.5% - 4.8%
2	Rime-icing downtime	1.0%	2.5%
3	De-icing energy (taken from the grid)	1.0%	2.5%
4	Low-temperature curtailment	0.7%	1.1% - 2.7%
5	Transformer losses	4.0%	4.0%
6	Sub-optimal performance	1.0%	1.0%
7	Maintenance	2.0%	2.0%
	Annual net production (% of gross output)	**86% - 89%**	**81% - 86%**

Other restrictions may apply, such as curtailment of the wind turbines due to overcapacity of energy production during the summer. These limitations are outside the scope of this study and are not considered in Table 7 and other analyses of this report.

Figure 36: Monthly Mean Net Power Output for a GE-100-1.7 MW Turbine at Cyprus Mine

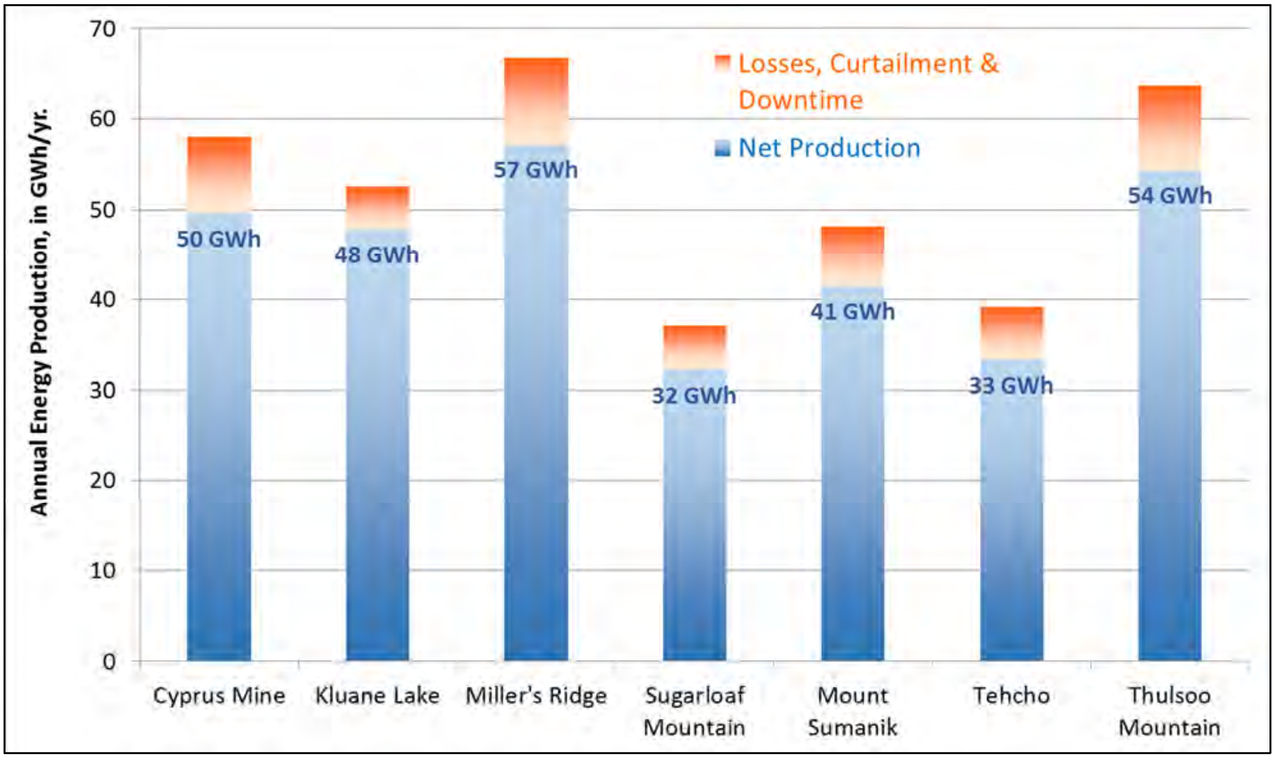


4.3 Annual Net Energy Production

The following graph compares the seven sites in terms of their annual net energy production (Figure 37) by site. Thulsoo and Miller's Ridge appear to be the highest yield sites, followed by Cyprus Mine. Sugarloaf Mountain, Sumanik Mountain and Tehcho are expected to produce significantly less energy. Kluane Lake, the only low elevation site, shows a sligthly lower annual gross output than the top performing sites. This comparison is based on a generic 2.0 MW turbine and does not take into account that different turbine choices might result in an improved performance. The overall ranking of the seven sites is unlikely to change.

A wind farm at Kluane Lake will still perform well due to lower de-icing losses and less curtailment due to extreme weather, such as temperatures below -30°C when most turbines are stalled to avoid failures. The financial analysis in the next chapter also takes lower site development costs for this site into account.

Figure 37 Summary Results of 20 MW Wind Farm Modelling: Annual net energy generation and losses;

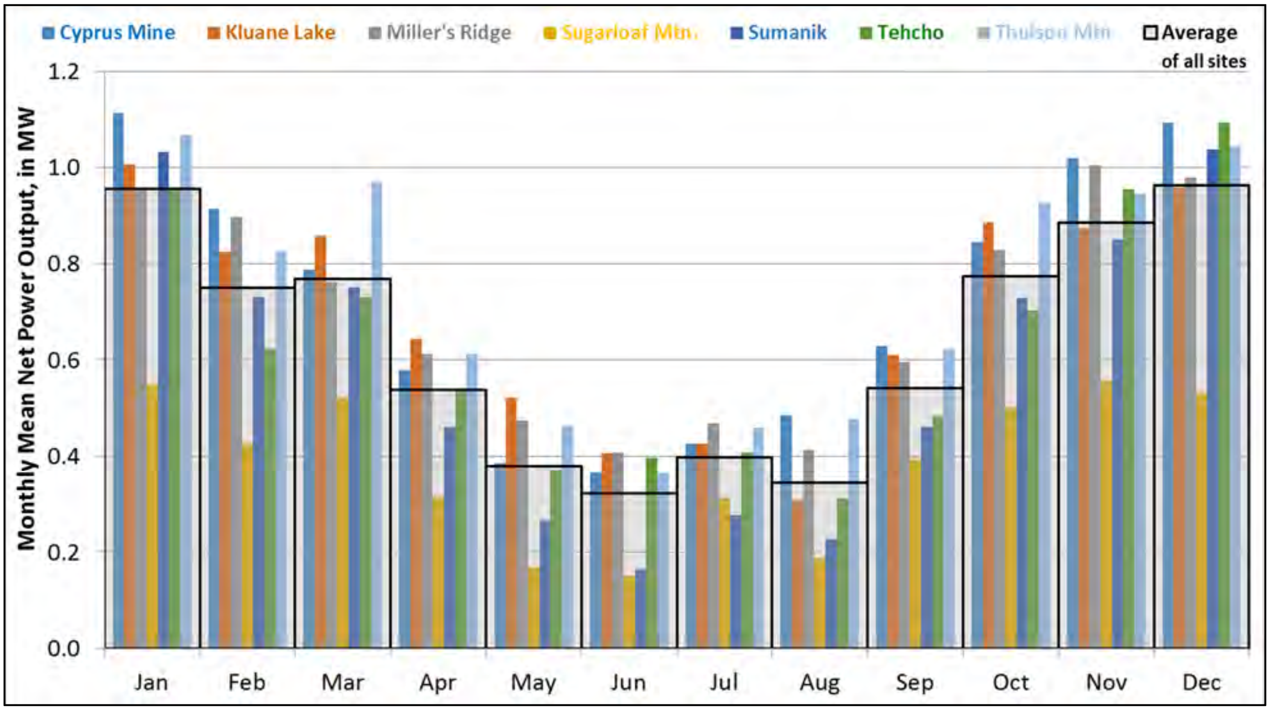


4.4 Monthly Generation Profile

All sites show a clear pattern of lower monthly mean power production in summer than in winter. This is despite the higher percentage of curtailment and parasitic electricity in winter. On average, two-thirds of the energy that the turbines feed into the grid are generated during the seven months from October to April. Mean power output in June and August is one third of the output in January. Wind power therefore fits well into YEC's demand profile.

There is no wind farm site that clearly outperforms all other sites for every month of the year – see Figure 38 below. The numbers below are based on the turbine model with the highest winter output. Wake losses are not included.

Figure 38 Monthly Power Output Profile of a Single 1.7 MW to 2.35 MW Turbine at the Seven Sites (excluding wake losses)



The mean annual power output is 26% to 28% of the nominal wind farm capacity, i.e. a 10 MW wind farm, for example, would generate on average 2.6 to 2.8 MW over the course of the year, more during the winter, less in summer.

For the purpose of creating data of monthly net electricity output of the three sizes of wind farms combined the annual gross energy production forecasted by the WAsP model with the monthly distribution of energy production of the AWS report. We then subtracted all other losses described in the main report to obtain monthly net electricity production data. The results given below are for a generic turbine (Vestas V-90) only. While the sum of the monthly electricity generation is accurate, the monthly data is an approximation only.

Table 8 Losses and Net Annual Energy Production of the Three Wind Farm Sizes
(after wake losses, after all other losses)

20 MW WINDFARM

Month	Cyprus	Kluane	Millers Ridge	Sugarloaf	Sumanik	Techho	Thulsoo
Jan	7.0 GWh	6.1 GWh	6.5 GWh	4.1 GWh	6.8 GWh	4.5 GWh	7.2 GWh
Feb	5.0 GWh	4.4 GWh	5.2 GWh	2.7 GWh	4.0 GWh	2.4 GWh	4.8 GWh
Mar	4.6 GWh	5.1 GWh	5.3 GWh	3.8 GWh	4.6 GWh	3.2 GWh	6.3 GWh
Apr	3.1 GWh	3.6 GWh	4.1 GWh	2.0 GWh	2.6 GWh	2.2 GWh	3.5 GWh
May	2.1 GWh	3.1 GWh	3.4 GWh	1.0 GWh	1.4 GWh	1.6 GWh	2.7 GWh
Jun	2.0 GWh	2.3 GWh	2.8 GWh	1.0 GWh	0.8 GWh	1.7 GWh	2.1 GWh
Jul	1.9 GWh	2.0 GWh	2.8 GWh	2.0 GWh	1.2 GWh	1.5 GWh	2.3 GWh
Aug	2.9 GWh	1.7 GWh	3.0 GWh	1.3 GWh	1.3 GWh	1.4 GWh	3.0 GWh
Sep	3.5 GWh	3.5 GWh	4.2 GWh	2.8 GWh	2.7 GWh	2.1 GWh	3.7 GWh
Oct	4.9 GWh	5.4 GWh	6.0 GWh	3.6 GWh	4.5 GWh	3.1 GWh	5.9 GWh
Nov	5.9 GWh	5.0 GWh	7.0 GWh	3.9 GWh	5.0 GWh	4.3 GWh	5.9 GWh
Dec	6.7 GWh	5.7 GWh	7.0 GWh	3.9 GWh	6.7 GWh	5.2 GWh	6.8 GWh
Year	**49.6 GWh**	**47.8 GWh**	**57.3 GWh**	**32.3 GWh**	**41.5 GWh**	**33.4 GWh**	**54.4 GWh**

10 MW WINDFARM

Month	Cyprus	Kluane	Millers Ridge	Sugarloaf	Sumanik	Techho	Thulsoo
Jan	3.7 GWh	3.1 GWh	3.4 GWh	2.0 GWh	3.4 GWh	2.5 GWh	3.6 GWh
Feb	2.6 GWh	2.2 GWh	2.7 GWh	1.3 GWh	2.0 GWh	1.3 GWh	2.4 GWh
Mar	2.4 GWh	2.6 GWh	2.7 GWh	1.9 GWh	2.3 GWh	1.8 GWh	3.2 GWh
Apr	1.6 GWh	1.9 GWh	2.1 GWh	1.0 GWh	1.3 GWh	1.2 GWh	1.8 GWh
May	1.1 GWh	1.6 GWh	1.7 GWh	0.5 GWh	0.7 GWh	0.9 GWh	1.4 GWh
Jun	1.1 GWh	1.2 GWh	1.5 GWh	0.5 GWh	0.4 GWh	1.0 GWh	1.1 GWh
Jul	1.0 GWh	1.0 GWh	1.4 GWh	1.0 GWh	0.6 GWh	0.8 GWh	1.2 GWh
Aug	1.5 GWh	0.9 GWh	1.5 GWh	0.7 GWh	0.7 GWh	0.7 GWh	1.5 GWh
Sep	1.8 GWh	1.8 GWh	2.2 GWh	1.4 GWh	1.4 GWh	1.2 GWh	1.9 GWh
Oct	2.6 GWh	2.7 GWh	3.1 GWh	1.8 GWh	2.3 GWh	1.7 GWh	3.0 GWh
Nov	3.1 GWh	2.6 GWh	3.6 GWh	1.9 GWh	2.5 GWh	2.4 GWh	3.0 GWh
Dec	3.5 GWh	2.9 GWh	3.6 GWh	1.9 GWh	3.4 GWh	2.8 GWh	3.5 GWh
Year	**26.0 GWh**	**24.4 GWh**	**29.5 GWh**	**15.9 GWh**	**21.1 GWh**	**18.3 GWh**	**27.5 GWh**

6 MW WINDFARM

Month	Cyprus	Kluane	Millers Ridge	Sugarloaf	Sumanik	Techho	Thulsoo
Jan	2.3 GWh	1.9 GWh	2.1 GWh	1.3 GWh	2.3 GWh	1.4 GWh	2.3 GWh
Feb	1.6 GWh	1.4 GWh	1.6 GWh	0.8 GWh	1.4 GWh	0.7 GWh	1.5 GWh
Mar	1.5 GWh	1.6 GWh	1.7 GWh	1.2 GWh	1.6 GWh	1.0 GWh	2.0 GWh
Apr	1.0 GWh	1.1 GWh	1.3 GWh	0.6 GWh	0.9 GWh	0.7 GWh	1.1 GWh
May	0.7 GWh	1.0 GWh	1.1 GWh	0.3 GWh	0.5 GWh	0.5 GWh	0.9 GWh
Jun	0.7 GWh	0.7 GWh	0.9 GWh	0.3 GWh	0.3 GWh	0.5 GWh	0.7 GWh
Jul	0.6 GWh	0.6 GWh	0.9 GWh	0.6 GWh	0.4 GWh	0.5 GWh	0.7 GWh
Aug	0.9 GWh	0.5 GWh	0.9 GWh	0.4 GWh	0.5 GWh	0.4 GWh	1.0 GWh
Sep	1.1 GWh	1.1 GWh	1.3 GWh	0.9 GWh	0.9 GWh	0.7 GWh	1.2 GWh
Oct	1.6 GWh	1.7 GWh	1.9 GWh	1.1 GWh	1.5 GWh	1.0 GWh	1.9 GWh
Nov	1.9 GWh	1.6 GWh	2.2 GWh	1.2 GWh	1.7 GWh	1.3 GWh	1.9 GWh
Dec	2.2 GWh	1.8 GWh	2.2 GWh	1.2 GWh	2.3 GWh	1.6 GWh	2.2 GWh
Year	**16.1 GWh**	**15.0 GWh**	**18.1 GWh**	**9.9 GWh**	**14.2 GWh**	**10.3 GWh**	**17.3 GWh**

4.5 Reliable Winter Capacity

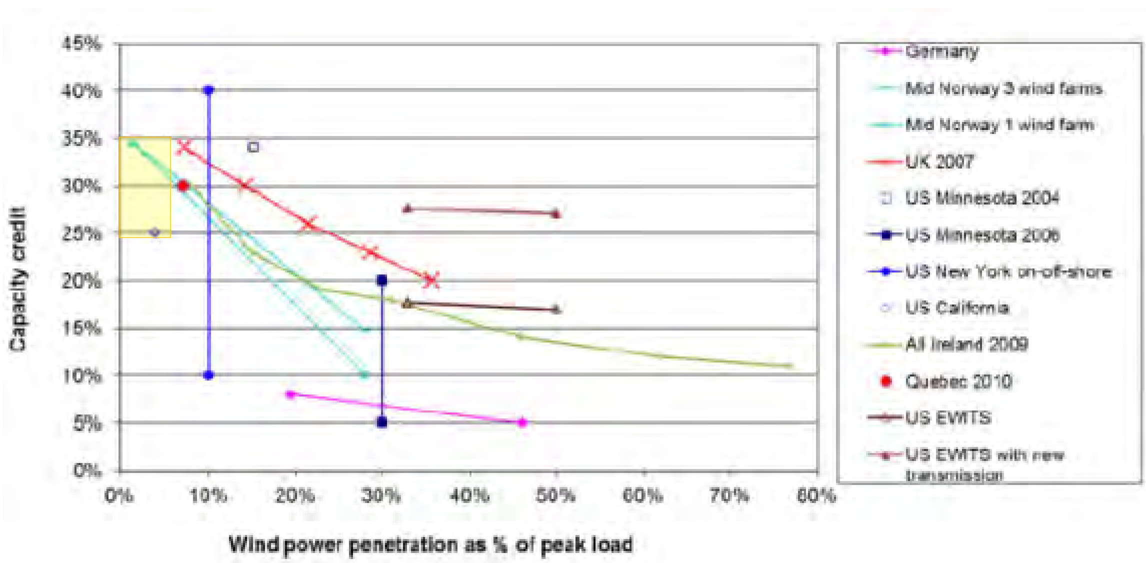
The Excel sheet for the financial analysis provided by YEC asks us to estimate "reliable winter capacity." We understand this to mean firm capacity for power generation, i.e. a minimum guaranteed output. Wind power is a variable resource and technically cannot guarantee any minimum output at any time of the year. There may be days when wind speeds are below the start-up wind speed, so output will drop to zero during these hours.

On the other hand, for planning purposes, wind power is recognized as having an ability to displace other power generation sources. For example, in Germany, the Effective Load Carrying Capability (ELCC) of wind power is valued at about 10% of its rated capacity for planning purposes.[9]

The capacity credit depends on various factors including grid penetration levels. The capacity credit decreases as the share of wind power on the grid grows. A 6-MW wind farm in the Yukon would have a 3% penetration of YEC's generation in 2015. For a 20-MW wind farm, the penetration level would increase to approximately 11% of the total generation in 2015 (416 GWh). A single wind farm in the Yukon can be considered low-penetration and would be located in the far left side of the graph below. [10] Worldwide, the ELCC for low penetration wind energy has been determined to be between 25% and 35% of total rated wind power capacity on the grid, see the yellow highlighted area in Figure 39 below.

At maximum output a 20-MW wind farm would deliver about one-quarter of the peak winter capacity demand and one-half of summer demand. There is a high correlation with the seasonally-changing load of YEC's grid: A wind farm will supply more energy in winter when more energy is needed.

Figure 39 Capacity Credit of Wind Power in Various Parts of the World[11]



[9] See http://www.wind-energy-the-facts.org/capacity-credit-values-of-wind-power.html

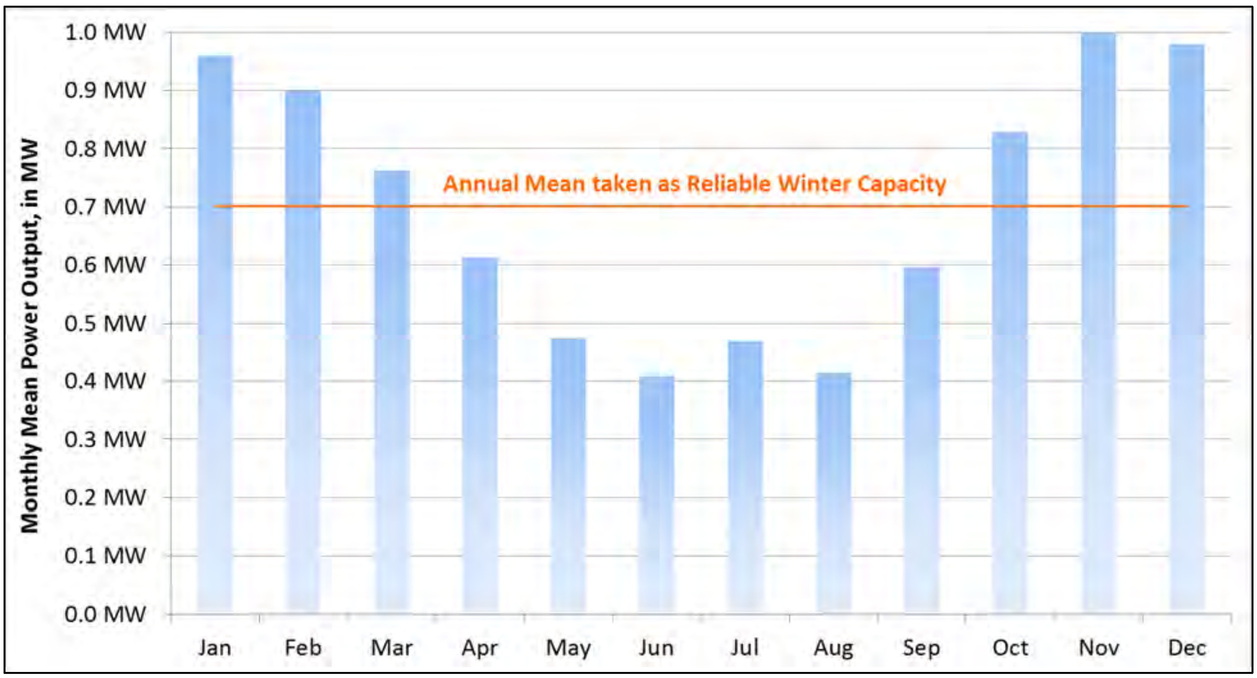
[10] Penetration is defined as the fraction of energy produced by wind compared with the total generation

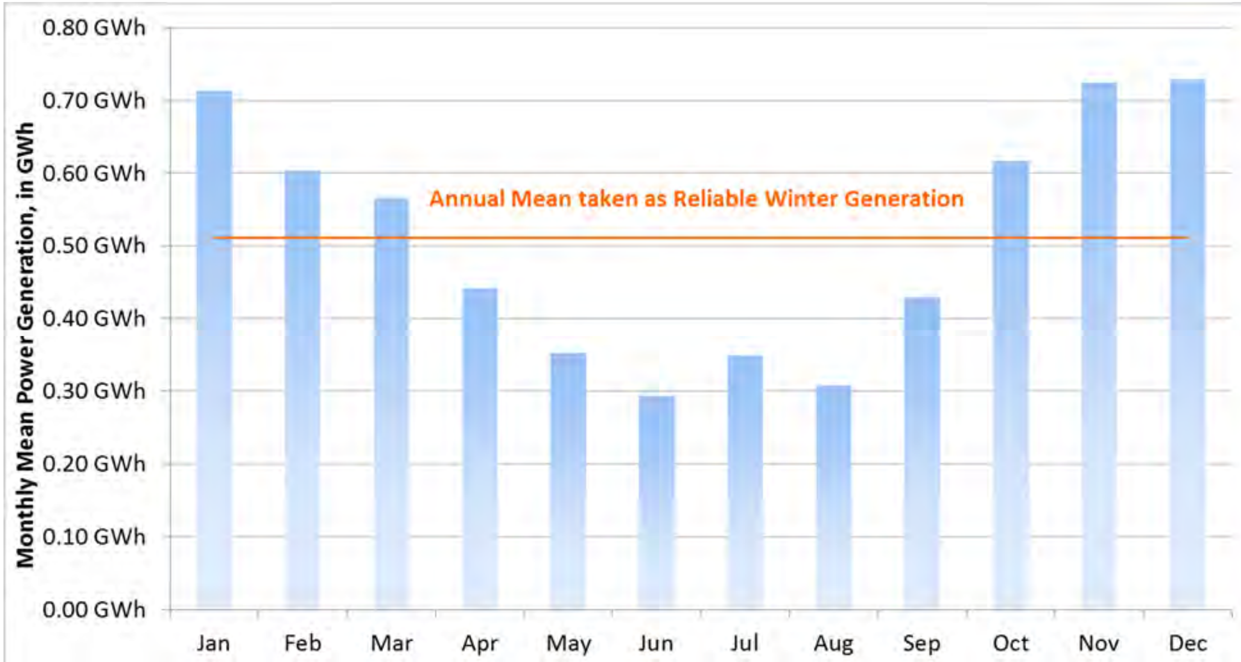
[11] Source: http://energyskeptic.com/2015/wind-capacity-value-elcc/

To account for varying capacity factors at the different sites examined, we estimate the reliable winter capacity is equal to the mean annual power output. This estimate is conservative, because the winter output from a wind farm in the Yukon is higher than the mean output see Figure 40 below.

This approach is an estimate and should be confirmed based on the Yukon energy mix, taking into account system flexibility, load profiles, and specific wind farm parameters. Additional wind farms would lower the capacity credit per farm; they could also increase the ability of wind to provide base load power (firm capacity) when they are geographically distant. This separation of sites increases the probability that wind will still blow at one site when it does not at the other. The combined wind farms will provide a minimum output because the start-up wind speed is virtually always reached at one of the wind farms.

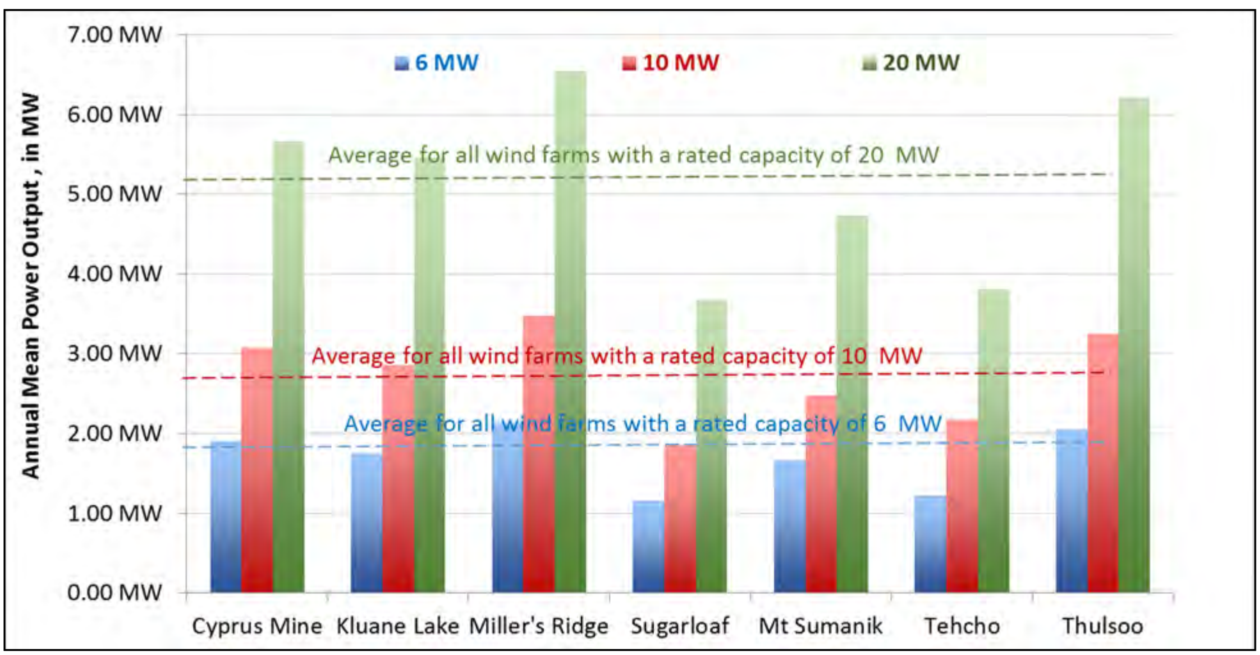
Figure 40 Seasonal Power Output and Reliable Winter Capacity of a 2.35 MW Enercon Turbine at Miller's Ridge





Applying this approach to all wind farm sizes and sites, the firm winter capacity ranges from 1.7 MW for a wind farm rated 6 MW (28% capacity factor) to 5.2 MW for a 20-MW wind farm (26% capacity factor) – see below.

Figure 41 Annual Mean Power Output taken as Reliable Winter Capacity



4.6 Turbine Choice

AWS Truepower Advanced Wind Site Assessment Reports were obtained for each of the seven selected sites. The advanced reports are designed to present an in-depth prediction of the wind resource of a site to include annual and month-specific mean wind speed, power density, Weibull distribution of wind speed, 50-year maximum gust, diurnal variation of speed and power density, and frequency and energy wind roses. The wind data in the AWS advanced reports is modelled at 80 meters above ground level, which is the hub height of the generic 2.0 MW wind turbine discussed in above and is a typical hub height of wind turbines in the approximately 2 MW class range. AWS Truepower Advanced Reports for each site can be found in Appendix I.

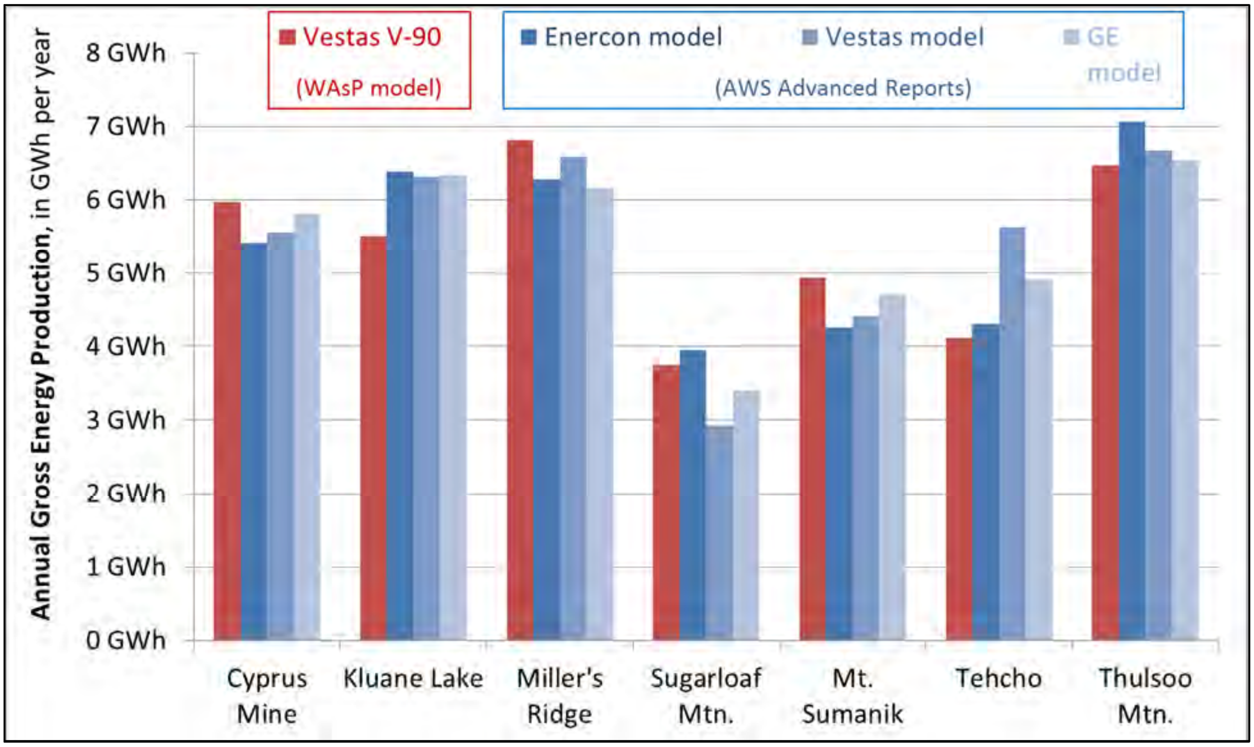
Besides a highly detailed description of the wind resource, AWS Truepower advanced reports contain annual energy production estimates for three different wind turbines selected by the user, at user-specified hub height. The project team focused on three wind turbine manufacturers: Enercon of Germany, Vestas of Denmark, and General Electric (GE) of the United States. All three are large, well-established companies with long track records of highly successful projects. For each of the seven profiled sites, an IEC wind classification was presumed based on the mean annual 80-meter height wind speed. With that, and by reference to the Enercon, Vestas, and GE websites, suitable 2 MW class wind turbine models were chosen and are listed in Table 9.

Table 9 Wind Turbines Profiled in AWS Truepower Advanced Reports

Site	Latitude	Longitude	Assumed IEC class	Enercon model	Vestas model	GE model
Cyprus Mine	62.422	-133.417	II-B	E92	V100-2.0	GE 1.7-100
Kluane Lake	61.214	-138.665	III-B	E92	V100-2.0	GE 1.7-100
Miller's Ridge	62.109	-136.568	II-B	E82 E2/2.3	V90-1.8	GE 1.85-87
Sugarloaf Mtn.	60.118	-134.642	III-B	E92	V110-2.0	GE 1.7-103
Mt. Sumanik	60.744	-135.284	III-B	E92	V100-2.0	GE 1.7-100
Tehcho	63.413	-136.677	III-B	E92	V110-2.0	GE 1.7-103
Thulsoo Mtn.	61.034	-136.932	II-B	E82 E2/2.3	V90-1.8	GE 1.85-87

With this selection AWS Truepower prepared Advanced Wind Site Assessment Reports for each of the seven sites (Appendix I). We then compared the annual gross energy output of each turbine provided in the Advanced Reports with the results of the WAsP model (Appendix G), see Figure 42 below.

Figure 42 Annual gross energy generation of various turbines using two models



For all sites, except Kluane Lake and Tehcho, the annual energy production predicted by AWS is in close agreement with the results of the WAsP model. In three out of the seven sites the Vestas V-90 turbine outperforms the best turbine of the Advanced Reports.

Table 10 Best Performing Turbine Models for each of the Seven Sites

Site	Best Turbine Model	Rated Capacity
Cyprus Mine	Vestas V-90	2.0 MW
Kluane Lake	Enercon E92	2.35 MW
Miller's Ridge	Vestas V-90	2.0 MW
Sugarloaf Mtn.	Enercon E92	2.35 MW
Mt. Sumanik	Vestas V-90	2.0 MW
Tehcho	Vestas V110-2.0	2.0 MW
Thulsoo Mtn.	Enercon E82 E2/2.3	2.35 MW

These results have to be taken with a grain of salt: A main difference in the two models is that the Advanced Reports determine the annual energy production of a turbine at only one particular location within the site. This site may not be the optimal location. WAsP, on the other hand, calculates wind speed and subsequently annual energy production at every location with the site. This allows placing turbines at the best spots. As a consequence WAsP tends to yield higher annual energy production than AWS. WAsP, on the other hand, takes the effect of the terrain's topography and turbulences created by neighbouring turbines into account. In general the agreement between the two models is within 10% of each other providing sufficient confidence in the outcome.

The comparison also does not take into account the difference in low-temperature curtailment. Gearless turbines, like all Enercon models, can be operated below -30°C. For some sites, such as Tehcho this might increase output by up to 3.7% and outweigh the advantage of an optimized foil design.

Finally, the data above are annual energy productions. Seasonal energy production, e.g. from October to mid-May when electricity is most needed and when wind speeds tend to be higher favours turbines optimized for high wind speeds. Appendix H provides further detail.

In detail the following can be said about the turbine choice at each site:

- **Cyprus Mine**: The advanced report turbines and the WAsP V90 (20 MW average) are in close agreement, there is little difference between the four turbine types.
- **Kluane Lake**: Clearly, the turbines profiled in the advanced reports are more suitable for the Kluane wind regime than the Vestas V90.
- **Miller's Ridge**: Like Cyprus, the advanced report turbines and the generic turbine used for WAsP are in close agreement. The models worked well together.
- **Sugarloaf**: This site was complicated to analyze, with significant differences between the WAsP and AWS models. The close agreement of the results between the two is coincidental and masks these differences. Results for this site should therefore be regarded preliminary and would require on-site monitoring to confirm the resource.
- **Mount Sumanik**: The advanced report turbines and the WAsP V90 (20 MW average) are in close agreement. The models worked well together. That said, there are significant differences between the WAsP and AWS models.
- **Tehcho**: The turbines profiled in the advanced reports are more suitable for the Tehcho wind regime than the Vestas V90. Note though that the annual energy production of the Vestas V110 is quite a bit higher than the other two. Consultation with Vestas would be required to ensure that it is indeed a suitable choice for the site.
- **Thulsoo Mountain**: The advanced report and the WAsP V90 are in close agreement except with the Enercon E82. The other two choices are very similar. Consultation with Enercon would be required to ensure that it is indeed a suitable choice for the site.

Note that wind turbine manufacturer and model choice is a complex task and should a large wind project be developed in the Yukon, YEC is encouraged to consider not only other manufacturers besides Enercon, Vestas, and GE, but also the full suite of available models from each. It is possible, of course, that more optimal turbine choices are possible than those profiled in the AWS Truepower advanced reports.

5 FINANCIAL ANALYSIS

We conducted financial analyses for the seven sites described in the previous two chapters. The analyses are based on three main inputs:

1. Gross and net energy production of the wind farms
2. Capital cost estimates
3. Operational cost estimates

A predetermined Excel file supplied by YEC was used to determine various financial parameters. The file calculates these parameters in the same way for all energy technologies, allowing cross comparisons. The cost data feeding into the financial model were determined based on a variety of sources as outlined below, including direct quotes, expert estimates, previous studies, and experience with similar projects in remote areas.

For the financial analysis, we used the same turbines for all sites to allow for better comparability. In reality, turbine choices (brands and capacities) may vary between sites and should only be selected once one year of wind monitoring results are available.

5.1 Capital and Development Cost Estimates

We estimated capital costs for each of the seven sites and each of the three capacity sizes, 6 MW, 10 MW and 20 MW. The cost presented includes hard and soft costs, such as financing and project development costs. All costs are calculated at the point of interconnection to YEC's transmission line and in constant 2015 dollars.

Where applicable, we factored costs according to parameters determined during the layout of the wind farm as described in Chapter 3 above. Details are provided as Appendix C in the form of three Excel-files, one for each wind farm size.

The overall accuracy of these cost estimates is ± 30%, commensurate with the project definition of a pre-feasibility or screening level study (AACE Class 4). This accuracy can only be applied to the total capital cost, not individual line items.

For each site, we grouped capital costs into nine categories:

1. Logistics
2. Civil Works
3. Electrical Works
4. Labour Costs not already included in other cost items
5. Financing Costs
6. Land Costs
7. Project Development Costs
8. Equipment Costs
9. Contingencies

5.1.1 Logistics

This item summarizes all costs related to transporting the equipment to the site, including the following:

Transportation cost: $500,000 for transporting one complete turbine from the manufacturer by sea to either the Port of Skagway, Alaska,[12] or from the port of Vancouver, Oregon by train through Nelson, BC and on by truck. From the port it will take three trips per turbine by truck to transport mast, nacelle, tower, and other wind-farm-related parts, such as transformers. A 20-MW wind farm would require three trips to the site. Each trip is assumed to cost $100 per km, including empty returns. Transportation costs for a 20-MW wind farm range from $5.3 million for Kluane Lake to $6.5 million for Cyprus Mine, the farthest site from the port.

90-tonne crane for lay down etc.: A crane for taking equipment off the trucks and laying it down will be needed. A hydraulic crane of this capacity is available in Whitehorse. A lump sum of $30,000 is assumed for mobilization and de-mobilization plus $2,500 per day in the field. On average, four days are required to erect a turbine. High wind conditions may require an additional two days per turbine, for a total of six days. The total cost of the 90-tonne crane is $180,000 for a 20-MW wind farm.

550-tonne crane: A larger 550-tonne crane is required to erect the mast and lift the assembled rotors and nacelle in its location. Again, six days are assumed to erect a turbine, including idling time due to high or gusting wind conditions. This crane will have to be brought in from Edmonton at a cost of $200,000. Daily rental costs are assumed to be $15,000, whether in operation or idle. The total cost of the 550-tonne crane is $1,100,000 for a 20-MW wind farm.

Erection cost: Operating the crane and all other labour involved in the erection and installation of the complete wind turbine is budgeted at $450,000 per turbine. This is based on previous experience in remote BC and AB locations.

5.1.2 Civil Works

Construction costs include several items relating to access, site preparation, foundations, and transport of construction material such as gravel. These costs also vary based on site location, the length of the access road, and distance to Whitehorse. Additional factors can be the type of prevalent rock and the gradient to reach the site.

In general, gradients should not exceed 10% with a maximum of 14% to transport turbines by truck. Road width is five meters, the maximum road loading 70 tonnes. The minimum turning radius is 25 meters. This may require adjusting the access roads sketched out for this assessment, which may then become longer than anticipated at the prefeasibility level. It may also be necessary to use blasting to create access.

Road ways and road sides can be accurately planned using high-resolution LIDAR-derived digital elevation maps.

[12] Transport via White Pass and Highway #2 is unrestricted up to 77 tonnes (Dan Nickason, Highways & Public Works, April 2016)

Table 11 Costs of Civil Works

#	Item	Specific Cost	Comments
1.	Geo-technical report, Digital terrain model, Road way design	$75,000 total	Assume an engineer from AB or BC, some of the cost is mobilization; LIDAR map taken from flight over site
2.	Access road	250,000 $/km	From existing road to turbine road; may vary significantly according to geotechnical conditions
3.	Turbine road	250,000 $/km	Assuming gravel pit within 20 km distance
4.	Cement supply for foundation	300 m^3 per base, $575 per m^3	Mobile concrete plant
5.	Cost of rebar including delivery	35,000 kg per base, $1.5 per lb	Delivered to site
6.	Foundation installa-tion cost	$60,000 per base, including labour	Depends on type of foundation (geo-tech conditions)

The construction of a wind farm is expected to take at least three years in the Yukon, due to the short construction season of only five months. We assume that the road would be built in one year and then the turbines would be purchased and set up in the following year. Turbine parts would be transported by truck, with two blades and two nacelles per truck.

Note that a special permit is necessary for transporting loads heavier than 77 tonnes.[13] The construction crane may weigh considerably more than this, but components such as the boom or counter weights are usually transported separately. Without these the transport weight of the crane would be 54 tonnes.

We anticipate about 90 days of construction activity to pour ten foundations for wind turbines. This concrete needs to cure for about 30 days, which means that turbine erection can start halfway into the concrete-pouring task while the last foundations are still being completed. Turbine foundations may be either anchors or concrete foundations (assumed here, and conservatively costlier than anchors). We have based our estimate on a quote for labour and material from a local construction company, resulting in costs between $475,000 to $1,029,000 per turbine, depending on the size of the wind farm.

For the access and turbine-connecting roads, we assume a cost of $250,000 per km. A local service provider quoted a budget price above $1 million per km though. This quote is, however, not in line with previous Yukon experience and is based on trucking gravel from Whitehorse. On the other hand, the need for blasting or adjusting gradients and poor geotechnical conditions may increase road construction costs at specific sites.

5.1.3 Electrical Infrastructure

The following items were considered for the cost of the electrical infrastructure:

[13] The stator/rotor of an Enercon turbine may weigh more than 80 tonnes.

Table 12 Electrical Infrastructure Costs

#	Item	Specific Costs	Comment
1.	Low voltage step-up transformers	$60,000 per piece	Per turbine 1 kV/12.47 kV step-up transformer
2.	Collection system	$200,000 per km	Underground cable
3.	Substation	$2,500,000 total	12.47 kV/138 kV step up transformer & switching yard
4.	Interconnection to existing transmission line	$500,000 per km + 17% engineering and interest	Including labour; see Table 13 for details
5.	Line-tap & protection system	$1,500,000 total	From high voltage transmission to utility tx (gang switch with fused cut-outs)

To interconnect the turbines before they are connected to the transmission line transformer (collection lines), we assumed costs of $200,000 per km, including the cost of burying cables and/or a concrete channel.

The estimate for transmission line construction (about $500,000 per km plus 17% owner's cost) is informed by the Stewart Keno project cost estimate, see Table 13 below.

Table 13 Per-Kilometre Line Construction Costs

Cost Item	Yukon, Stewart Keno Project Estimate
Material, labour & line	$366,882
Contingency & Escalation	$67,632
Project management	$51,312
Other	$12,684
Sub-total	**$498,510**
Owner's cost (17%)	$84,747
TOTAL	**$583,257**

In addition to transmission line construction, a protective switch (line-tap & protection system from high voltage to utility transmission) needs to be installed at the interconnection with existing long-distance transmission. We ascribed this cost to transmission cost and budgeted $1.5 million. Transformers ($600,000 per wind farm) were considered part of the wind farm capital cost and are thus are not included in the transmission costs.

Total interconnection cost range from $3.5 million for Tehcho to $9.4 million for Miller's Ridge. Land costs are not included and are given in Table 14 below.

5.1.4 Labour Costs

Much of the labour cost has been included in the estimated above, e.g. for road and transmission construction. Additional labour costs for personnel involved in turbine erection and other tasks above and beyond what is already accounted for are estimated at 10-person-years per site and 1 person-year per turbine. We assumed labour costs of $200,000 per person-year including overhead, but excluding per diem. The latter adds $150 per day per person for 250 days of construction over a two-year period. Again it is assumed that most of these personnel will come from outside the Territory or will be too far from their homes and therefore require accommodation.

5.1.5 Financing Costs

Legal costs to arrange financing are estimated at $800,000, independent of the size of the project. Additionally, we budgeted bank financing costs or lender charges at 1.5% of capital cost, i.e. around $1 million for a 20 MW farm. These are charges leveraged by credit institutions to cover for the administrative costs of arranging for a loan.

5.1.6 Land Costs

We have estimated land costs based on the surface area required for both the wind farm and road and transmission access, for each of the seven sites as laid down in Chapter 3.8 above. For land without existing ownership as per the GeoYukon site, we assume the land will be purchased at a rate of $500 per acre.[14] At this rate, costs range between $60,000 and $230,000, less than 1% of the total cost.

For turbines, roads and/or transmission lines on First Nation land we assume land will be leased. Annual leasing rates for First Nation land are assumed as 10% of purchasing costs, and are not included here but under operational costs in Chapter 5.2.

Total land area to be acquired, including access roads and easement for power lines, range between 76 ha (Kluane Lake) and 189 ha (Miller's Ridge) for a 20 MW farm, see Table 14 below. Land for Kluane Lake and Sugarloaf Mountain will have to be leased. A developer may want to rent enough land to set up the turbines for the initial three years of the project and then purchase only the land required by the turbines.

Table 14 Land Costs for a 20 MW wind farm

Site	Total road length	Total power line length	Land area	Land price	Land Cost
Cyprus Mine	13.4 km	16.2 km	146 ha	$2,000 /acre	$703,956
Kluane Lake	2.0 km	6.2 km	76 ha	$2,500 /acre	Lease only
Miller's Ridge	8.3 km	21.8 km	189 ha	$2,000 /acre	$913,294
Sugarloaf Mountain	6.8 km	10.6 km	74 ha	$2,500 /acre	Lease only
Sumanik	7.5 km	10.7 km	99 ha	$2,500 /acre	$596,511
Tehcho	7.4 km	10.8 km	69 ha	$2,000 /acre	$332,088
Thulsoo Mountain	8.5 km	19.2 km	178 ha	$2,000 /acre	$860,283

[14] YEC paid up to $2,000 per acre for the development of the Mayo B plant area in 2010. According to the YUKON AGRICULTURE STATE OF THE INDUSTRY REPORT 2010–2011–2012, titled agricultural lands within 30 minutes from Whitehorse have been valued at over $3,000 per acre while land located 30 to 60 minutes from Whitehorse has been valued at around $2,500 per acre.

5.1.7 Development Costs

We budgeted eight items for the development of a wind energy project. Development costs presented include all aspect of project development. Table 15 itemizes individual items.

Development costs are estimated at $1.9 million. This also includes wind monitoring,[15] bird/bat studies, stakeholder relations and internal personnel costs.

Development costs are a fixed cost and are the same for a 6 MW wind farm as for a 20 MW wind farm.

Table 15 Development Costs (2015 $)

#	Item	Cost	Comments
1.	Wind measurement campaign	$200,000	LIDAR equipment lease or Met-tower purchase, installation & operation
2.	Environmental assessment (incl. FN consultation)	$300,000	Bird/bat studies
3.	Stakeholder relations	$100,000	Open houses, etc.
4.	Engineering	$300,000	For logistics, construction layout, interconnection studies, turbine supply
5.	Legal fees (various)	$500,000	Leases/land agreements, FN joint agreement, construction contracts, project equity
6.	Legal fees for turbine supply agreement	$250,000	Sales contract
7.	Legal fees for stakeholder relations	$50,000	Appeals, tribunals
8.	Development personnel and travel	$200,000	Owner's cost / YEC staff
	TOTAL	**$1,900,000**	

5.1.8 Equipment Costs

Wind turbine costs for the Vestas V-90 2.0 MW turbine, including de-icing kits, are estimated as $1.2 million per MW, delivered-duty-paid (DDP). A comparable Enercon turbine would be $1.3 million per MW but would likely have less curtailment and lower maintenance costs. Higher up-front capital costs would be traded for lower operational costs. This option, however, has not been modelled but should be researched during the next phase of the project.

5.1.9 Contingencies

10% contingency is included in the capital cost estimate. This includes the risk of currency fluctuations.

[15] To develop a wind site in the Yukon, both wind monitoring and icing monitoring are necessary. The report on Ferry Hill (Tehcho) estimates costs of about $200,000 for the wind monitoring mast with icing detector, as well as annual costs of about $25,000 for a generator and cell phone connection.

5.1.10 Total Capital and Development Costs

Figure 43 compares the capital costs of each of the seven wind farm sites selected for this assessment. Land and development costs are small items compared to equipment costs, transmission (electrical), and labour required for wind farm construction. Road costs are included in civil works, together with the turbine foundations, but are not among the most significant cost items.

Most of the larger cost items are fairly well established based on past experience with wind farms. As such, it appears that currency exchange risk is the most important factor that could affect wind farm construction costs, since it may affect equipment costs and also much of the labour cost anticipated. Site-specific differences, such as more expensive road construction, would not by themselves have a major impact on overall capital costs. Capital costs for the seven sites range from $3.0 million to $3.6 million per MW of rated capacity and are within a 20% margin of each other.

As Figure 44 shows, less than one-third of the total capital expense is for the turbine equipment itself. Most of the money will be spent in the Yukon. Kluane Lake would be the cheapest to develop as it would be right next to a planned transmission line.

Figure 43 Capital and Development Costs of the Seven 20 MW Wind Farm Sites

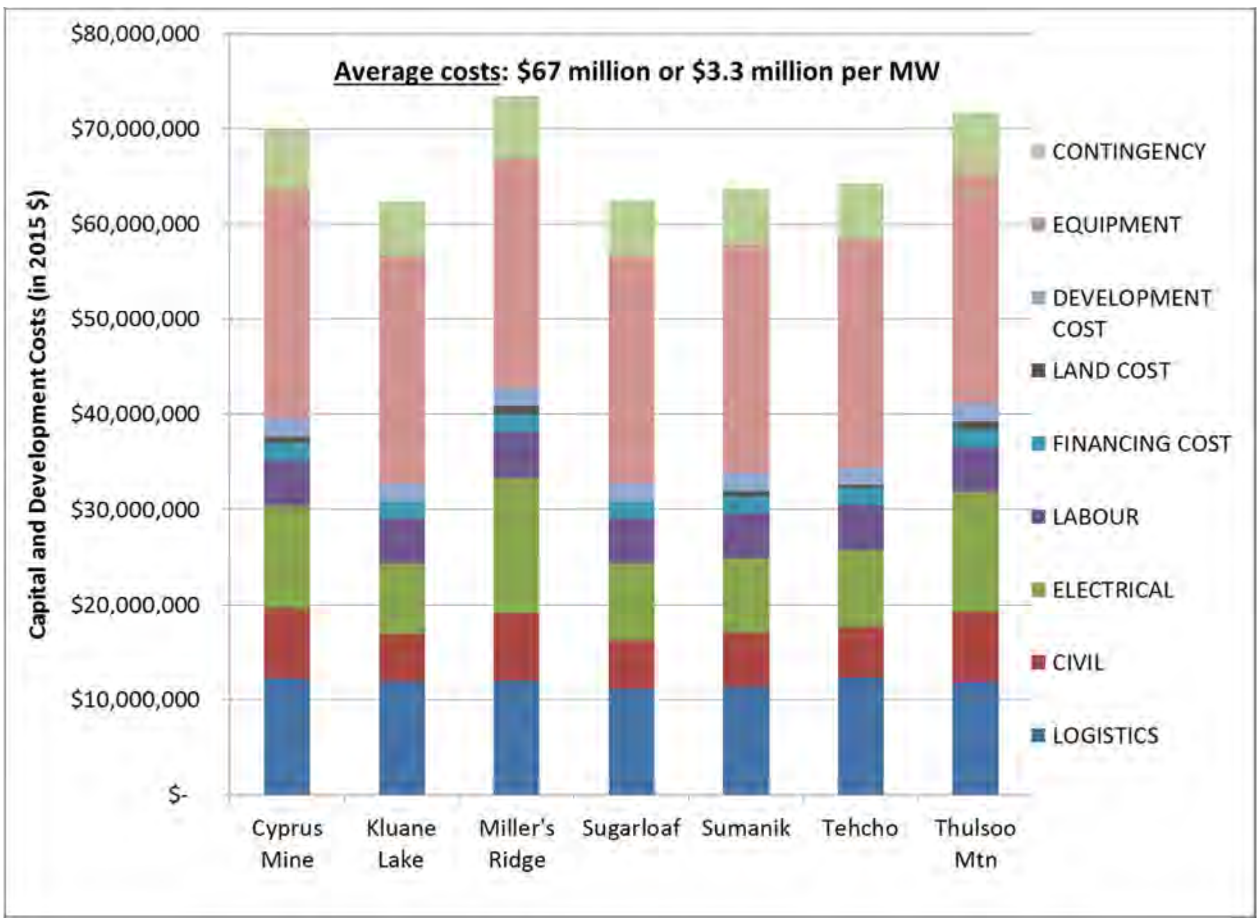


Figure 44 Capital and Development Costs of a 20 MW Wind Farm at Miller's Ridge

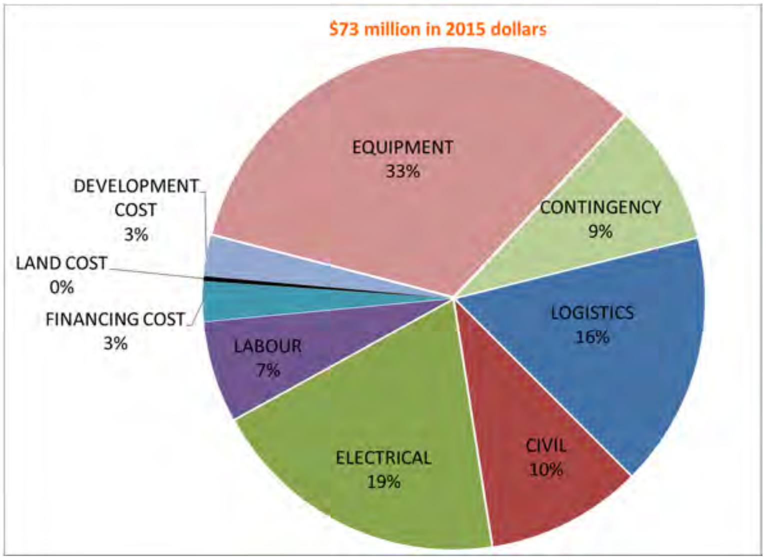
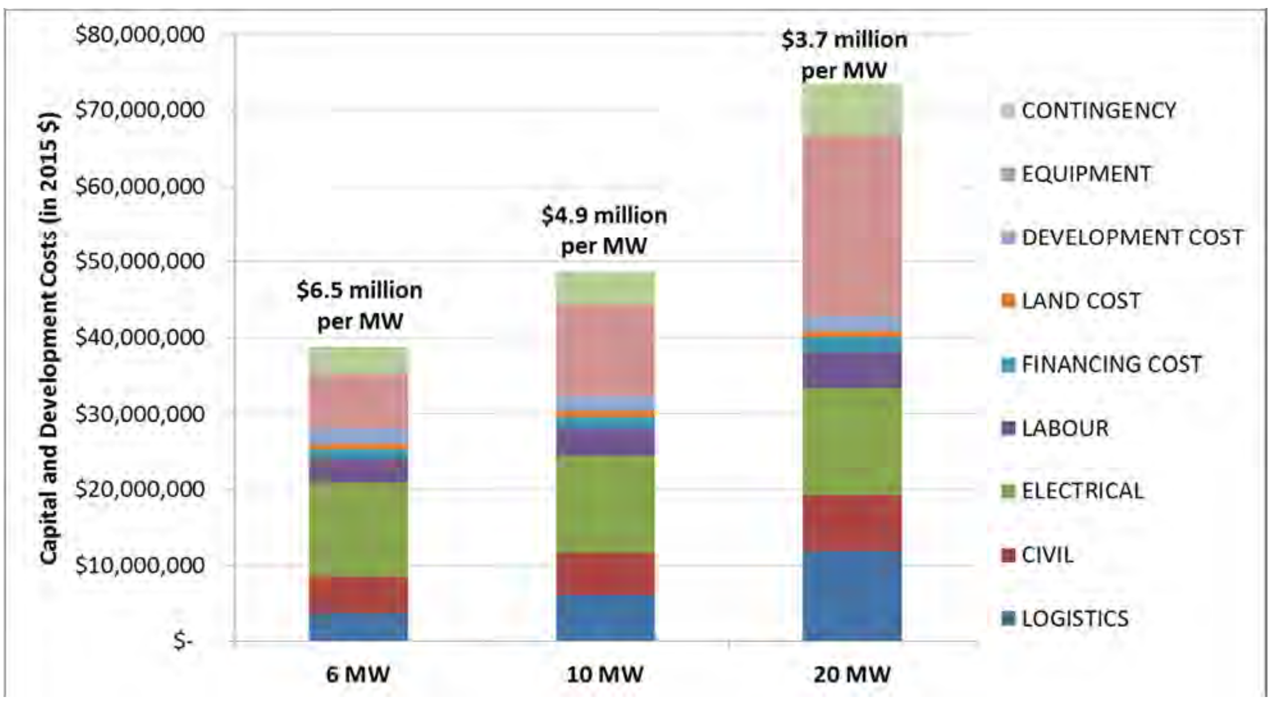


Figure 45 compares the capital cost items for three different wind farm sizes for Miller's Ridge. Since development costs and much of the electrical costs (transmission line) are fixed, their proportion of the capital costs increases as the farm size decreases. Equipment costs are an average of 33% for the 20-MW wind farms, 25% for a 10-MW size and only 20% for the 6-MW wind farms. For this site, the specific capital costs increase from $3.6 million per MW for a 20-MW wind farm to $4.8 million for a 10-MW farm and $6.5 million for a 6-MW wind farm.

Figure 45 Capital and Development Costs of Three Sizes of Wind Farms at Miller's Ridge



5.2 Operational Costs Estimate

5.2.1 Fixed Operational Costs

YEC would have to employ two technicians to be working out of an office near any of the planned wind farms for small maintenance and troubleshooting and other operational purposes. Most sites are within about 200 km from Whitehorse, and the Tehcho farm would likely be serviced out of the existing Mayo office. We therefore assume $60,000 annual office rental costs only for the Cyprus Hill and Kluane sites. The salaries of these technicians have been considered at a cost of $100,000 per year, per person. Other fixed costs include:

- For turbines on aboriginal land, we assume the land will be leased at a cost of 10% of the theoretical purchasing price of $2,500 per acre.[14]
- Insurance costs are estimated at 0.15% of capital costs.
- There is a cost per turbine for its own electricity consumption (mainly for de-icing, some for lighting) but we accounted for this by reducing net output due to icing losses.

We further assume that no property taxes will have to be paid as none of the sites examined lie within municipal administrative borders.

Table 16 Fixed Operational Costs (2015$)

#	Item	Specific Cost	Annual Costs
1.	Operators	Two staff per wind farm	$200,000
2.	Office	$5,000 per month, (only for sites too far from existing YEC offices)	$60,000
3.	Insurance	$0.15 per $100 of CAPEX	$90,000 to $107,000 for 20-MW farm
4.	Land lease	10% of $2,500 per acre = $603/ha [14]	$46,000 (Kluane) to $45,000 (Sugar-loaf) for 20-MW farm

5.2.2 Variable Operational Costs

Wind turbine manufacturers offer service contracts that are calculated based on turbine output. For the Vestas V-90, annual service contracting costs of $15/MWh are assumed. This cost only applies to the first five years, increasing to $25/MWh until year 10, then to $30 after that.[16] This cost would include gearbox replacements every seven years (the Vestas turbine is not gearless; gearless turbines are discussed in Section 4.6).

In addition, royalties will have to be paid for turbines on aboriginal land. We assume that 5% of wind farm revenue would be paid to aboriginal landowners. Revenue is based on net energy output and valued at $120 per MWh, similar to retail electricity prices). We also applied a 5% contingency to variable costs.

[16] Enercon has lower rates that only increase once, after 10 years. This has not been modelled.

Table 17 Operational Costs for a 20 MW Wind Farm (annual, Year 1 -5)

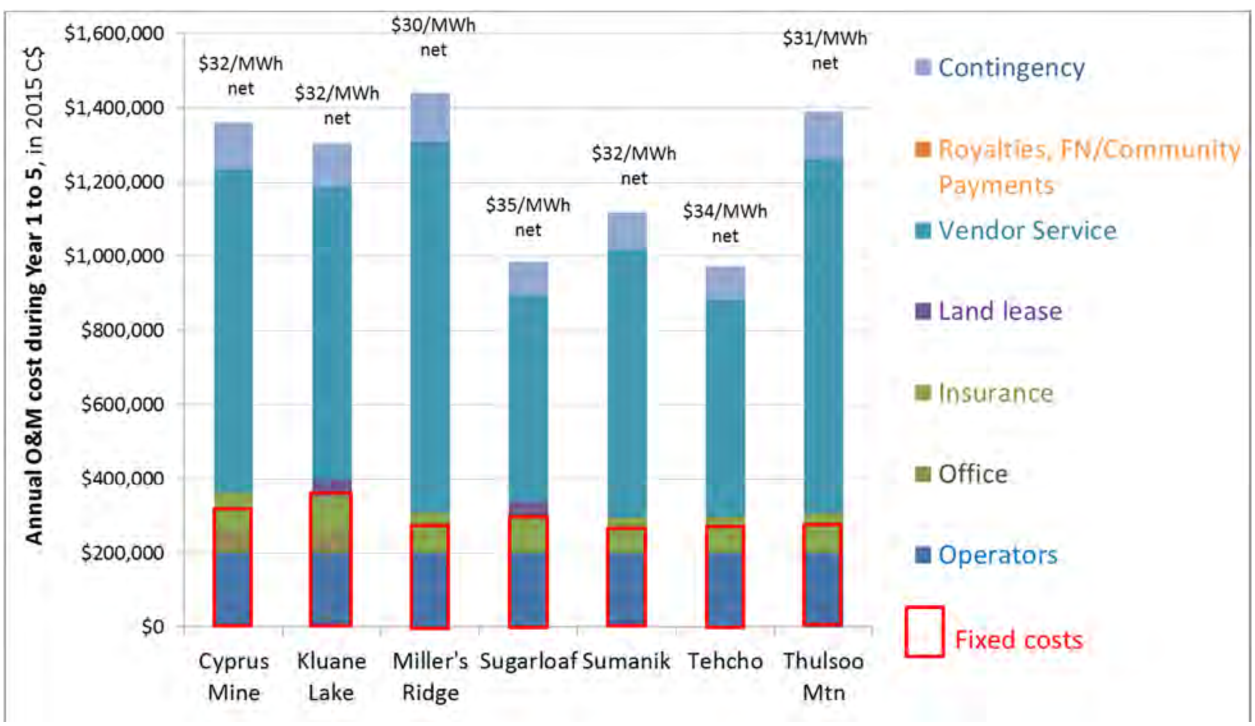
Site	Fixed Costs				Variable Costs		
	Office costs	Operators	Land lease	Insurance	Contin-gency	Royalties	Vendor Service*
Cyprus Mine	$60,000	$200,000		$104,018	$123,661	$0	$871,725
Kluane Lake	$60,000	$200,000	$45,858	$93,560	$118,777	$0	$788,355
Miller's Ridge	n/a	$200,000		$110,238	$131,093	$0	$1,000,695
Sugarloaf	n/a	$200,000	$44,573	$93,649	$89,487	$0	$556,650
Sumanik	n/a	$200,000		$95,476	$101,743	$0	$721,950
Tehcho	n/a	$200,000		$96,460	$88,374	$0	$587,280
Thulsoo Mtn	n/a	$200,000		$107,556	$126,361	$0	$956,055

Note: Sites in *italics* are on aboriginal land; assumes land lease; * Service contracts are based on turbine gross output

The largest share of the O&M costs are the vendor service contract: For a 20 MW turbine 55% of the operational costs are spent on getting the turbines regularly serviced and parts replaced by trained technicians. Because service contracts are based on energy generated, YEC may consider shutting the turbines down during the summer period when no power is required.

Figure 46 illustrates the magnitude of the individual O&M costs.

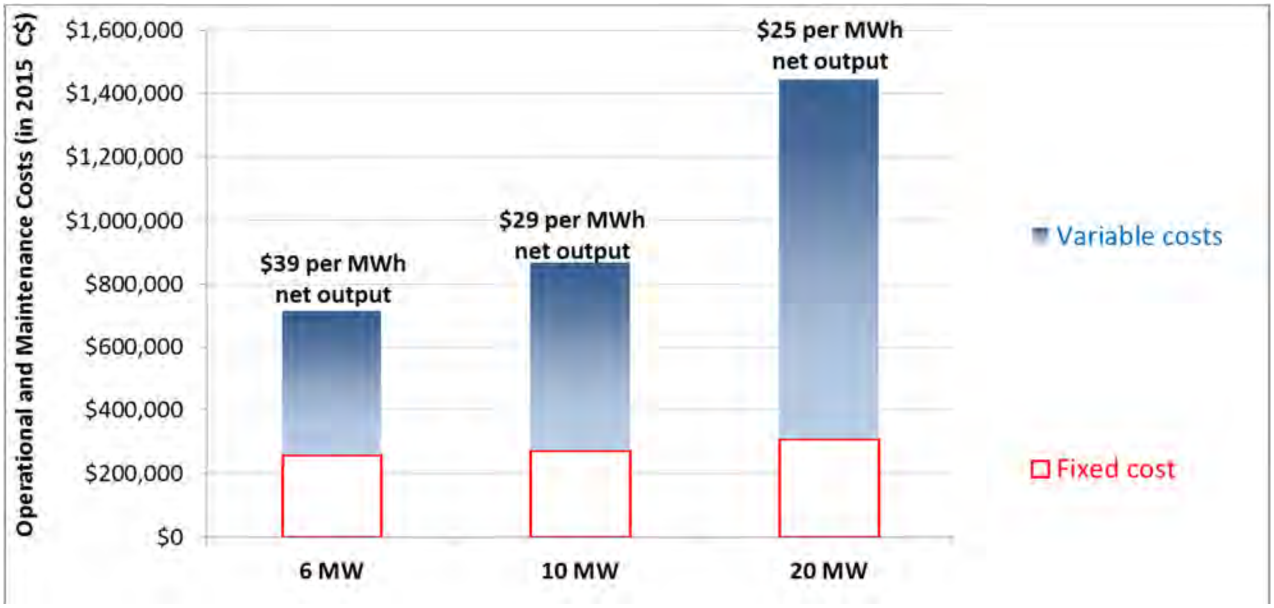
Figure 46 Operation and Maintenance Costs of a 20 MW Wind Farms at the Seven Sites



Operational costs were very similar for each site: fixed costs $265,000 for a 20 MW wind farm to $317,000 per year for a 6 MW wind farm and variable costs of about $24/MWh for all sizes of wind farms. Sugarloaf and Tehcho have low capacity factors (based on net production after losses due to icing, maintenance, etc.), which explain their lower financial performance.

Because the bulk of O&M costs are variable, there is only a small reduction of O&M cost from building larger-size wind farms. Figure 47 illustrates this.

Figure 47 Operation and Maintenance Costs of Three Wind Farms Sizes at Miller's Ridge



5.3 Financial Modelling

Table 18 summarizes the economic modelling results for each site. More detailed results can be found in Appendix D. The values below are based on a real weighted average cost of capital (WACC) of 3.38%. Two more cases (4.61 and 8.82%) can be found in the appendix. The lifetime of each of the wind farms is assumed to be 25 years.

At 3.38% WACC, the levelized cost of energy (at full utilisation, i.e. no curtailment) at almost all sites and all sizes remains under the current Yukon standard offer price of 21¢/kWh [17] but above the residential rate of 12¢/kWh [18] , see the Table 18 and Figure 48 below. For some sites the self-generation costs, the levelized cost of energy, is as low as 12.5¢/kWh. This is not as good as some more southern wind farms, which may produce at between 8 and 10¢/kWh, but highlights the good wind regime at some Yukon sites.

Of the seven sites selected, five show above-average performance in terms of the cost of energy produced. These sites are, in the order of performance, Kluane Lake, Miller's Ridge near Carmacks,

[17] Yukon Energy Mines and Resources: „ENERGY STRATEGY FOR YUKON - Independent Power Production Policy" May 20, 2014, page 7

[18] YEC's Residential Rate Schedule 1160 (Hydro, Non-Government) in May 2016: 12.14 ¢ per kWh for the first 1,000 kWh.

Thulsoo Mountain near the Aishihik hydroelectric facility, a mountain ridge near Cyprus Mine, close to Faro, and Mt. Sumanik near Whitehorse. On the other hand, we notice that both Sugarloaf Mountain and Tehcho have lower performance than the remaining sites, with Kluane Lake and Miller's Ridge showing the best financial performance. There is some, but not a lot of difference in energy production cost between these five sites; non-monetary factors may play an important role in selecting the preferred location.

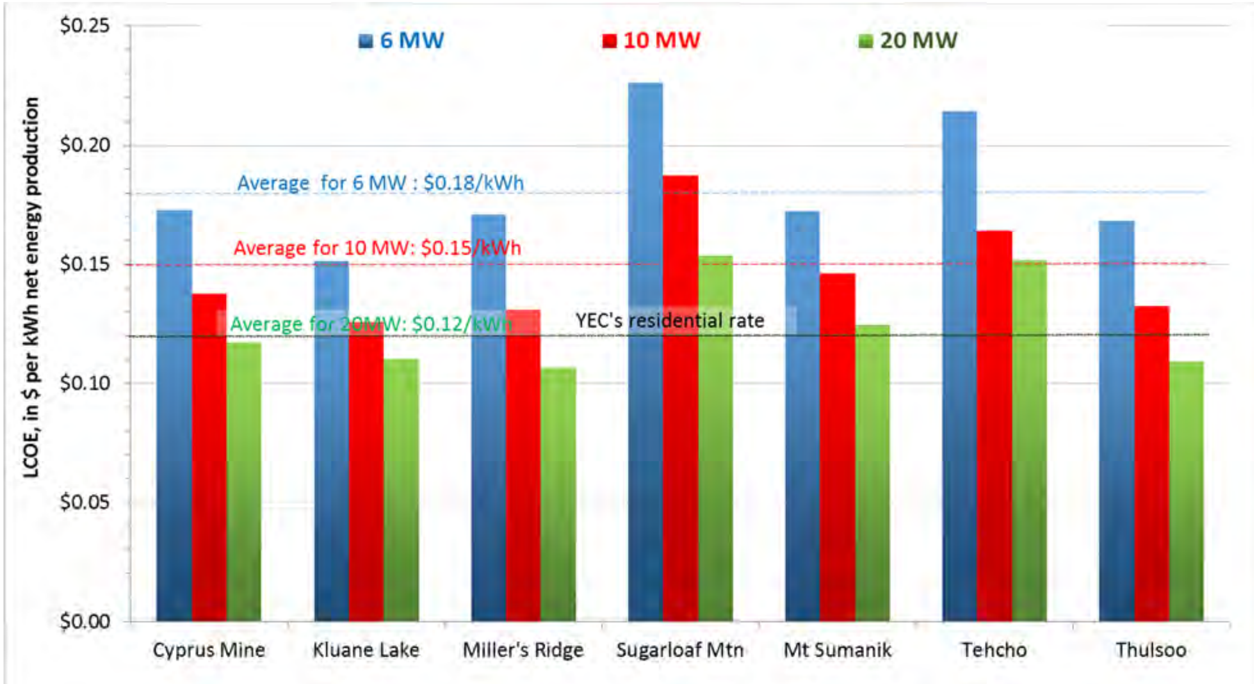
Table 18 Financial Modelling Results

Site	6 MW		10 MW		20 MW	
	Capital Cost (million $)	Levelized Cost of Energy *	Capital Cost (million $)	Levelized Cost of Energy *	Capital Cost (million $)	Levelized Cost of Energy *
Cyprus Mine	34	17.3¢/kWh	44	13.8¢/kWh	69	11.7¢/kWh
Kluane Lake	26	15.1¢/kWh	36	12.6¢/kWh	62	11.0¢/kWh
Miller's Ridge	39	17.1¢/kWh	49	13.1¢/kWh	73	10.7¢/kWh
Sugarloaf Mountain	28	22.6¢/kWh	38	18.7¢/kWh	62	15.3¢/kWh
Mt. Sumanik	30	17.2¢/kWh	39	14.6¢/kWh	64	12.4¢/kWh
Tehcho (Ferry Hill)	28	21.4¢/kWh	39	16.4¢/kWh	64	15.1¢/kWh
Thulsoo Mountain	36	16.8¢/kWh	46	13.2¢/kWh	72	10.9¢/kWh
Average	**32**	**18.2¢/kWh**	**42**	**14.6¢/kWh**	**67**	**12.5¢/kWh**

** at 3.38% real weighted average cost of capital (WACC), 25 years life expectancy, no curtailment*

Financially, the site at Kluane Lake performs best of all seven sites, despite its mediocre wind resources. This can be explained by the very short transmission connection required once the new line is built. Also, less rime icing and less frequent low temperature curtailment helps to increase the net energy generation. Though there are plans, currently there is no transmission line at this site.

Figure 48: Levelized Cost of Energy (LCOE) by Site and Wind Farm Size at 3.38% Real WACC



Due to fixed costs and economies of scale, larger wind farms have lower energy production costs than smaller ones. The cost of energy at the seven sites averages 13 ¢/kWh for a 20-MW wind farm, but increases to 18 ¢/kWh for a 6-MW capacity, see the table below. Our modelling assumes that all energy produced will be used. Curtailment of the operation during the summer when YEC has a surplus of power would increase the cost of energy produced during the rest of the year by more than a third.

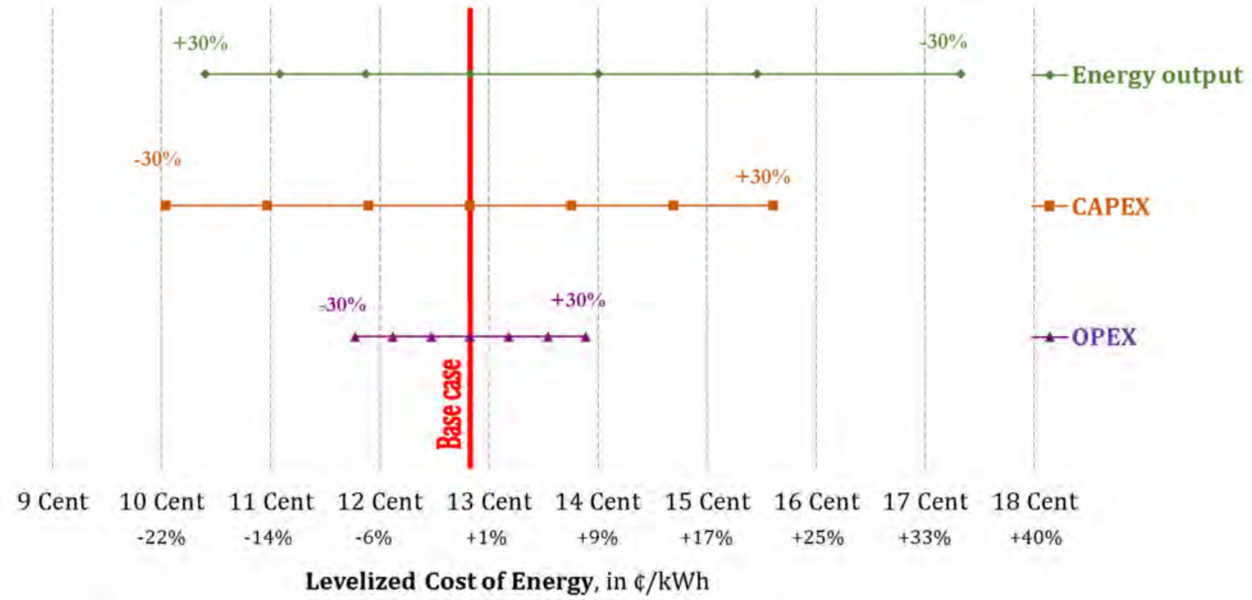
5.4 Sensitivity Analyses

The data above are based on the given assumptions and naturally contain errors. We estimate the margin of error as ±30% for each of the three main inputs: energy production, capital costs and operational costs.

We conducted a sensitivity analysis on key variables affecting the financial results. This involved recalculating the cost of energy (LCOE) for different values of the energy production, capital costs and operational costs. Varying these input parameters, one at a time, by as much as +30% to -30% of the original value, we noted the change in the financial evaluation. The impact of the parameters on the cost of energy is illustrated in the graph below for a 10-MW wind farm at Kluane Lake. The results of the sensitivity analysis for the 20 MW wind farm at Miller's Ridge were comparable. Other sites are likely to show a similar sensitivity.

The results indicate that the project is most sensitive to the forecasted energy production. Assuming a 30% lower net energy production than forecasted would result in energy costs (LCOE) of 16.8 cents per kWh rather than the 12.5 cents determined in the base case. 30% higher operational costs, on the other hand would only increase the cost of energy to 13.5 cents per kWh. A 30% error in capital costs would yield a 22% error in energy costs. All numbers use weighted average cost of capital (WCAA) of 3.38%.

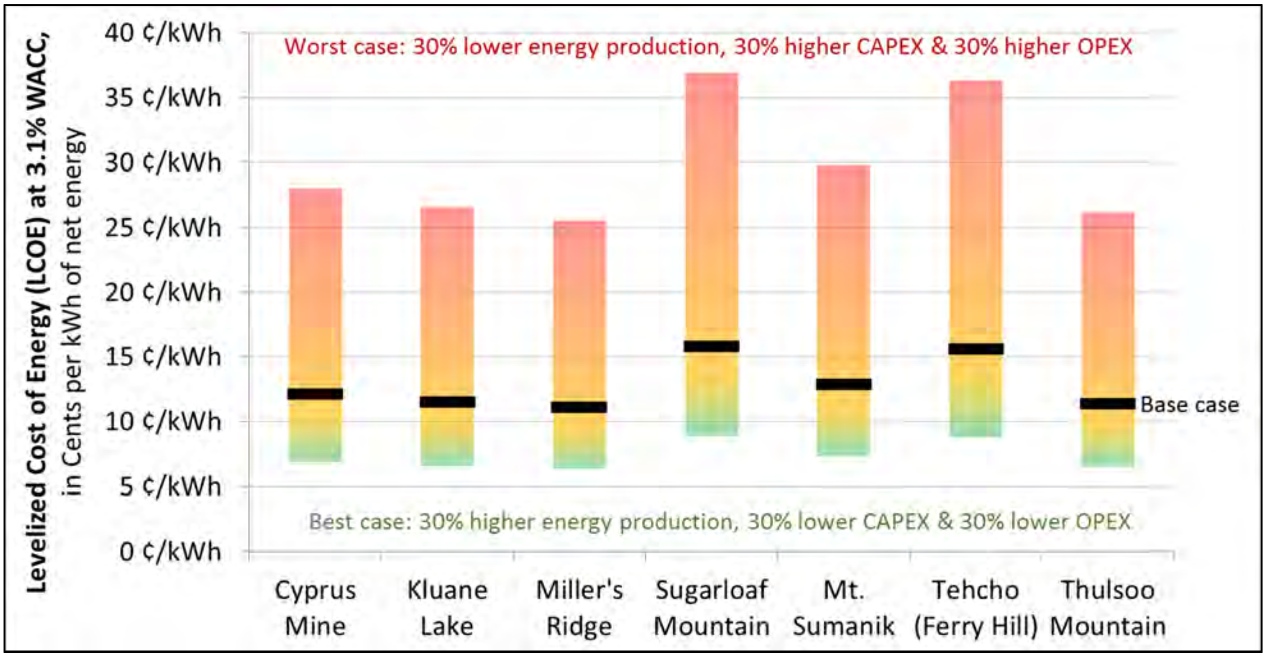
Figure 49 Sensitivity of the Cost of Energy (LCOE) of a 10 MW Wind Farm Size at Kluane Lake at 3.38% Real WACC



This underlines the importance of monitoring wind speed, rime icing, and temperature at selected sites. These are key parameters that will determine the output of a generator and thereby the financial performance of the wind farm.

Because the margin of error is 30% for each of the three main input parameters, a worst-case scenario would be 30% lower annual energy generation and 30% higher capital and 30% higher operational costs then determined in the base case. Conversely, a best-case scenario would be 30% higher energy production and 30% lower capital and operational costs. The resulting margin of error of the cost of energy is + 75%/-43% and is illustrated in Figure 50 below. Further project definition is needed to reduce the error margin.

Figure 50 Margin of Error of the Cost of Energy (LCOE) of the 20 MW Wind Farms



6 ADDITIONAL INFORMATION

6.1 Ice Mitigation Review

Rime icing of concern for wind power forms when small, wind-driven, super-cooled water droplets in clouds rapidly freeze on contact with a surface at sub-freezing temperatures. This often occurs during winter on high elevation mountains and ridges exposed to humid, maritime climate-influenced winds. At sub-arctic latitudes such as in the Yukon, rime icing conditions occur at lower elevations and are of longer seasonal duration than at temperate latitudes.

Figure 51 Rime Icing on Guy Wire of Collapsed Met Tower in Alaska

The frozen droplets contain a mixture of ice and trapped air, are rough surfaced and crystalline in structure, and are opaque to semi-transparent (see Figure 51). Rime ice can be heavy and quite tenacious in its grip on the contact surface and to itself, which can lead to a tremendous accumulation of weight. Rime ice accumulation on the wings, propellers and/or engine nacelles of aircraft has resulted in many aviation fatalities and explains why commercial aircraft are often carefully de-iced (and coated with an anti-icing solution) prior to take-off during the winter when atmospheric icing conditions are antici-pated.

Wind turbine rotor blades are rotating airfoils, and can accumulate rime ice on the leading edges during icing conditions. In contrast to an aircraft which flies through an icing risk zone relatively quickly, a wind turbine is fixed in place and for energy production reasons, especially in higher-latitude, mountainous terrain, must be located at sites with considerable environmental rime icing risk. Rime icing ad-versely affects wind turbine performance in three ways:

- Ice accumulation on the leading edges of the rotor blades reduce aerodynamic efficiency and spoil lift,
- Asymmetric accumulation of ice on the rotor blades leads to vibration and subsequent shutdown,
- Ice accumulation on control sensors results in erroneous control functions, such as main-taining the turbine in shut-down mode even with sufficient wind for energy production.

A number of wind-power studies and journal articles address Yukon icing potential for wind power operations. These papers proved very helpful to the project team for consideration of icing risks and anticipated energy production cost in the Yukon. They include:

- Maissan, John, *Wind Power Development in Sub-Arctic Conditions with Severe Rime Icing*, Circumpolar Climate Change Summit and Exposition, March 2001
- Pinard, Jean-Paul, *Wind Climate in the Whitehorse Area*, Arctic, September 2007
- Pinard, Jean-Paul, *Wind Climate in Yukon Mountainous Terrain*, PhD thesis, University of Alberta, 2008.
- Green, Mark, *Ferry Hill Wind Feasibility Study*: Stage 1, Tasks 1, 2 & 3, Natural Power, September 2010
- *Mt. Sumanik Wind Assessment and Feasibility Study*, AECOM, March 2011
- Maissan, John, *Wind Development in Yukon*, presentation to Yukon Energy wind workshop, March 2013

A number of more recent reports and studies reference a paper presented by Bengt Tammelin and Henry Seifert, *Large Wind Turbines go into Cold Climate Regions,* presented at European Wind Energy Conference 2001 in Copenhagen. This paper notes that at particularly severe rime icing sites, annual energy production losses may range from 20 to 50 percent without de-icing and/or anti-icing features, especially if the turbine is not operated during winter when icing conditions are expected (Figure 52). Note that de-icing refers to active or passive removal of ice from rotor blades while anti-icing refers to prevention or mitigation of ice accumulation.

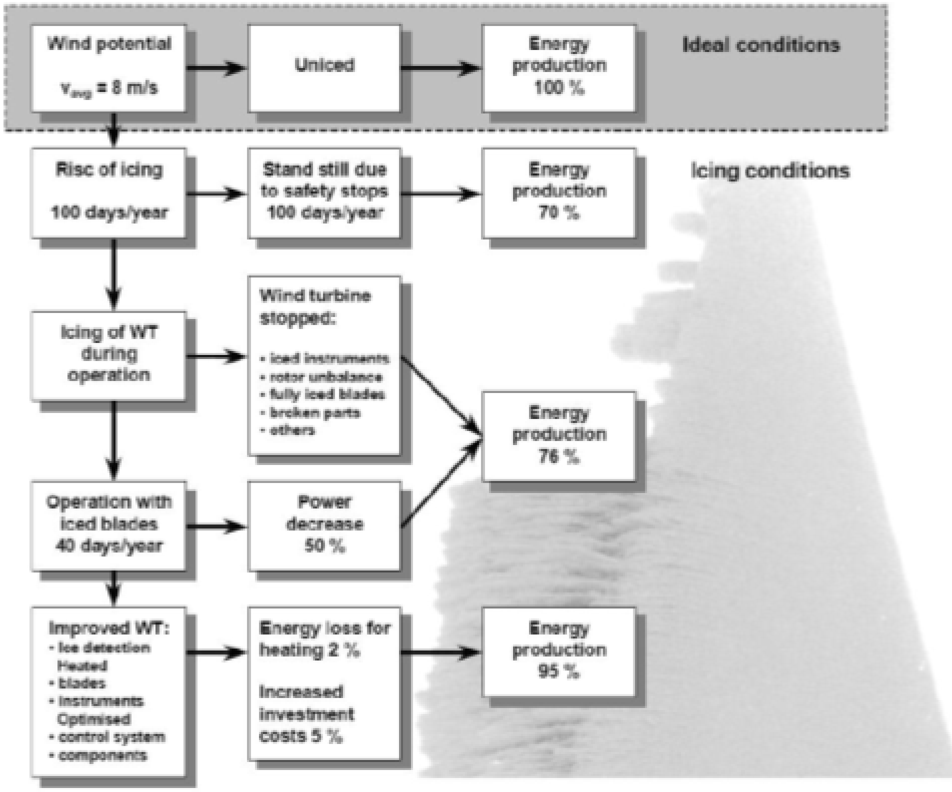
With continued reference to Figure 52, energy production loss decreases somewhat, but nevertheless remains substantial, if wind turbines operate during winter but are shut down during bad icing conditions (instrumentation ice-up, rotor imbalance, power output/wind speed mismatch, etc.). Last, energy loss due to icing can be maintained at acceptable levels with de-icing and anti-icing mitigation measures. These measures come at a cost though in terms of capital expense, energy usage for de-ice heating, and operator involvement to operate ice mitigation systems.

With reference to John Maissan's 2013 Yukon Energy wind workshop presentation and based on YEC's own experience with the two Haeckel Hill wind turbines near Whitehorse, all high elevation sites in the Yukon are at risk of substantial winter energy production loss due to rime icing conditions without mitigation measures. This is the inherent nature of high latitude, mountainous environments exposed to maritime climate-influenced storms.

Rime icing mitigation can be separated into two distinct measures: anti-icing and de-icing. Anti-icing includes heated turbine control instrumentation (this is absolutely critical), software to detect mild icing conditions (power output vs. wind speed mismatch) and retaining the operational status of the turbine as long as there is no rotor imbalance, as well as the use of black hydrophobic blades to allow for passive de-icing. Passive de-icing aside, active de-icing includes direct measures to rid the rotor blades of ice. Primary methods to achieve this are leading edge resistive heaters and internal blade air heating. Both methods have proven effective with wind turbines in North America and Europe, but these methods are not automatic; they require operator involvement and control.

Naturally, there are benefits and costs for any ice-mitigation measure and inclusion of features where not necessary, or where icing is infrequent, would be wasteful. Conversely, exclusion of ice mitigation measures where necessary could be very costly with potentially significant energy production loss due to icing conditions.

Figure 52 Illustration from Tammelin and Seifert, 2001



Naturally, there are benefits and costs for any ice-mitigation measure and inclusion of features where not necessary, or where icing is infrequent, would be wasteful. Conversely, exclusion of ice mitigation measures where necessary could be very costly with potentially significant energy production loss due to icing conditions.

Of the seven potential projects sites profiled in this report, only Kluane Lake is relatively low elevation and likely largely free of significant rime icing potential. Kluane Lake aside, significant rime ice mitigation investment will be necessary for successful wind turbine operations during the all-important winter season when YEC's hydropower resources are less productive. For the remaining six higher-elevation, mountainous sites, anti-icing and de-icing (passive and active) are recommended[19] unless site-specific met tower or Lidar data and modelling prove they would not be necessary, or are not cost effective.

Atmospheric rime icing and wind turbine icing mitigation are complex topics and a truly comprehensive analysis for Yukon wind energy production is beyond the scope of this project. Besides the papers and reports already mentioned in this section, the reader is urged to consult the following additional sources for papers, presentations, and background information. Beyond that, prospective wind turbine site wind data that includes direct or inferred ice detection is highly recommended.

Also recommended is participation in Winterwind International Wind Energy Conference, sponsored by the Swedish Windpower Association and held annually – typically in February – in Swe-

[19] Note that Enercon sells all its turbines in Canada with de-icing kits.

den, and the recently-organized Optimizing Wind Farms in Cold Climate conference, most recently held in Helsinki, Finland in December 2015.

Recommended Reading:

- Lasko, Timo et al, *State-of-the-art of Wind Energy in Cold Climates*, VTT Working Papers 152, October 2010
- Tammelin, Bengt and Seifert, Henry, *Large Wind Turbines go into Cold Climate Regions,* paper presented at European Wind Energy Conference, Copenhagen, Denmark, 2001
- Winterwind 2016 conference presentations: http://winterwind.se/program/presentations-2016/
- Winterwind, previous conferences (navigate to find presentations): http://winterwind.se/previous-conferences/

6.2 Birds and Parks

For any wind farm, a detailed bird and bat impact study needs to be completed. For this assessment, we have merely reviewed a few key sites of interest to highlight potential conflicts with wildlife and parks.

Three major migration routes through the Yukon are identified on birdnature.com:

1. The *Pacific Flyway (*gulls, ducks and other water birds*)* leads from the delta of the Yukon River in Alaska through the southern area of the Yukon (Dawson and Whitehorse) into BC and then the US and Mexico.
2. The *Central Flyway* uses two parallel routes from Alaska through the Yukon and BC/Alberta into the central US.
3. The *Mississippi Flyway* (ducks, geese, shorebirds, blackbirds, sparrows, warbler and thrushes,) stretches all the way from Alaska to the Mississippi Delta, passing by the northern end of the Rocky Mountains and crossing the Prairies.

Many of the birds will fly through the Tintina Trench,[20] which crosses the Yukon diagonally from the southeast to the northwest and lies further north than most of the proposed wind sites. The Trench crosses the Campbell Region in the south-central Yukon, close to the Ross River sites and also along Tehcho and Willow Hill. The area is known as one of the best migration observation sites in the Yukon.[21] No major concerns may exist as the birds usually migrate through the middle of the trench and not along the higher elevations to the side where potential sites were identified.

[20] http://sightsandsites.ca/central/site/tintina-trench
[21] A BIrder's Checklist of the Faro and Ross River Region. Yukon Environment, 2003

Further south lies the Shakwak trench, which is also a bird migration pathway. The Shakwak Trench is between eight and 12 km wide and stretches from the southern end of Kluane Lake towards Haines Junction. The Paint and Hard Time Mountain sites are close to this pathway, and the Kluane Lake sites are situated towards its end.

A birdwatching area is situated in the vicinity of the Minto Hill and Sugarloaf Mountain sites, at Tagish Bridge Recreation Site.[22] In the same general area, the Swan Haven Interpretive Centre, about 45 km south of Whitehorse, is located on the shores of M'Clintock Bay on Marsh Lake, YT. This area is one of the first areas of open water every spring and, combined with a delta formed by the M'Clintock River, creates a rich foraging area attracting swans, geese, ducks, gulls, and shorebirds in the spring. At the northern end of Marsh Lake lies the Lewes River Marsh, which is likewise important bird habitat. The turbine sites do, however, appear to be far enough from these sensitive areas.

The Anticline Mountain site lies in the same area as the Aishihik Lake Campground, which is a habitat for waterfowl. Again, the site is somewhat removed from the lake so as to avoid impacts on birds.

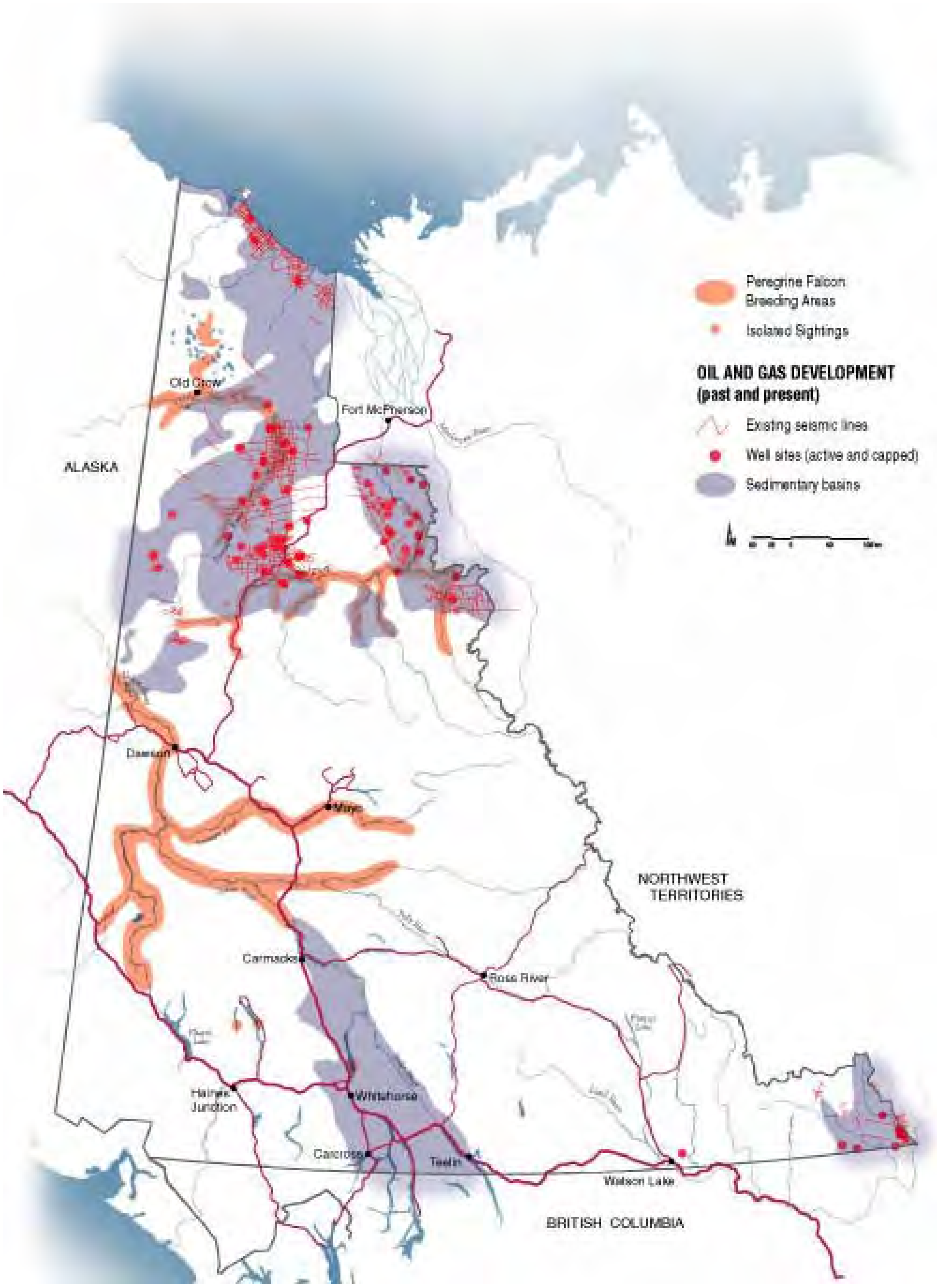
Figure 53 Eagle Migration Zones

Source: http://eaglewatch.ca/wp/wp-content/uploads/2013/04/migration-sites-ab_1.jpg

The Yukon is also an important area for eagles. Figure 38 shows the general migratory path for eagles and their territory, which stretches from the Yukon into Alaska. Deaths of Golden Eagles and other eagle species due to collisions with wind turbines and cables have been the reason for controversy around wind park development in the US in recent years.[23] As for peregrine falcons, it appears that their habitat around Stewart Crossing lies between the wind sites identified in this area (Wareham/Site 16, Willow Hills) and does not overlap (Figure 54).

[22] http://www.env.gov.yk.ca/animals-habitat/bestviewingsites.php#Hwy8
[23] See http://planetark.org/wen/74421

Figure 54 Peregrine Falcon Habitat[24]



6.3 Comparison to Recent Site-Specific Consultant Reports

Two reports, one on the Tehcho site (full report) and one on the Mt Sumanik site (wind monitoring results for June 2016 only), were either recently prepared or are currently being completed for YEC. As can be expected from the use of different models, there are some differences between the yield estimated between these reports and this one. These cannot be fully explained without more

[24] Source: http://www.cpawsyukon.org/images/map-oilgas-peregrines.jpg

detailed comparisons as to the specific assumptions made and mode inputs used but Table 19 provides a brief appreciation of these differences and offers some high-level conclusions.

Table 19 Comparison of AWS Results to Site-Specific Report Results

Site	This Report	Consulting Reports	Comments
Mount Sumanik	The actual summit of Mt. Sumanik (location of the ZephIR Lidar unit) seemed an unlikely location for wind turbines considering that the best approach route for a road is that quarry on the north side. Plus, winds modeled higher on the ridges north of Mt. Sumanik than on the summit itself, hence also why the AWS data point was not on the actual summit.	In June, the ZephIR wind monitoring report[1] recorded a mean wind speed of 5.88 m/s (at 76 m) and AWS predicts 3.98 m/s (at 80 m).	The ZephIR report covers only the month of June, wind data is not corrected for long-term variability and uses a different location (about 2.2 km from the one used in this report). Data are therefore not directly comparable. Once monitoring data for a complete year is available, AWS model outputs could be compared to the outputs obtained by the model used by ZephIR.
Tehcho	AWS data was used, not monitoring data, to remain consistent with how the other sites were assessed. AWS estimated a wind speed of 5.8m at 80 meters. Annual net output is 33 GWh per year for a 20 MW wind farm. The same GE 1.7-100 turbine was used for modeling.	Average wind speed at 60m is 5.7m, which is in line with about 5.8m at 80m height based on AWS. Annual energy production is higher in the *Natural Power* (NP) report[2] (54 GWh per year for a 25 MW wind farm- considerably higher than what would be expected from the results of this report) than this report but it is not clear why that is so without having access to the underlying data and assumptions.	Data recovery from the met tower – note that this was highlighted as well in the earlier reports that we were sent – was highly problematic with long periods of missing data and lots of icing problems. This data was corrected to create a complete data set, but that is an imperfect process. Generally, the site does not appear to be a good side whether AWS of NP outputs are used.

[1] Post-QC Anemometry Summary: Mt Sumanik (DRAFT), ZephIR-300 Monitoring Results from June 2016
[2] McDonald, Scott: Ferry Hill Wind Project – Indicative Energy Yield Assessment. Natural Power, Saratoga Springs, NY, December 2014

7 PRELIMINARY PROJECT SCHEDULE

Developing a wind farm in the Yukon will likely take three to four years. This includes the following phases:

Year 1: Wind monitoring campaign – a necessary basis for an investment decision. While the campaign will be for two years, one year of data collection should suffice to make a go/no-go decision on whether to proceed.

Year 2: Project development phase: permitting, financial engineering and stakeholder involvement. Except for the geotechnical assessment, all of these tasks are off-site. Based on the results of the assessment during the first half of this phase, a decision to go ahead will have to be taken. Tasks such as detailed engineering and negotiations will only take place after this decision has been taken. Wind monitoring continues during the second year.

Year 3: Site preparation: access to and preparation of the site.

Year 4: Erection of turbines, grid intertie and commissioning. The schedule for this phase is rather tight and may have to be stretched over two years. An early start with pouring concrete for the foundations in April will require covering the area with plastic and heating the interior. If the work started in May there might be scheduling problems with turbine erection by October (a minimum of one month curing should be allowed, pushing the erection of the towers towards the end of the construction season).

The schedule laid down in Figure 55 is for a 20-MW wind farm with no existing access road. The earliest in-service date would be October 2020, provided the wind measurement campaign starts no later than June 2017.

For sites with existing access roads or for smaller wind farms, the schedule may be more relaxed. The wind farms in Kodiak and Kasigluk, Alaska took four years to develop,[25] although subsequent farms may have been realized in shorter timeframes.

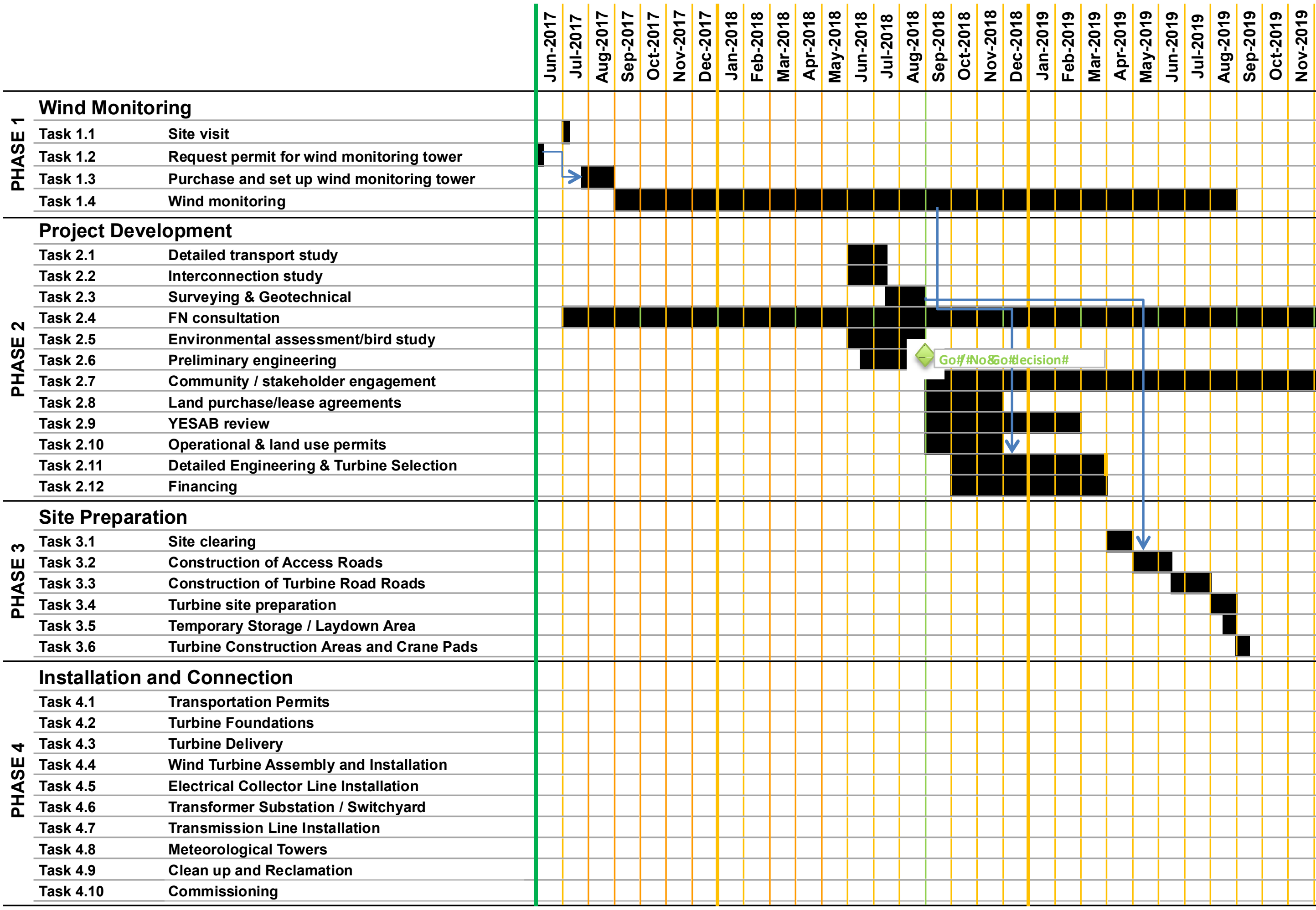
Erecting wind turbines is constrained by weather and wind conditions (wind speeds must be below 10 m/s), i.e. the process for a 20-MW wind farm may take three months due to waiting periods until conditions allow each turbine to be erected. There are also periods when heavy loads may not be allowed on the road (shoulder seasons). Generally, we assume:

- One year of wind monitoring must precede any development;
- Sites with existing good road access could be constructed within a single construction season;
- Sites where extensive road construction is necessary would be built over two construction seasons.

Risks identified in the next chapter may extend the schedule. Notably, it may take up to two years to obtain the necessary permits, which would add to the time required to complete the project.

[25] COMMUNITY WIND TOOLKIT: A Guide to Developing Wind Energy Projects in Alaska Renewable Energy Alaska Project (REAP) March 2011

Figure 55 Preliminary Project Schedule



8 RISK ASSESSMENT

8.1 Introduction

This chapter provides a high-level[26] risk assessment of wind-farm construction. Table 20 summarizes the risks and mitigation measures. Given that YEC would be developing the first commercial-scale wind farm in the Yukon, risks relating to construction expertise and permitting need to be more carefully considered.

8.2 Key Risks

Permitting: Whereas YEC is likely able to obtain all necessary permits for a wind farm, there may be unexpected delays with obtaining permits due to the inexperience of permit authorities with this type of project. Also, projects involving multiple levels of permit authorities (municipal/First Nation, territorial, federal) may incur additional delays as one permit may depend on another, or additional studies and requirements may be imposed. In Alaska, permitting for typical wind projects can take anywhere from two to four years once the site is selected. Permitting should therefore be initiated fairly early in the process (once siting is confirmed and land purchasing is reasonably underway) to reduce this risk. A project development consultant may be of assistance in securing permits and providing project experience from other wind farms in Canada to authorities to facilitate the process, and ensure best practices are applied to project design, construction, and operation.

Stakeholders' opposition: It is best practice to involve stakeholders early in the project development process. This will help identify issues early on and will help design the project so its impacts on stakeholder interests are lessened. Also, land ownership issues can be addressed early to conclude agreements on compensation or land leasing so the project can move forward smoothly. Given that most of the recommended seven sites are on Commissioner's land and the interest by Yukon aboriginal groups in wind power project development, we do not anticipate major resistance against wind projects, and have not classified this as a 'high risk' area. Still, interest groups need to be identified early and included in discussions around project design, also addressing any economic interests stakeholders may legitimately have in the project.

Schedule risk: Due to the short construction season in the Yukon (likely even shorter at the selected locations due to their elevation), there is considerable risk associated with construction activities. We have built extra days into the schedule (Chapter 7) to account for weather-related delays. Nevertheless, several components may cause delays, including turbine and crane transport, availability of key personnel and permitting delays. These risks can be mitigated by contracting out project construction to an experienced EPC company. Usually, turbine vendors will function as EPC contractors for turbine delivery and erection. They will then confirm a realistic schedule, identify the best transport routes and methods, and also look after turbine erection. They may also cooperate with local companies for site preparation, access road and line construction, and the electric and foundational works required. Otherwise, YEC may look after site preparation and civil works based on the specifications provided by the turbine vendor.

[26] For a more in-depth treatment of wind-farm-related project risks, consult http://writepass.com/journal/2012/11/risk-assessment-of-a-wind-farm/

Icing risk: This will essentially be dealt with through de-icing devices integrated into the turbines. However, during the wind monitoring phase, icing should also be monitored to quantify this risk. As mentioned above, the report on the Mt Sumanik wind farm identified a potentially severe icing risk, which may lead to severe power output losses during winter, even with de-icing measures. If icing is too severe and would reduce power output by more than 10% (with de-icing measures), the site may have to be abandoned as unsuitable for wind power production.

Curtailment: This risk is more likely to occur during the summer than during winter, given the Yukon's electricity consumption profile. However, curtailment during the summer will negatively affect the economic performance of the wind farm. This aspect was not the subject of the current study but needs to be assessed when deciding on wind farm siting and size.

8.3 Lesser Risks

Financial: As a utility, YEC is well positioned to develop and finance a wind farm. As such, no major risks are related to financing. We identified currency exchange risk as one potential financial risk. This risk can be monetized by a forward currency purchasing contract. A 30% increase in turbine costs and some labour costs would only result in about an 11% increase in the project budget though.

Transport: Transportation can become a major issue when the existing infrastructure is insufficient. The heavy 550 t crane required to set up large-scale turbines as proposed in this study weighs about 90 tonnes (it can be disassembled; the counterweight alone weighs 36 tonnes). Any weight above 77 tonnes will require a special permit from Yukon Highways and Public Works. It is uncertain that such a permit can be granted for all sites, however. Length is another restriction: trucks transporting turbine blades can be 60 m long or more, making navigation around needle turns difficult or impossible. Also, the access road to be built needs to be smooth and have a gradient no steeper than about 10-14%. Wherever a transport study shows that it is not possible to bring the required equipment to the site, infrastructure must either be specially built, equipment transported in sections and reassembled at the site, or smaller turbines could be selected to reduce transport bottlenecks.

Wildlife and vandalism: Two problems may arise with respect to wildlife. During the environmental assessment, sensitive areas may be identified near the site, which could require changing transmission or access road routes to avoid harming protected species. Wild animals can also be a hazard for workers on site and may have to be deterred from accessing the site either by fencing the area or using other deterrents. Vandalism may also be a risk in some areas. A developer should speak to locals to identify both wildlife and vandalism risks and take countermeasures if need be.

Delivery: Related to schedule risk, deliveries of equipment and turbine sections may be delayed due to vendor-caused delays, weather events or other unforeseen problems with transport, such as accidents or truck breakdowns. Usually, this risk is contractually passed on to the vendor within a turbine purchasing contract that essentially makes the vendor an EPC contractor for timely delivery and turbine erection.

Some other issues have not been included in the tables such as ice throw (turbine sites are remote), budget risks (will be reduced at the detailed engineering stage and are addressed by contingencies), inflation or interest rate changes (thought to be low at this time in Canada), bankability (YEC as the project developer expected to provide value of a PPA), engineering risks/design failures (typically mitigated by assessing company capabilities through an RFP process), and accidents (covered by insurance; adequate on-site worker training presumed).

Table 20 Risk Factors and Mitigation

Risk	Importance	Probability	Impact	Mitigation
Currency exchange increases cost of turbines and some services	Low	High	Low	Obtain binding quotes; rely on Canadian labour and material inputs as much as possible
Icing events reduce turbine output	High	High	**High**	Icing monitoring and de-icing measures
Schedule/weather risk during construction	High	Medium	**High**	Provide conservative timeframes for construction; split up construction over two years; contract out project to an EPC firm to pass on risk to contractor
Operational risk	High	Low	Low	Obtain servicing contracts and warranties; buy new turbines with a cold-weather track record; keep crucial spare parts near site; stall turbines at temperatures below -30 °C
Wind resource variability and turbine choice	Medium	Low	Low	Obtain more than 12 months of monitoring data, select turbine late in project development process based on monitoring results
Local operation/know-how	High	Low	Low	Train two technicians to perform routine turbine maintenance
Curtailment/financial losses	High	High	**High**	Assess capacity of grid to absorb wind farm output and size farm accordingly
Community protest against wind farm	High	Medium	Medium	Engage community and stakeholders early in the process; offer co-benefits to landowners; select sites to avoid scenic, tourist, heritage or recreational locations; confirm low wildlife impacts through environmental assessment
Crane and nacelle transport may exceed permissible weight and length thresholds	High	Medium	Medium	Work with authorities early in the process to determine best routes; provide adequate road access to site; split up components where possible; select smaller turbines if necessary

Risk	Importance	Probability	Impact	Mitigation
Permits take longer than expected	High	High	**High**	Work with authorities early in the process; provide examples from other jurisdictions for authorities; follow best practices in terms of siting, signalization, access road and transmission routing; contract a development consultant to deal with permitting
Wildlife & vandalism risk	Medium	Medium	Medium	Assess potential of appearance of protected and/or hazardous wildlife (e.g., wolves, bears) at planned site and take mitigation measures if needed to ensure worker safety or take precautionary measures to protect wildlife during construction; set up guards if there is a perceived risk of vandalism
Delivery risk	High	Medium	Medium	When purchasing turbines and scheduling machinery, include damage clauses in contracts in case of delays caused by the vendor

9 CONCLUSIONS AND RECOMMENDATIONS

This study identified 26 potential sites for wind farms. Of these, 17 were considered further and seven selected for a detailed analysis. The selection process was tailored to the prerequisites of the project. These prerequisites may change over time. The shortlist should not be taken as final and YEC may want to look further into some of the sites that were not selected.

Of the seven sites selected, five show an above-average performance in terms of the cost of energy produced. These sites are, in the order of performance, Kluane Lake, Miller's Ridge near Carmacks, and a mountain ridge near Cyprus Mine, close to Faro. There is not a lot of difference in energy production cost between these five sites; non-monetary factors may play an important role in selecting the preferred location.

Miller's Ridge near Carmacks and Thulsoo Mountain near the Aishihik hydroelectric facility are the sites with the highest wind resource and a low cost of energy (LCOE). Thulsoo Mountain is near an existing facility, but Miller's Ridge has more expansion potential. Sumanik Mountain is attractive due to its location near Whitehorse. Cyprus Mountain is the furthest from Whitehorse, but appealing due its brownfield nature next to an abandoned mine. Kluane Lake gets a qualified recommendation because of its low elevation and low energy costs (LCOE), but requires a transmission line first. Tehcho and Sugarloaf are not recommended because the other site options clearly are superior, both in terms of annual energy production and energy cost.

The levelized cost of energy (LCOE, assuming no curtailment) at almost all sites and all sizes remains under the standard offer price of 21 ¢/kWh but many are still above the average residential retail price of 12 ¢/kWh. Financially, the sites at Sugarloaf and at Kluane Lake perform best in terms of capital costs. In terms of LCOE, the Miller's Ridge site (20 MW) performs best but is closely followed by the Thulsoo and Kluane Lake sites, despite the mediocre wind regime of the latter. This can be explained by the very short transmission connection required once the new line is built. Also, less rime icing and less frequent low temperature curtailment helps to increase the net energy generation at Kluane Lake. Though there are plans, currently there is no transmission line at this site.

Our modelling assumes that all energy produced will be used. Curtailment of the operation during the summer when YEC has a surplus of power would increase the cost of energy produced during the rest of the year by more than a third. This needs to be considered when assessing the sites. If the update to YEC's 20-year plan yields that wind power is a viable source of electricity, then further research should be done on the five sites mentioned above. We recommend a full-scale feasibility study for one or all of the five top sites. This includes, but is not limited to:

1. Wind velocity, temperature and rime ice monitoring;
2. Determining the maximum size of the wind farm;
3. Modelling of monthly power generation based on monitored data;
4. Modelling and selection of various wind turbine models and sizes;
5. Review of the geotechnical conditions on site and procuring LIDAR elevation maps;
6. Conceptual design of roads and their routing;
7. Capital costing based on quotes;
8. Review of service contracts and costs;
9. Transportation study.

YUKON Wind Site Inventory

Appendices

RFP 2015-060

Prepared for:

YUKON ENERGY

Prepared by:

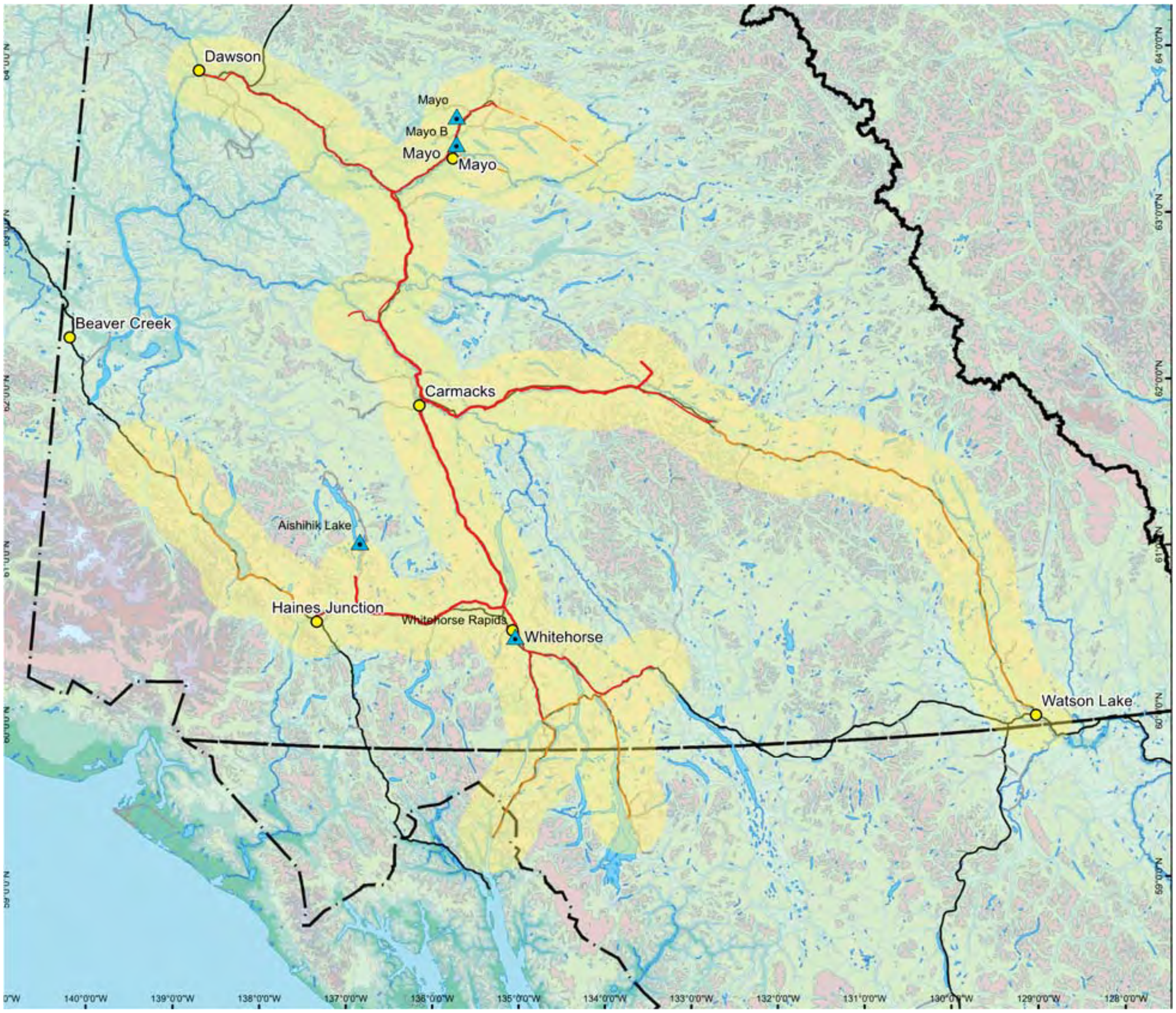
CBER

with

envint Consulting *and* V3 Energy, LLC

August 24, 2016

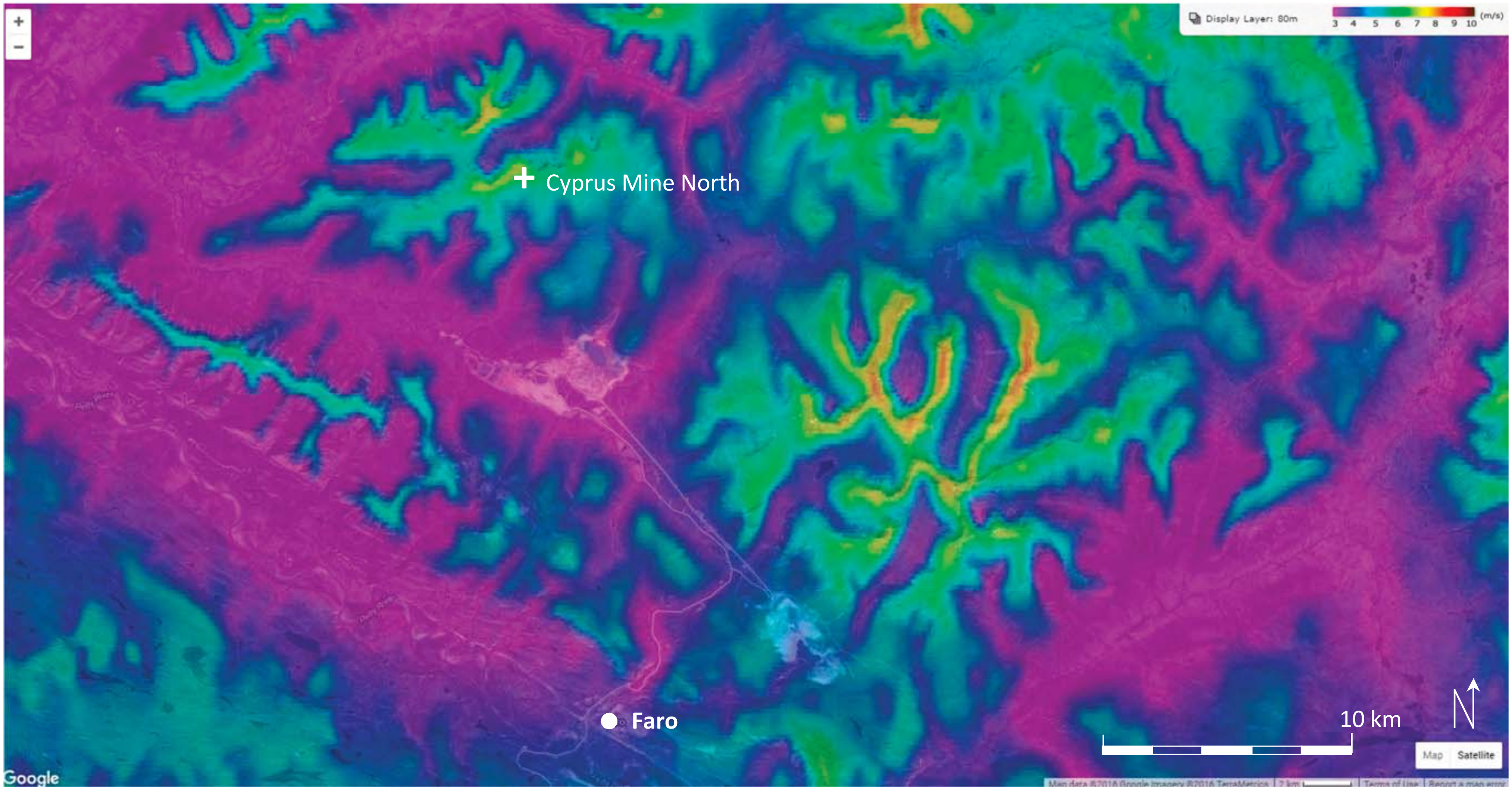
APPENDIX A – YUKON POWER TRANSMISSION INFRASTRUCTURE MAP



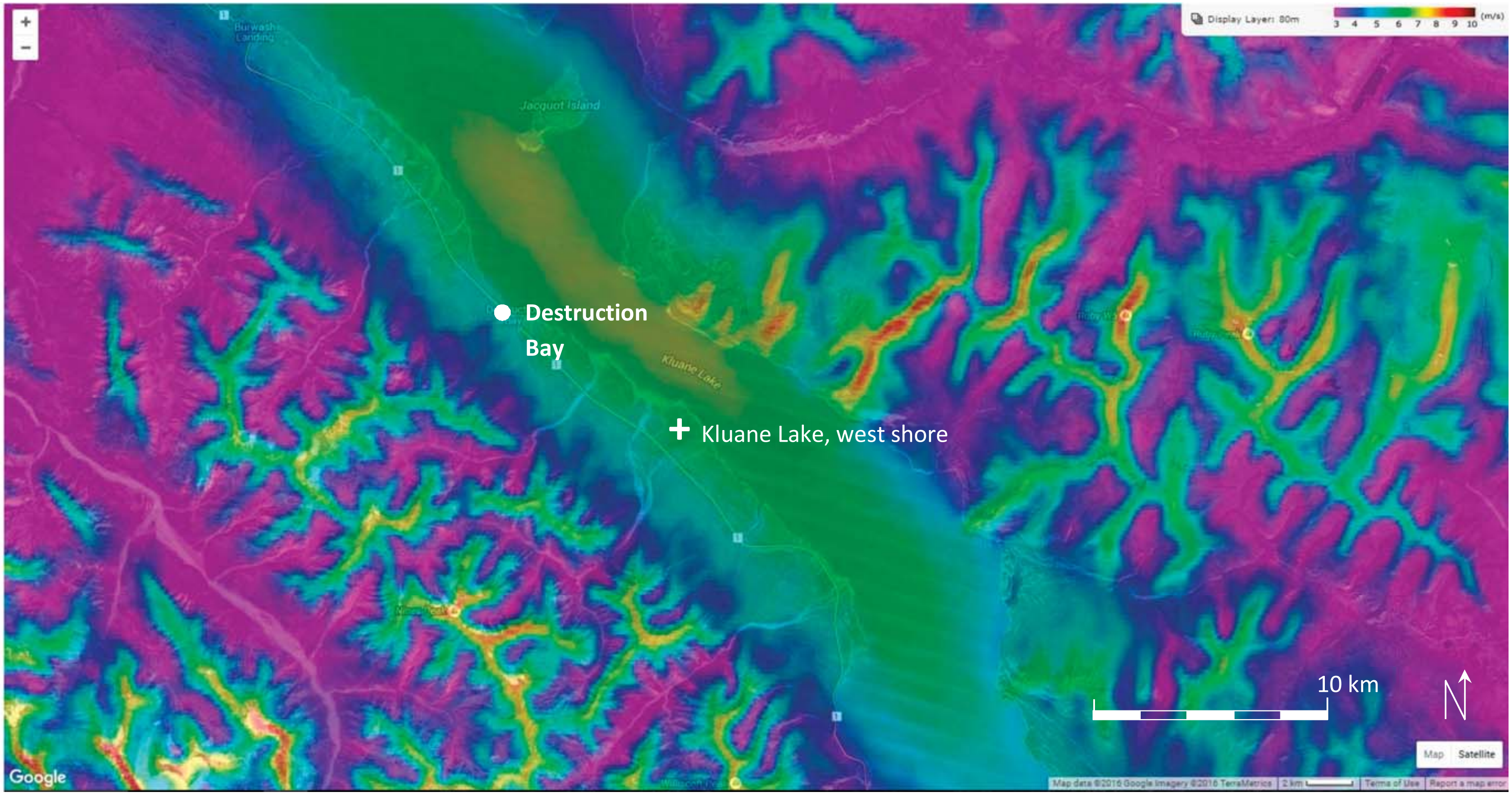
Note: Red lines = existing transmission lines; beige lines = planned lines (Source: YEC)

APPENDIX B – SELECTED SITES AWS TRUEPOWER WIND MAPS

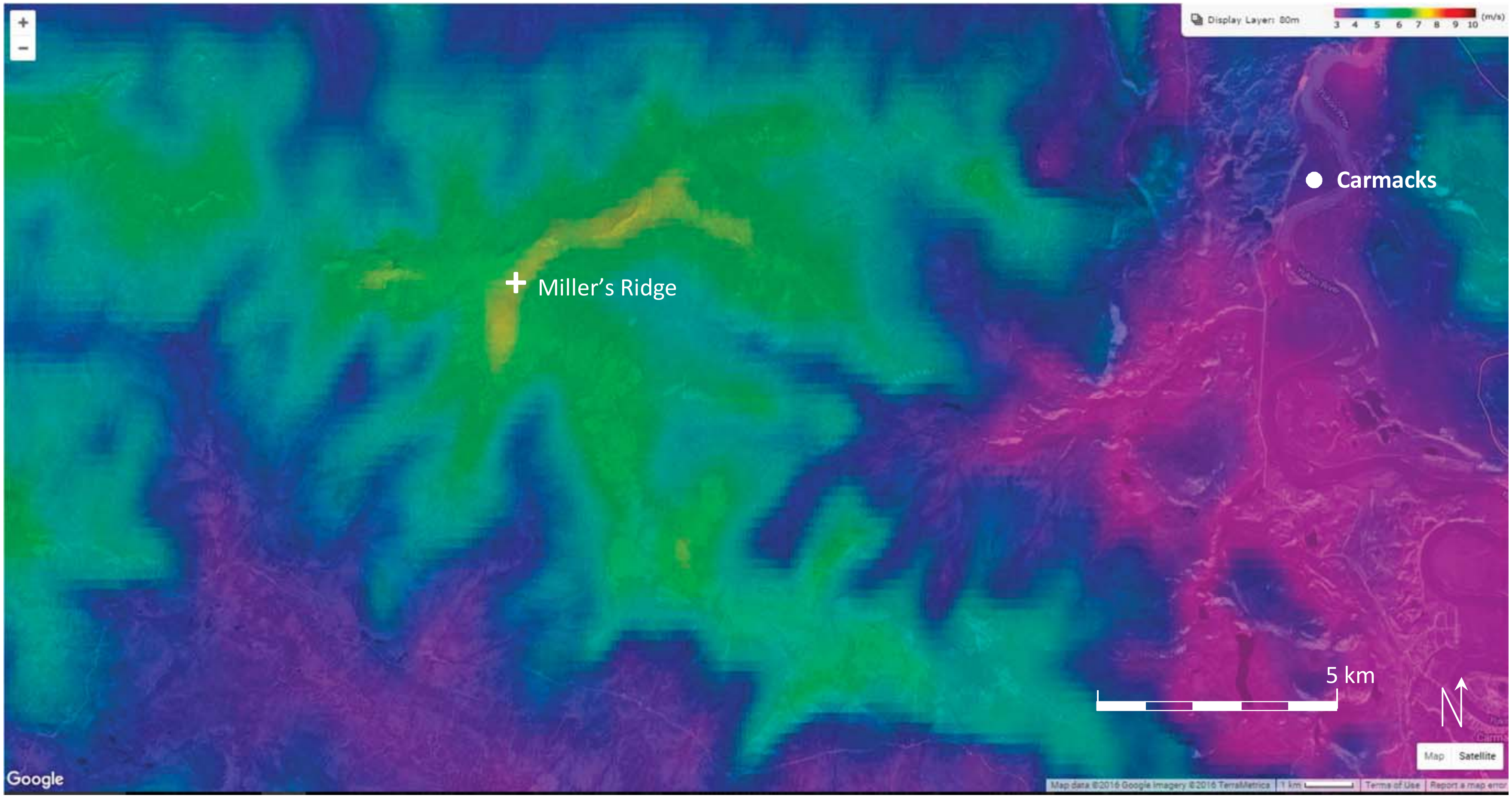
Cyprus Mine



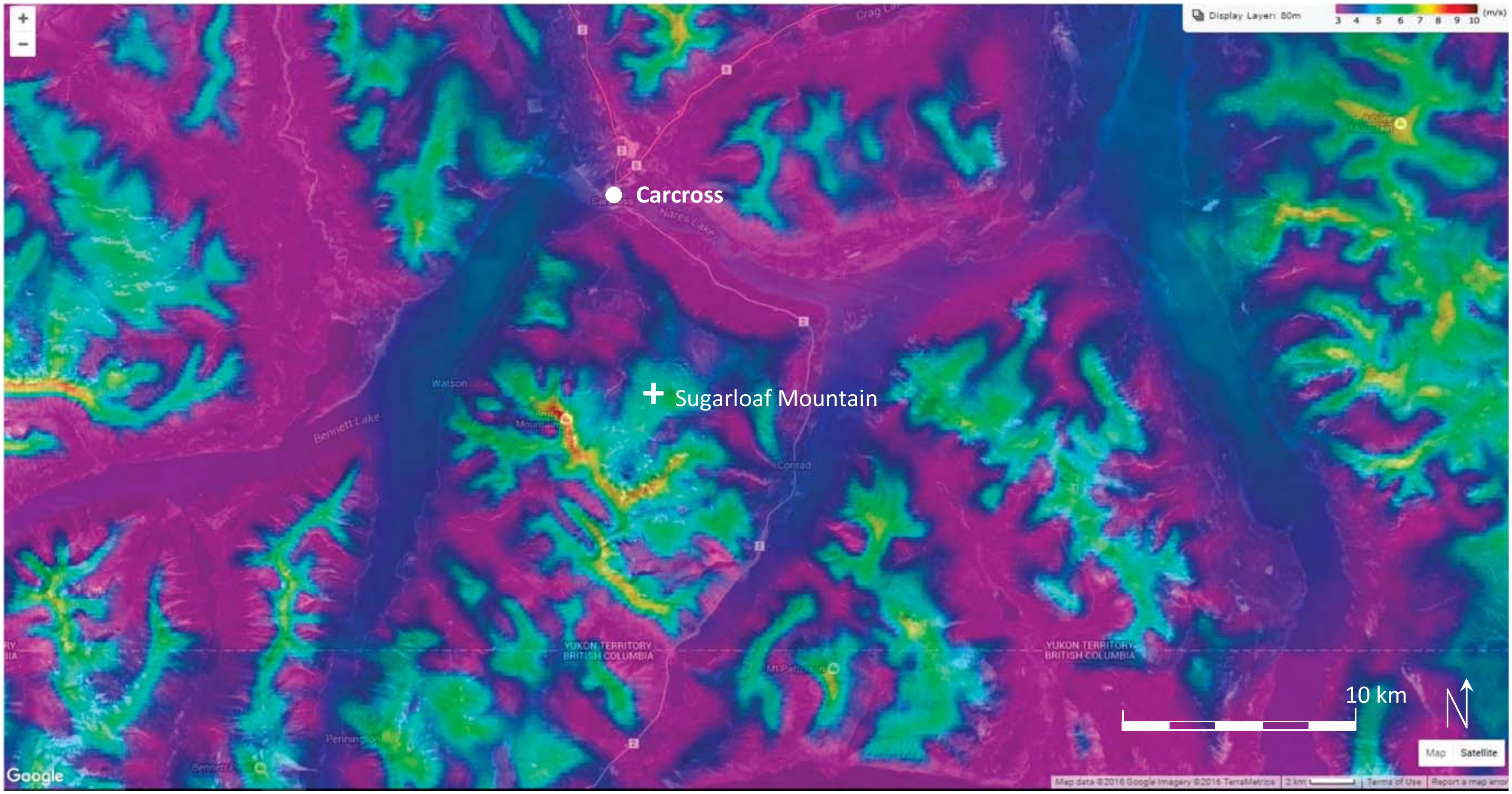
Kluane Lake (West)



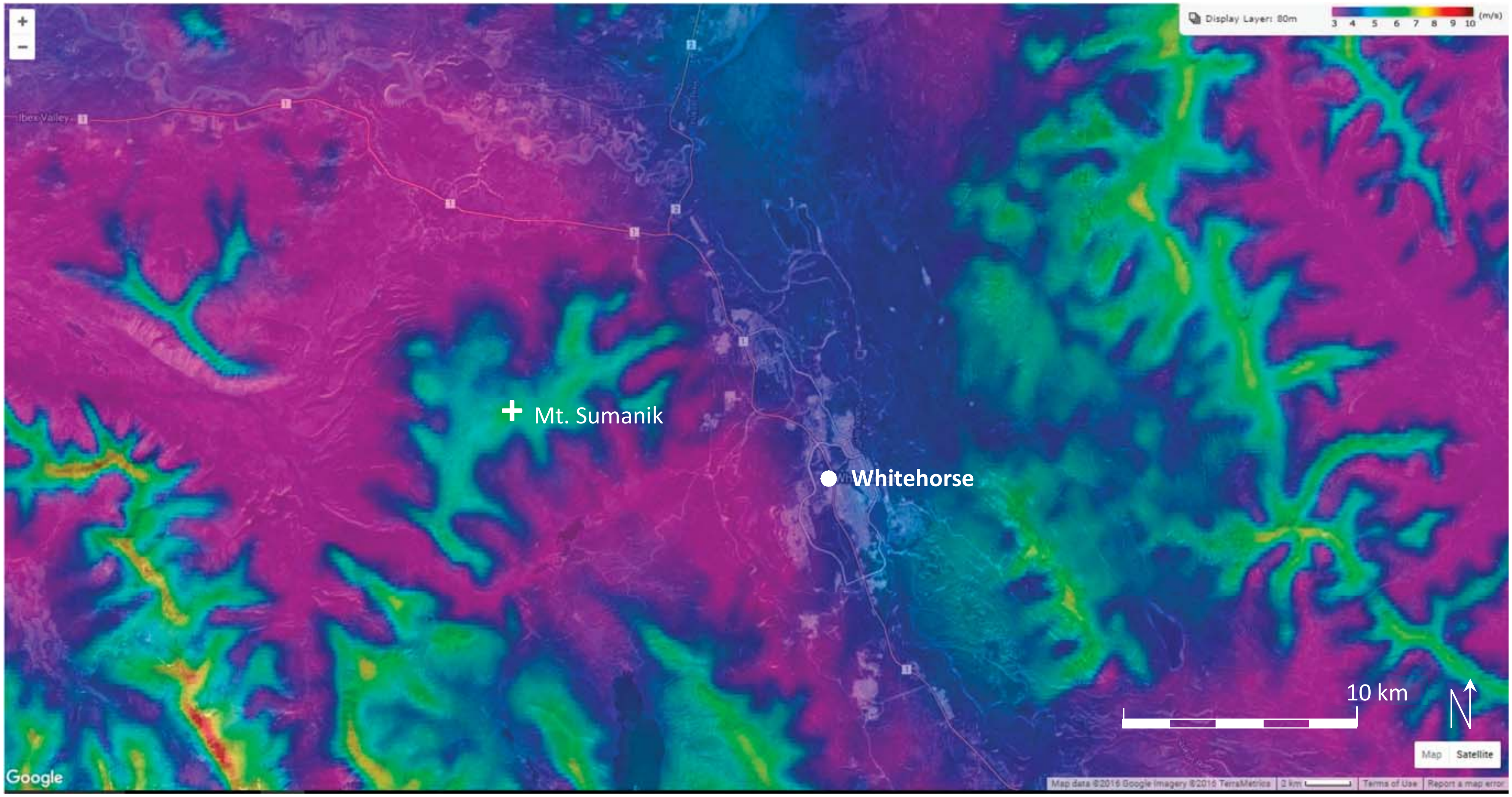
Miller’s Ridge



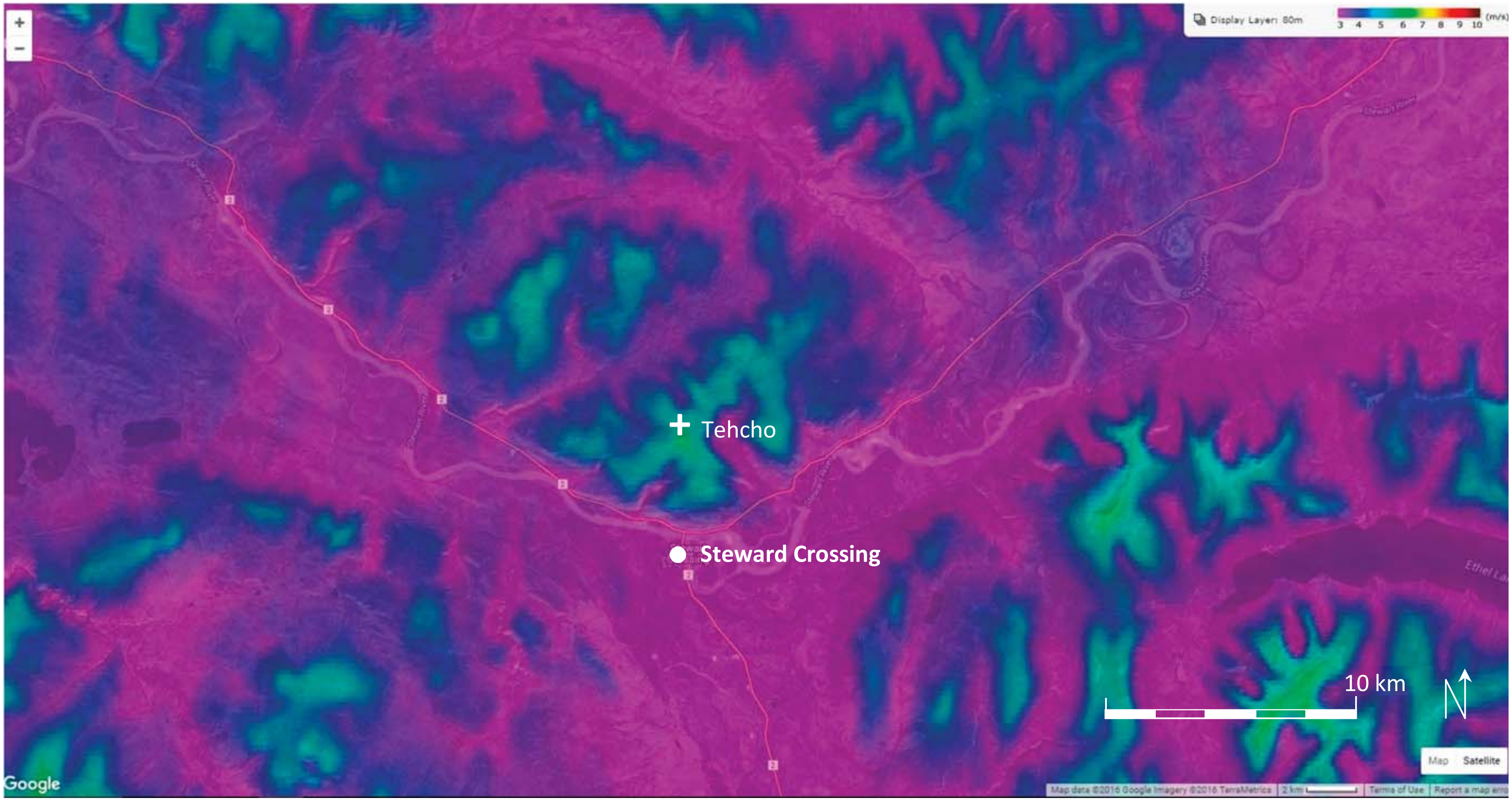
Sugarloaf Mountain



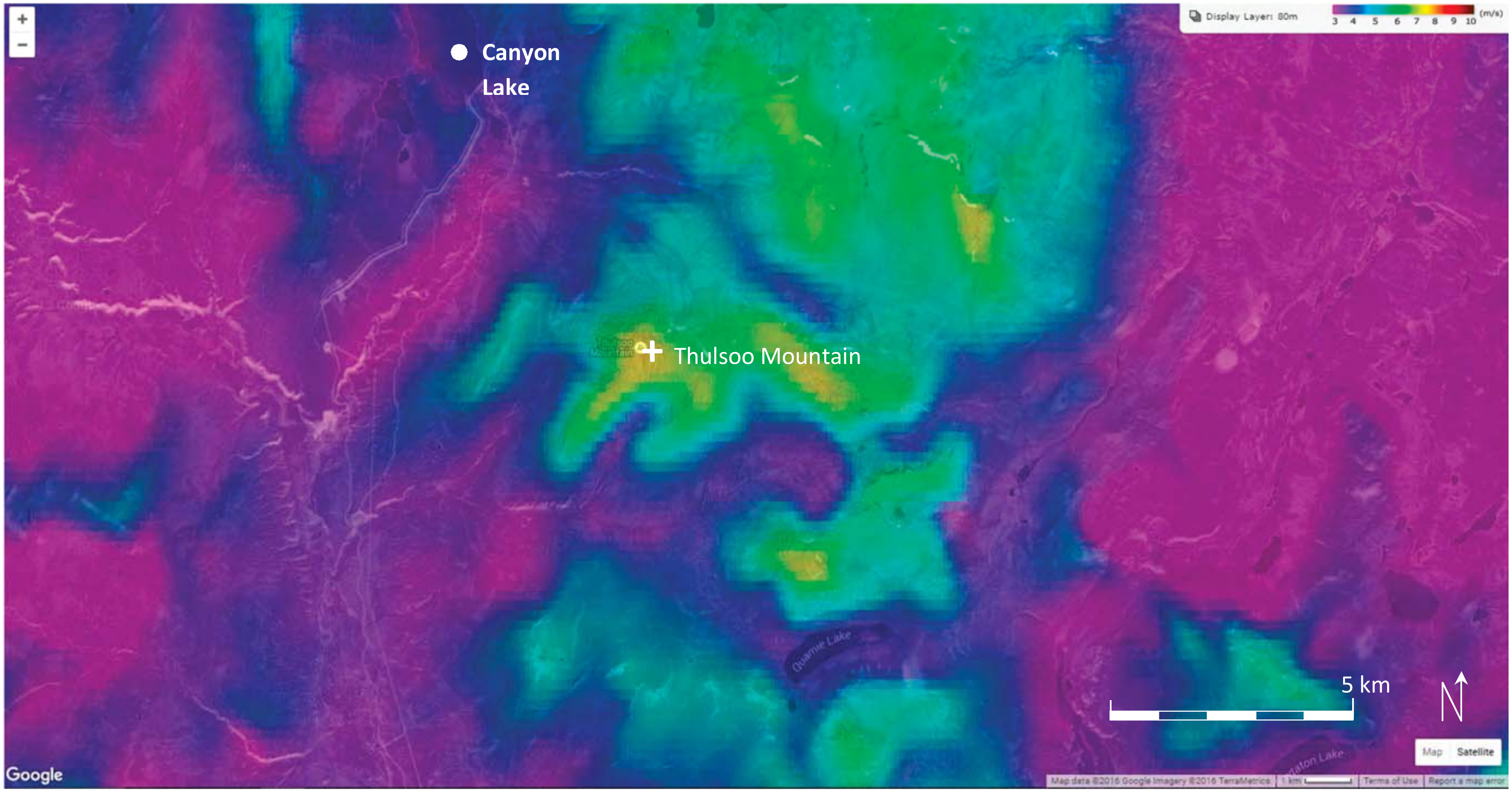
Mount Sumanik



Tehcho


Display Layer: 80m
3 4 5 6 7 8 9 10 (m/s)
Tehcho
Steward Crossing
10 km
N
Map
Satellite
Google

Thulsoo


Canyon Lake
Thulsoo Mountain
5 km
N
Display Layer: 80m
3 4 5 6 7 8 9 10 (m/s)
Map
Satellite
Google

APPENDIX C – CAPITAL AND OPERATIONAL COST SHEETS

SUMMARY

Capacity: 6 MW (3 x 2 MW)

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
	Nameplate capacity of turbine type	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW
	Number of turbines	3	3	3	3	3	3	3

CAPEX AND DEVELOPMENT COSTS

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
1	**LOGISTICS**							
1.1	Transportation cost	$ 1,941,900	$ 1,838,400	$ 1,842,000	$ 1,593,600	$ 1,658,400	$ 1,974,300	$ 1,793,400
1.2	550-tonne crane	$ 470,000	$ 470,000	$ 470,000	$ 470,000	$ 470,000	$ 470,000	$ 470,000
1.3	Erection cost	$ 1,350,000	$ 1,350,000	$ 1,350,000	$ 1,350,000	$ 1,350,000	$ 1,350,000	$ 1,350,000
1.4	90-tonne crane for lay down etc.	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000
2	**CIVIL**							
2.1	Geotech report	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000
2.2	Access road	$ 1,712,500	$ 359,000	$ 3,440,250	$ 330,750	$ 1,570,000	$ -	$ 2,963,250
2.3	Turbine road	$ 732,000	$ -	$ 227,000	$ 326,250	$ 221,750	$ 242,250	$ 228,000
2.4	Cement supply for foundation	$ 652,500	$ 517,500	$ 517,500	$ 517,500	$ 342,000	$ 630,000	$ 517,500
2.5	Cost of rebar including delivery	$ 347,228	$ 347,228	$ 347,228	$ 347,228	$ 347,228	$ 347,228	$ 347,228
2.6	Foundation installation cost	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000
3	**ELECTRICAL**							
3.1	Capacity of site							
3.2	Low voltage step-up transformers	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000
3.3	Collection system	$ 705,600	$ 120,000	$ 301,600	$ 381,000	$ 297,400	$ 313,800	$ 302,400
3.4	Substation (step up transformer & switching yard)	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000
3.5	Interconnection to exising transmission line	$ 4,481,100	$ 785,655	$ 7,897,500	$ 2,234,700	$ 2,558,790	$ 1,959,750	$ 6,047,145
3.6	Line-tap & protection system	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
4	**LABOUR**							
4.1	Labour/wage for misc. construction-related activities	$ 2,600,000	$ 2,600,000	$ 2,600,000	$ 2,600,000	$ 2,600,000	$ 2,600,000	$ 2,600,000
4.2	Accomodation and per diem	$ 487,500	$ 487,500	$ 487,500	$ 487,500	$ 487,500	$ 487,500	$ 487,500
5	**FINANCING COST**							
5.1	Legals for financing closing & independent engineer	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000
5.2	Lender charges	$ 510,000	$ 380,000	$ 570,000	$ 420,000	$ 440,000	$ 420,000	$ 540,000
6	**SITE COST**							
6.1	Land cost	$ 546,646	$ -	$ 827,777	$ -	$ 433,240	$ 138,917	$ 681,297
7	**DEVELOPMENT COST**	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000
8	**EQUIPMENT**	$ 7,200,000	$ 7,200,000	$ 7,200,000	$ 7,200,000	$ 7,200,000	$ 7,200,000	$ 7,200,000
9	**CONTINGENCY**	$ 3,094,697	$ 2,366,528	$ 3,528,835	$ 2,546,853	$ 2,718,631	$ 2,534,374	$ 3,273,772
10	**TOTAL**	$ 34,041,671	$ 26,031,811	$ 38,817,190	$ 28,015,380	$ 29,904,938	$ 27,878,119	$ 36,011,492

OPERATING & MAINTENANCE COSTS

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
1	**ANNUAL NET PRODUCTION**	**16,111 MWh/yr.**	**14,955 MWh/yr.**	**18,110 MWh/yr.**	**9,889 MWh/yr.**	**14,180 MWh/yr.**	**10,300 MWh/yr.**	**17,269 MWh/yr.**
2	**O&M COSTS PER YEAR**	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5
2.1	Owner Staff	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
2.2	Office	$60,000	$60,000	$0	$0	$0	$0	$0
2.3	Insurance	$51,063	$39,048	$58,226	$42,023	$44,857	$41,817	$54,017
2.4	Land lease	$0	$12,642	$0	$25,668	$0	$0	$0
2.5	Vendor Service	$283,215	$246,660	$316,530	$170,685	$246,765	$181,230	$303,525
2.6	Royalties, land leases, FN/Community Payments	$0	$0	$0	$0	$0	$0	$0
2.7	Contingency	$59,428	$55,835	$57,476	$43,838	$49,162	$42,305	$55,754
2.8	**TOTAL per year**	$653,705	$614,184	$632,231	$482,214	$540,785	$465,352	$613,296
2.9	Fixed cost	$311,063	$311,689	$258,226	$267,691	$244,857	$241,817	$254,017
2.10	Variable costs	$342,643	$302,495	$374,006	$214,523	$295,927	$223,535	$359,279
3	**SPECIFIC COSTS**							
3.1	Fixed cost per MWh (net)	$19.31	$20.84	$14.26	$27.07	$17.27	$23.48	$14.71
3.2	Variable costs per MWh (net)	$21.27	$20.23	$20.65	$21.69	$20.87	$21.70	$20.81
3.2	**Total O&M cost per MWh (net output)**	**$40.58**	**$41.07**	**$34.91**	**$48.76**	**$38.14**	**$45.18**	**$35.52**

SUMMARY

Capacity: 10 MW (5 x 2 MW)

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
	Nameplate capacity of turbine type	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW
	Number of turbines	5	5	5	5	5	5	5

CAPEX AND DEVELOPMENT COSTS

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
1	**LOGISTICS**							
1.1	Transportation cost	$ 3,236,500	$ 3,064,000	$ 3,070,000	$ 2,656,000	$ 2,764,000	$ 3,290,500	$ 2,989,000
1.2	550-tonne crane	$ 650,000	$ 650,000	$ 650,000	$ 650,000	$ 650,000	$ 650,000	$ 650,000
1.3	Erection cost	$ 2,250,000	$ 2,250,000	$ 2,250,000	$ 2,250,000	$ 2,250,000	$ 2,250,000	$ 2,250,000
1.4	90-tonne crane for lay down etc.	$ 105,000	$ 105,000	$ 105,000	$ 105,000	$ 105,000	$ 105,000	$ 105,000
2	**CIVIL**							
2.1	Geotech report	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000
2.2	Access road	$ 1,710,250	$ 632,000	$ 3,157,500	$ 330,750	$ 1,268,500	$ -	$ 2,743,000
2.3	Turbine road	$ 1,084,750	$ -	$ 575,000	$ 663,500	$ 651,250	$ 797,500	$ 446,500
2.4	Cement supply for foundation	$ 1,087,500	$ 862,500	$ 862,500	$ 862,500	$ 570,000	$ 1,050,000	$ 862,500
2.5	Cost of rebar including delivery	$ 578,713	$ 578,713	$ 578,713	$ 578,713	$ 578,713	$ 578,713	$ 578,713
2.6	Foundation installation cost	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
3	**ELECTRICAL**							
3.1	Capacity of site							
3.2	Low voltage step-up transformers	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
3.3	Collection system	$ 1,067,800	$ 200,000	$ 660,000	$ 730,800	$ 721,000	$ 838,000	$ 557,200
3.4	Substation (step up transformer & switching yard)	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000
3.5	Interconnection to exising transmission line	$ 4,481,100	$ 1,327,950	$ 7,897,500	$ 2,208,375	$ 1,828,710	$ 1,959,750	$ 6,326,190
3.6	Line-tap & protection system	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
4	**LABOUR**							
4.1	Labour/wage for misc. construction-related activities	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000	$ 3,000,000
4.2	Accomodation and per diem	$ 562,500	$ 562,500	$ 562,500	$ 562,500	$ 562,500	$ 562,500	$ 562,500
5	**FINANCING COST**							
5.1	Legals for financing closing & independent engineer	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000
5.2	Lender charges	$ 660,000	$ 530,000	$ 720,000	$ 570,000	$ 590,000	$ 590,000	$ 690,000
6	**SITE COST**							
6.1	Land cost	$ 607,595	$ -	$ 855,454	$ -	$ 437,686	$ 235,264	$ 707,528
7	**DEVELOPMENT COST**	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000
8	**EQUIPMENT**	$ 12,000,000	$ 12,000,000	$ 12,000,000	$ 12,000,000	$ 12,000,000	$ 12,000,000	$ 12,000,000
9	**CONTINGENCY**	$ 4,045,671	$ 3,313,766	$ 4,431,917	$ 3,454,314	$ 3,535,236	$ 3,528,223	$ 4,184,313
10	**TOTAL**	$ 44,502,378	$ 36,451,429	$ 48,751,083	$ 37,997,452	$ 38,887,595	$ 38,810,450	$ 46,027,444
Check		$ 44,502,378	$ 36,451,429	$ 48,751,083	$ 37,997,452	$ 38,887,595	$ 38,810,450	$ 46,027,444

OPERATING & MAINTENANCE COSTS

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Techcho	7 - Thulsoo Mtn
1	**ANNUAL NET PRODUCTION**	**25,983 MWh/yr.**	**24,415 MWh/yr.**	**29,537 MWh/yr.**	**15,947 MWh/yr.**	**21,137 MWh/yr.**	**18,295 MWh/yr.**	**27,467 MWh/yr.**
2	**O&M COSTS PER YEAR**	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5	Year 1-5
2.1	Operators	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
2.2	Office	$60,000	$60,000	$0	$0	$0	$0	$0
2.3	Insurance	$66,754	$54,677	$73,127	$56,996	$58,331	$58,216	$69,041
2.4	Land lease	$0	$21,914	$0	$32,821	$0	$0	$0
2.5	Vendor Service	$456,750	$402,690	$516,255	$275,250	$367,830	$321,915	$482,775
2.6	Royalties, FN/Community Payments	$0	$0	$0	$0	$0	$0	$0
2.7	Contingency	$78,350	$73,928	$78,938	$56,507	$62,616	$58,013	$75,182
2.8	**TOTAL per year**	$861,854	$813,209	$868,320	$621,573	$688,778	$638,144	$826,998
2.9	Fixed cost	$326,754	$336,591	$273,127	$289,817	$258,331	$258,216	$269,041
2.10	Variable costs	$535,100	$476,618	$595,193	$331,757	$430,446	$379,928	$557,957
3	**SPECIFIC COSTS**							
3.1	Fixed cost per MWh (net)	$12.58	$13.79	$9.25	$18.17	$12.22	$14.11	$9.80
3.2	Variable costs per MWh (net)	$20.59	$19.52	$20.15	$20.80	$20.36	$20.77	$20.31
3.2	**Total O&M cost per MWh (net output)**	**$33.17**	**$33.31**	**$29.40**	**$38.98**	**$32.59**	**$34.88**	**$30.11**

SUMMARY

Capacity: 20 MW (10 x Vestas V90 2.0 MW)

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Tehcho	7 - Thulsoo Mtn
	Nameplate capacity of turbine type	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW
	Number of turbines	10	10	10	10	10	10	10

CAPEX AND DEVELOPMENT COSTS

		1 - Cyprus Mine	2 - Kluane Lake	3 - Miller's Ridge	4 - Sugarloaf	5 - Sumanik	6 - Tehcho	7 - Thulsoo Mtn
1	**LOGISTICS**							
1.1	Transportation cost	$ 6,473,000	$ 6,128,000	$ 6,140,000	$ 5,312,000	$ 5,528,000	$ 6,581,000	$ 5,978,000
1.2	550-tonne crane	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000	$ 1,100,000
1.3	Erection cost	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000	$ 4,500,000
1.4	90-tonne crane for lay down etc.	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000
2	**CIVIL**							
2.1	Geotech report	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000	$ 75,000
2.2	Access road	$ 1,710,250	$ 1,407,750	$ 2,157,500	$ 330,750	$ 1,268,500	$ -	$ 2,330,000
2.3	Turbine road	$ 1,645,250	$ -	$ 1,575,000	$ 1,206,000	$ 1,383,500	$ 1,340,500	$ 1,631,500
2.4	Cement supply for foundation	$ 2,175,000	$ 1,725,000	$ 1,725,000	$ 1,725,000	$ 1,140,000	$ 2,100,000	$ 1,725,000
2.5	Cost of rebar including delivery	$ 1,157,426	$ 1,157,426	$ 1,157,426	$ 1,157,426	$ 1,157,426	$ 1,157,426	$ 1,157,426
2.6	Foundation installation cost	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000
3	**ELECTRICAL**							
3.1	Capacity of site							
3.2	Low voltage step-up transformers	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000	$ 600,000
3.3	Collection system	$ 1,716,200	$ 400,000	$ 1,660,000	$ 1,364,800	$ 1,506,800	$ 1,472,400	$ 1,705,200
3.4	Substation (step up transformer & switching yard)	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000
3.5	Interconnection to exising transmission line	$ 4,462,965	$ 2,479,815	$ 7,897,500	$ 2,206,035	$ 1,828,710	$ 2,012,400	$ 6,223,230
3.6	Line-tap & protection system	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
4	**LABOUR**							
4.1	Labour/wage for misc. construction-related activities	$ 4,000,000	$ 4,000,000	$ 4,000,000	$ 4,000,000	$ 4,000,000	$ 4,000,000	$ 4,000,000
4.2	Accomodation and per diem	$ 750,000	$ 750,000	$ 750,000	$ 750,000	$ 750,000	$ 750,000	$ 750,000
5	**FINANCING COST**							
5.1	Legals for financing closing & independent engineer	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000	$ 800,000
5.2	Lender charges	$ 1,020,000	$ 900,000	$ 1,080,000	$ 950,000	$ 950,000	$ 960,000	$ 1,070,000
6	**SITE COST**							
6.1	Land cost	$ 703,956	$ -	$ 913,294	$ -	$ 596,511	$ 332,088	$ 860,283
7	**DEVELOPMENT COST**	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000	$ 1,900,000
8	**EQUIPMENT**	$ 24,000,000	$ 24,000,000	$ 24,000,000	$ 24,000,000	$ 24,000,000	$ 24,000,000	$ 24,000,000
9	**CONTINGENCY**	$ 6,356,905	$ 5,670,299	$ 6,681,072	$ 5,675,701	$ 5,786,445	$ 5,846,081	$ 6,518,564
10	**TOTAL**	**$ 69,925,951**	**$ 62,373,290**	**$ 73,491,791**	**$ 62,432,712**	**$ 63,650,891**	**$ 64,306,895**	**$ 71,704,203**
	Check	$ 69,925,951	$ 62,373,290	$ 73,491,791	$ 62,432,712	$ 63,650,891	$ 64,306,895	$ 71,704,203

OPERATING & MAINTENANCE COSTS

		Cyprus Mine	Kluane Lake	Miller's Ridge	Sugarloaf	Sumanik	Tehcho	Thulsoo Mtn
1	**ANNUAL NET PRODUCTION**	**49,589 MWh/yr.**	**47,797 MWh/yr.**	**57,253 MWh/yr.**	**32,250 MWh/yr.**	**41,486 MWh/yr.**	**33,377 MWh/yr.**	**54,393 MWh/yr.**

		Cyprus Mine	Kluane Lake	Miller's Ridge	Sugarloaf	Sumanik	Tehcho	Thulsoo Mtn
2	**O&M COSTS per year (Year 1 to 5, in 2015 $)**							
2.1	Operators	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
2.2	Office	$60,000	$60,000	$0	$0	$0	$0	$0
2.3	Insurance	$104,889	$93,560	$110,238	$93,649	$95,476	$96,460	$107,556
2.4	Land lease	$0	$45,858	$0	$44,573	$0	$0	$0
2.5	Vendor Service	$871,725	$788,355	$1,000,695	$556,650	$721,950	$587,280	$956,055
2.6	Royalties, FN/Community Payments	$0	$0	$0	$0	$0	$0	$0
2.7	Contingency	$123,661	$118,777	$131,093	$89,487	$101,743	$88,374	$126,361
2.8	**TOTAL per year**	$1,360,275	$1,306,550	$1,442,026	$984,359	$1,119,169	$972,114	$1,389,972
2.9	Fixed cost	$364,889	$399,418	$310,238	$338,222	$295,476	$296,460	$307,556
2.10	Variable costs	$995,386	$907,132	$1,131,788	$646,137	$823,693	$675,654	$1,082,416
3	**SPECIFIC COSTS**							
3.1	Fixed cost per MWh (net)	$7.36	$8.36	$5.42	$10.49	$7.12	$8.88	$5.65
3.2	Variable costs per MWh (net)	$20.07	$18.98	$19.77	$20.04	$19.85	$20.24	$19.90
3.2	**Total O&M cost per MWh (net output)**	**$27**	**$27**	**$25**	**$31**	**$27**	**$29**	**$26**

APPENDIX D – FINANCIAL ANALYSIS

Table 1: Summary Yukon Energy Corporation Wind Power Generation Options

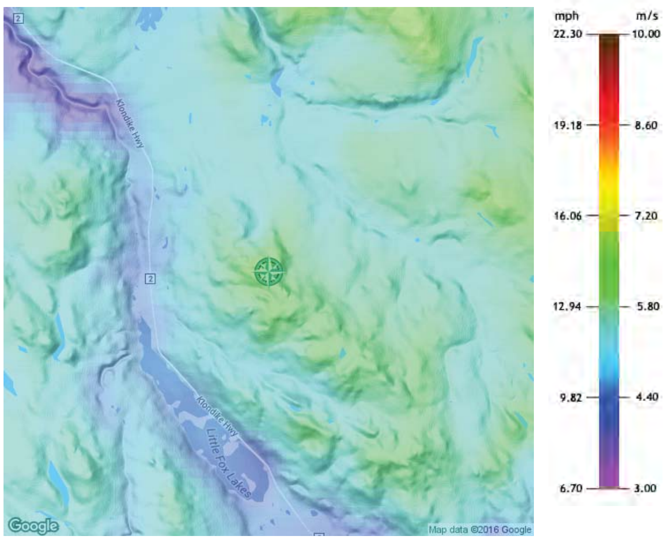
CAPEX +/- 0% OPEX +/- 0% Energy +/- 0%

Wind Power Options	Option Assumptions											Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)					
	Capital Cost (2015$)			Annual Fixed O&M Costs (2015$)	Annual Variable O&M Costs (2015$)	Capacity	Reliable Winter Capacity	Annual Average Capacity Factor	Annual Average Energy	Expected Life	Expected In-Service Date (January 1)	3.38% Real WACC		4.61% Real WACC		8.82% Real WACC	
	Plant Capital Cost	Transmission Capital Cost	Total Capital Cost									LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)
	$000	$000	$000	$000	$/MW.h	MW	MW	%	GW.h	Years	Year	$/kW.h	$/MW	$/kW.h	$/MW	$/kW.h	$/MW
A	B	C	D=B+C	E	F	G	H	I=J/8.76/G	J	K	L	M	N	O	P	Q	R
Cyprus Mine: 6 MW	$28,061	$5,981	$34,042	$301	$25.54	6.0	-	31%	16.1	25	2021	$0.178		$0.196		$0.264	
Cyprus Mine: 10 MW	$38,521	$5,981	$44,502	$327	$20.59	10.0	-	30%	26.0	25	2021	$0.142		$0.156		$0.211	
Cyprus Mine: 20 MW	$63,963	$5,963	$69,926	$365	$20.07	20.0	-	28%	49.6	25	2021	$0.117		$0.129		$0.174	
Kluane Lake: 6 MW	$23,746	$2,286	$26,032	$291	$24.06	6.0	-	28%	15.0	25	2025	$0.154		$0.168		$0.224	
Kluane Lake: 10 MW	$33,623	$2,828	$36,451	$337	$19.52	10.0	-	28%	24.4	25	2025	$0.128		$0.140		$0.188	
Kluane Lake: 20 MW	$58,393	$3,980	$62,373	$399	$18.98	20.0	-	27%	47.8	25	2025	$0.110		$0.121		$0.163	
Miller's Ridge: 6 MW	$29,420	$9,398	$38,817	$258	$25.18	6.0	-	34%	18.1	25	2021	$0.176		$0.193		$0.262	
Miller's Ridge: 10 MW	$39,354	$9,398	$48,751	$273	$20.15	10.0	-	34%	29.5	25	2021	$0.134		$0.148		$0.201	
Miller's Ridge: 20 MW	$64,094	$9,398	$73,492	$310	$19.77	20.0	-	33%	57.3	25	2021	$0.107		$0.117		$0.159	
Sugarloaf Mtn: 6 MW	$24,281	$3,735	$28,015	$243	$25.39	6.0	-	19%	9.9	25	2021	$0.230		$0.253		$0.344	
Sugarloaf Mtn: 10 MW	$34,289	$3,708	$37,997	$290	$20.80	10.0	-	18%	15.9	25	2021	$0.190		$0.210		$0.287	
Sugarloaf Mtn: 20 MW	$58,727	$3,706	$62,433	$338	$20.04	20.0	-	18%	32.3	25	2021	$0.153		$0.169		$0.232	
Mt Sumanik: 6 MW	$25,846	$4,059	$29,905	$244	$25.22	6.0	-	27%	14.2	25	2021	$0.176		$0.194		$0.262	
Mt Sumanik: 10 MW	$35,559	$3,329	$38,888	$258	$20.36	10.0	-	24%	21.1	25	2021	$0.149		$0.165		$0.224	
Mt Sumanik: 20 MW	$60,322	$3,329	$63,651	$295	$19.85	20.0	-	24%	41.5	25	2021	$0.124		$0.137		$0.186	
Tehcho: 6 MW	$24,418	$3,460	$27,878	$243	$25.81	6.0	-	20%	10.3	25	2021	$0.221		$0.244		$0.331	
Tehcho: 10 MW	$35,351	$3,460	$38,810	$258	$20.77	10.0	-	21%	18.3	25	2021	$0.170		$0.187		$0.255	
Tehcho: 20 MW	$60,794	$3,512	$64,307	$296	$20.24	20.0	-	19%	33.4	25	2021	$0.151		$0.167		$0.229	
Thulsoo: 6 MW	$28,464	$7,547	$36,011	$274	$25.40	6.0	-	33%	17.3	25	2021	$0.174		$0.191		$0.258	
Thulsoo: 10 MW	$38,201	$7,826	$46,027	$269	$20.31	10.0	-	31%	27.5	25	2021	$0.137		$0.150		$0.204	
Thulsoo: 20 MW	$63,981	$7,723	$71,704	$308	$19.90	20.0	-	31%	54.4	25	2021	$0.109		$0.120		$0.163	

APPENDIX E – AWS TRUEPOWER COMPASS REPORTS

Site Characteristics

Site ID: 23



Latitude: 61.37173 Longitude: -135.62794

Wind Speed (100.0 m): 6.46 m/s

Roughness: 0.1000 m Elevation: 1,235.4 m (4,053.1 ft)

Air Density: 1.111 kg/m3

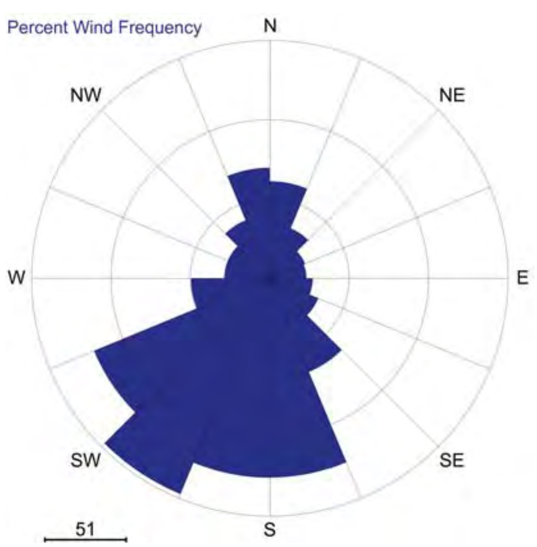
Mean Power Density: 269 W/m^2

Uncertainty Value: 0.35 +/- m/s

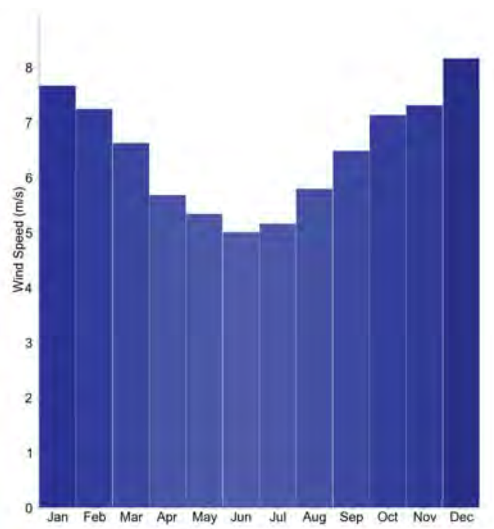
Weibull A: 7.29 Weibull k: 2.13

Mean annual wind speed map at 100 m hub height for Anticline Mtn.

200m Graphs



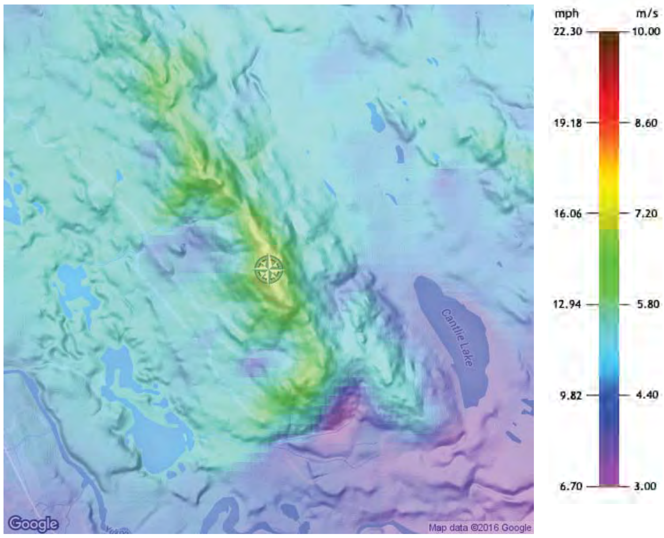
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 9



Mean annual wind speed map at 100 m hub height for Canyon Mtn., Whitehorse.

Latitude: 60.67688 Longitude: -134.90456

Wind Speed (100.0 m): 7.28 m/s

Roughness: 0.0500 m Elevation: 1,416.8 m (4,648.3 ft)

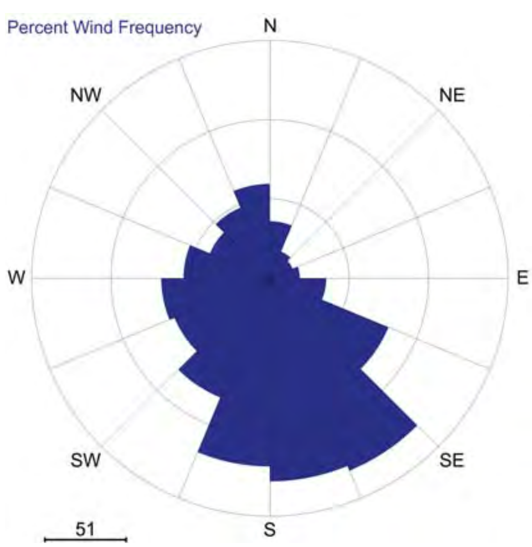
Air Density: 1.105 kg/m3

Mean Power Density: 382 W/m^2

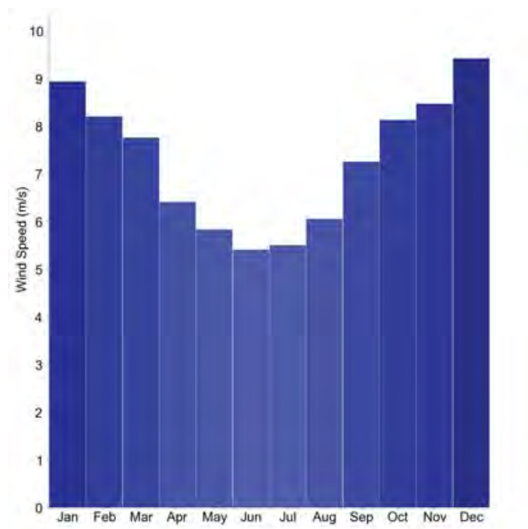
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.22 Weibull k: 2.14

200m Graphs



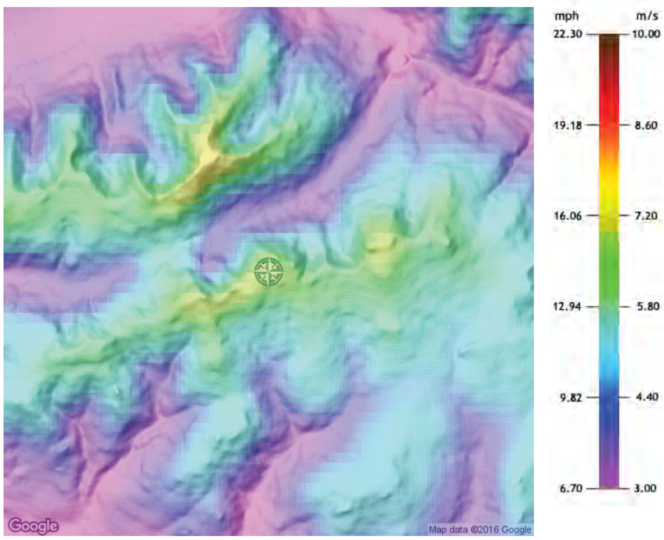
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 1



Mean annual wind speed map at 100 m hub height for Cyprus Mine north.

Latitude: 62.42074 Longitude: -133.42518

Wind Speed (100.0 m): 7.19 m/s

Roughness: 0.0100 m Elevation: 1,849.7 m (6,068.6 ft)

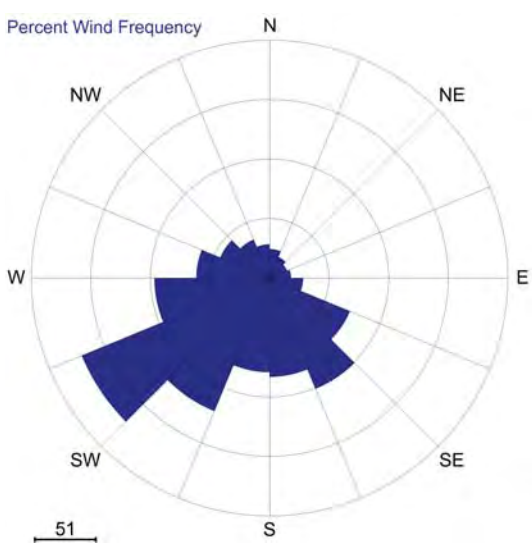
Air Density: 1.081 kg/m3

Mean Power Density: 354 W/m^2

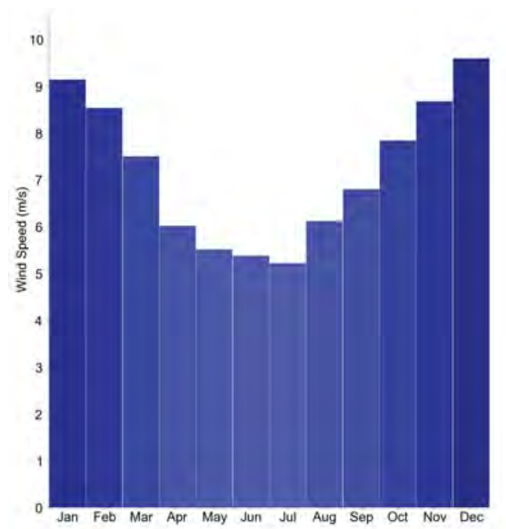
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.12 Weibull k: 2.18

200m Graphs



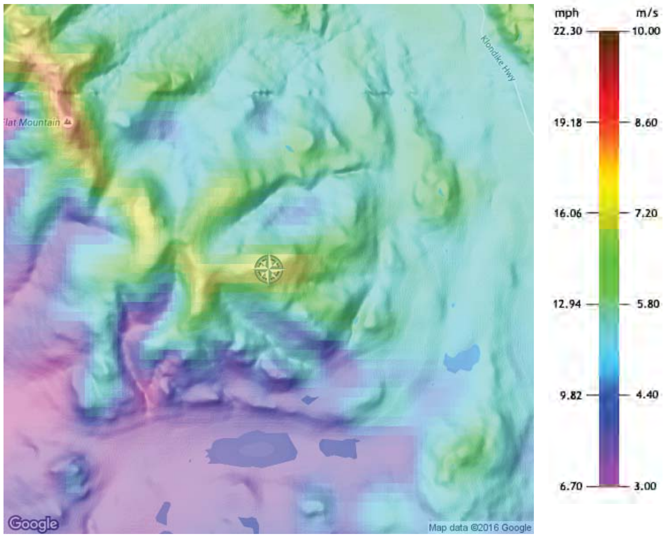
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 15



Mean annual wind speed map at 100 m hub height for Flat Mtn. SE ridge.

Latitude: 60.96678 Longitude: -135.29766

Wind Speed (100.0 m): 7.6 m/s

Roughness: 0.0100 m Elevation: 1,535.1 m (5,036.4 ft)

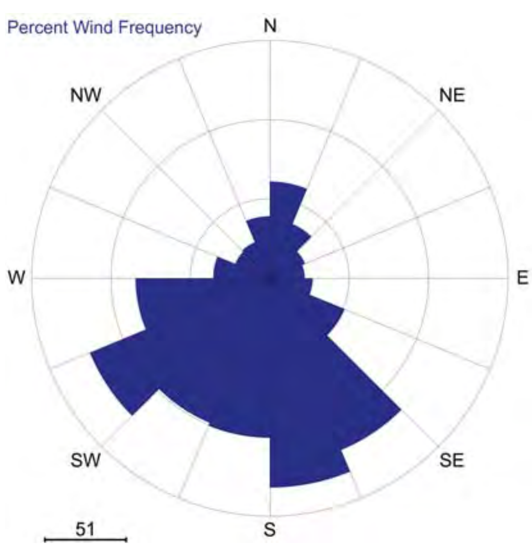
Air Density: 1.097 kg/m3

Mean Power Density: 429 W/m^2

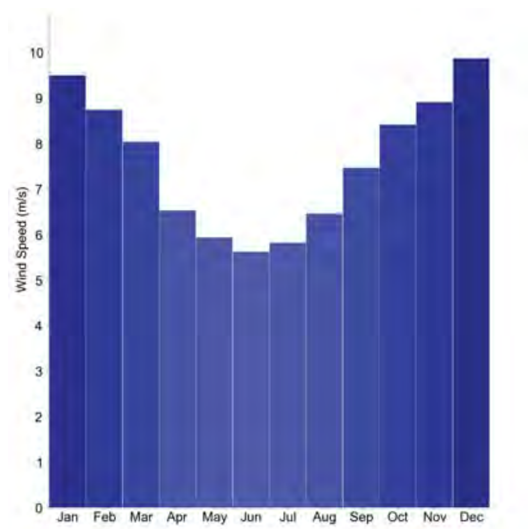
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.58 Weibull k: 2.15

200m Graphs



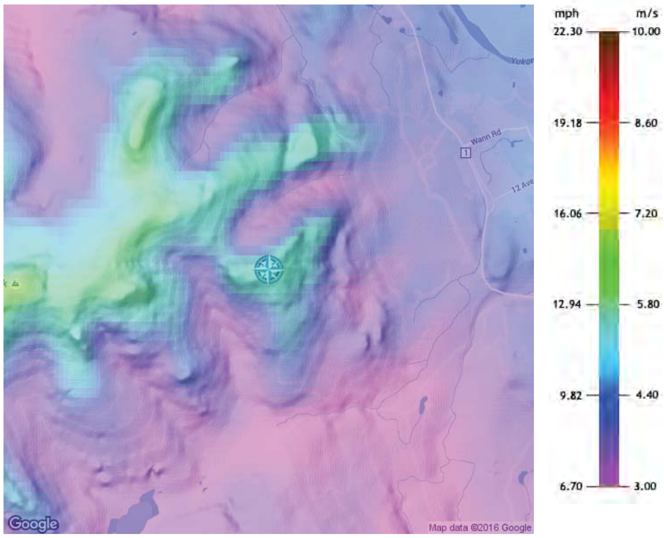
Wind Rose



Monthly Distribution

Site Characteristics

(for comparison only)



Mean annual wind speed map at 100 m hub height for Haeckel Hill.

Latitude: 60.7491 Longitude: -135.22591

Wind Speed (100.0 m): 5.32 m/s

Roughness: 0.1000 m Elevation: 1,374.4 m (4,509.2 ft)

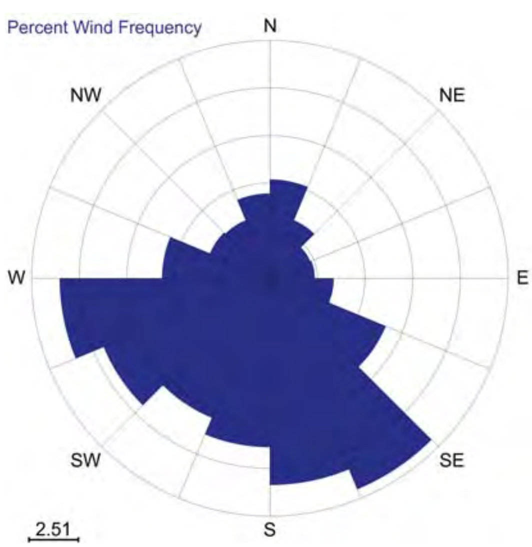
Air Density: 1.107 kg/m3

Mean Power Density: 156 W/m^2

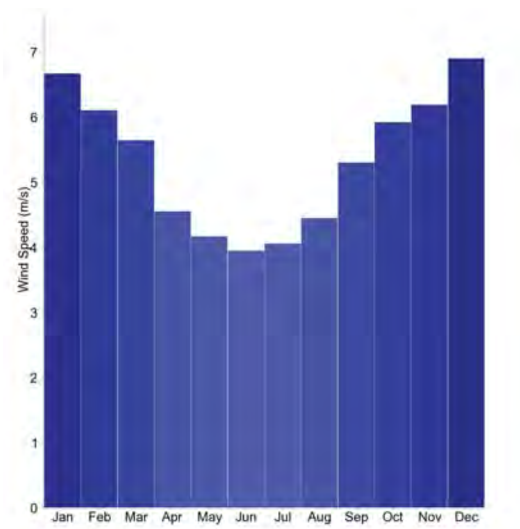
Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.00 Weibull k: 2.04

200m Graphs



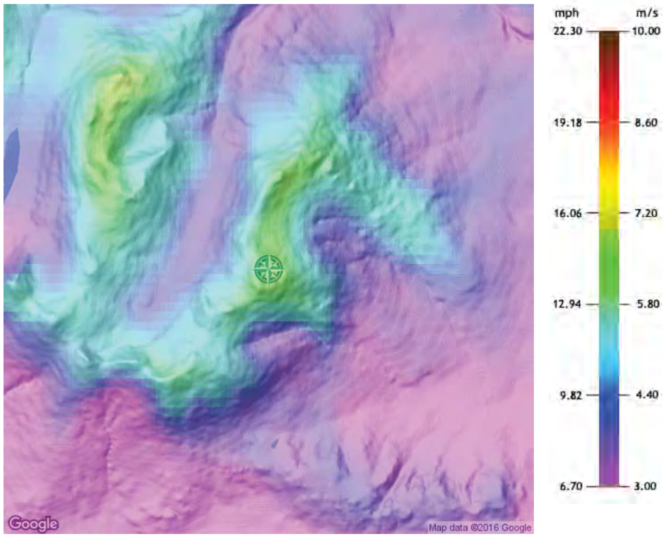
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 20



Mean annual wind speed map at 100 m hub height for Hard Time Mtn.

Latitude: 60.91642 Longitude: -137.17873

Wind Speed (100.0 m): 6.67 m/s

Roughness: 0.0100 m Elevation: 1,844.6 m (6,051.8 ft)

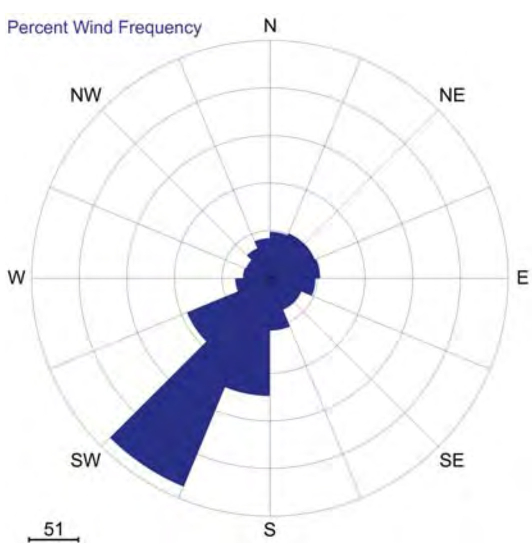
Air Density: 1.071 kg/m3

Mean Power Density: 308 W/m^2

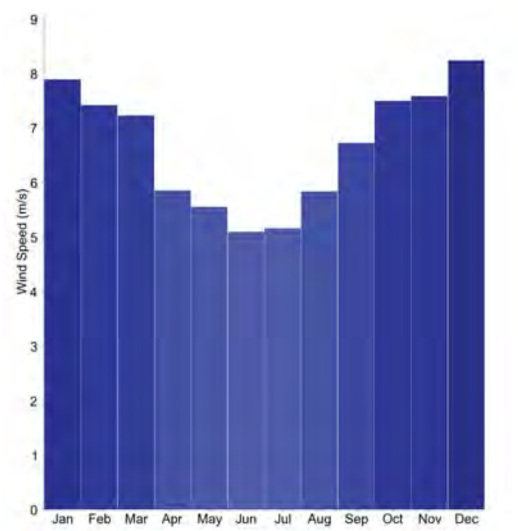
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.52 Weibull k: 1.97

200m Graphs



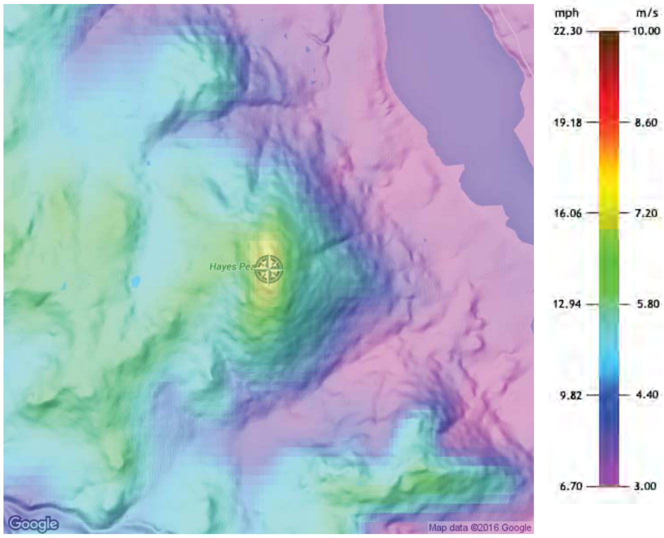
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 13



Mean annual wind speed map at 100 m hub height for Hayes Peak, J. Crossing.

Latitude: 60.39554 Longitude: -133.30605

Wind Speed (100.0 m): 7.53 m/s

Roughness: 0.1000 m Elevation: 1,810.5 m (5,940.0 ft)

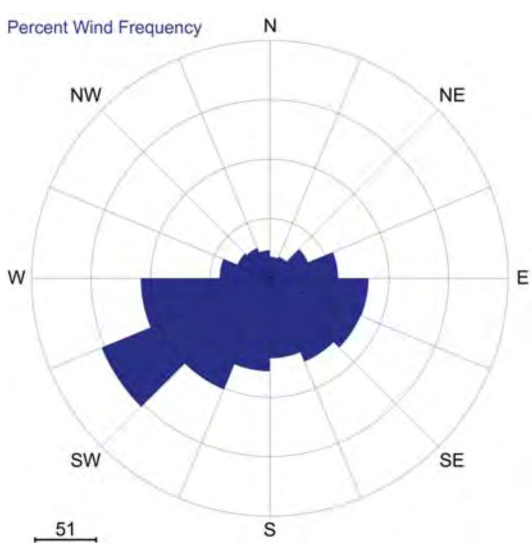
Air Density: 1.070 kg/m3

Mean Power Density: 379 W/m^2

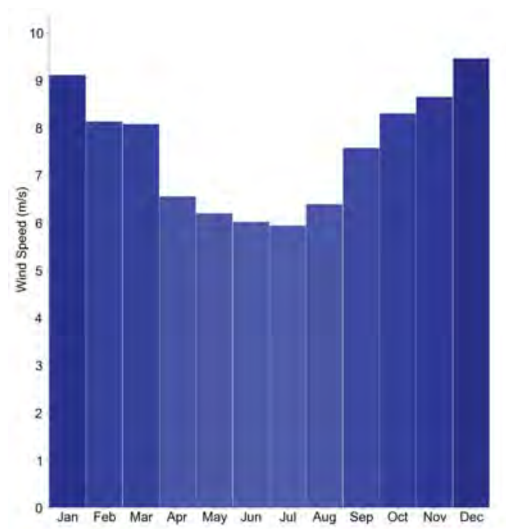
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.50 Weibull k: 2.34

200m Graphs



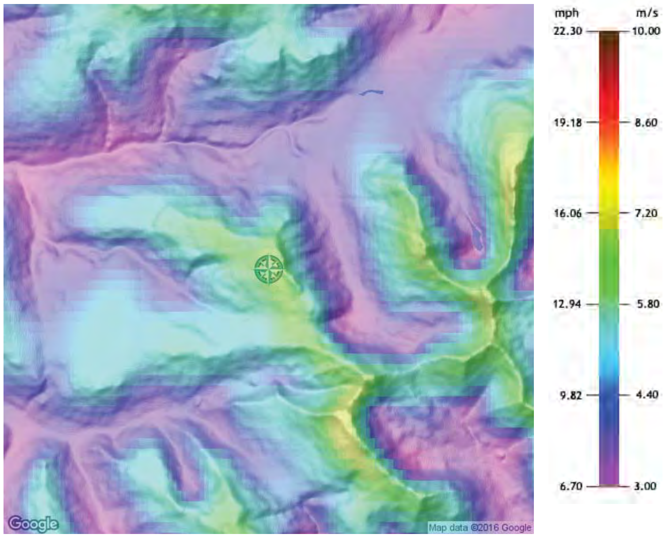
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 16



Mean annual wind speed map at 100 m hub height for Keno City.

Latitude: 63.8948 Longitude: -135.15999

Wind Speed (100.0 m): 6.87 m/s

Roughness: 0.1000 m Elevation: 1,804.6 m (5,920.6 ft)

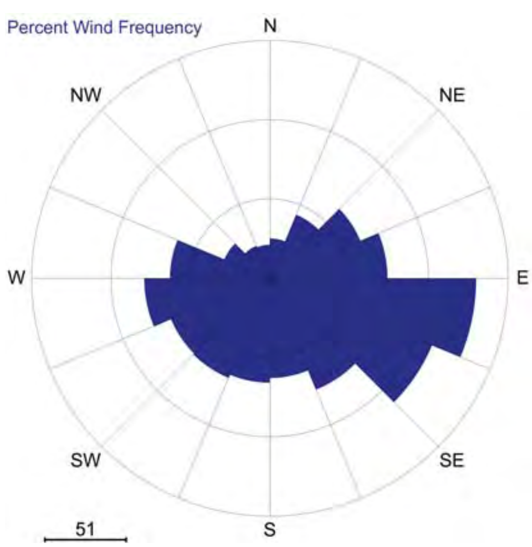
Air Density: 1.104 kg/m3

Mean Power Density: 311 W/m^2

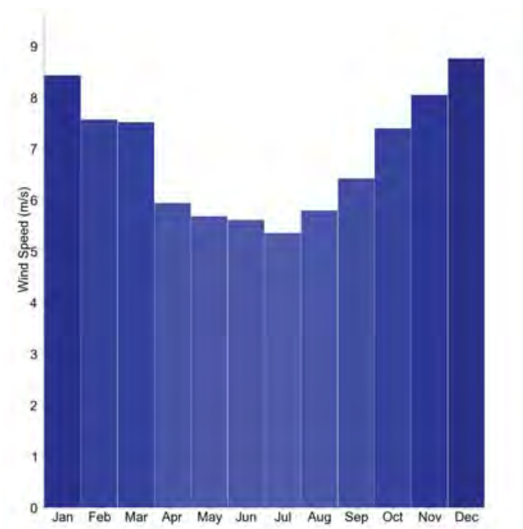
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.76 Weibull k: 2.21

200m Graphs



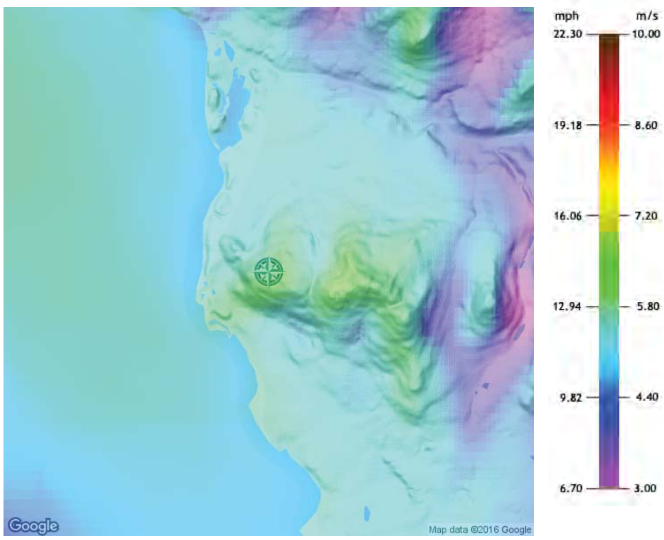
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 14



Latitude: 61.12401 Longitude: -138.41125

Wind Speed (100.0 m): 6.35 m/s

Roughness: 1.1250 m Elevation: 1,173.5 m (3,850.1 ft)

Air Density: 1.132 kg/m3

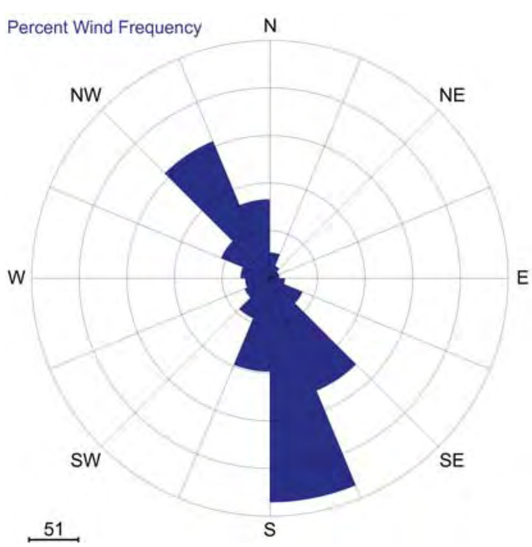
Mean Power Density: 300 W/m^2

Uncertainty Value: 0.35 +/- m/s

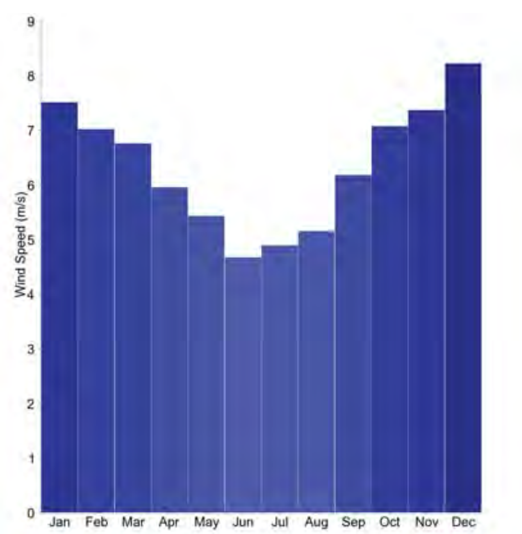
Weibull A: 7.15 Weibull k: 1.85

Mean annual wind speed map at 100 m hub height for Kluane Lake, east shore.

200m Graphs



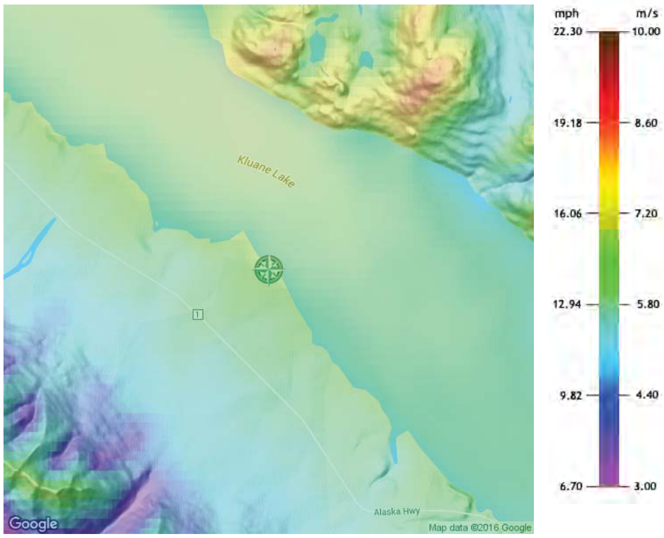
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 2



Latitude: 61.2144 Longitude: -138.66531

Wind Speed (100.0 m): 6.75 m/s

Roughness: 0.0010 m Elevation: 765.4 m (2,511.2 ft)

Air Density: 1.167 kg/m3

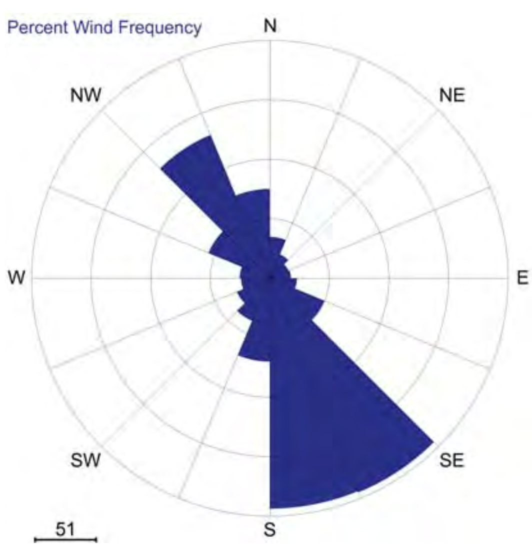
Mean Power Density: 410 W/m^2

Uncertainty Value: 0.35 +/- m/s

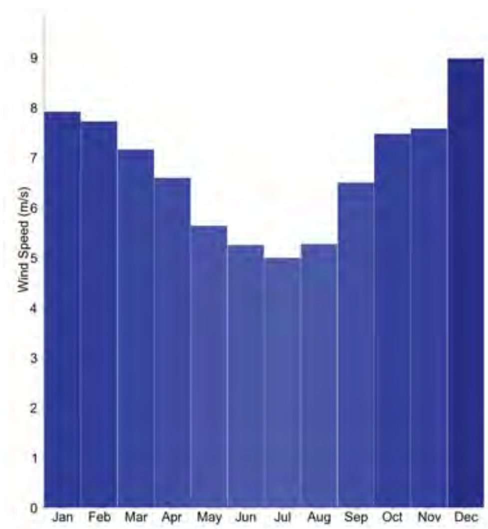
Weibull A: 7.57 Weibull k: 1.70

Mean annual wind speed map at 100 m hub height for Kluane Lake, west shore.

200m Graphs



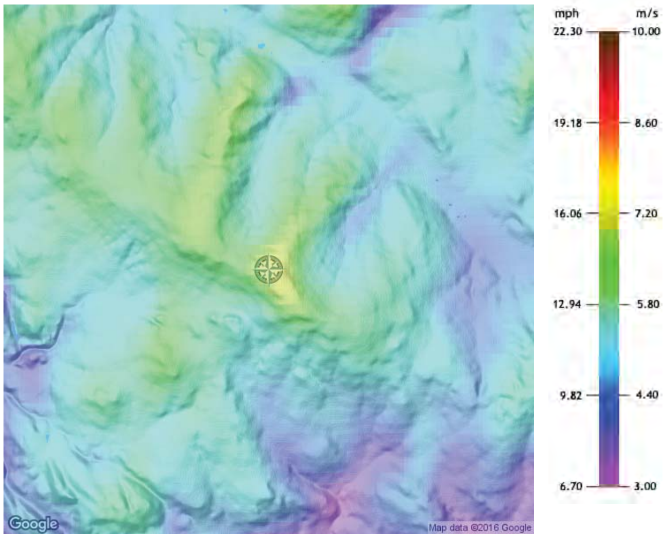
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 18



Mean annual wind speed map at 100 m hub height for Little Salmon hill.

Latitude: 62.14594 Longitude: -135.54794

Wind Speed (100.0 m): 7.41 m/s

Roughness: 0.1000 m Elevation: 1,523.5 m (4,998.4 ft)

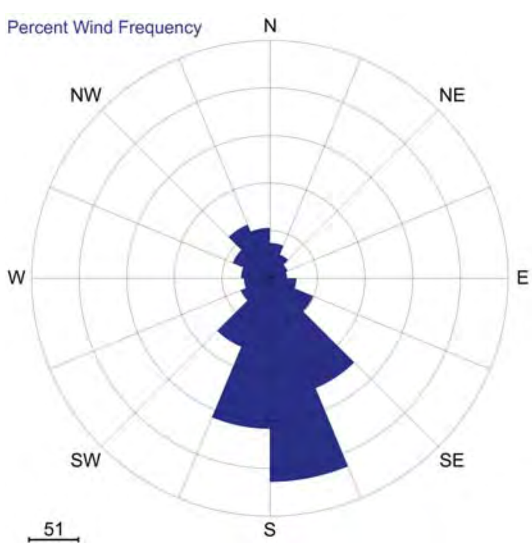
Air Density: 1.090 kg/m3

Mean Power Density: 411 W/m^2

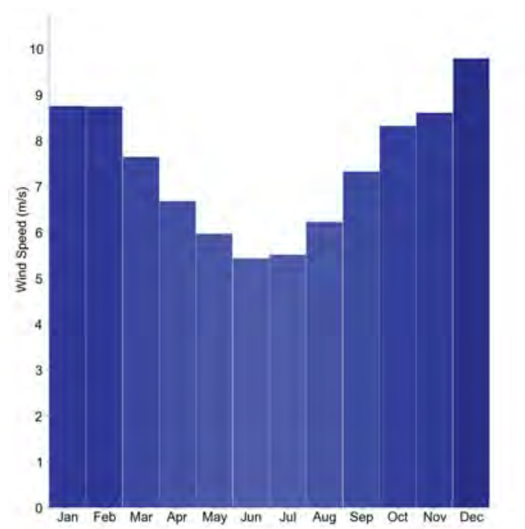
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.36 Weibull k: 2.06

200m Graphs



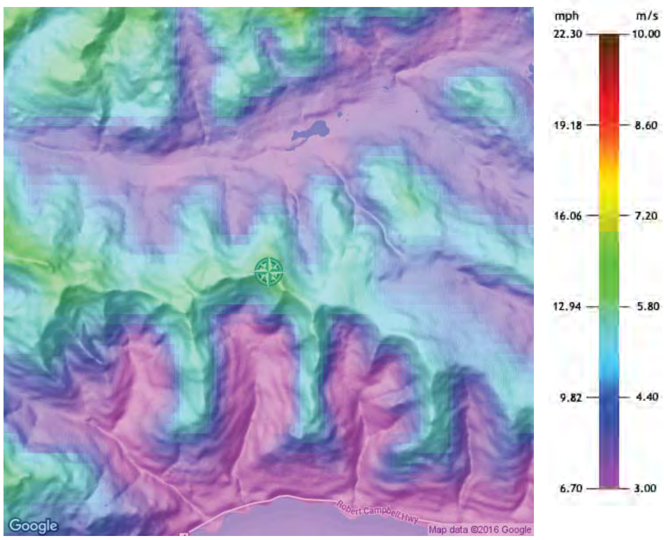
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 22



Mean annual wind speed map at 100 m hub height for Little Salmon/Drury.

Latitude: 62.24811 Longitude: -134.82491

Wind Speed (100.0 m): 6.29 m/s

Roughness: 0.0500 m Elevation: 1,689.2 m (5,542.0 ft)

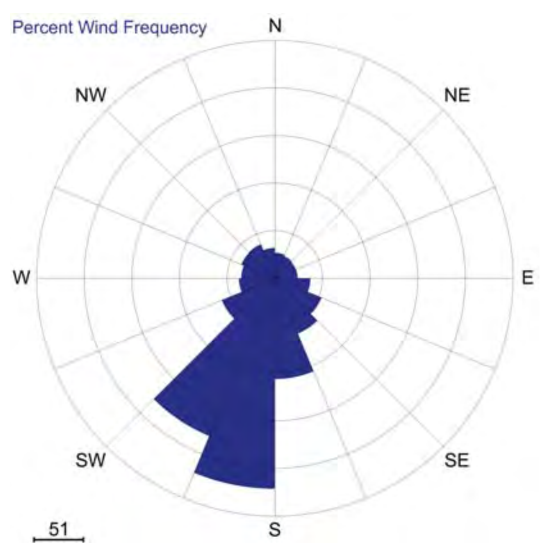
Air Density: 1.174 kg/m3

Mean Power Density: 255 W/m^2

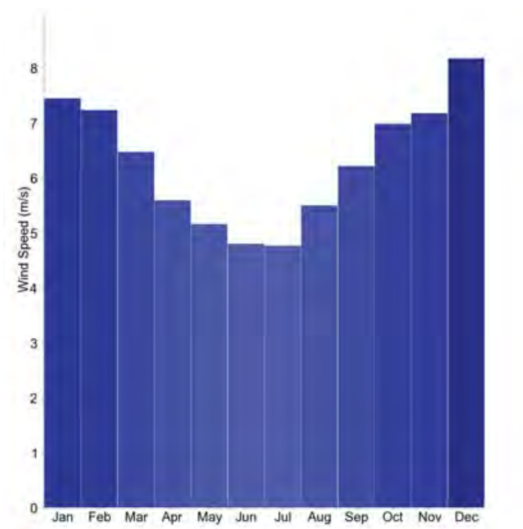
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.11 Weibull k: 2.21

200m Graphs



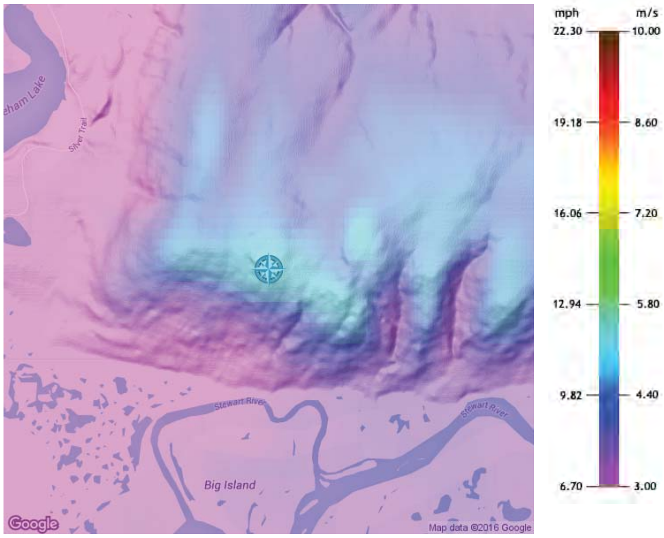
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 10



Latitude: 63.64839 Longitude: -135.76561

Wind Speed (100.0 m): 4.89 m/s

Roughness: 0.1000 m Elevation: 1,121.5 m (3,679.5 ft)

Air Density: 1.156 kg/m3

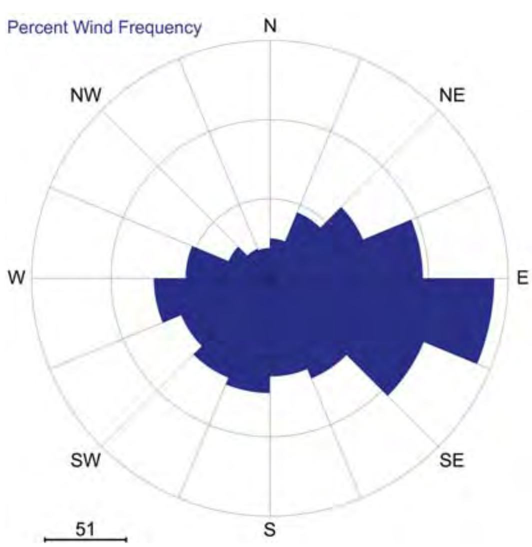
Mean Power Density: 122 W/m^2

Uncertainty Value: 0.35 +/- m/s

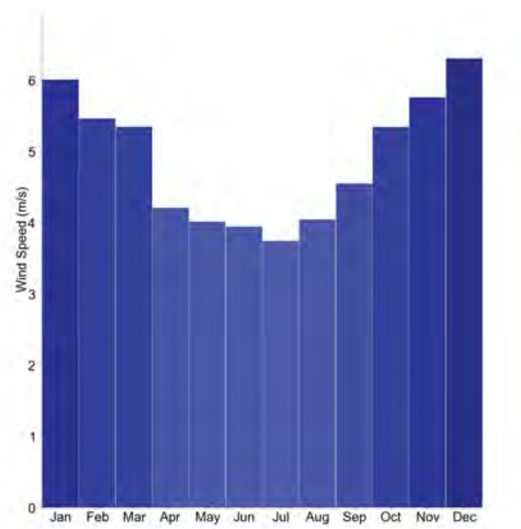
Weibull A: 5.52 Weibull k: 2.13

Mean annual wind speed map at 100 m hub height for Mayo.

200m Graphs



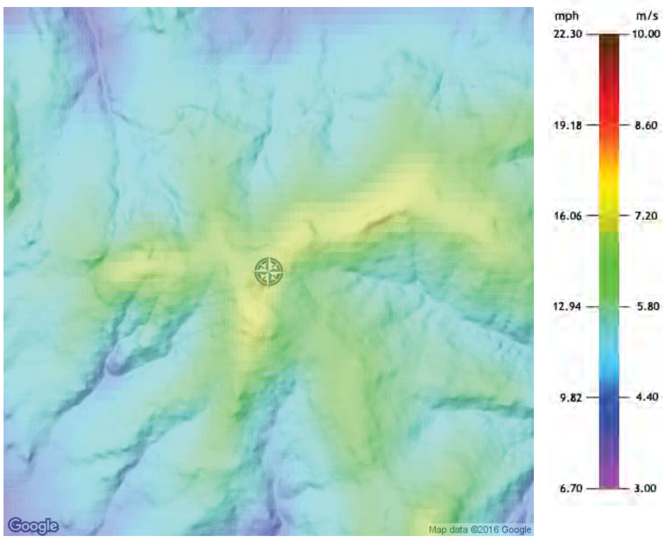
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 3



Mean annual wind speed map at 100 m hub height for Miller's Ridge, Carmacks.

Latitude: 62.16839 Longitude: -136.6555

Wind Speed (100.0 m): 7.32 m/s

Roughness: 1.1250 m Elevation: 1,458.3 m (4,784.4 ft)

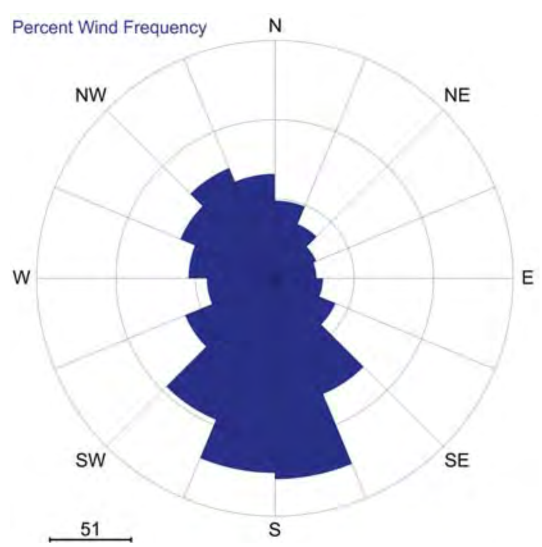
Air Density: 1.092 kg/m3

Mean Power Density: 416 W/m^2

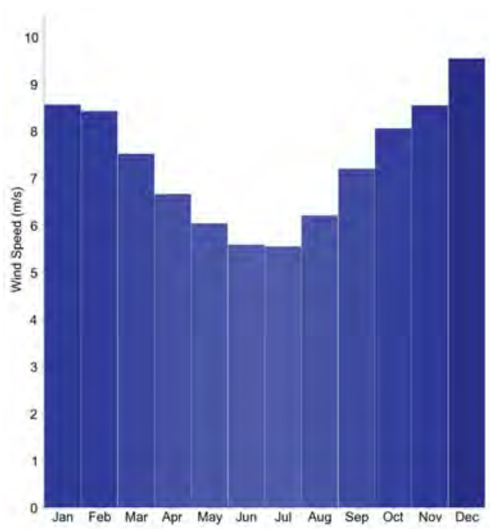
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.26 Weibull k: 1.96

200m Graphs



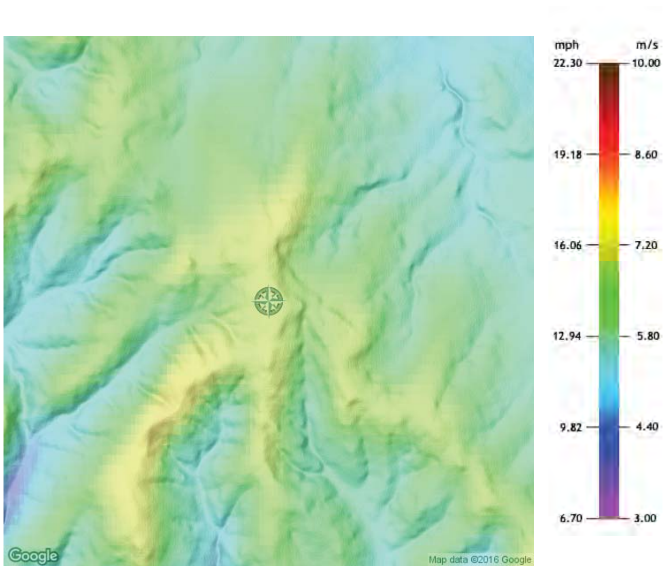
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 17



Mean annual wind speed map at 100 m hub height for Hill E of Minto.

Latitude: 62.54526   Longitude: -136.35544

Wind Speed (100.0 m): 7.15 m/s

Roughness: 0.1000 m   Elevation: 1,243.8 m (4,080.7 ft)

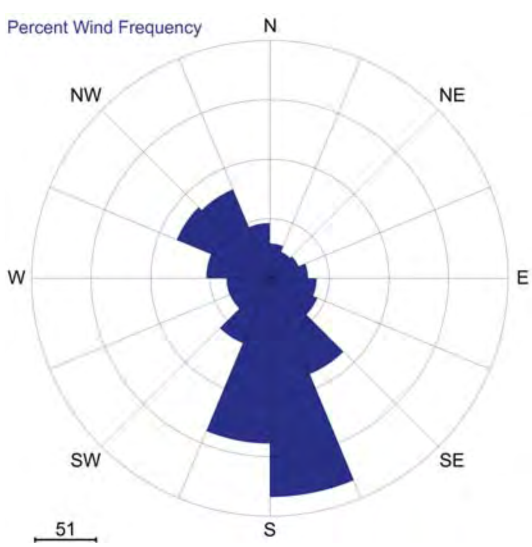
Air Density: 1.108 kg/m3

Mean Power Density: 400 W/m^2

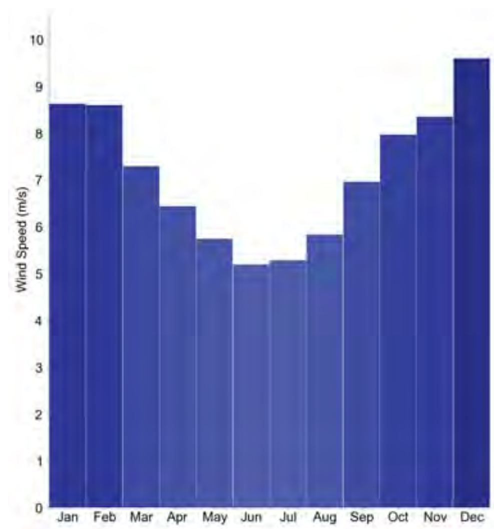
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.06   Weibull k: 1.94

200m Graphs



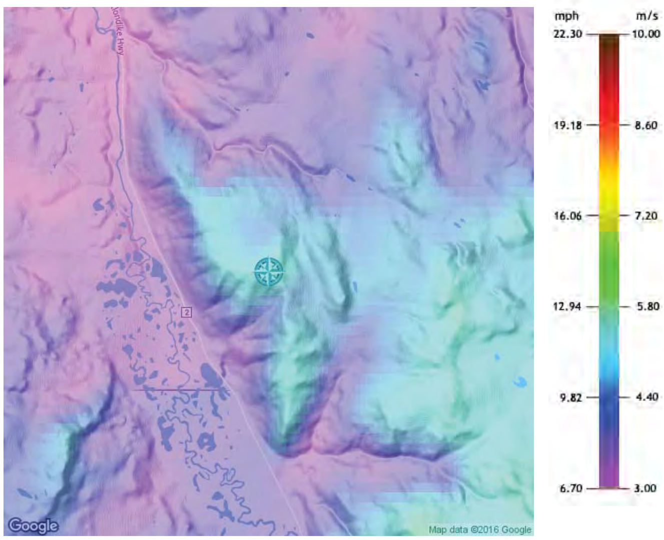
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 21



Mean annual wind speed map at 100 m hub height for Mt. Berdoe.

Latitude: 62.02153 Longitude: -136.22189

Wind Speed (100.0 m): 5.54 m/s

Roughness: 0.1000 m Elevation: 1,051.9 m (3,451.1 ft)

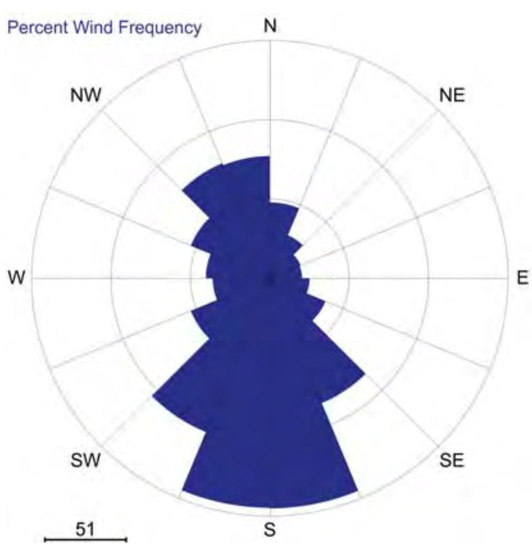
Air Density: 1.145 kg/m3

Mean Power Density: 186 W/m^2

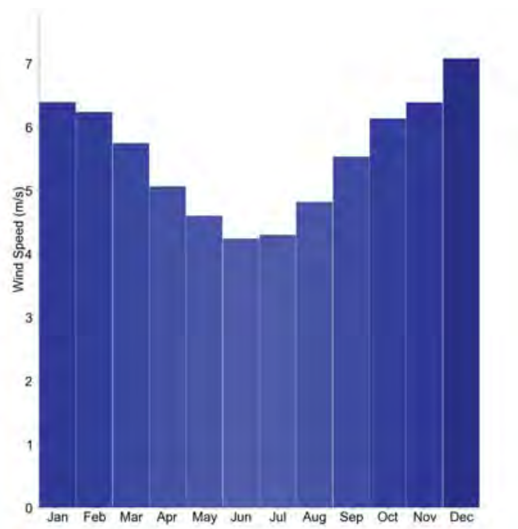
Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.26 Weibull k: 2.01

200m Graphs



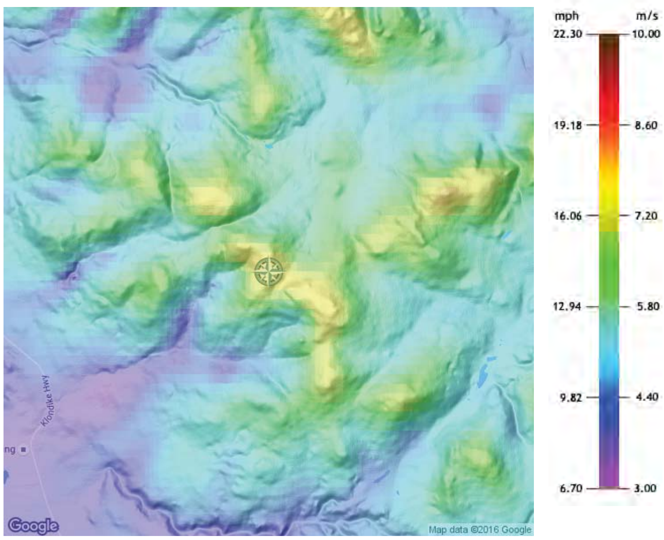
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 8



Mean annual wind speed map at 100 m hub height for Mt. Lorne subpeak.

Latitude: 60.39367 Longitude: -134.69444

Wind Speed (100.0 m): 7.71 m/s

Roughness: 0.1000 m Elevation: 1,703.9 m (5,590.2 ft)

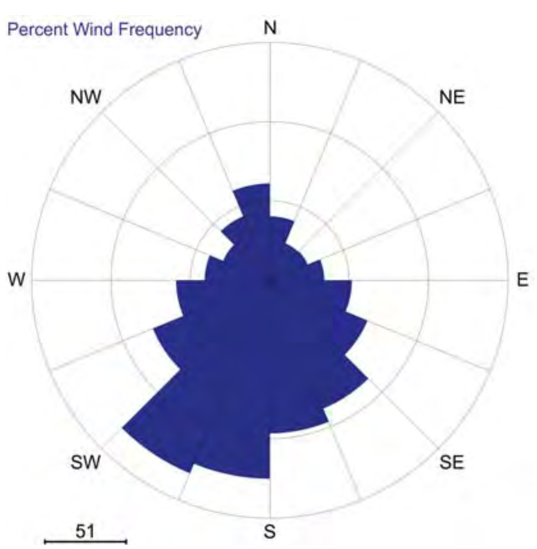
Air Density: 1.078 kg/m3

Mean Power Density: 457 W/m^2

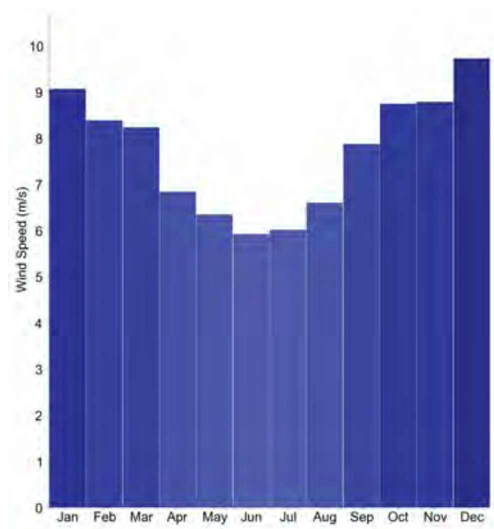
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.70 Weibull k: 2.07

200m Graphs



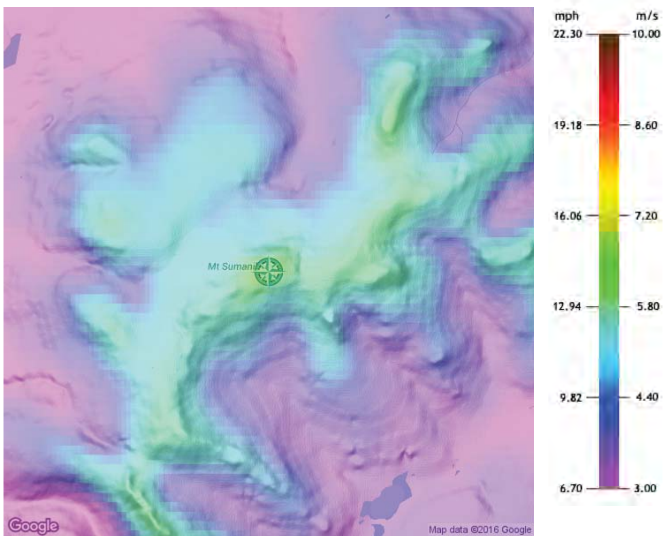
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 4



Mean annual wind speed map at 100 m hub height for Mt. Sumanik.

Latitude: 60.7454 Longitude: -135.3241

Wind Speed (100.0 m): 6.7 m/s

Roughness: 0.0100 m Elevation: 1,674.8 m (5,494.8 ft)

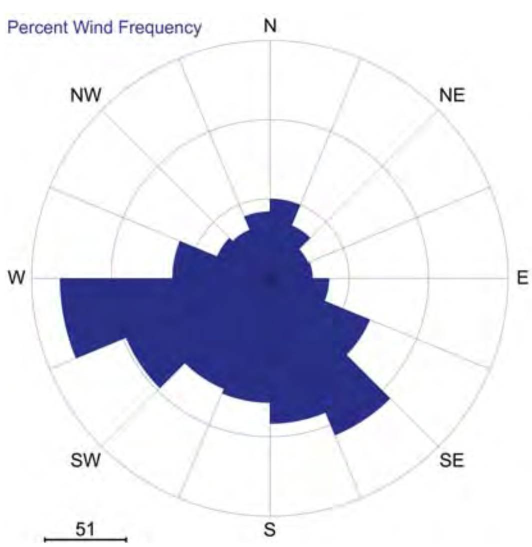
Air Density: 1.084 kg/m3

Mean Power Density: 309 W/m^2

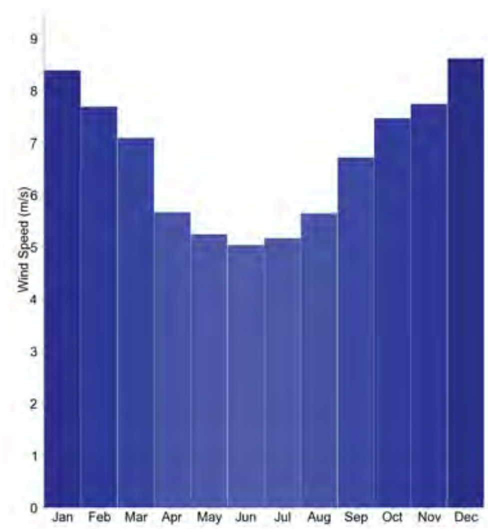
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.57 Weibull k: 2.02

200m Graphs



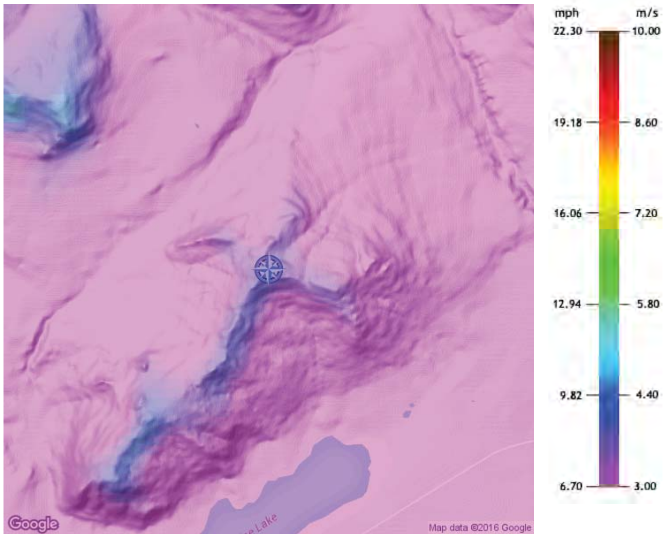
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 24



Latitude: 60.86631 Longitude: -137.44446

Wind Speed (100.0 m): 3.92 m/s

Roughness: 0.1000 m Elevation: 1,488.4 m (4,883.2 ft)

Air Density: 1.102 kg/m3

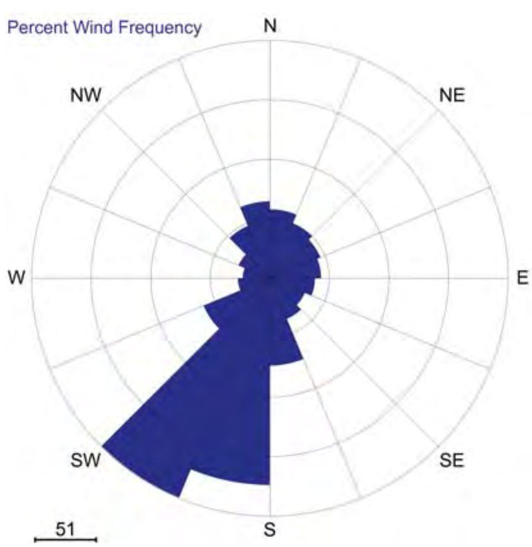
Mean Power Density: 66 W/m^2

Uncertainty Value: 0.35 +/- m/s

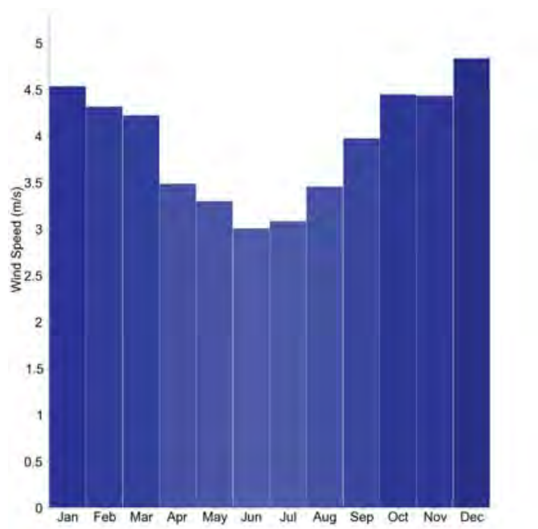
Weibull A: 4.41 Weibull k: 1.92

Mean annual wind speed map at 100 m hub height for Paint Mtn.

200m Graphs



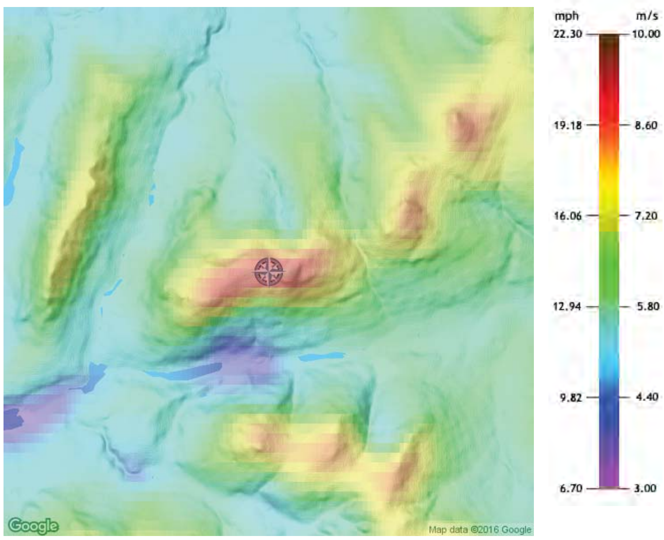
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 26



Latitude: 61.5649 Longitude: -131.37554

Wind Speed (100.0 m): 9.1 m/s

Roughness: 0.0500 m Elevation: 1,704.7 m (5,592.8 ft)

Air Density: 1.124 kg/m3

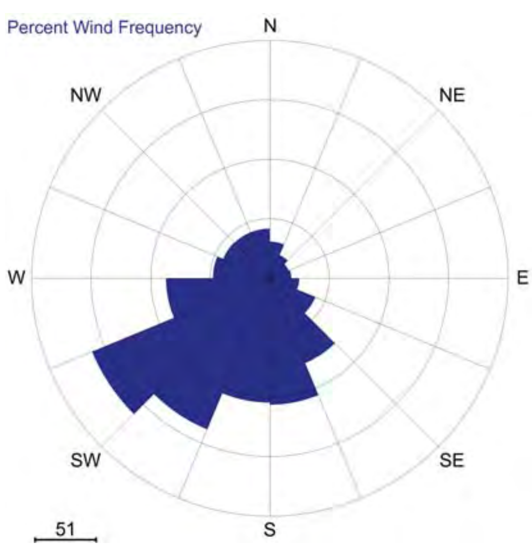
Mean Power Density: 850 W/m^2

Uncertainty Value: 0.35 +/- m/s

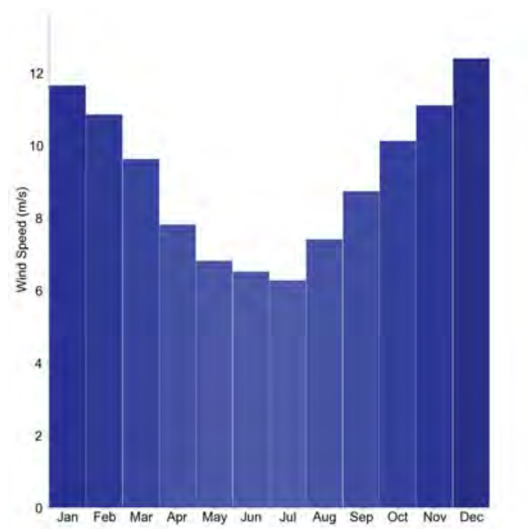
Weibull A: 10.26 Weibull k: 1.91

Mean annual wind speed map at 100 m hub height for Hill 75 km SE Ross River.

200m Graphs



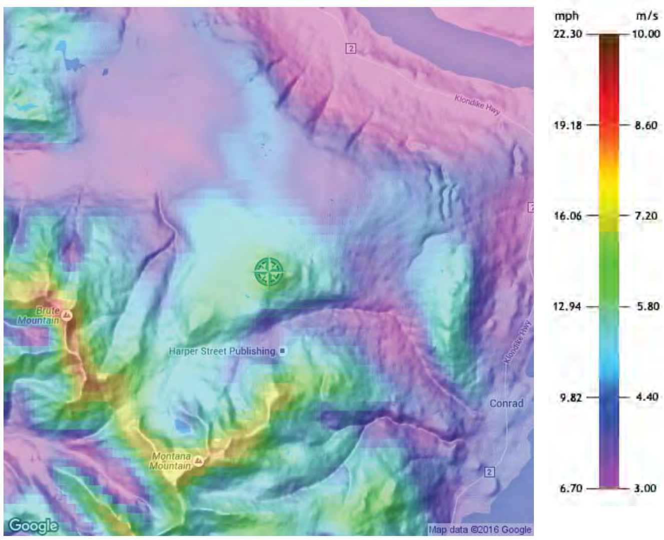
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 5



Mean annual wind speed map at 100 m hub height for Sugarloaf Mtn.

Latitude: 60.09481 Longitude: -134.66389

Wind Speed (100.0 m): 6.45 m/s

Roughness: 0.1000 m Elevation: 1,787.7 m (5,865.2 ft)

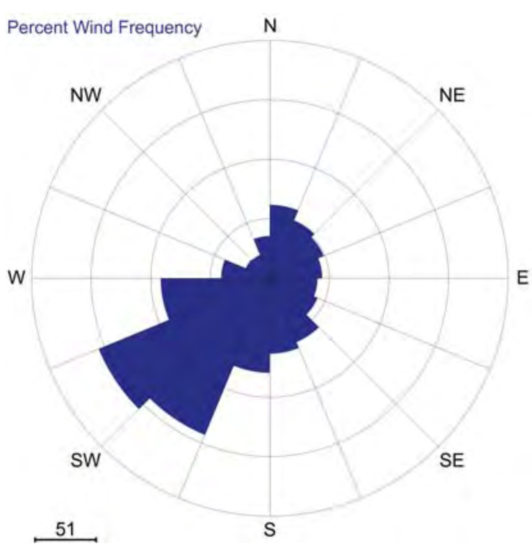
Air Density: 1.062 kg/m3

Mean Power Density: 280 W/m^2

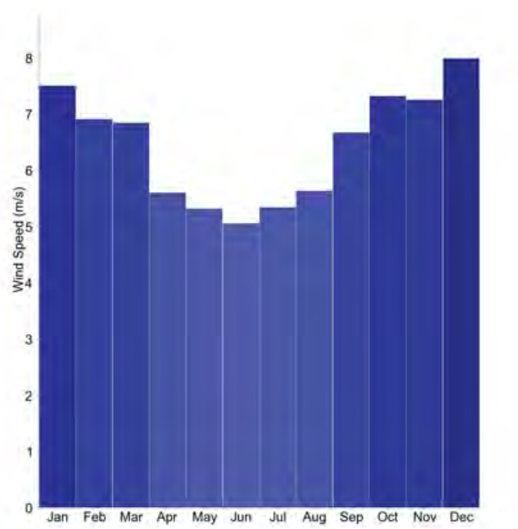
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.28 Weibull k: 1.95

200m Graphs



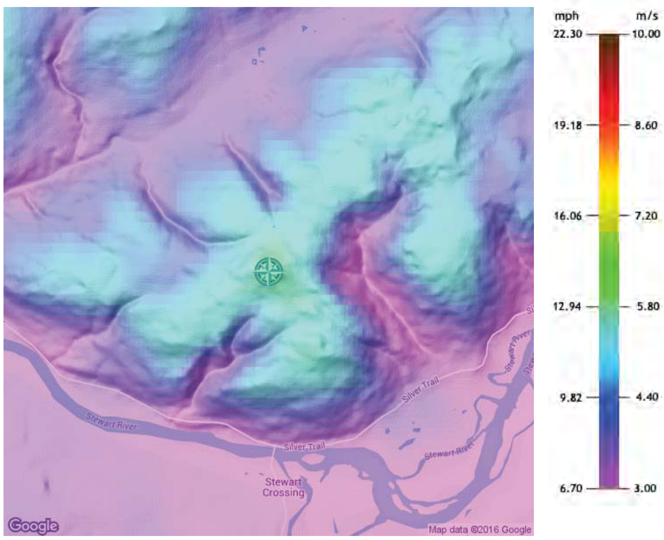
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 6



Mean annual wind speed map at 100 m hub height for Tehcho.

Latitude: 63.41273 Longitude: -136.68365

Wind Speed (100.0 m): 5.97 m/s

Roughness: 0.1000 m Elevation: 1,211.3 m (3,974.1 ft)

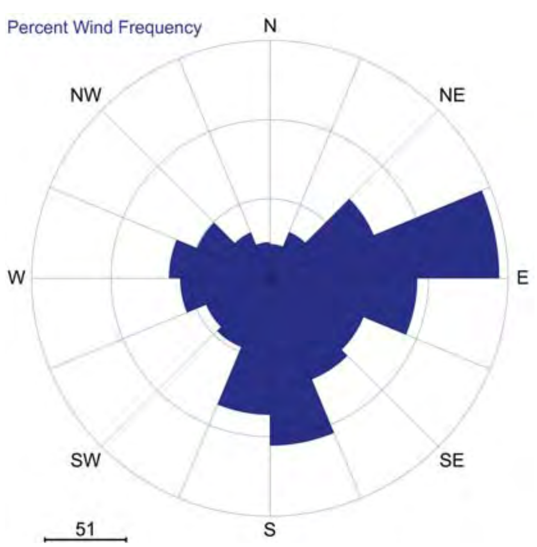
Air Density: 1.135 kg/m3

Mean Power Density: 219 W/m^2

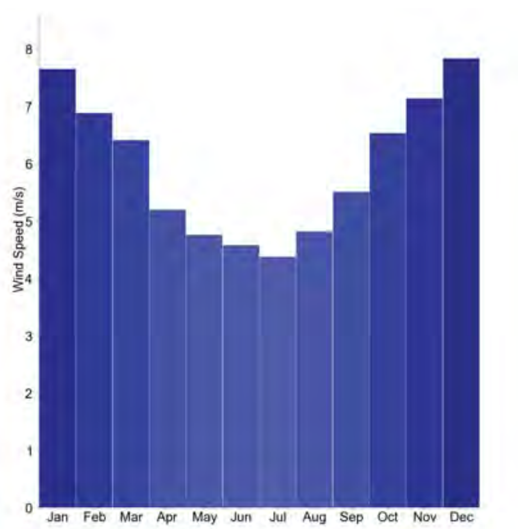
Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.74 Weibull k: 2.11

200m Graphs



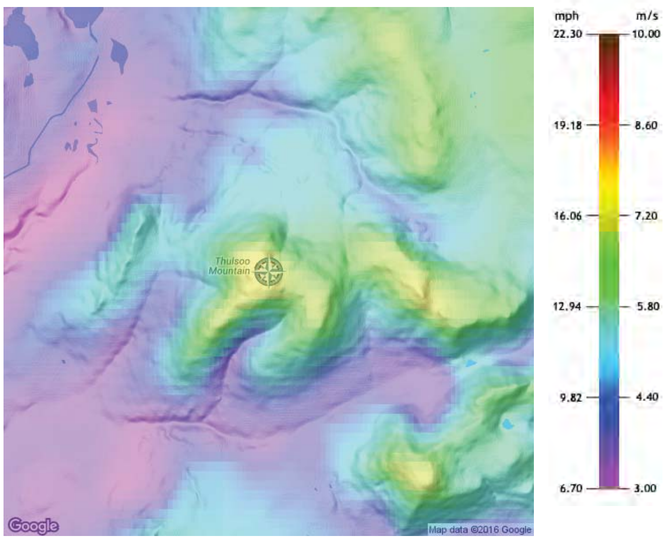
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 7



Latitude: 61.03419 Longitude: -136.93222

Wind Speed (100.0 m): 7.66 m/s

Roughness: 0.0100 m Elevation: 1,876.5 m (6,156.5 ft)

Air Density: 1.065 kg/m3

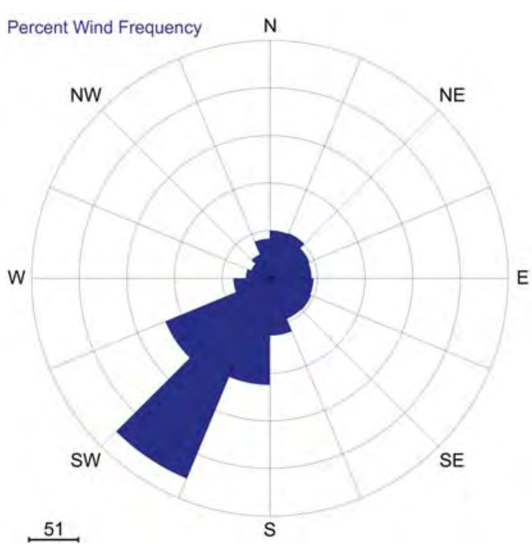
Mean Power Density: 439 W/m^2

Uncertainty Value: 0.35 +/- m/s

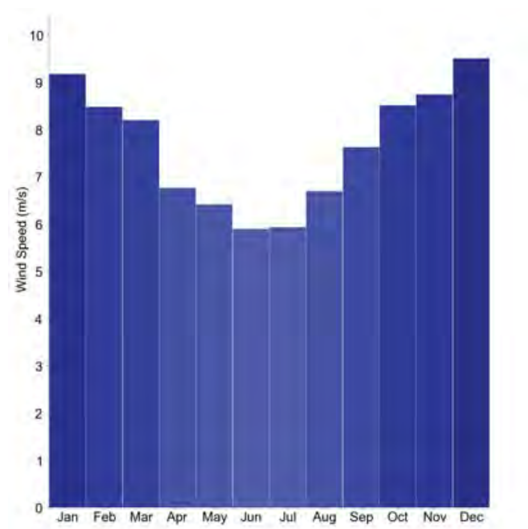
Weibull A: 8.65 Weibull k: 2.08

Mean annual wind speed map at 100 m hub height for Thulsoo Mtn.

200m Graphs



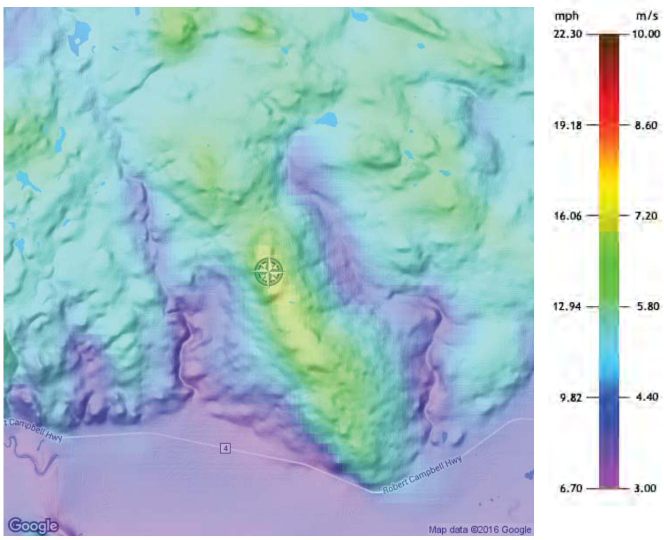
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 11



Mean annual wind speed map at 100 m hub height for West of Faro, N of Hwy 4.

Latitude: 62.20139 Longitude: -133.91785

Wind Speed (100.0 m): 7.31 m/s

Roughness: 0.1000 m Elevation: 1,371.9 m (4,501.0 ft)

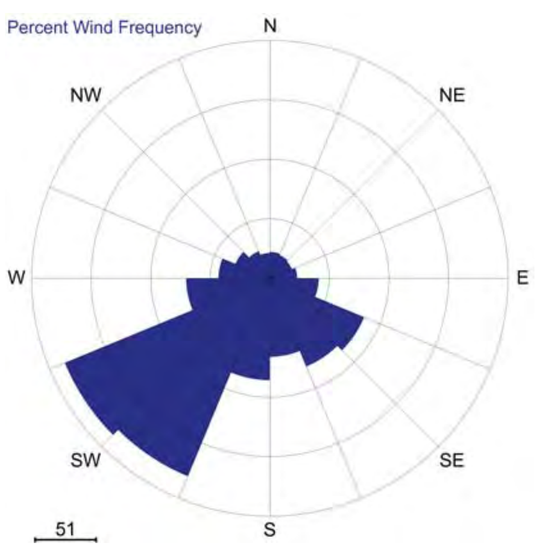
Air Density: 1.142 kg/m3

Mean Power Density: 414 W/m^2

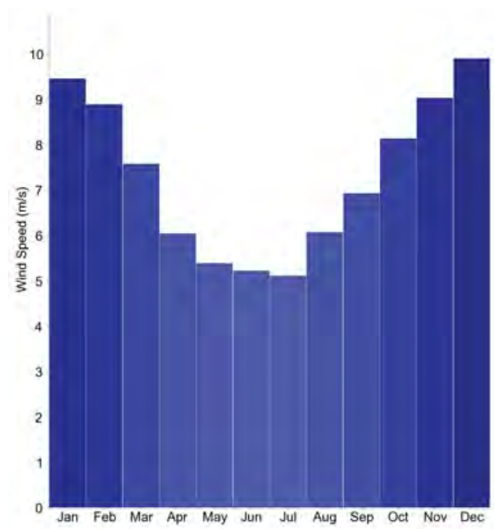
Uncertainty Value: 0.35 +/- m/s

Weibull A: 8.25 Weibull k: 2.06

200m Graphs



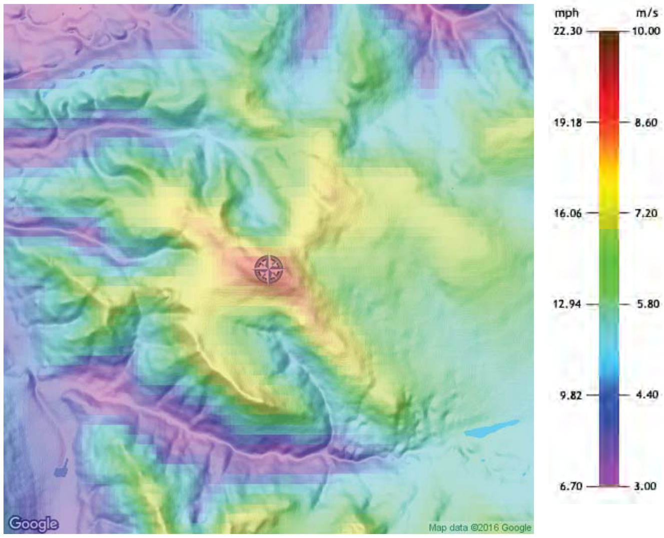
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 12



Latitude: 62.07624 Longitude: -133.77022

Wind Speed (100.0 m): 8.83 m/s

Roughness: 0.0100 m Elevation: 1,852.3 m (6,077.1 ft)

Air Density: 1.054 kg/m3

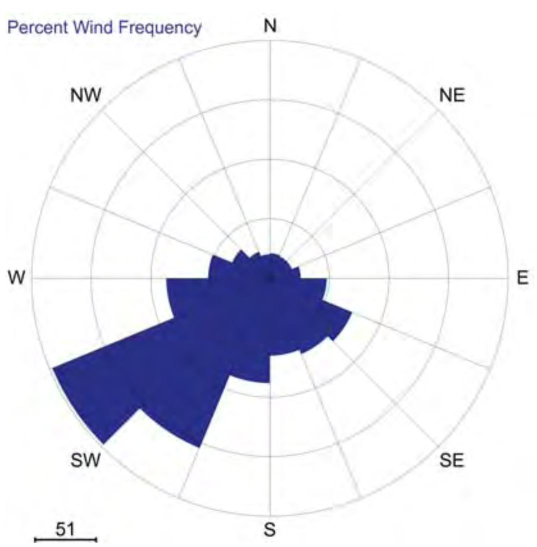
Mean Power Density: 683 W/m^2

Uncertainty Value: 0.35 +/- m/s

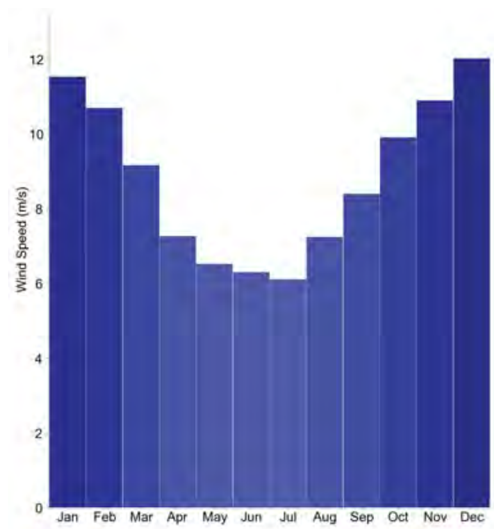
Weibull A: 9.97 Weibull k: 2.03

Mean annual wind speed map at 100 m hub height for West of Faro, S of Hwy 4.

200m Graphs



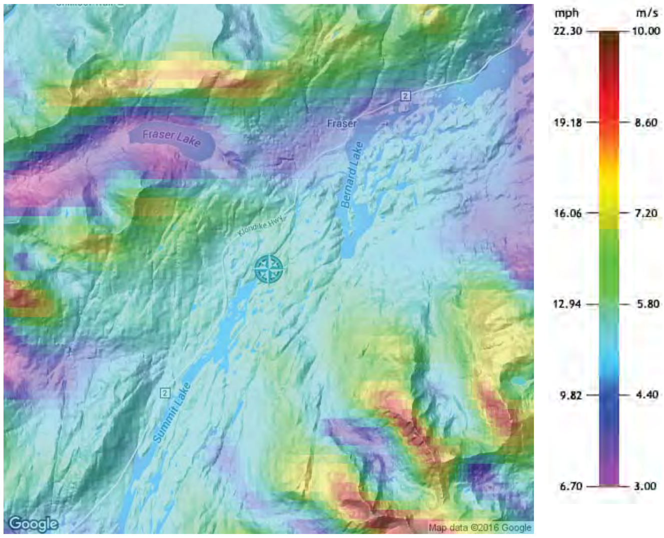
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 25



Mean annual wind speed map at 100 m hub height for White Pass.

Latitude: 59.68854 Longitude: -135.07759

Wind Speed (100.0 m): 5.4 m/s

Roughness: 0.0010 m Elevation: 886.7 m (2,909.1 ft)

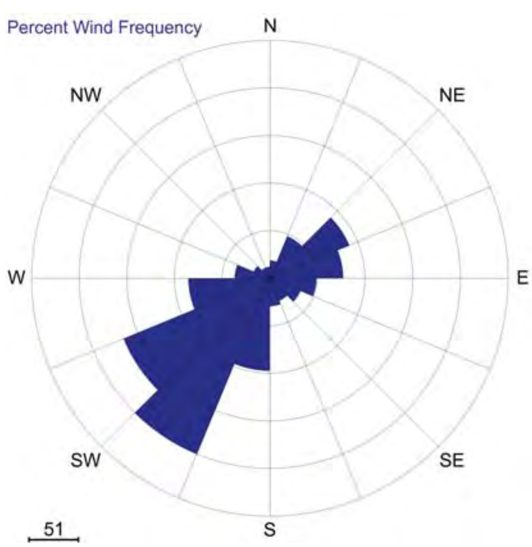
Air Density: 1.137 kg/m3

Mean Power Density: 169 W/m^2

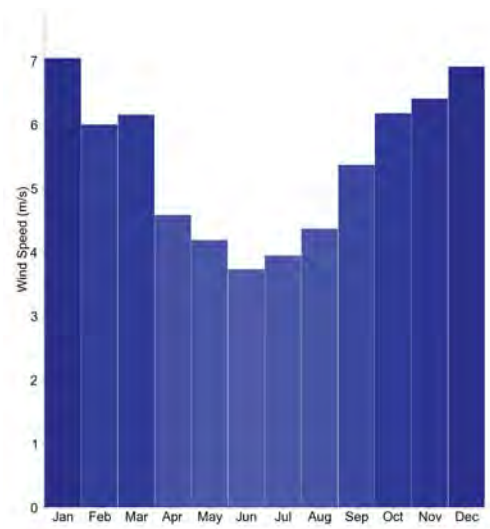
Uncertainty Value: 0.35 +/- m/s

Weibull A: 6.09 Weibull k: 2.02

200m Graphs



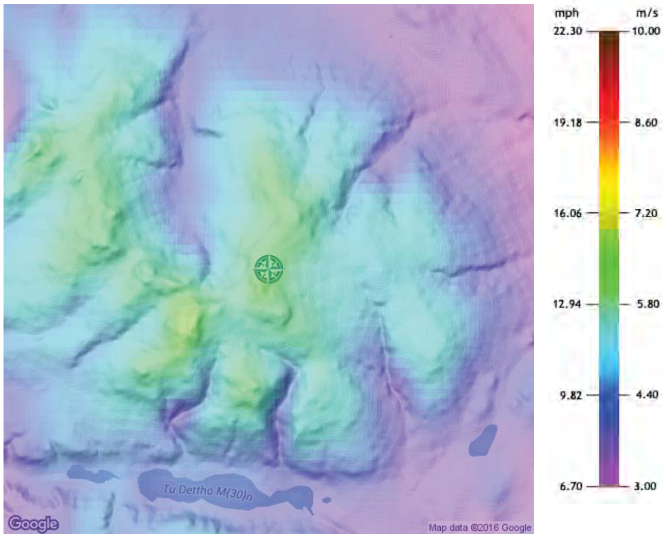
Wind Rose



Monthly Distribution

Site Characteristics

Site ID: 19



Mean annual wind speed map at 100 m hub height for Willow Hills.

Latitude: 63.2262 Longitude: -136.75919

Wind Speed (100.0 m): 6.53 m/s

Roughness: 0.1000 m Elevation: 1,305.6 m (4,283.5 ft)

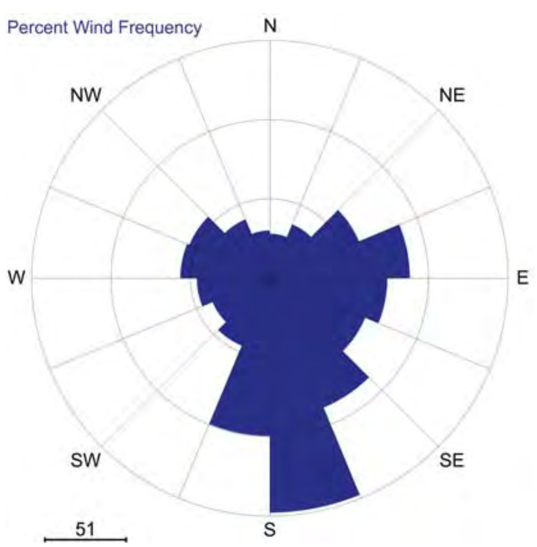
Air Density: 1.115 kg/m3

Mean Power Density: 286 W/m^2

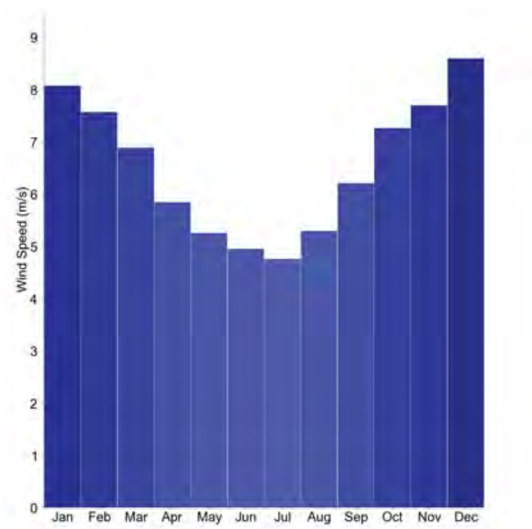
Uncertainty Value: 0.35 +/- m/s

Weibull A: 7.37 Weibull k: 2.07

200m Graphs



Wind Rose



Monthly Distribution

APPENDIX F – ADDITIONAL PHOTOS FROM SITE VISITS

(in alphabetical order)

Anticline Mtn Ridges, view North

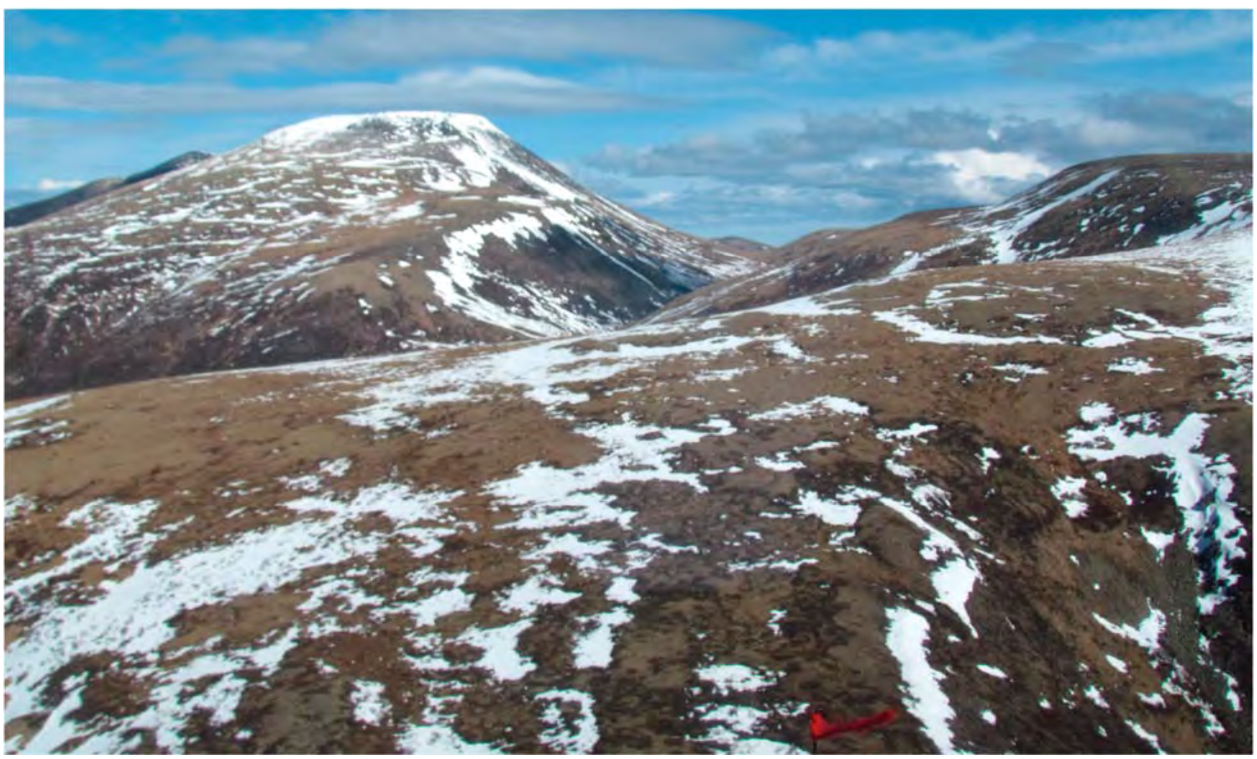
Anticline Mtn, South Ridge detail, view NW

Cyprus Mine Hill, alternate SE ridge, view north

Cyprus Mine Hill, north ridge, access point, view SE

Flat Mountain, view north

Flat Mountain complex, view north



Hayes Peak Ride Area, view SW

Hayes Peak, view S

Kluane Lake East Shore, view East

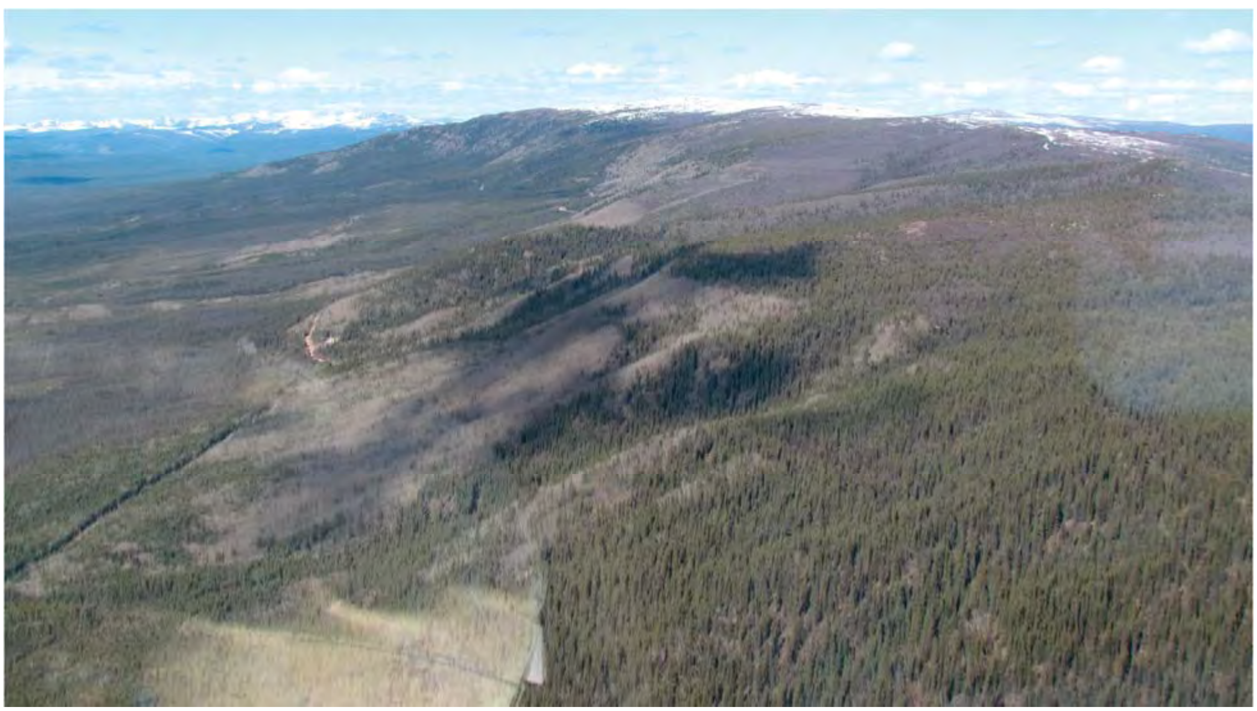
Little Salmon Hill, view west, showing access road

Little Salmon Hill, south ridge, view E

Little Salmon Hill, north ridge, view E

Miller's Ridge, view to Murray Peak, view N

Miller's Ridge, from near Carmacks, view W



Minto Hill, view NW

Mount Berdoe, view North

Mount Berdoe summit, view W

Mount Lorne Subpeak, view NW

Mount Lorne Subpeak, southside, view N

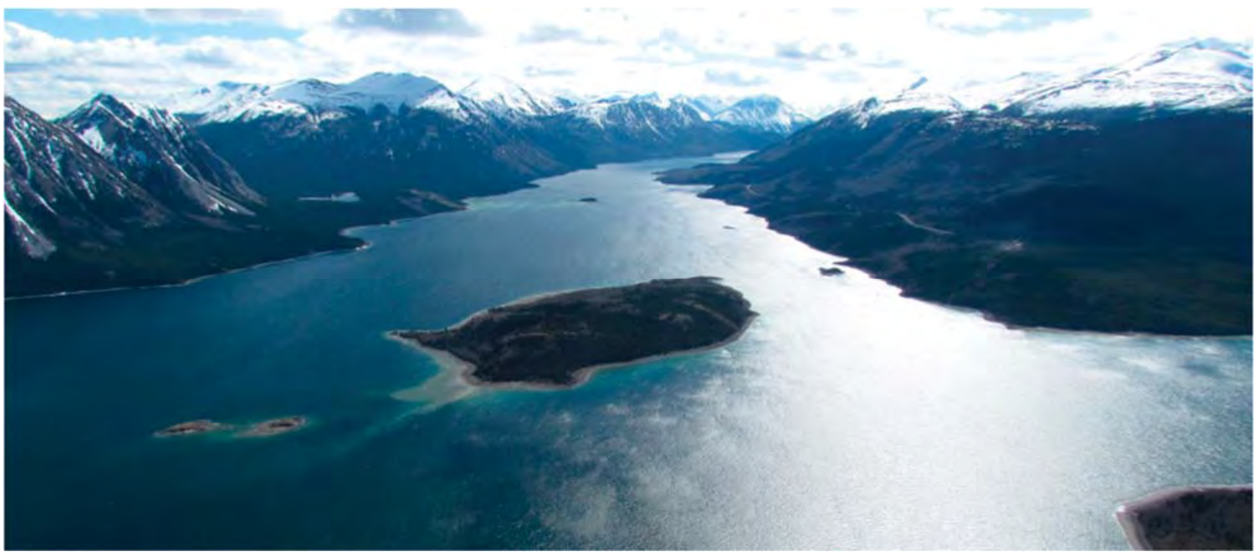
Paint Mountain, view north

Sugarloaf Mtn, Northeast face, view N

Sugarloaf Mtn, Montana Mtn, access road, view S

Mt Sumanik ridge, view N

Tagish Lake and Bowe Mountain, view south



APPENDIX G – WASP WIND FARM REPORTS

Cyprus Mine Hill

Table 1 Cyprus 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,810 m	5.44 GWh	0.36%	6.87 m/s	283 W/m²
Turbine #2	1,850 m	5.80 GWh	4.25%	7.23 m/s	330 W/m²
Turbine #3	1,840 m	5.75 GWh	1.73%	7.10 m/s	326 W/m²
Turbine #4	1,850 m	5.88 GWh	2.73%	7.22 m/s	335 W/m²
Turbine #5	1,825 m	5.20 GWh	3.69%	6.83 m/s	277 W/m²
Turbine #6	1,850 m	6.18 GWh	5.94%	7.55 m/s	378 W/m²
Turbine #7	1,822 m	5.89 GWh	1.92%	7.23 m/s	350 W/m²
Turbine #8	1,850 m	6.39 GWh	1.10%	7.46 m/s	353 W/m²
Turbine #9	1,850 m	6.15 GWh	3.32%	7.41 m/s	351 W/m²
Turbine #10	1,784 m	5.44 GWh	1.16%	6.90 m/s	282 W/m²
Average		**5.81 GWh**	**2.62%**	**2.62%**	**2.62%**
Total		**58.12 GWh**			

* Including wake losses, but excluding other losses

Table 2 Cyprus 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,850 m	6.48 GWh	1.41%	7.55 m/s	378 W/m²
Turbine #2	1,822 m	5.97 GWh	0.65%	7.23 m/s	350 W/m²
Turbine #3	1,850 m	6.41 GWh	0.85%	7.46 m/s	353 W/m²
Turbine #4	1,850 m	6.16 GWh	3.22%	7.41 m/s	351 W/m²
Turbine #5	1,784 m	5.44 GWh	1.10%	6.90 m/s	282 W/m²
Average		**6.09 GWh**	**1.45%**	**7.31 m/s**	**343 W/m²**
Total		**30.45 GWh**			

* Including wake losses, but excluding other losses

Table 3 Cyprus 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,850 m	6.48 GWh	1.38%	7.55 m/s	378 W/m²
Turbine #2	1,822 m	5.97 GWh	0.62%	7.23 m/s	350 W/m²
Turbine #3	1,850 m	6.43 GWh	0.47%	7.46 m/s	353 W/m²
Average		**6.29 GWh**	**0.82%**	**7.41 m/s**	**360 W/m²**
Total		**18.88 GWh**			

* Including wake losses, but excluding other losses

Kluane Lake (West shore)

Table 4 Kluane Lake 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	821 m	5.34 GWh	3.42%	6.57 m/s	310 W/m²
Turbine #2	816 m	5.18 GWh	5.25%	6.53 m/s	305 W/m²
Turbine #3	821 m	5.21 GWh	5.69%	6.57 m/s	310 W/m²
Turbine #4	828 m	5.37 GWh	4.00%	6.61 m/s	316 W/m²
Turbine #5	815 m	5.32 GWh	1.63%	6.49 m/s	301 W/m²
Turbine #6	803 m	5.25 GWh	4.60%	6.55 m/s	309 W/m²
Turbine #7	800 m	5.10 GWh	6.22%	6.52 m/s	303 W/m²
Turbine #8	801 m	5.14 GWh	5.89%	6.53 m/s	306 W/m²
Turbine #9	808 m	5.27 GWh	4.95%	6.58 m/s	313 W/m²
Turbine #10	806 m	5.37 GWh	2.89%	6.57 m/s	312 W/m²
Average		**5.26 GWh**	**4.45%**	**6.55 m/s**	**309 W/m²**
Total		**52.56 GWh**			

* Including wake losses, but excluding other losses

Table 5 Kluane Lake 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	821 m	5.34 GWh	3.49%	6.57 m/s	310 W/m²
Turbine #2	828 m	5.41 GWh	3.33%	6.61 m/s	316 W/m²
Turbine #3	815 m	5.33 GWh	1.42%	6.49 m/s	301 W/m²
Turbine #4	808 m	5.38 GWh	3.13%	6.58 m/s	313 W/m²
Turbine #5	806 m	5.40 GWh	2.31%	6.57 m/s	312 W/m²
Average		**5.37 GWh**	**2.74%**	**6.56 m/s**	**310 W/m²**
Total		**26.85 GWh**			

* Including wake losses, but excluding other losses

Table 6 Kluane Lake 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	821 m	5.40 GWh	2.29%	6.57 m/s	310 W/m²
Turbine #2	828 m	5.53 GWh	1.06%	6.61 m/s	316 W/m²
Turbine #3	808 m	5.51 GWh	0.69%	6.58 m/s	313 W/m²
Average		**5.48 GWh**	**1.35%**	**6.59 m/s**	**313 W/m²**
Total		**16.44 GWh**			

* Including wake losses, but excluding other losses

Miller's Ridge

Table 7 Miller's Ridge 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,404 m	6.99 GWh	1.48%	7.86 m/s	511 W/m²
Turbine #2	1,417 m	6.90 GWh	1.78%	7.80 m/s	498 W/m²
Turbine #3	1,441 m	7.06 GWh	1.85%	7.88 m/s	504 W/m²
Turbine #4	1,450 m	6.81 GWh	2.19%	7.70 m/s	461 W/m²
Turbine #5	1,450 m	6.47 GWh	2.50%	7.51 m/s	426 W/m²
Turbine #6	1,450 m	6.28 GWh	2.65%	7.40 m/s	407 W/m²
Turbine #7	1,450 m	6.40 GWh	2.01%	7.48 m/s	432 W/m²
Turbine #8	1,450 m	6.58 GWh	1.06%	7.57 m/s	456 W/m²
Turbine #9	1,500 m	6.76 GWh	2.18%	7.70 m/s	456 W/m²
Turbine #10	1,500 m	6.46 GWh	2.58%	7.47 m/s	404 W/m²
Average		**6.67 GWh**	**2.03%**	**7.64 m/s**	**456 W/m²**
Total		**66.71 GWh**			

* Including wake losses, but excluding other losses

Table 8 Miller's Ridge 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,404 m	7.00 GWh	1.43%	7.86 m/s	511 W/m²
Turbine #2	1,417 m	6.91 GWh	1.64%	7.80 m/s	498 W/m²
Turbine #3	1,441 m	7.07 GWh	1.69%	7.88 m/s	504 W/m²
Turbine #4	1,450 m	6.84 GWh	1.70%	7.70 m/s	461 W/m²
Turbine #5	1,450 m	6.60 GWh	0.53%	7.51 m/s	426 W/m²
Average		**6.88 GWh**	**1.40%**	**7.75 m/s**	**480 W/m²**
Total		**34.42 GWh**			

* Including wake losses, but excluding other losses

Table 9 Miller's Ridge 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,404 m	7.00 GWh	1.31%	7.86 m/s	511 W/m²
Turbine #2	1,417 m	6.93 GWh	1.36%	7.80 m/s	498 W/m²
Turbine #3	1,441 m	7.17 GWh	0.32%	7.88 m/s	504 W/m²
Average		**7.03 GWh**	**1.00%**	**7.85 m/s**	**504 W/m²**
Total		**21.10 GWh**			

* Including wake losses, but excluding other losses

Sugarloaf Mountain

Table 10 Sugarloaf 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,203 m	3.96 GWh	0.58%	5.84 m/s	205 W/m²
Turbine #2	1,206 m	3.60 GWh	0.95%	5.57 m/s	187 W/m²
Turbine #3	1,306 m	3.78 GWh	1.15%	5.70 m/s	199 W/m²
Turbine #4	1,303 m	3.43 GWh	1.17%	5.52 m/s	174 W/m²
Turbine #5	1,397 m	3.53 GWh	1.36%	5.60 m/s	183 W/m²
Turbine #6	1,406 m	3.68 GWh	1.39%	5.70 m/s	191 W/m²
Turbine #7	1,402 m	3.88 GWh	0.90%	5.81 m/s	207 W/m²
Turbine #8	1,403 m	3.74 GWh	1.12%	5.73 m/s	198 W/m²
Turbine #9	1,402 m	3.80 GWh	1.30%	5.77 m/s	203 W/m²
Turbine #10	1,395 m	3.71 GWh	0.56%	5.70 m/s	196 W/m²
Average		**3.71 GWh**	**1.05%**	**5.69 m/s**	**194 W/m²**
Total		**37.11 GWh**			

* Including wake losses, but excluding other losses

Table 11 Sugarloaf 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,203 m	3.96 GWh	0.52%	5.84 m/s	205 W/m²
Turbine #2	1,206 m	3.60 GWh	0.87%	5.57 m/s	187 W/m²
Turbine #3	1,306 m	3.79 GWh	1.06%	5.70 m/s	199 W/m²
Turbine #4	1,303 m	3.44 GWh	0.84%	5.52 m/s	174 W/m²
Turbine #5	1,397 m	3.56 GWh	0.58%	5.60 m/s	183 W/m²
Average		**3.67 GWh**	**0.77%**	**5.65 m/s**	**190 W/m²**
Total		**18.35 GWh**			

* Including wake losses, but excluding other losses

Table 12 Sugarloaf 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,203 m	3.96 GWh	0.50%	5.84 m/s	205 W/m²
Turbine #2	1,206 m	3.61 GWh	0.69%	5.57 m/s	187 W/m²
Turbine #3	1,306 m	3.81 GWh	0.42%	5.70 m/s	199 W/m²
Average		**3.79 GWh**	**0.54%**	**5.70 m/s**	**197 W/m²**
Total		**11.38 GWh**			

* Including wake losses, but excluding other losses

Mount Sumanik

Table 13 Mount Sumanik 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,470 m	5.66 GWh	1.70%	6.89 m/s	324 W/m²
Turbine #2	1,500 m	5.54 GWh	1.86%	6.83 m/s	325 W/m²
Turbine #3	1,500 m	5.14 GWh	1.82%	6.57 m/s	290 W/m²
Turbine #4	1,500 m	4.83 GWh	1.46%	6.38 m/s	258 W/m²
Turbine #5	1,543 m	4.38 GWh	2.90%	6.15 m/s	232 W/m²
Turbine #6	1,553 m	4.45 GWh	2.59%	6.17 m/s	246 W/m²
Turbine #7	1,563 m	4.25 GWh	2.89%	6.05 m/s	229 W/m²
Turbine #8	1,581 m	4.18 GWh	3.25%	6.03 m/s	222 W/m²
Turbine #9	1,583 m	4.85 GWh	4.62%	6.50 m/s	263 W/m²
Turbine #10	1,600 m	4.86 GWh	0.92%	6.39 m/s	252 W/m²
Average		**4.81 GWh**	**2.40%**	**6.40 m/s**	**264 W/m²**
Total		**48.13 GWh**			

* Including wake losses, but excluding other losses

Table 14 Mount Sumanik 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,500 m	5.56 GWh	1.52%	6.83 m/s	325 W/m²
Turbine #2	1,500 m	5.15 GWh	1.72%	6.57 m/s	290 W/m²
Turbine #3	1,500 m	4.84 GWh	1.16%	6.38 m/s	258 W/m²
Turbine #4	1,543 m	4.42 GWh	2.03%	6.15 m/s	232 W/m²
Turbine #5	1,553 m	4.55 GWh	0.27%	6.17 m/s	246 W/m²
Average		**4.90 GWh**	**1.34%**	**6.42 m/s**	**270 W/m²**
Total		**24.52 GWh**			

* Including wake losses, but excluding other losses

Table 15 Mount Sumanik 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,470 m	5.67 GWh	1.53%	6.89 m/s	324 W/m²
Turbine #2	1,500 m	5.56 GWh	1.51%	6.83 m/s	325 W/m²
Turbine #3	1,500 m	5.22 GWh	0.34%	6.57 m/s	290 W/m²
Average		**5.48 GWh**	**1.13%**	**6.76 m/s**	**313 W/m²**
Total		**16.45 GWh**			

* Including wake losses, but excluding other losses

Tehcho (Ferry Hill)

Table 16 Tehcho 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,145 m	3.35 GWh	7.60%	5.65 m/s	167 W/m²
Turbine #2	1,186 m	4.00 GWh	4.83%	5.94 m/s	192 W/m²
Turbine #3	1,196 m	4.07 GWh	7.22%	6.03 m/s	201 W/m²
Turbine #4	1,124 m	3.63 GWh	6.19%	5.71 m/s	176 W/m²
Turbine #5	1,101 m	4.25 GWh	4.28%	5.99 m/s	209 W/m²
Turbine #6	1,061 m	3.87 GWh	3.44%	5.80 m/s	182 W/m²
Turbine #7	1,098 m	3.56 GWh	8.15%	5.71 m/s	177 W/m²
Turbine #8	1,093 m	4.27 GWh	4.53%	6.03 m/s	207 W/m²
Turbine #9	1,061 m	4.36 GWh	1.38%	6.03 m/s	203 W/m²
Turbine #10	970 m	3.82 GWh	0.66%	5.71 m/s	174 W/m²
Average		**3.92 GWh**	**4.83%**	**5.86 m/s**	**189 W/m²**
Total		**39.15 GWh**			

* Including wake losses, but excluding other losses

Table 17 Tehcho 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,186 m	4.07 GWh	3.15%	5.94 m/s	192 W/m²
Turbine #2	1,196 m	4.24 GWh	3.15%	6.03 m/s	201 W/m²
Turbine #3	1,101 m	4.38 GWh	1.26%	5.99 m/s	209 W/m²
Turbine #4	1,093 m	4.36 GWh	2.46%	6.03 m/s	207 W/m²
Turbine #5	1,061 m	4.41 GWh	0.23%	6.03 m/s	203 W/m²
Average		**4.29 GWh**	**2.05%**	**6.00 m/s**	**202 W/m²**
Total		**21.46 GWh**			

* Including wake losses, but excluding other losses

Table 18 Tehcho 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,186 m	4.08 GWh	2.86%	5.94 m/s	192 W/m²
Turbine #2	1,196 m	4.21 GWh	3.99%	6.03 m/s	201 W/m²
Turbine #3	1,124 m	3.80 GWh	1.83%	5.71 m/s	176 W/m²
Average		**4.03 GWh**	**2.89%**	**5.89 m/s**	**190 W/m²**
Total		**12.08 GWh**			

* Including wake losses, but excluding other losses

Thulsoo Mountain

Table 19 Thulsoo 20 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,850 m	7.05 GWh	1.39%	7.91 m/s	459 W/m²
Turbine #2	1,850 m	6.50 GWh	1.40%	7.55 m/s	407 W/m²
Turbine #3	1,826 m	6.60 GWh	0.90%	7.62 m/s	438 W/m²
Turbine #4	1,811 m	6.14 GWh	1.09%	7.31 m/s	380 W/m²
Turbine #5	1,803 m	5.84 GWh	0.68%	7.10 m/s	332 W/m²
Turbine #6	1,781 m	6.38 GWh	1.30%	7.50 m/s	419 W/m²
Turbine #7	1,800 m	5.97 GWh	3.78%	7.32 m/s	381 W/m²
Turbine #8	1,800 m	6.53 GWh	2.68%	7.67 m/s	447 W/m²
Turbine #9	1,789 m	6.59 GWh	1.15%	7.65 m/s	448 W/m²
Turbine #10	1,769 m	6.14 GWh	0.30%	7.28 m/s	366 W/m²
Average		**6.37 GWh**	**1.47%**	**7.49 m/s**	**408 W/m²**
Total		**63.74 GWh**			

* Including wake losses, but excluding other losses

Table 20 Thulsoo 10 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,850 m	7.06 GWh	1.30%	7.91 m/s	459 W/m²
Turbine #2	1,850 m	6.50 GWh	1.34%	7.55 m/s	407 W/m²
Turbine #3	1,826 m	6.61 GWh	0.82%	7.62 m/s	438 W/m²
Turbine #4	1,811 m	6.15 GWh	0.90%	7.31 m/s	380 W/m²
Turbine #5	1,803 m	5.87 GWh	0.29%	7.10 m/s	332 W/m²
Average		**6.44 GWh**	**0.93%**	**7.50 m/s**	**403 W/m²**
Total		**32.18 GWh**			

* Including wake losses, but excluding other losses

Table 21 Thulsoo 6 MW Wind Farm Site-Specific Data at 80 m Hub Height; Generic Turbine

Site	Elevation above sea level	Annual electricity production*	Wake loss	Wind speed	Wind energy
Turbine #1	1,850 m	7.06 GWh	1.19%	7.91 m/s	459 W/m²
Turbine #2	1,850 m	6.52 GWh	1.13%	7.55 m/s	407 W/m²
Turbine #3	1,826 m	6.66 GWh	0.11%	7.62 m/s	438 W/m²
Average		**6.75 GWh**	**0.81%**	**7.69 m/s**	**435 W/m²**
Total		**20.24 GWh**			

* Including wake losses, but excluding other losses

APPENDIX H – ENERGY PERFORMANCE OF THE SELECTED SITES

1 CYPRUS MINE HILL

Wind turbines at Cyprus Mine would perform well. A 2.0 MW turbine would produce between 5.2 and 6.5 GWh of energy annually, depending on the size of the wind farm and the particular location of the turbine within the site. This is 14% to 17% less than the same turbine at Miller's Ridge, the top wind resource site.

1.1 Annual Energy Production

WAsP modeling of the three wind farm capacity options – 20 MW, 10 MW and 6 MW – indicates an approximate 33% wind turbine net capacity factor based on the net annual energy production (AEP) given in Table 22 below.[1] A 33% capacity factor is very good but perhaps could be slightly improved upon with a wind turbine model more attuned to this site, in place of the generic 2 MW model for the modeling exercise. Chapter 1.2 below describes the impact of various turbine models.

Figure 1 and Table 22 below state the key production parameters. Given are the potential energy output, the gross energy production and the net energy production. The gross energy production is representative of the wind energy resource were there no wake losses due to terrain roughness and neighbouring turbines. Subtracting these wake losses yields the gross energy production. Conversion or efficiency losses, curtailment, downtime and parasitic energy consumption further reduce the annual output. The remaining net energy production is what will be fed into YEC's grid.

[1] Capacity factor of a wind turbine is defined as the mean annual power output divided by rated power or the total annual power output divided by the capacity and by 8760, the number of hours in a year.

Table 22 Cyprus Mine Hill Wind Farm Annual Energy Production, 2 MW generic turbine

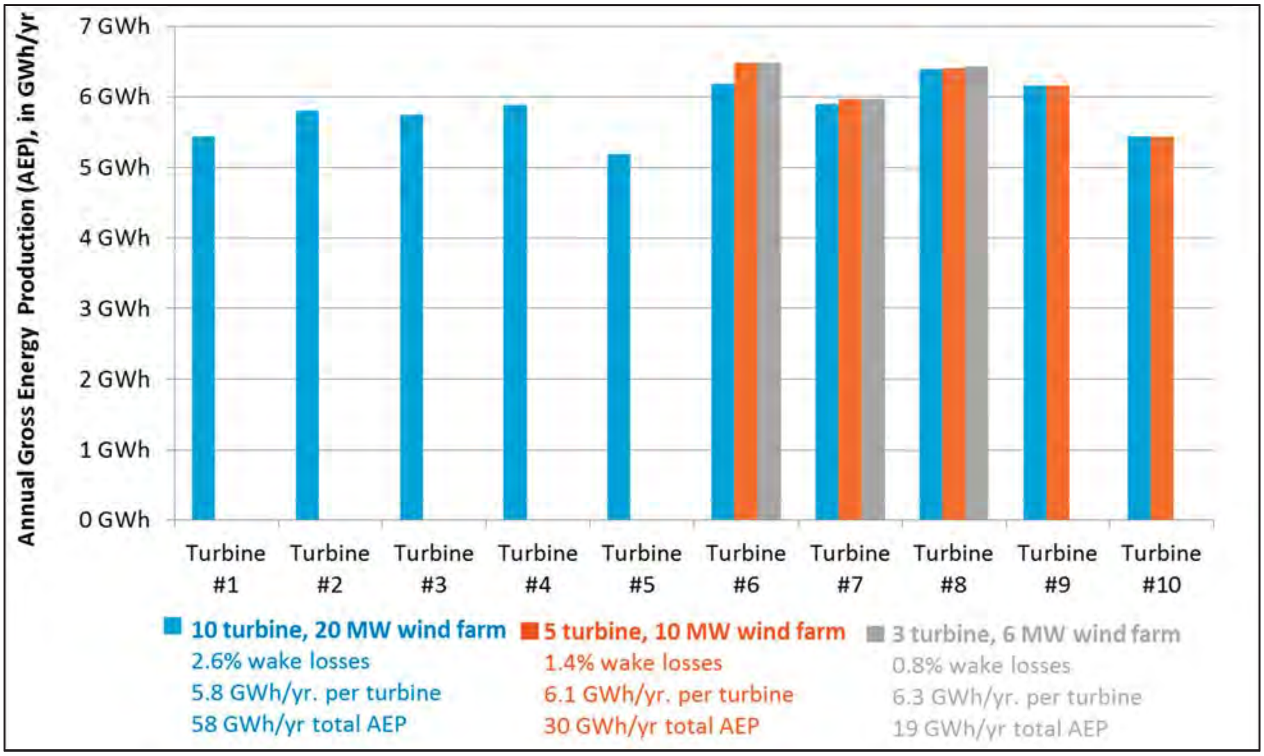
Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	59.7	5.97	5.40	6.57
	Wake loss	2.7%	-	-	-
	AEP after Wake Loss	58.1	5.81	5.20	6.39
	Additional Losses and Downtime	14.7%			
	Net AEP	**49.6**			
10 MW	Gross AEP	30.9	6.18	5.50	6.57
	Wake loss	1.5%	-	-	-
	AEP after Wake Loss	30.5	6.09	5.44	6.48
	Additional Losses and Downtime	14.7%			
	Net AEP	**26.0**			
6 MW	Gross AEP	19.0	6.35	6.01	6.57
	Wake loss	0.8%	-	-	-
	AEP after Wake Loss	18.9	6.29	5.97	6.48
	Additional Losses and Downtime	14.7%			
	Net AEP	**16.1**			

Losses and downtime are calculated as a percentage and are therefore proportionally smaller for a small wind farm than for large wind farm. The difference in relative losses between the three sizes of wind farms modeled is solely due to wake losses. These tend to increase with the size of a wind farm because the individual turbines start to 'shade' each other or create a wake, turbulences or reduced wind speed that effects a downwind or adjacent turbine.

Figure 1 indicates the annual gross energy output of the site turbines. The ten turbine 20 MW capacity turbine layout was developed first and selected turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Retained turbines were chosen to reduce the site footprint *and* retain the higher performing locations. This approach applies to all seven selected sites.

For the five-turbine (10 MW) option at Cyprus Mine, Turbines 6 through 10 were retained (refer to Figure 10 in Chapter 3.1 of the body of the report). For the three-turbine (6 MW) wind farm location, Turbines 6, 7 and 8 were retained as the model demonstrates high energy production for turbines at these locations and the turbines are near each other, minimizing infrastructure costs.

Figure 1 Annual Net (wake loss only) Energy Generation, Cyprus Mine Hill



For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance. Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

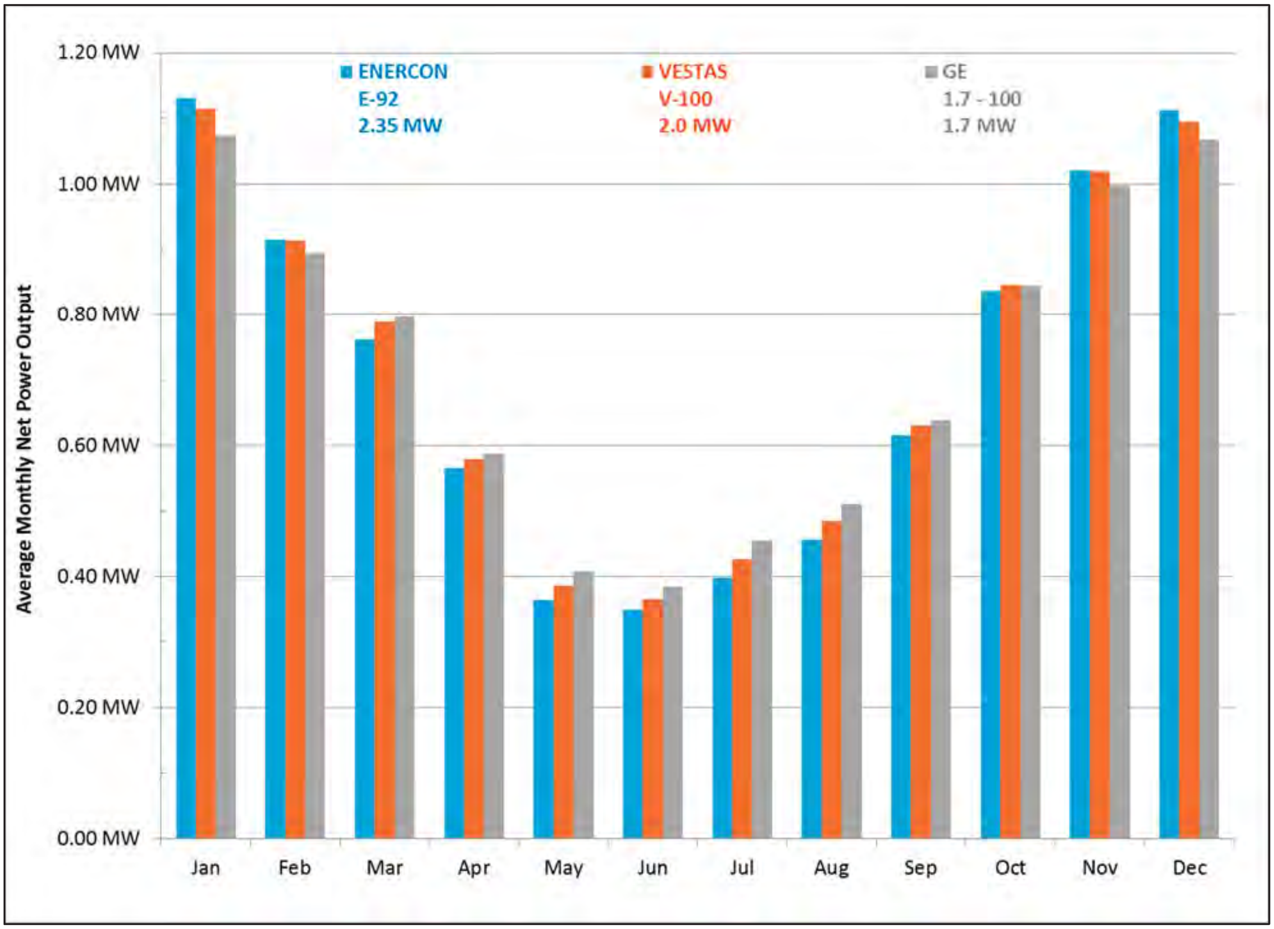
1.2 Turbine Choice

The numbers presented above are based on a generic 2.0 MW turbine. This may not be the best choice for this site. To gauge the impact of different types and sizes of turbines we compared three alternate types of turbines. Modeling of an Enercon E-92, a Vestas V-100 and a GE-1.7-100 turbine showed that a smaller General Electric 1.7 MW turbine yields a slightly higher (1%) output than the larger capacity 2.3 MW Enercon E-92. In the higher wind speed period from October to April, however, the Vestas V-100 performs slightly better than the other two turbines, see Figure 2 below.

1.3 Monthly Generation Profile

As for all sites selected, a wind farm at Cyprus Mine generates more energy in winter than summer, as one would expect. Modeling indicates that 69% to 71% of annual energy production will occur October to April (see Figure 2).

Figure 2 Monthly Generation Profile of a three types of wind turbines at Cyprus Mine Hill

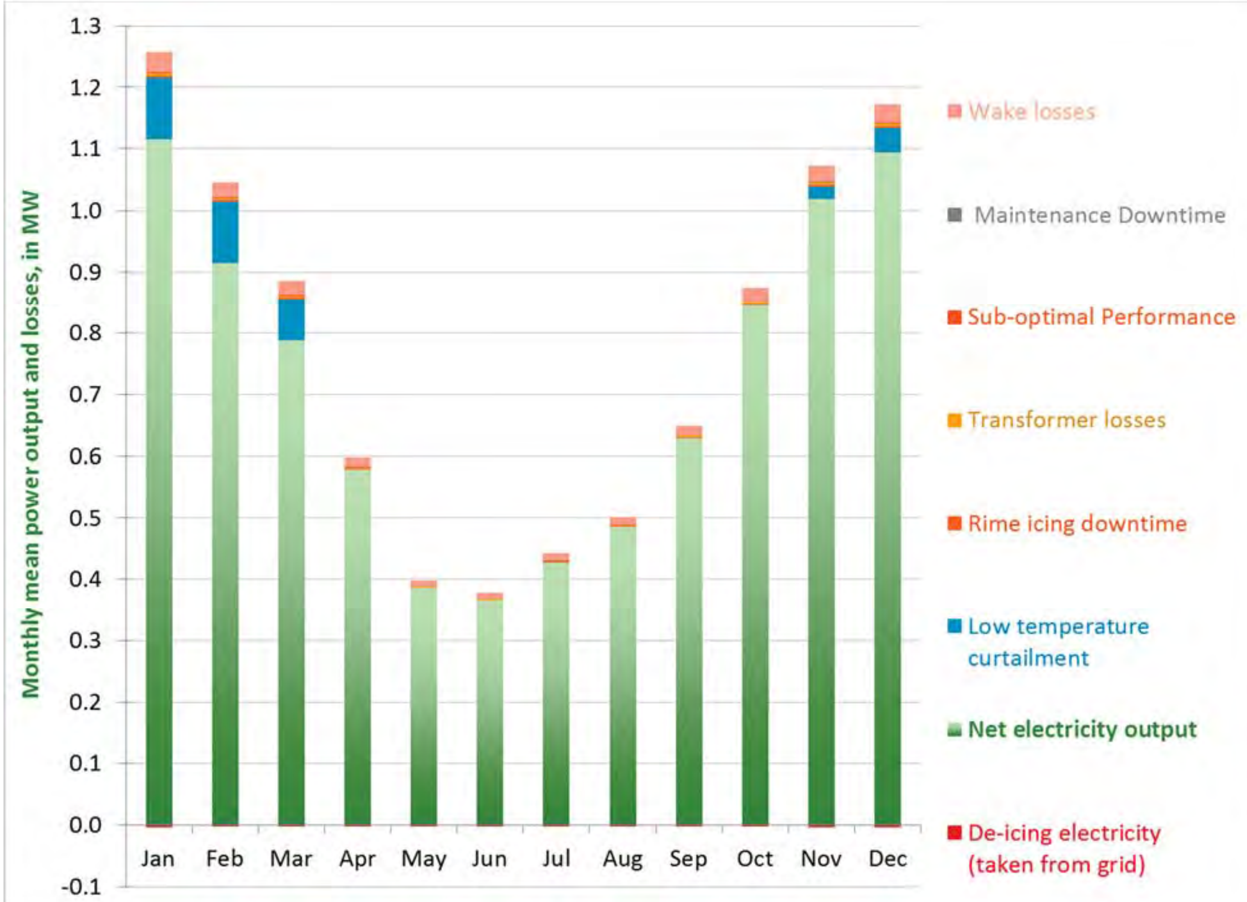


The numbers presented above are the net energy production delivered to the grid of a single turbine. Wake losses from terrain features or nearby turbines are not taken into account. The mean power outputs to the grid presented above are relevant in terms of turbine selection and monthly generation profile rather than as absolute numbers. AWS software does not take the impact of terrain features and nearby turbines into account the way WAsP modeling does.

Just as power output, monthly losses, curtailment, and downtime described in Chapter 4.2 of the body of the report vary over the course of the year. Figure 2 below displays monthly losses in relation to the monthly mean power that will be fed into the grid assuming a Vestas V-100 turbine at Cyprus Mine. Energy production is higher during the winter months and so are losses. De-icing energy is shown as negative because it will actually draw power from the grid. Over the course of the year 14.7% of the annual energy that could be generated at Cyprus Mine will be lost due to downtime, curtailment, losses or energy consumption for de-icing.

This scheme is similar for all seven sites, though there are differing losses depending on the air temperature over the course of the year and the elevation of the site.

Figure 3: Monthly Mean Net Power Output for a GE-100-1.7 MW Turbine at Cyprus Mine



For the purpose of creating data of monthly net electricity output we combined the annual gross energy production forecasted by the WAsP model with the monthly distribution of energy production of the AWS report. We then subtracted all other losses described in the main report to obtain monthly net electricity production data.

Table 23 Cyprus Mine Hill: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	8.0 GWh	0.4 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	1.1 GWh	**7.0 GWh**
Feb	6.1 GWh	0.5 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	1.1 GWh	**5.0 GWh**
Mar	5.7 GWh	0.4 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	1.0 GWh	**4.6 GWh**
Apr	3.7 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**3.1 GWh**
May	2.5 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**2.1 GWh**
Jun	2.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.0 GWh**
Jul	2.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.6 GWh	0.9 GWh	**1.9 GWh**
Aug	3.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.9 GWh**
Sep	4.0 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**3.5 GWh**
Oct	5.6 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**4.9 GWh**
Nov	6.6 GWh	0.1 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.7 GWh	**5.9 GWh**
Dec	7.5 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.8 GWh	**6.7 GWh**
Overall	**58.1 GWh**	**1.6 GWh**	**1.5 GWh**	**1.5 GWh**	**2.3 GWh**	**0.6 GWh**	**1.2 GWh**	**8.5 GWh**	**49.6 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	4.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**3.7 GWh**
Feb	3.2 GWh	0.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**2.6 GWh**
Mar	3.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**2.4 GWh**
Apr	1.9 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.6 GWh**
May	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
Jun	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
Jul	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.3 GWh	0.5 GWh	**1.0 GWh**
Aug	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.5 GWh**
Sep	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.8 GWh**
Oct	2.9 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.6 GWh**
Nov	3.5 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.1 GWh**
Dec	3.9 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.5 GWh**
Overall	**30.5 GWh**	**0.8 GWh**	**0.8 GWh**	**0.8 GWh**	**1.2 GWh**	**0.3 GWh**	**0.6 GWh**	**4.5 GWh**	**26.0 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.6 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.3 GWh**
Feb	2.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**1.6 GWh**
Mar	1.8 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.5 GWh**
Apr	1.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.0 GWh**
May	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**0.7 GWh**
Jun	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.7 GWh**
Jul	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.3 GWh	**0.6 GWh**
Aug	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.9 GWh**
Sep	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
Oct	1.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.6 GWh**
Nov	2.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.9 GWh**
Dec	2.4 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.2 GWh**
Overall	**18.9 GWh**	**0.5 GWh**	**0.5 GWh**	**0.5 GWh**	**0.8 GWh**	**0.2 GWh**	**0.4 GWh**	**2.8 GWh**	**16.1 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

2 KLUANE LAKE (WEST SHORE)

2.1 Annual Gross Energy Production

Despite its low elevation Kluane Lake features a reasonable wind resource and good energy production compared to the other six, high-elevation sites. A generic 2.0 MW turbine would generate between 5.1 and 5.6 GWh a year, mainly depending on the size of the wind farm and resulting wake loses.

Wind farm (WAsP) modeling of the three wind farm capacity options – 20 MW, 10 MW and 6 MW – indicates an approximate 30% wind turbine net capacity factor based on the gross annual energy production in Table 24 below.

Kluane Lake is unique of the seven sites profiled in this report in that icing loss and/or icing-related operational challenges is expected to be relatively low. Apart from wake losses only 9.1% of the gross energy production are lost due factors such as icing, operations and maintenance, and electrical efficiency.

Table 24 Kluane Lake Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	55.0	5.50	5.40	5.59
	Wake loss	4.5%	-	-	-
	AEP after Wake Loss	52.6	5.26	5.10	5.37
	Additional Losses and Downtime	9.1%			
	Net AEP	**47.8**			
10 MW	Gross AEP	27.6	5.52	5.40	5.59
	Wake loss	2.7%	-	-	-
	AEP after Wake Loss	26.8	5.37	5.33	5.41
	Additional Losses and Downtime	9.1%			
	Net AEP	**24.4**			
6 MW	Gross AEP	16.7	5.56	5.53	5.59
	Wake loss	1.4%	-	-	-
	AEP after Wake Loss	16.4	5.48	5.40	5.53
	Additional Losses and Downtime	9.1%			
	Net AEP	**14.9**			

As for all other sites the ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations.

Due to the prevailing wind parallel to the shoreline there are higher wake losses than for other 20 MW wind farm sites considered in this report. This could be mitigated by either locating the turbines further apart or reducing the size of the wind farm. A 6 MW wind farm has only 1.35% wake losses, a 20 MW farm almost three times as much.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance. Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

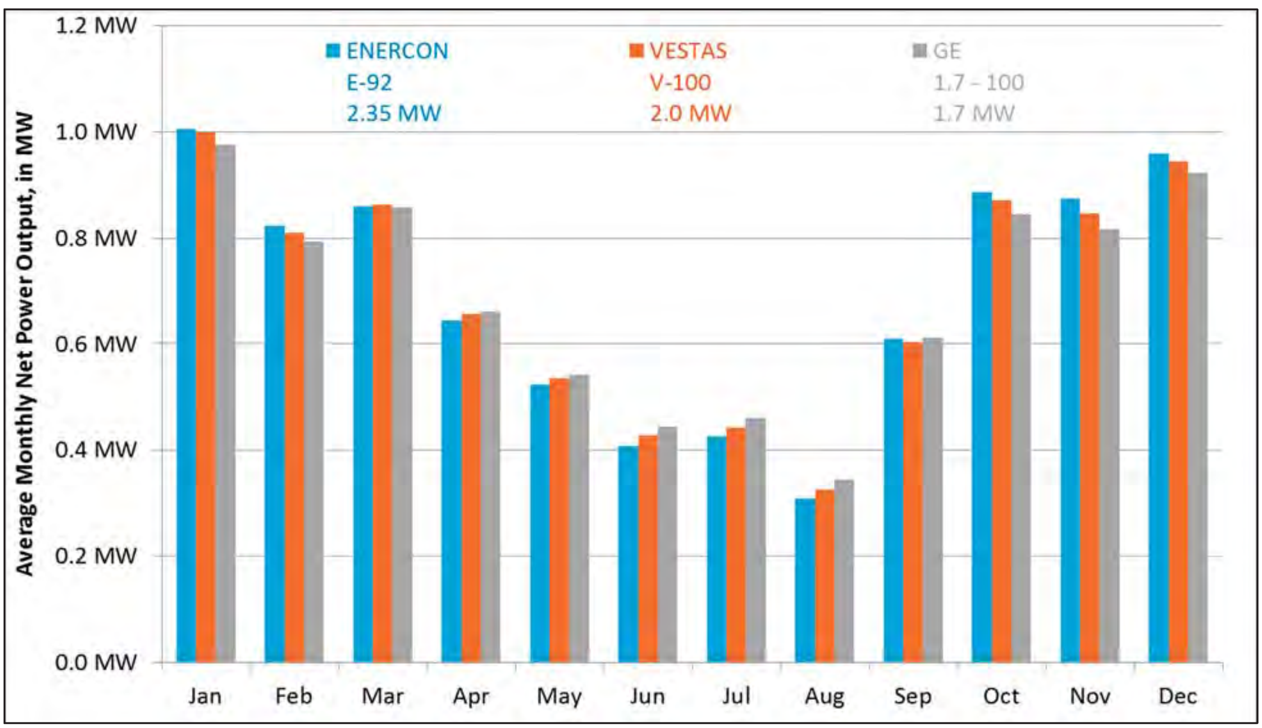
2.2 Monthly Generation Profile

Peak production for a turbine at Kluane Lake is December and January. As at all the selected sites, a wind farm at Kluane Lake would generate more energy in winter than summer. According to AWS modeling, 71% to 73% of the energy will be produced from October to April, see Figure 4 below.

2.3 Turbine Choice

Kluane Lake should have fewer rime ice problems than the other sites. Temperatures at Kluane Lake also tend to be higher and hence present less of a cold weather operational concern than the other sites. Geared drive turbines could be considered for Kluane Lake. Modeling of alternative turbines shows, however, that the gearless 2.35 MW Enercon E-92 model has 1% to 3% better performance in the period from October to April than the other two, smaller, but geared turbines. Considering that the site is next to the Alaska Highway and that there are no steep access roads, a larger turbine may also be considered from a logistics point of view.

Figure 4 Monthly Generation Profile of a three types of wind turbines at Kluane Lake



Data on the monthly losses and net production is provided below.

Table 25 Kluane Lake: Losses and Net Annual Energy Production of the three sizes of a wind farm

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	NET ELECTRICITY PRODUCTION
Jan	7.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	6.8 GWh
Feb	5.5 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.4 GWh	5.1 GWh
Mar	5.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	4.7 GWh
Apr	3.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.4 GWh	3.0 GWh
May	2.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	2.0 GWh
Jun	2.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	1.8 GWh
Jul	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.6 GWh	0.8 GWh	1.8 GWh
Aug	2.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	2.6 GWh
Sep	3.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	3.4 GWh
Oct	5.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	4.7 GWh
Nov	6.0 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.4 GWh	5.6 GWh
Dec	6.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.4 GWh	6.3 GWh
Overall	**52.6 GWh**	**0.0 GWh**	**0.5 GWh**	**0.5 GWh**	**2.1 GWh**	**0.5 GWh**	**1.1 GWh**	**4.8 GWh**	**47.8 GWh**
	100%	**0%**	**1%**	**1%**	**4%**	**1%**	**2%**	**9%**	**91%**
Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	3.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**3.5 GWh**
Feb	2.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.6 GWh**
Mar	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.4 GWh**
Apr	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.5 GWh**
May	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Jun	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.9 GWh**
Jul	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.3 GWh	0.4 GWh	**0.9 GWh**
Aug	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.3 GWh**
Sep	1.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.7 GWh**
Oct	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.4 GWh**
Nov	3.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.9 GWh**
Dec	3.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**3.2 GWh**
Overall	**26.8 GWh**	**0.0 GWh**	**0.3 GWh**	**0.3 GWh**	**1.1 GWh**	**0.3 GWh**	**0.5 GWh**	**2.4 GWh**	**24.4 GWh**
	100%	**0%**	**1%**	**1%**	**4%**	**1%**	**2%**	**9%**	**91%**
Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**2.1 GWh**
Feb	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.6 GWh**
Mar	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.5 GWh**
Apr	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.9 GWh**
May	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Jun	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Jul	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.2 GWh	**0.6 GWh**
Aug	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Sep	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.1 GWh**
Oct	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.5 GWh**
Nov	1.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.7 GWh**
Dec	2.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**2.0 GWh**
Overall	**16.4 GWh**	**0.0 GWh**	**0.2 GWh**	**0.2 GWh**	**0.7 GWh**	**0.2 GWh**	**0.3 GWh**	**1.5 GWh**	**15.0 GWh**
	100%	**0%**	**1%**	**1%**	**4%**	**1%**	**2%**	**9%**	**91%**

3 MILLER'S RIDGE

Miller's Ridge has the best wind resource of all sites reviewed.

3.1 Annual Energy Production

With its excellent wind conditions, Miller's Ridge has the highest gross energy production of all sites. A 2.0 MW turbine would be able to generate 6.3 to 7.2 GWh of energy, depending on the size of the wind farm and the particular location of the individual turbine, see Table 26 below.

WAsP modeling of the three wind farm capacity options – 20, 10 and 6 MW – indicates an approximate 39% wind turbine net capacity factor based on the gross annual energy production given in Table 26 below. A 39% capacity factor is extraordinarily good. If a larger capacity turbine more suitable for higher energy winds is chosen, overall net capacity factor will decrease slightly.

Table 26 Miller's Ridge Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	68.1	6.81	6.45	7.19
	Wake loss	2.0%	-	-	-
	AEP after Wake Loss	66.7	6.67	6.28	7.06
	Additional Losses and Downtime	14.2%			
	Net AEP	**57.2**			
10 MW	Gross AEP	34.9	6.98	6.63	7.19
	Wake Loss	1.4%	-	-	-
	AEP after Wake Loss	34.4	6.88	6.60	7.07
	Additional Losses and Downtime	14.2%			
	Net AEP	**29.5**			
6 MW	Gross AEP	21.3	7.10	7.03	7.19
	Wake Loss	1.0%	-	-	-
	AEP after Wake Loss	21.1	7.03	6.93	7.17
	Additional Losses and Downtime	14.2%			
	Net AEP	**18.1**			

The ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance. Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

Miller's Ridge is long and oriented perpendicular to the prevailing wind direction, south-south-west. Additional four turbines could be installed southeast of turbine #1 (WTG1) without creating significant additional wake losses (refer to Figure 18 in Chapter 3.3 of the body of the report). This would bring the maximum capacity up to 28 MW.

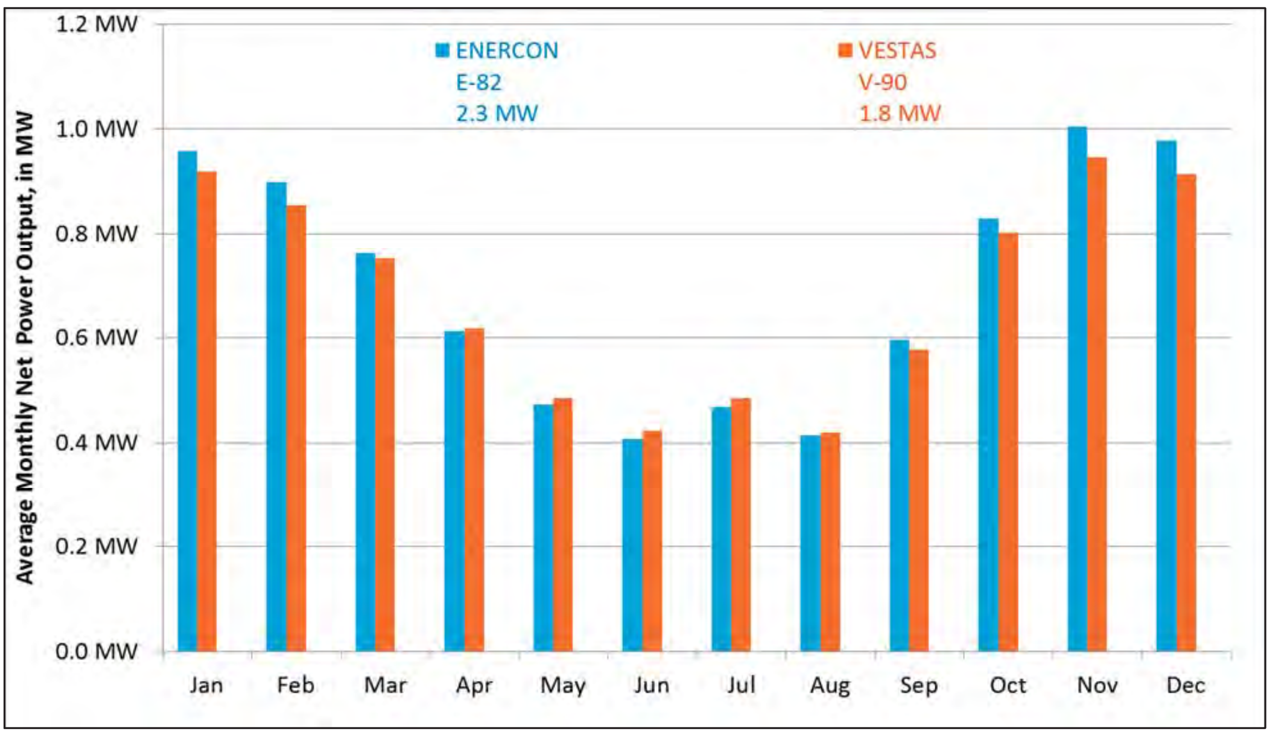
3.2 Monthly Generation Profile

As for all sites selected a wind farm at Miller's Ridge produces more energy in winter than in summer. According to AWS modeling 71% to 72% of the energy will be produced from October to April, see Figure 5 below.

3.3 Turbine Choice

From a wind speed and wind direction point of view Miller's Ridge is likely one of the best sites in Yukon. AWS' advanced reports model the highest yield for the Enercon E-92 turbine. A larger IEA Class II turbine, such as the E-82 with 2.3 MW rated capacity can be expected to perform better at Miller's Ridge than the smaller 1.8 MW Class III Vestas V-90 model. The E-82 series performs better during the high wind speed winter months and worse during the summer with generally lower wind speed, see Figure 5 below. A decision regarding turbine choice, however, would require site-specific wind monitoring data.

Figure 5 Monthly Production Profile for three types of turbines at Miller's Ridge Site



Data on the monthly losses and net production is provided below.

Table 27 Miller's Ridge: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	NET ELECTRICITY PRODUCTION
Jan	9.2 GWh	0.5 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	1.3 GWh	7.9 GWh
Feb	7.0 GWh	0.6 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	1.4 GWh	5.6 GWh
Mar	6.5 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.8 GWh	5.6 GWh
Apr	4.2 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.7 GWh	3.5 GWh
May	2.9 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.5 GWh	2.5 GWh
Jun	2.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.3 GWh	2.3 GWh
Jul	3.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.7 GWh	1.0 GWh	2.2 GWh
Aug	3.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.3 GWh	3.3 GWh
Sep	4.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.4 GWh	4.2 GWh
Oct	6.4 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.7 GWh	5.7 GWh
Nov	7.6 GWh	0.1 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.9 GWh	6.7 GWh
Dec	8.6 GWh	0.1 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.9 GWh	7.7 GWh
Overall	**66.7 GWh**	**1.5 GWh**	**1.7 GWh**	**1.7 GWh**	**2.7 GWh**	**0.7 GWh**	**1.3 GWh**	**9.5 GWh**	**57.3 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	4.8 GWh	0.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.7 GWh	**4.1 GWh**
Feb	3.6 GWh	0.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.7 GWh	**2.9 GWh**
Mar	3.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.9 GWh**
Apr	2.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**1.8 GWh**
May	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.3 GWh**
Jun	1.4 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.2 GWh**
Jul	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.4 GWh	0.5 GWh	**1.2 GWh**
Aug	1.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.7 GWh**
Sep	2.4 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.2 GWh**
Oct	3.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.9 GWh**
Nov	3.9 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**3.5 GWh**
Dec	4.4 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**4.0 GWh**
Overall	**34.4 GWh**	**0.8 GWh**	**0.9 GWh**	**0.9 GWh**	**1.4 GWh**	**0.3 GWh**	**0.7 GWh**	**4.9 GWh**	**29.5 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.9 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.5 GWh**
Feb	2.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**1.8 GWh**
Mar	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.8 GWh**
Apr	1.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
May	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Jun	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.7 GWh**
Jul	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.3 GWh	**0.7 GWh**
Aug	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Sep	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.3 GWh**
Oct	2.0 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.8 GWh**
Nov	2.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.1 GWh**
Dec	2.7 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.4 GWh**
Overall	**21.1 GWh**	**0.5 GWh**	**0.5 GWh**	**0.5 GWh**	**0.8 GWh**	**0.2 GWh**	**0.4 GWh**	**3.0 GWh**	**18.1 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

4 SUGARLOAF MOUNTAIN

Of all sites selected, Sugarloaf Mountain is the site with the lowest wind resource

WAsP modeling of the three wind farm capacity options – 20, 10 and 6 MW – indicates an approximate 21% wind turbine net capacity factor based on the Gross Annual Energy Production given in Table 28 below. A 21% capacity factor is low and could be improved upon with a wind turbine model more attuned to this site in place of the generic 2 MW model for the modeling exercise. A decision for the latter, however, would require site-specific wind monitoring data to verify a likely IEC Class III wind regime, i.e. a low wind speed class.

4.1 Annual Energy Production

As expected from the wind resource, modeling of three wind farm sizes at Sugarloaf Mountain yields lower energy production than the remaining six sites selected. The annual mean gross energy production of a single 2.0 MW turbine is only 3.7 to 3.8 GWh. This is 39% to 51% less than the mean output of the same turbine at Miller's Ridge.

These numbers are the gross energy production and only reflect wake, or wind turbine array efficiency, loss though. Other loss factors such as icing, operations and maintenance, and electrical losses are determined in Chapter 4.2 in the body of the report.

Table 28 Sugarloaf Mountain Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	37.5	3.75	3.47	3.98
	Wake Loss	1.0%	-	-	-
	AEP after Wake Loss	37.1	3.71	3.43	3.96
	Additional Losses and Downtime	13.1%			
	Net AEP	**32.2**			
10 MW	Gross AEP	18.5	3.70	3.47	3.98
	Wake Loss	0.8%	-	-	-
	AEP after Wake Loss	18.4	3.67	3.44	3.96
	Additional Losses and Downtime	13.1%			
	Net AEP	**15.9**			
6 MW	Gross AEP	11.4	3.81	3.63	3.98
	Wake Loss	0.5%	-	-	-
	AEP after Wake Loss	11.4	3.79	3.61	3.96
	Additional Losses and Downtime	13.1%			
	Net AEP	**9.9**			

The ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations. For Sugarloaf, a reduction of the site footprint was paramount and the lower capacity turbine layouts successively removed the southern-most turbines.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance. Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

4.2 Monthly Generation Profile

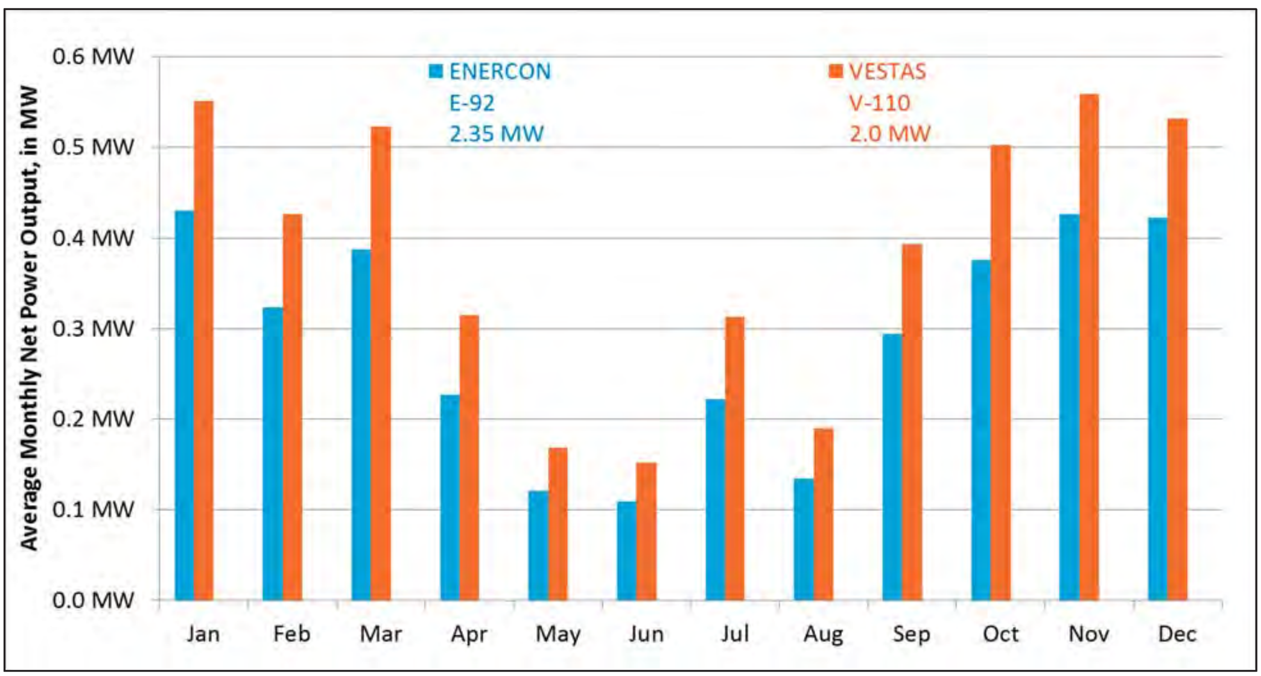
Sugarloaf Mountain is a site with medium to low wind speeds. There is a more pronounced difference between winter and summer than for other sites; especially during the summer months the output and capacity factor is low, see Figure 6 below.

Despite the generally favorable monthly production profile the site is low performing: During the winter months the sites produces only 55% of a wind turbine during the same period at the best performing site, Miller's Ridge.

4.3 Turbine Choice

Being a low-wind speed site, a IEA Class III turbine, such as the Vestas V-110 is a better choice than a Class II Enercon E-92 model. AWS models that the 2.35 MW Enercon E-92 produces 25% less energy annually than the less powerful (2.0 MW) Vestas V-110.

Figure 6 Monthly Production Profile for three Turbine Types at Sugarloaf Mountain



Data on the monthly losses and net production is provided below.

Table 29 Sugarloaf Mountain: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	5.1 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**4.5 GWh**
Feb	3.9 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**3.3 GWh**
Mar	3.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.2 GWh**
Apr	2.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**1.9 GWh**
May	1.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.3 GWh**
Jun	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.3 GWh**
Jul	1.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.4 GWh	0.6 GWh	**1.2 GWh**
Aug	2.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.8 GWh**
Sep	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.3 GWh**
Oct	3.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.2 GWh**
Nov	4.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.8 GWh**
Dec	4.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**4.3 GWh**
Overall	**37.1 GWh**	**0.4 GWh**	**0.9 GWh**	**0.9 GWh**	**1.5 GWh**	**0.4 GWh**	**0.7 GWh**	**4.9 GWh**	**32.3 GWh**
	100%	**1%**	**3%**	**3%**	**4%**	**1%**	**2%**	**13%**	**87%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.5 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.2 GWh**
Feb	1.9 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.6 GWh**
Mar	1.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.6 GWh**
Apr	1.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.0 GWh**
May	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.7 GWh**
Jun	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Jul	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.3 GWh	**0.6 GWh**
Aug	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.9 GWh**
Sep	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.1 GWh**
Oct	1.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.6 GWh**
Nov	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.9 GWh**
Dec	2.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**2.1 GWh**
Overall	**18.4 GWh**	**0.2 GWh**	**0.5 GWh**	**0.5 GWh**	**0.7 GWh**	**0.2 GWh**	**0.4 GWh**	**2.4 GWh**	**15.9 GWh**
	100%	**1%**	**3%**	**3%**	**4%**	**1%**	**2%**	**13%**	**87%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.4 GWh**
Feb	1.2 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.0 GWh**
Mar	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Apr	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
May	0.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.4 GWh**
Jun	0.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.4 GWh**
Jul	0.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.2 GWh	**0.4 GWh**
Aug	0.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Sep	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.7 GWh**
Oct	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Nov	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.2 GWh**
Dec	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.3 GWh**
Overall	**11.4 GWh**	**0.1 GWh**	**0.3 GWh**	**0.3 GWh**	**0.5 GWh**	**0.1 GWh**	**0.2 GWh**	**1.5 GWh**	**9.9 GWh**
	100%	**1%**	**3%**	**3%**	**4%**	**1%**	**2%**	**13%**	**87%**

5 MOUNT SUMANIK

Compared to the other sites reviewed Mount Sumanik has an average wind resource. Consequently, the energy production is below the average of the seven sites.

5.1 Annual Gross Energy Production

Modeling of three wind farm sizes at Mount Sumanik yields lower energy production than the remaining six sites selected. The annual mean gross energy production of a single 2.0 MW turbine is 4.8 to 5.5 GWh. This is 21% to 29% less than the output of the same turbine at Miller's Ridge.

WAsP modeling of the three wind farm capacity options – 20, 10 and 6 MW – indicates an approximate 27% wind turbine net capacity factor based on the Gross Annual Energy Production in Table 30 below. A 27% capacity factor is good but perhaps could be improved upon with a wind turbine model more attuned to this site, in place of the generic 2 MW model for the modeling exercise. A decision for the latter, however, would require a review of the site data collected to date and more detailed terrain wind flow modeling to confirm the suitability of the northern and lower elevation ridges of Mount Sumanik for turbines.

Table 30 Mount Sumanik Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	49.3	4.93	4.32	5.76
	Wake Loss	2.4%	-	-	-
	AEP after Wake Loss	48.1	4.81	4.18	5.66
	Additional Losses and Downtime	13.8%			
	Net AEP	**41.5**			
10 MW	Gross AEP	24.9	4.97	4.51	5.65
	Wake Loss	1.4%	-	-	-
	AEP after Wake Loss	24.5	4.90	4.42	5.56
	Additional Losses and Downtime	13.8%			
	Net AEP	**21.1**			
6 MW	Gross AEP	16.6	5.55	5.24	5.76
	Wake Loss	1.2%	-	-	-
	AEP after Wake Loss	16.5	5.48	5.22	5.67
	Additional Losses and Downtime	13.8%			
	Net AEP	**14.2**			

The ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations.

Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance.

5.2 Monthly Generation Profile

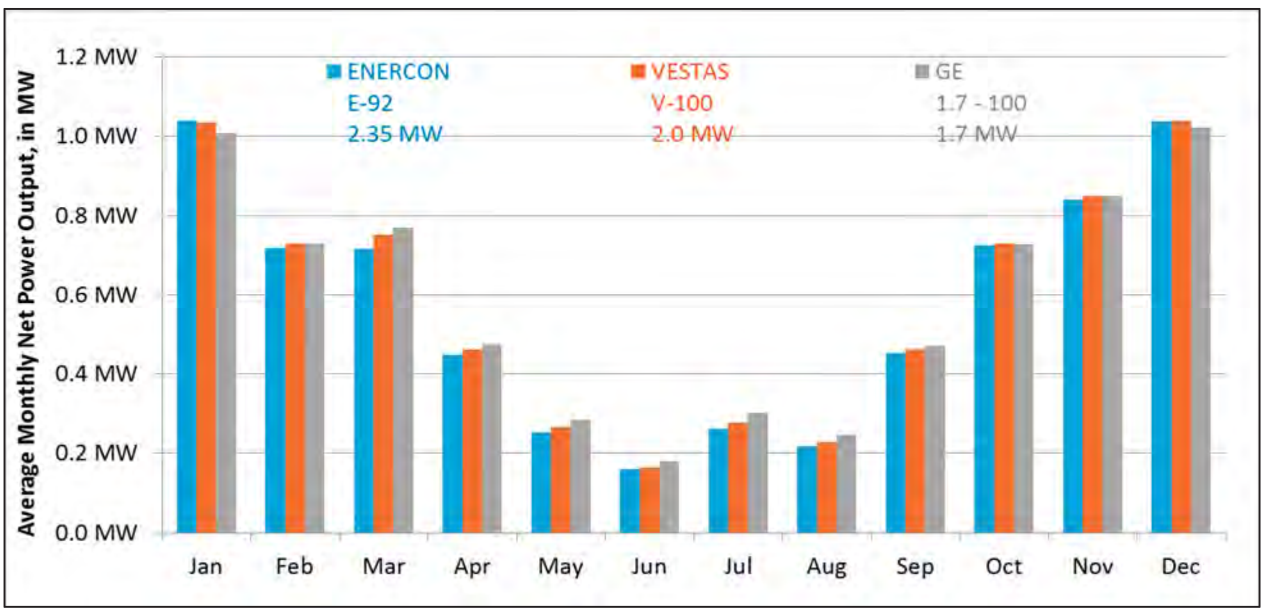
Mount Sumanik has a good power output in January and December, but rather low wind resources during the summer period. Moreover, wind direction changes by 90° from winter to summer, increasing wake losses in summer as the turbines start shading each other.

According to AWS modeling 79% to 81% of the energy will be produced from October to April, see Figure 7 below.

5.3 Turbine Choice

Comparing three options of turbine choices, AWS modeling yields that over the course of the year the GE-1.7-100 model with a rated capacity of only 1.7 MW yields slightly higher annual output than the 2.0 MW Vestas V-100 or the 2.3 MW Enercon E-92 turbine. In the period from October to April the Vestas V-100 turbine slightly outperforms the other two models.

Figure 7 Monthly Production Profile for three Turbine Types at Mount Sumanik Site



Data on the monthly losses and net production is provided below.

Table 31 Mt. Sumanik: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	NET ELECTRICITY PRODUCTION
Jan	6.6 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.7 GWh	5.9 GWh
Feb	5.1 GWh	0.4 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.9 GWh	4.1 GWh
Mar	4.7 GWh	0.1 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.6 GWh	4.1 GWh
Apr	3.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	2.5 GWh
May	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.4 GWh	1.7 GWh
Jun	1.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	1.7 GWh
Jul	2.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.5 GWh	0.7 GWh	1.6 GWh
Aug	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.2 GWh	2.4 GWh
Sep	3.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.3 GWh	3.0 GWh
Oct	4.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.5 GWh	4.1 GWh
Nov	5.5 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.7 GWh	4.8 GWh
Dec	6.2 GWh	0.1 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.0 GWh	0.0 GWh	0.6 GWh	5.6 GWh
Overall	**48.1 GWh**	**0.9 GWh**	**1.2 GWh**	**1.2 GWh**	**1.9 GWh**	**0.5 GWh**	**1.0 GWh**	**6.6 GWh**	**41.5 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	3.4 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**3.0 GWh**
Feb	2.6 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**2.1 GWh**
Mar	2.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.1 GWh**
Apr	1.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.3 GWh**
May	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**0.9 GWh**
Jun	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.9 GWh**
Jul	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.3 GWh	0.4 GWh	**0.8 GWh**
Aug	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.2 GWh**
Sep	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.5 GWh**
Oct	2.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.1 GWh**
Nov	2.8 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.4 GWh**
Dec	3.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.8 GWh**
Overall	**24.5 GWh**	**0.4 GWh**	**0.6 GWh**	**0.6 GWh**	**1.0 GWh**	**0.2 GWh**	**0.5 GWh**	**3.4 GWh**	**21.1 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.0 GWh**
Feb	1.7 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.4 GWh**
Mar	1.6 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.4 GWh**
Apr	1.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**0.9 GWh**
May	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Jun	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Jul	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.2 GWh	**0.6 GWh**
Aug	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Sep	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Oct	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.4 GWh**
Nov	1.9 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.6 GWh**
Dec	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.9 GWh**
Overall	**16.5 GWh**	**0.3 GWh**	**0.4 GWh**	**0.4 GWh**	**0.7 GWh**	**0.2 GWh**	**0.3 GWh**	**2.3 GWh**	**14.2 GWh**
	100%	**2%**	**3%**	**3%**	**4%**	**1%**	**2%**	**14%**	**86%**

6 TEHCHO (FERRY HILL)

6.1 Annual Gross Energy Production

Tehcho is a site with an average wind resource compared to the remaining six sites. Modeling of three wind farm sizes at Mount Sumanik yields lower energy production than the remaining six sites selected. The annual mean gross energy production of a single 2.0 MW turbine is 3.4 to 4.4 GWh, depending on the size of the wind farm and the location of the individual turbine. This is 41% to 46% less than the output of the same turbine at Miller's Ridge.

These numbers are the gross energy production and only reflect wake, or wind turbine array efficiency, loss though. On a net energy basis a wind farm at Tehcho has a 39% to 43% lower output than the same size wind farm with the same turbine at Miller's Ridge.

WAsP modeling of the three wind farm capacity options – 20, 10 and 6 MW – indicates an approximate 22% wind turbine net capacity factor based on the Gross Annual Energy Production in Table 32 below. A 22% capacity factor is low and could be improved upon with a wind turbine model more attuned to this site in place of the generic 2 MW model for the modeling exercise. A decision for the latter, however, would require additional site data, or re-review of the older met tower data, to verify a likely IEC Class III wind regime.

Table 32 Tehcho Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	41.1	4.11	3.63	4.47
	Wake Loss	4.8%	-	-	-
	AEP after Wake Loss	39.2	3.92	3.35	4.36
	Additional Losses and Downtime	14.8%			
	Net AEP	**33.4**			
10 MW	Gross AEP	21.9	4.38	4.20	4.47
	Wake Loss	2.0%	-	-	-
	AEP after Wake Loss	21.5	4.29	4.07	4.41
	Additional Losses and Downtime	14.8%			
	Net AEP	**18.3**			
6 MW	Gross AEP	12.4	4.15	3.87	4.38
	Wake Loss	2.9%	-	-	-
	AEP after Wake Loss	12.1	4.03	3.80	4.21
	Additional Losses and Downtime	14.8%			
	Net AEP	**10.3**			

The ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations.

Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance.

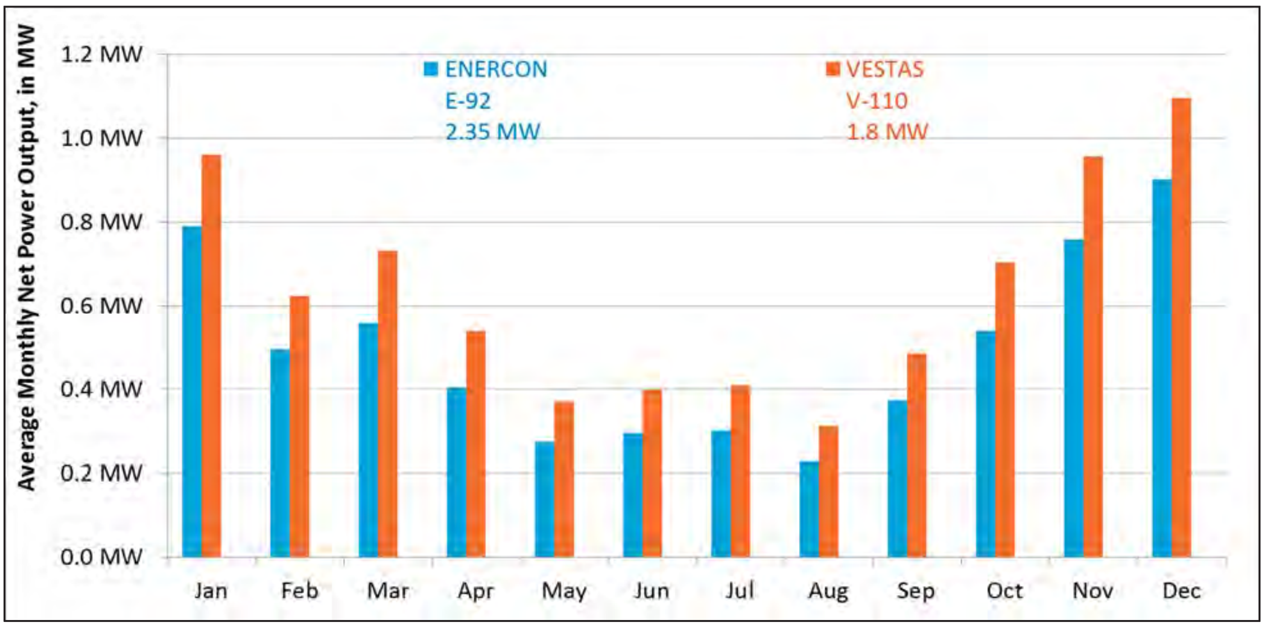
6.2 Monthly Generation Profile

As for all sites selected a wind farm at Tehcho produces more energy in winter than in summer. According to AWS modeling 75% to 76% of the energy will be produced from October to April, see Figure 8 below.

6.3 Turbine Choice

AWS modeling shows that for Tehcho (Ferry Hill) the 1.8 MW Vestas V-110 turbine yields 28% higher annual output than the 2.35 MW Enercon E-92 model. During the period from October to April the Vestas turbine still outperforms the Enercon turbine by 25%.

Figure 8 Monthly Production Profile for three Types of Turbines at Tehcho Site



Data on the monthly losses and net production is provided below.

Table 33 Techho: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	NET ELECTRICITY PRODUCTION
Jan	5.4 GWh	0.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.8 GWh	4.6 GWh
Feb	4.1 GWh	0.4 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.9 GWh	3.2 GWh
Mar	3.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	3.3 GWh
Apr	2.5 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	2.1 GWh
May	1.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	1.5 GWh
Jun	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	1.4 GWh
Jul	1.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.4 GWh	0.6 GWh	1.3 GWh
Aug	2.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	1.9 GWh
Sep	2.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	2.5 GWh
Oct	3.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	3.3 GWh
Nov	4.5 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.7 GWh	3.8 GWh
Dec	5.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	4.4 GWh
Overall	**39.2 GWh**	**1.1 GWh**	**1.0 GWh**	**1.0 GWh**	**1.6 GWh**	**0.4 GWh**	**0.8 GWh**	**5.8 GWh**	**33.4 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	3.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.5 GWh**
Feb	2.3 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**1.8 GWh**
Mar	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.8 GWh**
Apr	1.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.2 GWh**
May	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Jun	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Jul	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.3 GWh	**0.7 GWh**
Aug	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.1 GWh**
Sep	1.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.4 GWh**
Oct	2.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.8 GWh**
Nov	2.5 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.1 GWh**
Dec	2.8 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.4 GWh**
Overall	**21.5 GWh**	**0.6 GWh**	**0.5 GWh**	**0.5 GWh**	**0.9 GWh**	**0.2 GWh**	**0.4 GWh**	**3.2 GWh**	**18.3 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	1.7 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.4 GWh**
Feb	1.3 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.0 GWh**
Mar	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.0 GWh**
Apr	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
May	0.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.5 GWh**
Jun	0.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.4 GWh**
Jul	0.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.2 GWh	**0.4 GWh**
Aug	0.7 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.6 GWh**
Sep	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.8 GWh**
Oct	1.2 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Nov	1.4 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.2 GWh**
Dec	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.4 GWh**
Overall	**12.1 GWh**	**0.3 GWh**	**0.3 GWh**	**0.3 GWh**	**0.5 GWh**	**0.1 GWh**	**0.2 GWh**	**1.8 GWh**	**10.3 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

7 THULSOO MOUNTAIN

Thulsoo Mountain has excellent wind resources, the second best wind resource of the seven sites selected. The mean annual wind speed is almost as high as for Miller's Ridge and consistently SSW, perpendicular to the turbine array of (see Figure 35 in Chapter 3.7 of the body of the report)

7.1 Annual Gross Energy Production

Modeling of a 6 MW, a 10 MW and a 20 MW wind farm yields almost the same energy as Miller's Ridge, the site with the highest mean wind velocity. The annual mean gross energy production of a single 2.0 MW turbine is 5.8 to 7.1 GWh, depending on the size of the wind farm and the location of the individual turbine. This is only 5% to 8% less than the output of the same turbine at Miller's Ridge.

WAsP wind farm modeling indicates an approximate 36% wind turbine net capacity factor based on the Gross Annual Energy Production in Table 34 below. This applies to all three wind farm sizes. A 36% capacity factor is extraordinarily good.

Table 34 Thulsoo Mountain Wind Farm Annual Energy Production, 2 MW generic turbine

Wind Farm Capacity	Parameter	Total all turbines (GWh)	Average turbine (GWh)	Lowest turbine (GWh)	Best turbine (GWh)
20 MW	Gross Annual Energy Production (AEP)	64.7	6.47	5.88	7.15
	Wake Loss	1.5%	-	-	-
	AEP after Wake Loss	63.7	6.37	5.84	7.05
	Additional Losses and Downtime	14.7%			
	Net AEP	**54.4**			
10 MW	Gross AEP	32.5	6.50	5.88	7.15
	Wake Loss	1.0%	-	-	-
	AEP after Wake Loss	32.2	6.44	5.87	7.06
	Additional Losses and Downtime	14.7%			
	Net AEP	**27.5**			
6 MW	Gross AEP	20.4	6.80	6.59	7.15
	Wake Loss	0.8%	-	-	-
	AEP after Wake Loss	20.2	6.75	6.52	7.06
	Additional Losses and Downtime	14.7%			
	Net AEP	**17.3**			

As for the previous six sites the ten turbine, 20 MW capacity, turbine layout was developed first and turbines were removed for the 10 MW (five turbine) and 6 MW (three turbine) capacity wind farm options. Wind turbines selected for removal for the lower capacity options were chosen to reduce the site footprint *and* retain the higher performing locations.

For a detailed wind farm design of a lower capacity option, one may wish to reconsider turbine locations with just the intended number in mind as possibly this may yield higher performance. Detailed WAsP wind farm reports for the three capacity alternatives can be found in Appendix G.

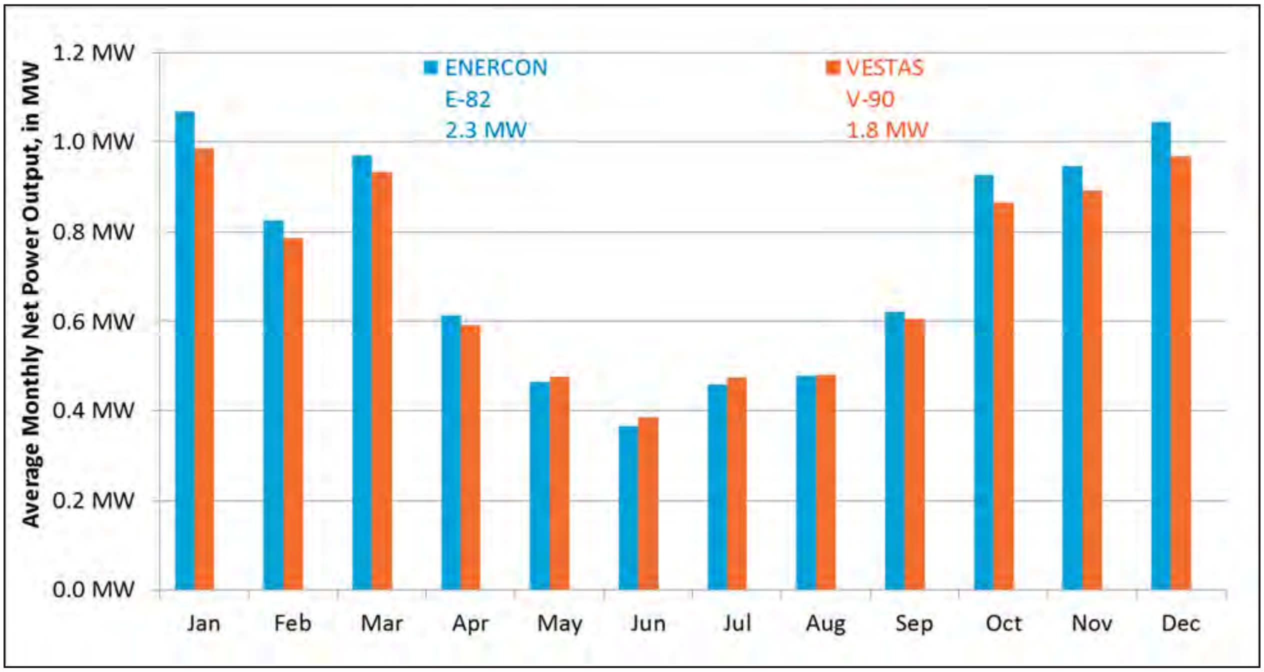
7.2 Monthly Generation Profile

As for all selected sites, a wind farm at Thulsoo Mountain produces more energy in winter than in summer. According to AWS modeling 72% to 74% of the energy will be produced from October to April, see Figure 9 below.

7.3 Turbine Choice

According to AWS modeling a larger (2.35 MW) Enercon E-92 turbine yields 6% to 8% higher annual energy production than the medium-sized 2.0 MW Vestas V-90 and the smaller size 1.7 MW GE 1.7-100 model. Thulsoo is a high wind speed site and a larger IEA Class II turbine, such as the E-92 can be expected to perform 4% better than the Class III GE-model.

Figure 9 Monthly Production Profile for Thulsoo Mountain Site



Data on the monthly losses and net production is provided below.

Table 35 Thulsoo Mountain: Losses and Net Annual Energy Production of the Three Wind Farm Sizes

Annual Energy Production of a 20 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	NET ELECTRICITY PRODUCTION
Jan	8.8 GWh	0.5 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	1.2 GWh	7.6 GWh
Feb	6.7 GWh	0.6 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	1.3 GWh	5.5 GWh
Mar	6.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.9 GWh	5.3 GWh
Apr	4.1 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.7 GWh	3.4 GWh
May	2.8 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.6 GWh	2.2 GWh
Jun	2.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.4 GWh	2.2 GWh
Jul	3.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.7 GWh	1.0 GWh	2.1 GWh
Aug	3.5 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.4 GWh	3.1 GWh
Sep	4.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.5 GWh	3.9 GWh
Oct	6.1 GWh	0.0 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.7 GWh	5.4 GWh
Nov	7.3 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.9 GWh	6.4 GWh
Dec	8.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.9 GWh	7.3 GWh
Overall	**63.7 GWh**	**1.7 GWh**	**1.6 GWh**	**1.6 GWh**	**2.5 GWh**	**0.6 GWh**	**1.3 GWh**	**9.3 GWh**	**54.4 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 10 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	4.4 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**3.9 GWh**
Feb	3.4 GWh	0.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.6 GWh	**2.8 GWh**
Mar	3.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**2.7 GWh**
Apr	2.0 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.7 GWh**
May	1.4 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.1 GWh**
Jun	1.3 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
Jul	1.6 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.3 GWh	0.5 GWh	**1.1 GWh**
Aug	1.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.6 GWh**
Sep	2.2 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.9 GWh**
Oct	3.1 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.7 GWh**
Nov	3.7 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**3.2 GWh**
Dec	4.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.5 GWh	**3.7 GWh**
Overall	**32.2 GWh**	**0.9 GWh**	**0.8 GWh**	**0.8 GWh**	**1.3 GWh**	**0.3 GWh**	**0.6 GWh**	**4.7 GWh**	**27.5 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

Annual Energy Production of a 6 MW WINDFARM									
Month	Production after wake losses	Low temperature curtailment	Rime icing downtime	De-icing electricity	Transformer losses	Sub-optimal Performance	Maintenance Downtime	TOTAL LOSSES	**NET ELECTRICITY PRODUCTION**
Jan	2.8 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**2.4 GWh**
Feb	2.1 GWh	0.2 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.4 GWh	**1.7 GWh**
Mar	2.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**1.7 GWh**
Apr	1.3 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.1 GWh**
May	0.9 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**0.7 GWh**
Jun	0.8 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**0.7 GWh**
Jul	1.0 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.2 GWh	0.3 GWh	**0.7 GWh**
Aug	1.1 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.1 GWh	**1.0 GWh**
Sep	1.4 GWh	0.0 GWh	0.0 GWh	0.0 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.2 GWh**
Oct	1.9 GWh	0.0 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.2 GWh	**1.7 GWh**
Nov	2.3 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.0 GWh**
Dec	2.6 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.1 GWh	0.0 GWh	0.0 GWh	0.3 GWh	**2.3 GWh**
Overall	**20.2 GWh**	**0.5 GWh**	**0.5 GWh**	**0.5 GWh**	**0.8 GWh**	**0.2 GWh**	**0.4 GWh**	**3.0 GWh**	**17.3 GWh**
	100%	**3%**	**3%**	**3%**	**4%**	**1%**	**2%**	**15%**	**85%**

APPENDIX I – AWS ADVANCED REPORTS

Separate PDF documents:

Cyprus Advanced Report.pdf

Kluane Advanced Report.pdf

Milers Advanced Report.pdf

Sugarloaf Advanced Report.pdf

Sumanik Advanced Report.pdf

Tehcho Advanced Report.pdf

Thulsoo Advanced Report.pdf