Appendix 5.11
Solar Site Inventory
(Solvest 2016)

Solar Site Inventory

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Prepared for:

YUKON ENERGY

Prepared by:

SOLVEST

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Abstract

The Yukon Energy Corporation (YEC) is entering a new planning cycle for future upgrades and improvements to the Yukon Territory's electricity supply. This report, prepared by Solvest Inc., is intended to assist in the future planning of the Yukon electricity grid by providing information on the viability of utility scale photovoltaic solar energy at several locations across the Yukon. Expected electricity generation capabilities are modelled, and a preliminary financial analysis presented. These numbers can be used to compare against other proposed energy projects in the areas of hydro, wind, geothermal and energy storage that are also currently being completed.

Four locations were initially investigated as potential sites for 1MW, 5MW or 10MW photovoltaic power plants. Of these sites, one at Haines Junction and one near Whitehorse were settled on as being the most appropriate. Both have large, flat, unshaded spaces, and are close to urban locations with high demand for electricity. The Haines Junction site is located close to both the airport and the dump, and is not likely to be ideal for many other uses. The Whitehorse site is already human impacted and clear of trees – an old quarry that is no longer in use.

The energy modeling revealed that the 1MW installations yielded 1050 – 1190 MWh annually for panels installed on fixed tilt racking. There was no significant influence on energy production due to location choice. For 1MW installations using single axis tracking, the annual energy yield jumped to 1290 – 1490 MWh. Moving from single axis tracking to dual axis tracking only improved the energy yield by about 6%, while increasing the cost and complexity of the installation significantly.

For 5MW installations, the annual energy yield for fixed tilt racking systems fell between 5230 and 5460 MWh. For single axis tracking systems, the yield was between 6000 and 6750 MWh depending on the choice of modules. For 10 MW fixed tilt racking systems, the annual energy yield was about 11,000 to 11,500 MWh.

Different inverter choices were also modeled, and the energy yield between the inverter options was similar. The major difference comes from the cost. Two different quotations for central inverters were obtained, which were significantly different. String inverters can be more expensive due to the increased number of inverters and wiring complexity, however the string inverter system costs here fell between the two central inverter costs.

The LCOE for the 1MW systems ranged from \$0.17 to \$0.20/kWh. The LCOE for the 5MW systems is quite attractive, ranging from \$0.14 to \$0.18 on average. For the 10MW system, additional battery storage is needing for smoothing in case of power fluctuations, since the 10MW system will have a greater penetration of the electricity grid. For the 10MW system along with battery storage, the LCOE is about \$0.21/kWh. Due to the area requirements, it will be difficult to fit 10MW of photovoltaics at the Haines Junction site. There is ample room at the Whitehorse Quarry site, however, so if a PV plant of this size is desired, it should be located at Whitehorse.

1. Introduction

There are three main groupings to this report: 1) All the information that defines the project and informs the site selection; 2) The energy modeling for each site and system option; and 3) The financial analysis of each option.

The site selection is outlined in Section 2: Site Selection Process, and includes the selection criteria and irradiance data. More helpful background information that will be required to complete the energy and financial sections is found in the technology review in Section 3, and the asset service life, operations and maintenance (O&M) plan, and the project schedule in Sections 4 through 6.

Sections 7 through 9 go through the energy modelling for the systems at each of the proposed site under the various technical options. Section 7 explains the loss inputs that were included in the PVSyst simulation. The complete monthly energy profile data can be found in Appendix A. Additional data from the energy simulations can be found in Appendix B.

Sections 10 through 12 walk through the highlights of the financial assessment. Section 10 describes the method by which the Levelized Cost of Electricity (LCOE) is calculated. Full tables of all the LCOE results for all the systems modeled can be found in Appendix C.

Conclusions, recommendations and potential show-stoppers are shared in the final section of the report.

In addition to this report, all the Excel files from the financial analysis, data from the PVSyst simulations, simulation reports, kmz and CAD files showing footprints of the sites, and project schedule Gantt charts are accompanying this report in a shared Dropbox folder. A “hard-copy” of all this data as well as the report will be submitted to YEC on either a CD or flash drive via mail.

2. Site Selection Process

2.1 Selection Criteria

The following criteria were evaluated when selecting the two sites for the proposed utility scale PV power plants:

1. **Solar Irradiance Profiles**. The solar irradiance data for each community on the Yukon Energy transmission grid was evaluated to determine which communities have favorable solar generation profiles. As shown in the chart above the solar irradiance profiles for the communities in the Yukon varies 8% between the lowest community (Keno Hill) and the highest community (Dawson).
2. **Proximity to existing transmission infrastructure**. By selecting sites close to existing substations, grid connection costs for the proposed power plants are minimized allowing lower transmission and distribution costs for Yukon Energy and a lower levelized cost of energy for the PV power plant.
3. **Proximity to communities**. In order to minimize construction costs and provide continued access for on-going maintenance, both sites selected are located close to existing communities. Additionally, given that a significant percentage of the load capacity on the Yukon electrical grid is located in the Whitehorse to Haines Junction corridor both sites selected are located in this area to minimize the distance from generation to the end consumer.
4. **Topographic Profile**. Utility scale solar generation requires a large amount of land (6-10 acres per MW) with minimal elevation changes across the property. Topographic maps of both Whitehorse and Haines Junction were carefully analyzed to determine which areas had enough flat land within close proximity to identified substations.
5. **Land Ownership**. Using the Yukon Lands-viewer tool (http://mapservices.gov.yk.ca/Lands/Load.htm) the identified areas were analyzed to confirm if there are any existing land use restrictions for the proposed sites such as wildlife reserves or residential development hold backs. Additionally, each site was verified against a data base to confirm that no third parties currently own the proposed properties.
6. **Open Land**. In order to minimize site preparation costs, sites with open land or minimal tree cover were selected. Mulching costs were estimated at $3500 an acre, so both chosen sites have minimal tree cover to try and reduce this cost.

2.2 Chosen locations

The solar irradiation map of the Yukon was investigated, and from the initial review four main sites of interest were chosen: Haines Junction, Whitehorse Copper, Takhini, and Canyon. Topographical maps were consulted, as well as site visits to the proposed locations, and from the initial four sites, Whitehorse and Haines Junction best fit the criteria. Takhini, from the topography graphs, had a very uneven site, and a large hill or ridge on the west side that would block the evening sun. Upon inspection, the site was also seen to be very boulder-strewn and construction would have been significantly difficult. Canyon was awkwardly shaped, and there was some question of land ownership. Both the Whitehorse Copper and Haines Junction sites were physically suitable and in close proximity to communities where the energy would be needed, and so they became the sites of choice.

Location #1: Whitehorse Copper

Nearest Community: Whitehorse

GPS Coordinates: 60.643440, -135.058548

Available Space: 120 Acres

Distance to Substation: 2.8 KM

Connection Voltage: 34.5 KV

Soil type: Mine Tailings

Geotechnical Analysis Required: Yes

Site Description: The chosen site is the old tailings pile for the Whitehorse Copper Mine which was operated from 1972 to 1982 near Mount Sima Ski Hill. The tailings pile was chosen as it is an abandoned mine site that cannot be used for traditional development projects without further reclamation work. The pile consists of 120 acres of open land with minimal fluctuations in elevation across the pile, which will reduce development costs for constructing the solar farm by eliminating land clearing costs and reducing the amount of compaction and excavation work required to prepare the site for construction.

Additional benefits of the site include, established road access, close proximity to the mount sima substation (2.8 Km), and a geotechnical profile consisting of fine grain mill material making it easy to drive piles to support the solar array. Finally, by being located within Whitehorse city limits, this site ensures that the distance from generation to the consumer is minimized and reduces construction costs by being located close to the main source of materials and labour within the Yukon.

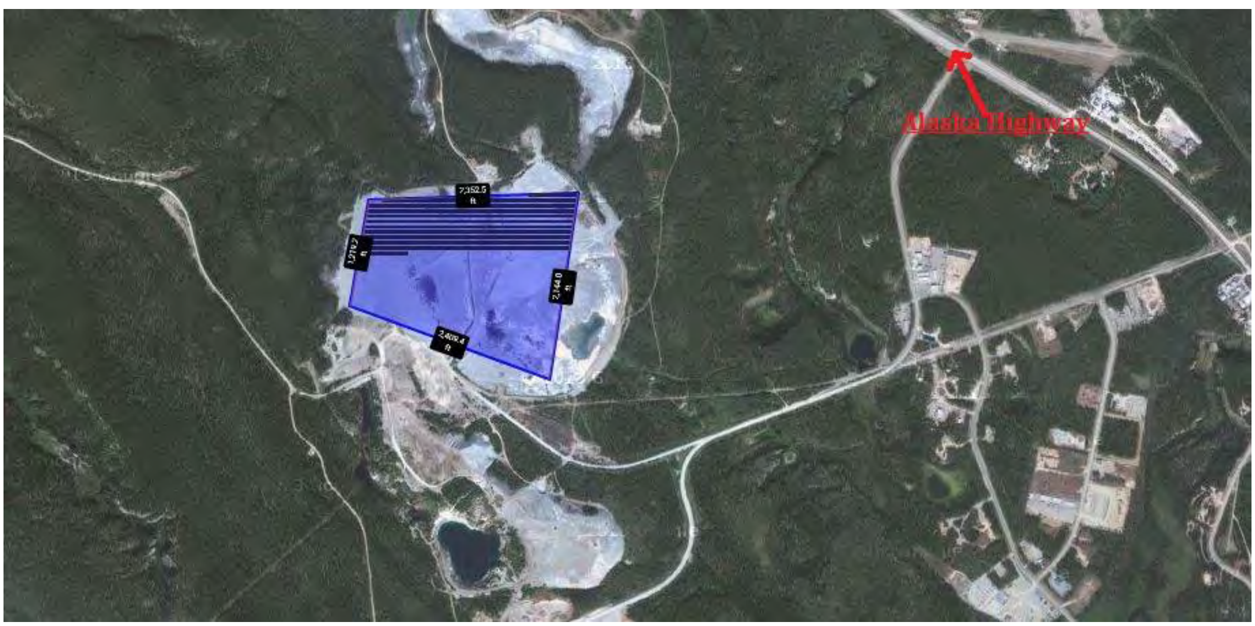

Figure 2.1: Proposed site of a PV power plant at Whitehorse Copper

Location #2: Haines Junction

Nearest Community: Haines Junction

GPS Coordinates: 60.784897, -137.505541

Available Space: 65 Acres

Distance to Substation: 3.4 KM

Connection Voltage: 25 KV

Soil type: Organics/Clay

Geotechnical Analysis Required: Yes

Site Description: The chosen site is located 1 km north of the Haines Junction dump in a 65 acre, semi-open area with minimal elevation changes across the site. This site was selected due to its close proximity to the highway (500 m) and substation (3.4 km) as well as the site consists of largely open land with thin tree cover reducing land clearing costs significantly.

Additionally, by being located within Haines Junction, this site ensures that construction costs will be reduced by having accommodations for construction crews in close proximity from site.

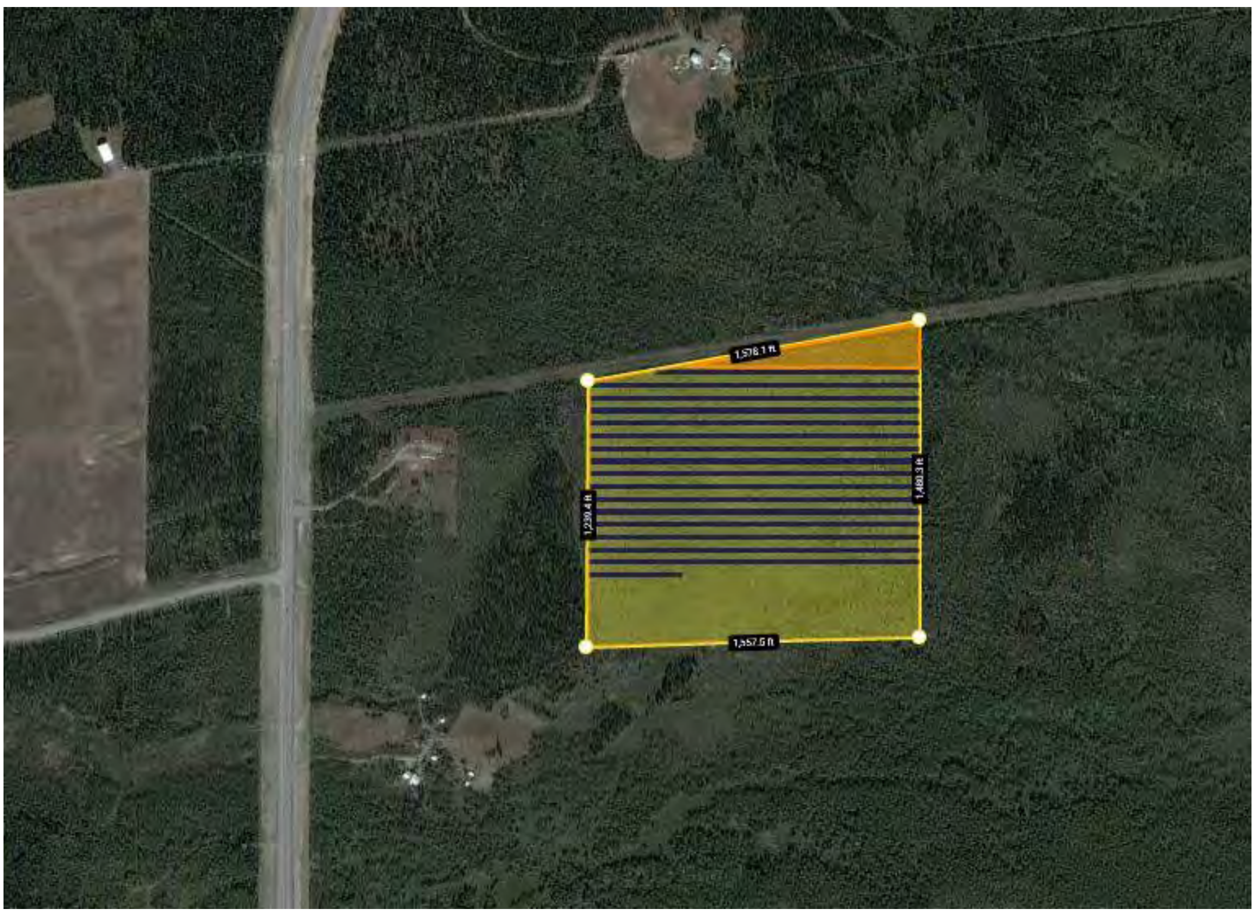

Figure 2.2: Proposed site of a PV power plant at Haines Junction

2.3 Irradiance Data

In order to determine the best locations in terms of solar resource in the Yukon, the solar irradiance data for the territory was analyzed. Table 2.1 shows the irradiance data for all major communities connected to the Yukon Energy transmission grid.

Table 2.1: Solar potential data for communities in the Yukon[1]

Municipality	**Solar Potential (kWh/kW)**
Whitehorse	985±158.0
Teslin	964±154.0
Tagish	981±157.0
Stewart Crossing	1011±162.0
Ross River	962±154.
Pelly Crossing	1016±163.0
Mayo	991±159.0
Marsh Lake	981±157.0
Keno Hill	961±154.0
Haines Junction	1038±166.0
Faro	966±155.0
Dawson	1043±167.0
Carmacks	1013±162.0
Carcross	978±157.0

Annual Irradiance figures shown were collected at a south facing tilt angle of latitude -15.

The data in Table 2.1 shows a variance of only 9% across all municipalities connected to the Yukon Energy Hydro Grid, and only 6 % variance from Whitehorse. Based on this information the two locations for further investigation will be Whitehorse and Haines Junction. This decision was made based on increased construction costs as one gets further from Whitehorse and will allow Yukon Energy to keep the proposed power plants close to existing electrical infrastructure and points of use.

Tables 2.2 and 2.3 show the solar irradiance data by month at various tilt angles for both Whitehorse and Haines Junction:

Table 2.2: Monthly irradiance data for Whitehorse (kWh/m^2/month)

Month	**South-facing vertical (tilt=90°)**	**South-facing, tilt=latitude**	**South-facing, tilt=lat+15°**	**South-facing, tilt=lat-15°**
January	31	30	31	26
February	63	63	65	58
March	97	108	105	104
April	97	123	112	127

[1] The data in Table 2.1 was obtained from NRCAN's website data base of solar irradiance data available at: http://pv.nrcan.gc.ca/index.php?m=s&lang=e&lang=e&prov=yk

May	84	119	103	129
June	80	116	99	128
July	77	111	95	122
August	81	110	98	116
September	68	83	78	83
October	49	53	53	51
November	30	30	31	27
December	17	16	17	14
Annual	**774±124.0**	**961±154.0**	**887±142.0**	**985±158.0**

Table 2.3: Monthly irradiance data for Haines Junction (kWh/m^2/month)

Month	**South-facing vertical (tilt=90°)**	**South-facing, tilt=latitude**	**South-facing, tilt=lat+15°**	**South-facing, tilt=lat-15°**
January	38	36	38	32
February	68	68	70	62
March	105	115	113	110
April	102	127	117	129
May	88	124	108	134
June	79	116	98	128
July	78	113	97	124
August	85	113	101	120
September	74	87	82	88
October	60	63	63	60
November	37	36	37	32
December	25	23	24	20
Annual	**838±134.0**	**1021±163.0**	**949±152.0**	**1038±166.0**

2.3.1 Comparison of Yukon PV Potential Against Global Utility-Scale PV Installation Sites

To further illustrate that solar is a good choice of renewable energy on a utility-level scale for the Yukon, Table 2.4 lists the solar potential of the selected Yukon sites (kWh/kW) against a selection of comparable jurisdictions that have implemented grid scale solar around the world (e.g. Germany, Ontario, etc). While the Yukon is on the low side in terms of solar PV potential in Canada, it has higher potential than Berlin, Germany. Germany has a number of utility-scale PV installations, close to 100 MW in size, close to Berlin (the Brandenburg-Briest Solar Park is located less than 100 km from Berlin, and is 91 MW in size). The Yukon also has better solar potential than Japan, which has embraced solar in the wake of the Fukushima nuclear disaster and now has a number of utility-scale PV plants located across the country (and notably in the Fukushima prefecture).

Table 2.4: Comparison of solar potential for various cities across Canada and around the World

Major Canadian cities and capitals	Yearly PV potential (kWh/kW)	Major cities worldwide	Yearly PV potential (kWh/kW)
Regina (Saskatchewan)	1361	Cairo, Egypt	1635
Calgary (Alberta)	1292	Capetown, South Africa	1538
Winnipeg (Manitoba)	1277	New Delhi, India	1523
Edmonton (Alberta)	1245	Los Angeles, U.S.A.	1485
Ottawa (Ontario)	1198	Mexico City, Mexico	1425
Montréal (Quebec)	1185	**Regina, Canada**	**1361**
Toronto (Ontario)	1161	Sydney, Australia	1343
Fredericton (New Brunswick)	1145	Rome, Italy	1283
Québec (Quebec)	1134	Rio de Janeiro, Brazil	1253
Charlottetown (Prince Edward Island)	1095	Beijing, China	1148
Yellowknife (Northwest Territories)	1094	Washington, D.C., U.S.A.	1133
Victoria (British Columbia)	1091	Paris, France	838
Halifax (Nova Scotia)	1074	**St. John's, Canada**	**933**
Iqaluit (Nunavut)	1059	Tokyo, Japan	885
Vancouver (British Columbia)	1009	Berlin, Germany	848
Whitehorse (Yukon)	960	Moscow, Russia	803
St. John's (Newfoundland and Labrador)	933	London, England	728
Source: Natural Resources Canada. (2007). Photovoltaic potential and solar resources maps of Canada. Retrieved February 1, 2010, from https://glfc.cfsnet.nfis.org/mapserver/pv/rank.php?NEK=e			

3 Technology Review

In recent years, the price of solar panels and their related systems has dropped significantly. This has been the result of both economies of scale and design improvements. With the design improvements, there are now a wide variety of module technologies, inverter technologies, and racking systems. This section explores the types of modules, inverters, and racking systems that are currently on the market, looks at their performance under conditions in the north as well as their costs, and helps us to arrive at the options that will be best for YEC. There is also a section at the end that comments on the types of energy storage options available for grid applications and the option that we recommend accompanies larger solar utility projects in the Yukon.

3.1 Module Technologies

In this section we'll look at the major cell and module technologies that are on the market today, and then briefly touch a few that are in the pipeline so that in 5 or 10 years, so that if more solar projects are planned in the future, the viability of these new technologies can be looked at as well. An explanation of the following module and cell types is presented here:

- P-type vs N-type silicon for solar cells
- Multicrystalline solar cells
- Monocrystalline solar cells
- Bi-facial cells and panels
- Thin film cells and panels
- Emerging technologies

3.1.1 P-type vs N-type Silicon

While not as widely adopted as p-type silicon technologies, n-type solar cells have been around for a long time, and have held the record for the highest-efficiency commercial solar products for about as long. The two most well-know are Sunpower's IBC (interdigitated back contact) cell, and Sayno's HIT cell (now owned by Panasonic). A number of other companies are now getting on board. Yingli's PANDA cell, Sunpreme's heterojunction bi-facial cell, and Suniva all make use of n-type silicon wafers.

N-type silicon has a number of benefits over p-type silicon, the first of which is that there is no light-induced degradation (LID) with n-type silicon. P-type silicon is typically doped with boron during the crystal growth process. Both Czochralski-grown and cast-multi silicon ingots are exposed to air during the casting process, which results in the presence of oxygen in the melt. When the silicon wafers later undergo high temperature processing during cell manufacturing, this creates boron-oxygen complexes, defects in the silicon, which activate after the cell is used in the light for the first time, and results in up to 2% degradation in module performance after deployment in the field. As n-type silicon is doped with phosphorous during the casting process, rather than boron, there is no chance for the boron-oxygen defects to form, resulting in a high quality material.

Similarly, n-type materials tend to be more resilient against other types of impurity defects as well, the most cited of which being iron. The lifetime of free electrons and holes in an n-type silicon wafer is also 3 times longer than in a p-type wafer due to the capture cross-section of the defects being smaller. For all these reasons, in an n-type wafer, once an electron has been generated by sunlight, the chance of that electron becoming part of the usable current of the solar cell is much, much higher.

While not an inherent material property, higher efficiency solar cells such as n-type solar cells, tend to have better temperature coefficients than p-type cells. When working in cold climates, the voltage change as a function of temperature becomes a critical design component. As temperature drops, the cell voltage increases. At very low temperatures, as can often be had in the Yukon, this voltage drop can risk exceeding the maximum allowable voltage on the inverters. As a result, strings of modules are limited to what the cold-temperature open-circuit voltage can reach. P-type solar modules have temperature coefficients of -0.31 %/°C typically (see Heliene and Canadian Solar data sheets). Sunpower's n-type modules have temperature coefficients in the range of -0.29 %/°C to -0.298 %/°C and Sanyo's HIT cell does even better with a temperature coefficient of -0.239 %/°C. This may be a function of the low-temperature manufacturing process that the HIT cell utilizes. Similar designs, such as Sunpreme's heterojunction bifacial cells, achieve a similar temperature coefficient of -0.23 %/°C. The benefit of having a temperature coefficient closer to zero is that you don't have to over-size your inverters to take into account high voltages in low weather, and you also don't have large voltages drops and resulting power drops in hot weather.

Despite the obvious benefits of using n-type wafers, their use has not become wide-spread yet due to several factors: the higher cost of the material; and difficulties in some of the processing steps. The material cost for n-type silicon is partly due to economies of scale – there is less demand for it, and so it is produced in smaller amounts by fewer manufacturers. The crystallization of n-type silicon also tends to be less uniform than that of p-type silicon, meaning that the phosphorous doping concentration in the silicon changes as the ingot crystallizes. This results in a range of material resistivities being produced during the casting process, and the resulting wafers need to be sorted and binned later to create batches with similar material characteristics. The processing steps become more difficult in two main places: high temperature boron diffusions for forming the p-n junction are difficult, and a good method was not discovered until the late '90s, and the typical surface passivation that is used on p-type solar cells (silicon nitride) does not work on n-type solar cells, and actually makes their performance worse, so alternate passivation methods had to be developed.

In summary, the benefits of modules employing n-type wafers is the absence of light-induced degradation, higher efficiency, better voltage performance in both high and low temperatures, and lower balance-of-system costs due to both the higher efficiency and better voltages. The only draw-back is due to the higher module price, but depending on the project, this may be offset due to the benefit in the aforementioned areas.

3.1.2 Polycrystalline

Polycrystalline, or multicrystalline, solar cells are produced from chunks of purified silicon which are heated in a ceramic crucible to above the melting point of silicon and then cooled in a controlled manner. This forms blocks of polycrystalline silicon which are then cut and sliced into in wafers to form solar cells. Recognizable by their square cell shape, polycrystalline solar modules are less efficient than monocrystalline modules due to breaks within the crystal structure of the cell. However due to lower manufacturing costs, polycrystalline solar modules account for over 75% of the solar modules manufactured annually as of 2015[2].

Benefits:

- Lower manufacturing costs. (10- 15 cents per watt cheaper than standard monocrystalline, 50% cheaper than high efficiency monocrystalline cells)

Drawbacks:

- Lower efficiency. (Polycrystalline cells range from 14.5% to 17% efficiency, Monocrystalline ranges from 16% to 22%)
- Less efficient in low light conditions[3].

3.1.3 Monocrystalline

Monocrystalline solar cells are made from single crystal silicon ingots formed using the Czochralski method. A single crystal of silicon is used as a seed and dipped into vat of liquid silicon. The seed is lifted and rotated at a controlled speed, growing a single crystal silicon ingot out of the bath as it rises. The tubular crystal is then sawn into wafers, and the edges cut straight, except for their corners. Recognizable by the diamond pattern formed by the gaps between the corners of cells, monocrystalline solar modules are high efficiency solar cells producing more energy per square meter than polycrystalline solar modules[2].

Benefits:

- Higher efficiency. (Polycrystalline cells range from 14.5% to 17% efficiency, Monocrystalline ranges from 16% to 22%)
- Lower temperature coefficient, leading to improved performance in hot climates compared to Polycrystalline. (Monocrystalline averages -0.31% per degree C, Polycrystalline averages -0.40% per degree C)
- Improved low light condition performance (sunrise and sunset, cloudy weather) over polycrystalline solar cells due to higher shunt resistance (i.e. fewer shorts or flaws in the p-n junction)[3].

Drawbacks:

[2] https://www.ihs.com/pdf/Top-Solar-Power-Industry-Trends-for-2015_213963110915583632.pdf
[3] http://www.ecn.nl/docs/library/report/2005/rx05034.pdf

- Higher cost to manufacture due to requirement for single crystal silicon ingots. (Standard monocrystalline cells are 10- 15 cents per watt more than Polycrystalline, high efficiency monocrystalline cells are twice the price per watt)

3.1.4 Bi-Facial

Bi-Facial Solar cells are manufactured to allow the cells to absorb light on both sides. Traditional solar cells join the silicon cell to a solid conductive backing made of aluminum or copper, bi-facial cells bond the silicon to a grid shaped backing allowing light to be absorbed on both sides. Recognizable by their transparent glass frames with visible cells on the back side.

Benefits:

- Very high efficiency. (19% to 28% with backside power production factored in)
- Improved winter performance due to reflected light of snow covered surfaces. (Up to 50% more power per square meter under certain albedo conditions)
- Improved low light performance, due to using an amorphous Si layer, which has higher light absorption, as well as using monocrystalline silicon[4].
- Can be installed at various angles and orientations with limited impact on power production.
- Aesthetically appealing (often used by architects for building integrated solar installations)

Drawbacks:

- Very expensive to manufacture. (30-60% more per watt to manufacturer than polycrystalline modules)
- Require customized racking that does not obstruct the cells on the backside of the module.

3.1.5 Thin Film

Thin Film solar cells are made from depositing very thin layers of photovoltaic materials "film" onto a conductive backing. Each layer of film absorbs a separate spectrum of light and combine to form a solar cell. This manufacturing process makes these solar cells extremely thin and flexible allowing them to be installed in a variety of applications including on curved roof surfaces or in calculators.

Benefits:

- Lower cost to manufacture. (10 to 20 cents per watt cheaper than polycrystalline modules)
- Best low light performance of all the technologies studied in this report[5].

Drawbacks:

- Much lower efficiency. (Thin film modules average 10% to 15% cell efficiency levels)
- Large space requirements for similar power yields to silicon solar technologies.
- High operating voltages prohibit micro inverter use.

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[4] http://www.ecn.nl/docs/library/report/2005/rx05034.pdf
[5] http://profs.sci.univr.it/~romeo/Publications/Derk_17Munich-1.pdf

- Reverse bias, as is experienced when portions of a module become shaded, can damage the junction.

Due to the damage that can be done to the module when it becomes shaded, which is highly likely in the event of snowfall, thin film panels are not recommended for use in the Yukon.

3.1.6 Developing Module Technologies

The following technologies are in various stages of development and commercialization. These technologies are being developed to address a variety of deficiencies with photovoltaics including low electrical conversion factors (efficiency), high manufacturing costs, and power density.

- **Organic Semiconductor Solar Cells** were discovered and tested by a team of scientists at Cambridge University in October 2014 studying how plants convert light to energy through the process of photosynthesis[6]. The team observed that plants are able to absorb both spin-triplet light photons and spin-singlet light photons, while current solar technologies can only capture spin-singlet light photons resulting in much of the available solar energy going to waste. This observation led them to create a unique solar cell with an organic semi-conductor layer to capture the spin-triplet light photons and an inorganic semi-conductor layer to capture the spin-singlet light photons leading to a world record cell efficiency of over 75%. While this technology is still in its infancy, if it can be successfully commercialized it has huge potential for the photovoltaics industry as it would drastically increase the power density of PV technology.
- **Perovskite Solar Cells** are solar cells formed with organic/in-organic compounds to mimic the cell structure of Perovskite, which is conducive to photovoltaic conductivity. By mimicking this cell structure scientists have been able to create thin, transparent solar cells with efficiencies ranging from 3.8-9% and semitransparent solar cells with efficiencies as high as 21%[7]. The manufacturing process for perovskite solar cells is much more cost effective than traditional silicon or thin-film solar technologies and could lead to a huge decline in module production prices. Additionally, the advent of transparent solar cells paves the way for use of photovoltaics in glass building construction which represents a huge growth market for photovoltaics. However, perovskites are very unstable and can dissolve in water so finding a cost effective and means of sealing the solar cells is critical in order to allow for commercialization[4].
- **Graphene Solar Cells** consist of using thin layers of graphene to form the conductive layer within the solar cells rather than silver and copper. Graphene's carbon nanostructure makes it an excellent conductor while being extremely strong, virtually transparent and flexible[8]. These traits could allow for high efficiency, transparent, and flexible solar cells that could be used widely in applications such as building integrated photovoltaics, however currently researchers are struggling to successfully integrate graphene with existing silicon photovoltaic technologies[5].
- **Concentrated Photovoltaics (CPV)** involve using lenses to concentrate the sun onto a solar cell, allowing for exponential power production per square meter. This technology has been

[6] http://www.cam.ac.uk/research/news/hybrid-materials-could-smash-the-solar-efficiency-ceiling

[7] http://www.rsc.org/chemistryworld/2015/10/thin-film-perovskite-solar-cell-passes-efficiency-test-0

[8] http://www.graphene-info.com/graphene-solar-panels

developed and successfully commercialized with over 500 MW of installed capacity as of 2014[9]. While CPV does significantly increase power density it does have a number of draw backs that have limited its wide spread implementation including:

- **Cooling problems:** concentrating the sun on a single point leads to increased temperatures which can damage and destroy solar cells if not effectively managed.
- **Requires direct sunlight:** this severely limits the number of locations in which CPV can be implemented[10].
- **Manufacturing costs**: concentrating lenses are made of highly reflective glass which is very costly to manufacture. Additionally, cooling systems for high concertation CPV can be complex and expensive.

3.2 Inverter Technologies

Inverters are critical component to any photovoltaic system from residential installations to large utility scale power plants. Photovoltaic modules produce direct current (DC) which must be converted to alternating current (AC) in order to be used in homes and buildings or transmitted through the electrical grid. Inverters convert DC power to AC power by "switching" the DC current off rapidly inducing an AC current in a secondary conductor. The AC signal is then smoothed out using a sine wave filter to ensure its frequency matches the electrical grid[11]. There are three types of inverters used in photovoltaic applications:

- Central inverters
- String inverters
- Micro inverters

3.2.1 Central Inverters

Central inverters are designed for large scale PV installations and range in size from 100 kW to 3 MW rated capacity. When installing a central inverter, multiple strings of PV modules are combined in parallel in combiner boxes before connecting to the inverter, the high voltage DC power is then inverted to 3 phase AC power before being transmitted to the grid. Additionally, many central inverters come with prewired transformer and switch gear packages allowing high voltage grid connection right at the inverter. Accounting for over 40% of all inverter sales globally, central inverters are the industry standard for large scale PV installations with ever evolving technology[12]. In 2016, central inverter designs are expected to shift from 1000VDC architecture to 1500 VDC designs to allow for longer string sizing and reduced balance of system costs for large installations[13].

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[9] https://www.ihs.com/pdf/Top-Solar-Power-Industry-Trends-for-2015_213963110915583632.pdf
[10] http://www.greenrhinoenergy.com/solar/market/micro_market.php
[11] http://www.homepower.com/articles/solar-electricity/equipment-products/how-inverters-work

[12] https://www.ihs.com/pdf/Top-Solar-Power-Industry-Trends-for-2015_213963110915583632.pdf

[13] http://www.greentechmedia.com/articles/read/1500-Volt-Systems-Will-Account-for-4.6-GW-of-Global-Utility-Scale-Solar-In

Benefits:

1. Low manufacturing cost per rated DC watt. (8 to 20 cents USD per watt)
2. Prewired, “plug and play” designs allow for quick installation times.
3. Proven, “bankable” technology. With over 8 GW in annual installations and a 100 GW installed globally, central inverters have a well-established track record for reliable performance for utility scale PV power plants[9].
4. Integrated design. Most major central inverter suppliers offer fully integrated containerized inverter solutions which feature central inverters, a transformer, switch gear, and SCADA platform allowing for easy system design and seamless grid integration.
5. Minimizes electrical architecture complexity, reducing electrical installation labor costs.

Drawbacks:

1. No module level monitoring or string optimization. This means central inverters cannot be used in areas with partial or constant shading concerns as shading one module will impact entire strings. Additionally, module level failures cannot be detected remotely and can only be identified using thermal scans of the power plant adding the to the maintenance costs.
2. Required Annual Maintenance. Due to the size of the inverters central inverters produce a lot of heat and require complex cooling systems in order to ensure they continue to function optimally.
3. Concentrated points of failure. With input capacities typically ranging from 250 KW to 1.5 MW when a central inverter fails a large portion of a PV power plant is down until the inverter is brought online. This can be a concern for remote locations where technicians are not readily available.
4. Lifespan. Central inverters typically require significant upgrades after 12 to 15 years, which must be budgeted for in order to allow for PV power plants to fulfill their 30 year operational lifespans.
5. Temperature sensitive. Central inverters cannot operate in temperatures below -25 C and must be housed in heated containers if installed in locations with winter temperatures below -30.
6. Heavy. Central inverters typically weight 1500 to 3000 KG or more if packaged with transformers and switch gear. This limits where they can be installed and generally require being installed on concrete pads.

3.2.2 String Inverters

String inverters are designed for a wide variety of PV installations and range in size from 2 KW single phase units to 40 KW three phase units. Typically string inverters have built in maximum power point tracking (MPPT) allowing the inverter to optimize the performance of 1-3 strings of modules depending on the inverter size. Single phase string inverters typically have a maximum DC input voltage of 600V while three phase string inverters allow for 1000V and in some cases 1500V DC input voltages[14].

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[14] http://www.greentechmedia.com/articles/read/1500-Volt-Systems-Will-Account-for-4.6-GW-of-Global-Utility-Scale-Solar-In

Benefits:

1. No maintenance. String inverters have self-contained cooling systems and are outdoor rated for operating temperatures as low as -40 C.
2. Small compact design allows for deployment on racking, sides of buildings or in containerized solutions, providing system designers flexibility.
3. Decentralized design. With rate capacities ranging from 2KW to 40 KW, if a string inverter fails on a large PV installation a small segment of the power plant is down during the repairs.
4. Allow for power optimizer use. Power optimizers provide module level DC voltage optimization and monitoring minimizing the effects of shading and allowing system operators to monitor the power production of each module.

Drawbacks:

1. Higher cost. String inverters are more expensive than central inverters per installed DC watt of PV capacity. (15 to 30 cents USD per watt)
2. Increased balance of system costs and electrical architecture complexity. Installing string inverters decentralizes the AC system architecture of a PV power plant leading to increased design and installation costs associated with additional AC wiring/infrastructure.
3. Lifespan. String inverters typically need replacing after 12 to 15 years of operating time depending on conditions. Replacement costs must be budgeted for in order for PV power plants to fulfill their 30 year operational lifespans.
4. Complex system integration. While increasingly common, string inverters are typically not designed for utility scale applications leading to potential problems when integrating them with grid connection SCADA platforms and secondary switchgear packages. It is recommended that installers using string inverters for utility scale applications purchase them from vertically integrated suppliers such as Schneider, ABB or SMA to ensure that there is available grid connection equipment that is compatible with the inverters.

3.2.3 Micro Inverters

Micro inverters are connected to each module and invert the DC power supply directly at the module, eliminating the need for DC wiring. While typically used for residential and small commercial applications, micro inverters can be used for utility scale power generation.

Benefits:

1. No high voltage DC wiring. This increases the safety of solar installations and minimizes line loss concerns.
2. Completely decentralized design. Micro inverter designs ensure that module and inverter failures do not have any impact on the rest of the system. Additionally, the “plug and play” nature of micro-inverters means that personnel with minimal training can safely perform repairs.
3. Life span. Micro inverters carry 25 year comprehensive warranties ensuring that they will last the entire service life off the PV power plant.

4. Module level MPPT. Micro Inverters provide module level DC voltage optimization minimizing the effects of shading as well as allow system operators to monitor the power production of each module.
5. Easy to install. Micro inverters are “plug and play” units allowing for low qualified personnel to install a larger percentage of the PV system architecture minimizing installation costs.

Drawbacks:

1. High cost. For utility scale PV installations micro inverters are typically 50% more than string inverters and twice the cost of central inverters per DC watt[15]. (30 to 50 cents per watt USD)
2. Increased balance of system costs and electrical architecture complexity. Micro inverters completely decentralize the electrical system architecture of a PV power plant leading to increased design and installation costs associated with adding combiner boxes, medium voltage transformers, and large amounts of high amperage AC wiring.
3. Complex system integration. Micro inverters were not designed for utility scale applications and are typically manufactured by companies that are not vertically integrated, making communicating with SCADA platforms and secondary switchgear packages more complex and expensive.

3.3 Racking Technologies

There are a number of options available for mounting solar panels depending on the situation and environment in which they’re being used. The most common for utility scale applications are fixed tile racking, single axis tracking, and dual axis tracking. More recently, rail trackers are also beginning to be used.

3.3.1 Fixed Racking

Over 90% of all utility scale PV power generation (systems >500KW) is installed as ground mount installations and of those 70% of the installations are fixed racking[16]. Ranging from concrete ballasted designs, to pile drive foundations, fixed racking provides PV power plant designers reliability and flexibility at an extremely low cost.

Benefits:

1. Very low cost. With an average price of $0.20 per watt USD fully installed for system over 1 MW, fixed ground mount racking is the lowest cost racking solution on the market[13].
2. Flexible. Ground mount racking can easily be customized to handle a variety of terrain and geotechnical conditions with varied foundation options including, driven piles, helical screws, concrete ballast, or rock bolts. This allows system designers to customize their racking to handle almost any terrain type allowing for solar installations in a wide variety of locations.

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[15] https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf
[16] https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

3. Robust and reliable. Comprised of galvanized steel or anodized aluminum with no moving parts, fixed ground mount racking ensures system operators that there will be no maintenance concerns and that the racking will outlast the life span of the project.
4. Ease of installation. Fixed racking designs are quite simple and can easily be assembled quickly by low qualified personnel lowering installation costs. Additionally, low continuous spans of racking make wire management easy to manage limiting the amount of work required by more expensive electrical personnel.

Drawbacks:

1. Lower power production as modules are fixed in place.

3.3.2 Single Axis Trackers

Single Axis trackers follow the sun as it moves east to west throughout each day leading to increased power production. With movement on only one axis, single axis tracker designs are relatively simple and light weight allowing for deployment in a variety of locations with only small amounts of maintenance required.

Benefits:

1. Increased power production. Single axis trackers allow for increased power production of 20 to 30% annually depending on the installation location.
2. Simple designs. By moving on a single axis these trackers have simple designs that require minimal annual maintenance.
3. Light weight/lower wind resistance. Typical single axis trackers are made of lightweight materials allowing for them to be installed using a ballasted design or helical screws making installations less complex than dual axis trackers.

Drawbacks:

1. Higher cost than racking. With an average price of $0.30 per watt USD fully installed for system over 1 MW.
2. Less power production that dual axis trackers.
3. Greater land use requirements due to inter-row shading as the trackers follow the sun throughout the day.
4. Annual maintenance is often required.
5. Less flexible foundation design than fixed racking.

3.3.3 Dual Axis Trackers

Dual Axis trackers follow track the sun both east-west as well as vertically across the sky throughout the day. This allows for maximum power yields per module as the modules will always be directly pointing at the sun.

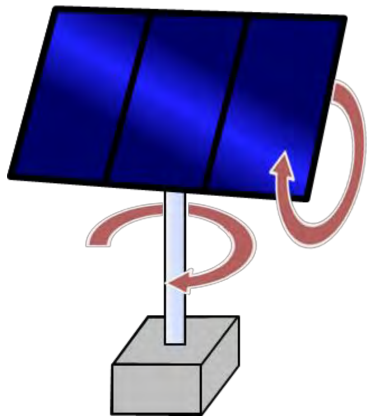

Photo Credit: Sedona Solar Technology

Benefits:

1. Maximum power generation per module producing up to 45% more power per module compared with fixed installations[17].

Drawbacks:

1. High Cost. With an average price of $0.70 per watt USD fully installed for system over 1 MW.
2. Single point of failure. Traditional dual axis trackers rotate around a complex single bearing that allows the tracker to move both directions and is required to support the weight of up to 40 solar modules. This design often leads to the bearing failure, causing the tracker to jam ad can lead to long down times and high maintenance costs.
3. High Wind Problems. Due to having 40 modules mounted side by side, traditional dual axis trackers are not designed to handle high winds and can experience structural failure in winds of 150 kph or more.
4. Large Foundation Requirements. The weight of traditional dual axis tracking systems requires large concrete foundations adding considerable costs to installing them.
5. Heavy Components. Due to the stresses being concentrated on a single point, dual axis trackers are constructed on heavily reinforced materials that weigh a considerable amount. This adds significant extra costs when transporting the trackers to remote locations.
6. Non Scalable. Each tracker is an isolated unit leading to limited cost savings when installing larger system.
7. Large land use requirements. Inter-tracker shading can be a significant problem if trackers are located too closely together leading to large land use requirements.

[17] https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

3.3.4 Rail Trackers

Rail trackers are a unique dual axis tracker that is designed to address many of shortfalls of dual axis trackers. While it is a new product on the market is has shown excellent potential to become a key player in the tracking market in the years to come.

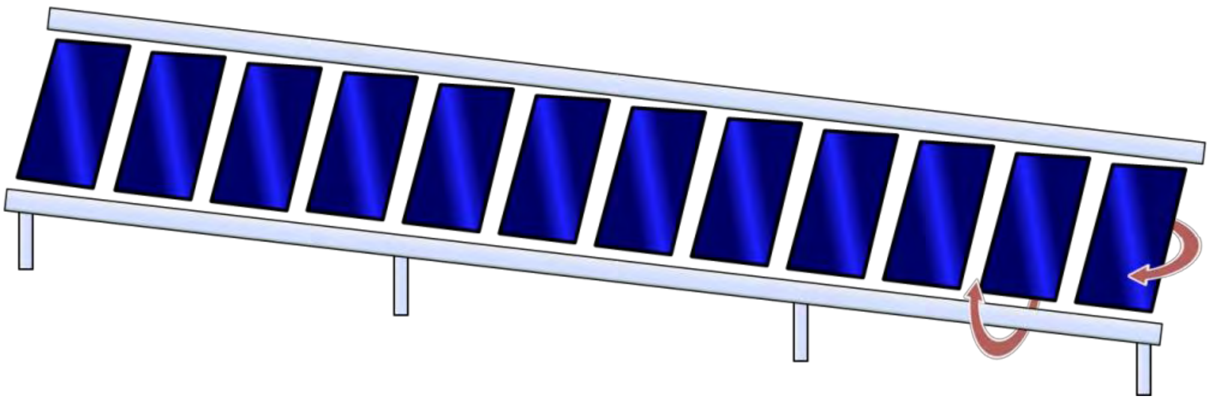

Photo Credit: Sedona Solar Technology

Benefits:

1. Maximizes power production per module by allowing for flexible frame sizes, allowing for designers to use large high wattage modules with minimal extra cost.
2. Low levelized cost of energy. Rail tracking prices are slightly lower than single axis trackers ($.25 USD per watt) while providing power production yields 5% lower than dual axis trackers.
3. Weight is spread out over the entire array significantly reducing the stress on the actuators.
4. Simple design. Rail trackers have just 2 moving parts that operate in a single axis, reducing complexity and making the system less prone to failure.
5. Does not require concrete foundations. This leads to significant savings in installation costs as well as decreased installation time.
6. Space between modules significantly decreases the wind resistance of the dual axis tracker enabling it to safely handle wind speeds of up to 240kph[18].
7. Scalable design allows for frames to share actuators, producing significant cost savings for utility scale projects.
8. Reduced land use requirements compared with standard dual axis trackers as trackers are long single rows with no inter-row shading concerns.

Drawbacks:

1. Limited track record. As this is a new technology there are a limited number of installations globally at this time providing a small data set from which to draw modeling and design conclusions. This is expected to change as more installations come online in 2016-2017 using rail trackers.

[18] http://sedonasolartechnology.com/technology/

2. Inter-module shading at higher latitude locations. Due to the frame design, when the sun is located at either true-east or true west, the modules will partially shade one another down the row limiting power production at those times. This has a small impact on annual power production compared with dual axis trackers in northern locations.

3.4 Energy Storage

For the Yukon, it's expected that battery storage for energy back-up will only be required for the 10MW installation scenario. It's been seen in Germany and other locations that the grid can handle solar PV penetration well above 10% before stability becomes an issue. It should be noted that the location of PV in relation to the loads should also be taken into account. Two locations are studied in this report – Whitehorse, and Haines Junction. As Whitehorse is the major centre of population and industry for the territory, and has a high demand for electricity, adding 5 to 10 MW of solar PV may only account for about 10 to 20% of the local energy use. For Whitehorse, storage may not be necessary. For Haines Junction, a 5 MW PV plant may make up a much larger chunk of the local electricity supply. For Haines Junction then, to ensure a stable grid locally, it may be desirable to include some energy storage. Figure 3.1 shows the type of storage options for grid scale applications that are good for various timescales. For maintaining grid stability, only 5 to 15 min of energy storage capacity is needed to bridge the gap until a back-up generation source, such as stored hydro, can be brought online, and so batteries would be a suitable option for the projects being looked at by YEC (if it's deemed they're needed – we would need a bit more data about the local energy demand to full answer that question).

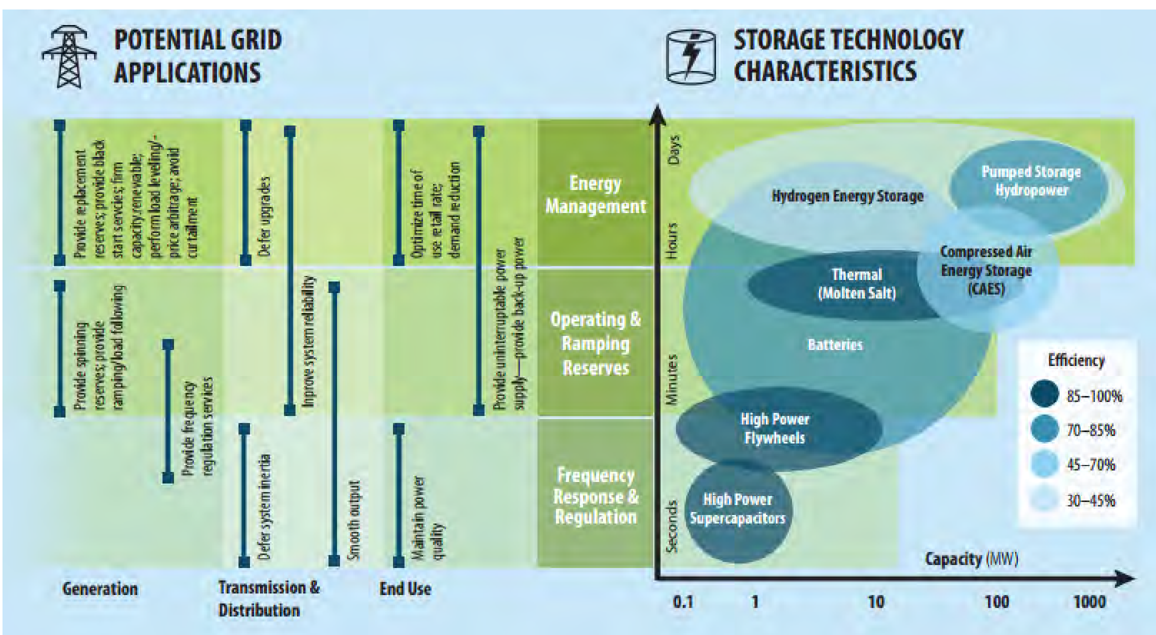

Figure 3.1: Energy storage options for grid applications[19]

[19] http://www.nrel.gov/docs/fy16osti/64764.pdf

For this reports, originally an 8 MW, 15 min battery storage option was included for the 10 MW power plant. This energy storage component was a Younicos system. The energy storage is no longer part of the financial analysis, but should you wish to include it, this was the system we were working with.

4 Asset Service Life

Typical asset service lifetimes are detailed in Table 4.1. As can be seen, the majority of the components of a PV system are expected to be good for at least 25 to 30 years. The only component that has a shorter lifetime that the system lifetime of 30 years is the inverters. As a result, a large investment in maintenance in Year 20 of the financial model reflects the expected replacing of the inverters at this point in the lifetime of the system.

Table 4.1: Asset service lifetimes

Component	Service Life	Warranty	Maintenance Costs (Annually)	Replacement Cost
Modules	30 + years	25 year power warranty 10 – 25 year product warranty	Cleaning = $1000 per MW	N/A
Inverters	20 years	10 years	$2000 per MW	$0.10 USD per W
Energy Storage Inverters	25 Years	10 years	$2000 per MW	
Battery	25 years	25 years	$65,000 per year	
SCADA/Plant Controller	25 years	5 years	$250 annual software update	
Racking	30 + years	5 years	None	N/A
Single Axis Trackers	25 + years	5 years basic + 5 year extended	$800 USD per MW	N/A
Medium Voltage Substations	30 years	2 years	None	N/A
DC Wiring	30 + Years	N/A	$2000 USD per MW	$0.90 CAD per M as needed
DC Combiner Boxes	30 + Years	2 Years	$3000 USD per MW	N/A
AC Wiring	30 + Years	N/A	None. Wire is buried in conduit/sheathed in armored cable.	
Chain Link Fence	30 + years	1 Year	None	N/A

5 Operations and Maintenance Plan

The operations and maintenance plan for the 1 MW and 5 MW power plants will be identical with the costs scaling proportionally. The O&M plan for a 10 MW facility will be more complex due to the overall size of the power plant and incorporation of batteries into the design.

5.1 Maintenance Training

Local workers would be trained in the following areas:

1. Module replacement.
2. DC Wiring/Combiner box repairs.
3. Tracker bearing/motor repairs.
4. String Inverter replacement.
5. Component communication system repairs.
6. General grounds keeping/fencing repairs.

5.2 Spare Parts List

As part of the construction costs a certain number of spare components will be purchased. These will include:

- Modules: 8 pallets – 200 modules
- Inverters: This only applies to string inverters, and 1 unit per MW would be kept on-hand.
- Tracker bearings: 25 bearing per MW or as manufacturer advises
- PV wire: 1 KM of positive and negative wire
- MC4 connectors: 100 connectors with a crimping kit
- Combiner boxes: 2 combiner boxes per MW

5.3 1 MW/5MW O&M Plan

Service	Frequency	Cost per MW	Description
Module Cleaning	Bi-Annually	$1000	Using a squeegee to clean modules and remove dust/animal droppings
DC Wiring Inspections	Annually	$1000	Inspect all above surface DC wiring for damage caused by animals or wires that have come loose from their clips.
Thermal Scans for the Modules	Annually	$2000	Using an infrared camera to can modules for faulty modules. Malfunctioning modules will have increased resistance leading to increased levels of heat.
Thermal Scans of Combiner Boxes	Annually	$1000	Using an infrared camera to scan combiner boxes. Boxes with loose connections will produce more heat due to higher resistance between connections.
Tracker Inspections	Annually	$1500	Inspecting motors and bearing ensuring they are operating as expected and not wearing unevenly.
Thermal Scans of Inverters	Annually	$1000	Scan the DC disconnects and combiner boxes connected to the inverter for loose connections.

HVAC Unit Inspection	Annually	$500	Inspecting the HVAC unit that heats the insulated containers housing the inverters and transformers.
General grounds Keeping	Spring/Fall	$2000	Trimming any weeds that are growing under the trackers/racking, repairing any damage to the fencing, and removing garbage.
24/7 System Monitoring	Always	$10,000	Third party monitoring usually provided by the inverter manufacture using a software platform that communicates with the telemetry of the inverters and trackers. This system is accessible by the monitoring company, the local utility and the plant owner.
Total Annual Cost:		$20,000/ $100,000	1 MW = $20,000 per year, 5 MW = $100,000 per year

5.4 10 MW O&M Plan

Service	Frequency	Cost	Description
Module Cleaning	Bi-Annually	$10,000	Using a squeegee to clean modules and remove dust/animal droppings
DC Wiring Inspections	Annually	$10,000	Inspect all above surface DC wiring for damage caused by animals or wires that have come loose from their clips.
Thermal Scans for the Modules	Annually	$20,000	Using an infrared camera to can modules for faulty modules. Malfunctioning modules will have increased resistance leading to increased levels of heat.
Thermal Scans of Combiner Boxes	Annually	$10,000	Using an infrared camera to scan combiner boxes. Boxes with loose connections will produce more heat due to higher resistance between connections.
Tracker Inspections	Annually	$15,000	Inspecting motors and bearing ensuring they are operating as expected and not wearing unevenly.
Thermal Scans of Inverters	Annually	$20,000	Scan the DC disconnects and combiner boxes connected to the inverter for loose connections.
HVAC Unit Inspection	Annually	$5,000	Inspecting the HVAC unit that heats the insulated containers housing the inverters and transformers.
General grounds Keeping	Spring/Fall	$20,000	Trimming any weeds that are growing under the trackers/racking, repairing any damage to the fencing, and removing garbage.
24/7 System Monitoring	Always	$130,000	Third party monitoring would be provided by the energy storage system supplier as the energy storage inverter system will have a built in SCADA controller that will integrate the PV and batteries into once control unit.
Total Annual Cost:		**$240,000**	

6 Project Schedules

The project schedules for the 1 MW, 5 MW and 10 MW plants are shown in this section. Copies of the Gantt charts can be found in the Excel files accompanying this report.

6.1 Whitehorse Schedule – 10 MW

Task	Require Time (Weeks)
Environmental Assessment	52
Geo-technical Assessment	4
Finalize System Layout	4
Structural Engineering Review	4
Finalize Electrical Schematics	4
Electrical Engineering Review	4
Materials Ordered	2
Finalize Construction Plan	4
Survey and Mark-out all racking, trenching and pad locations	2
Power Line construction from substation to site	4
Dig cable trenches and level pads	2
Chain link fence construction	2
Position Inverter Centers	1
Racking Construction	4
DC Electrical Work and Inverter Connections	2
Module Installation	4
AC wiring and MV Substation Connections	2
Grid Connection	1
SCADA Installation	1
System Testing	1

6.2 Haines Junction Schedule – 5 MW & 1MW

Task	Require Time (Weeks)
Environmental Assessment	52
Clear and Mulch Property	4
Geo-technical Assessment	4
Finalize System Layout	4
Structural Engineering Review	4
Finalize Electrical Schematics	4
Electrical Engineering Review	4
Finalize Construction Plan	4
Materials Ordered	2
Survey and Mark-out all racking, trenching and pad locations	2
Access Road Construction	6

Power Line construction from substation to site	4
Dig cable trenches and level pads	2
Chain link fence construction	2
Position Inverter Centers	1
Racking Construction	4
DC Electrical Work and Inverter Connections	2
Module Installation	4
AC wiring and MV Substation Connections	2
Grid Connection	1
SCADA Installation	1
System Testing	1
Power Plant Commissioned	1

7 Energy Modeling Methodology

There are a number of things that can affect the energy performance of a PV power plant. The efficiency of the panels chosen, the panel's response to temperature changes, the racking and tracking systems, the inverters, and the distance to the nearest substation all have an effect. To better understand how much energy can be generated at each site using different systems designs, simulations were run using PVSyst. The following system design components were evaluated in the simulations:

- Module type
- Inverter type
- Racking type
- Plant size

PVSyst is a powerful modeling program that's also capable of modeling a number of loss mechanisms in the plant. In this section we explain the rationale behind the modules, inverters, and racking systems that were modeled, as well as the various losses that were included in the simulations.

7.1 Systems Component Choices for the PVSyst Simulations

7.1.1 Module Selection

The following modules were analysed for their performance at Haines Junction using PVSyst:

- Heliene polycrystalline (320W)
- Canadian Solar monocrystalline (290W)
- Canadian Solar polycrystalline (320W)
- Sunpower n-type monocrystalline (445W)
- Panasonic Heterojunction with Intrinsic Thin layer (HIT) (330W), n-type
- Prism Solar bi-facial, n-type (343W)

Heliene – Based in Canada, so prices are more stable (priced in $CDN). Shipped from Ontario. Comparable to Canadian Solar modules, as they supply fairly standard p-type mono and p-type multi panels.

Canadian Solar – Headquartered in Canada, with manufacturing in both Canada and China. Again, more stable prices in Canadian dollars. They can ship from Canada or Asia, and costs on shipping by sea from Asia may actually be cheaper. Heliene and Canadian Solar mono- and multi-crystalline panels are both fairly standard panels with nothing special or surprising. Both manufacturers use p-type silicon, and hence are subject to 2% light-induced degradation (LID) once they go into use in the field.

Sunpower – US company, with manufacturing in Asia, mainly the Philippines. Prices are in USD, so subject to some fluctuation, shipping by boat from Asia should be a reasonable cost. These are n-type silicon solar cells, so not subject to the 2% LID experienced by the p-type cells. This is the only supplier studied that has a 25 year warranty on both the product and power production. The typical warranty terms for all the other panels are a 10 year product warranty, with a 20 to 25 year guarantee on power production (80% production guaranteed after 25 years in service, typically).

Panasonic – Originally the HIT was developed by Sanyo, and then this portion of the company was purchase by Panasonic. Based in Japan, however there is a presence in Canada as well (Panasonic Eco Solution, in Mississauga, does a lot of work with smart grids, green energy, and energy storage). The n-type heterojunction cell offered by Panasonic has the best temperature stability, meaning that the voltage does not fluctuate with temperature nearly as much as the other panels studied.

Prism Solar – Bi-facial cells. US company, Prism Solar has manufacturing in Arizona and New York for the modules. Quotes in USD, so price fluctuations based on currency exchange rates to be expected. Bi-facial cells are able to take advantage of light reflecting onto the back of the cell, boosting the current and hence the power output of the panels by up to 2%.

7.1.2 Inverter Selection

The following inverters were analysed for their performance using PVSyst:

- Schneider Electric central inverter – Conext Core XC-540
- SMA string inverter – Sunny Tripower 60-US-10
- ABB central inverter – PVS800

Micro inverters were not modeled, as there is some question as to whether or not they will be able to hold up to the harsh weather conditions experienced in the Yukon.

Also, it should be noted that after running a few simulations with the Schneider inverter and comparing them to the ABB inverter results, the difference in energy yield was negligible. The energy models were run using just one type of central inverter (the Schneider ones) after that. When doing the financial analysis, the central inverter energy results are used for both the Schneider and ABB analyses – the only differences come from the price difference between the two system.

7.1.3 Racking Selection

The following racking systems were analysed for their performance using PVSyst:

- Fixed tilt racking – (manufacturer not important for the energy analysis)
- Single axis trackers – Deger TOPTracker 40NT and 8.5
- Dual axis trackers – Deger D60H

For the most part, the supplier of the racking systems is not important in terms of energy production. The critical criteria, particularly for the trackers, is whether or not they can achieve the optimal angles for the Yukon. Panels should be at an angle of 45° in the Yukon for maximum energy yield, however the Deger TOPTrackers are limited to 30° according to the data sheets (see accompanying documentation). Other suppliers, or even Deger, should be able to provide a solution that meets YEC's needs, however there may be an extra engineering cost associated with this type of design change.

7.2 Assumptions Used in the PVSyst Model

The following assumptions were included in the PVSyst simulation:

Albedo:

- Snow albedo (0.8) November thru February
- March is half-way at 0.6, April and October at 0.4
- The rest of the year – 0.2 for grass

Fixed Rack Tilt:

- Fixed tilt angle is 45° - optimal tilt angle for the locations chosen

Soiling:

- Soiling in the winter is 20% (mostly due to snow). As the tilt angle is fairly high, snow is not expected to accumulate too much

Temperature:

- Maximum voltage was calculated at -40°C. PVSyst will not allow a lower temperature to be input, but some voltage space to allow for temperatures to drop to -45°C is recommended.

Maintenance:

- Down-time for maintenance 3 times per year, randomly distributed, total time down is 7.3 days for the year

Shading:

- Spacing between racking/modules was chosen to maintain less than 5% near shading as much as possible.

Electrical:

- Wiring loss was limited to 1.5% - default, and what the electrical design should aim for to avoid too much voltage loss during transmission

7.3 A Note on Spacing Requirements and Shading

A short test was done to illustrate the effect that shading has on the power generation of a PV installation. Here, 1 MW of Heliene monocrystalline modules are arranged in an array with the following dimensions:

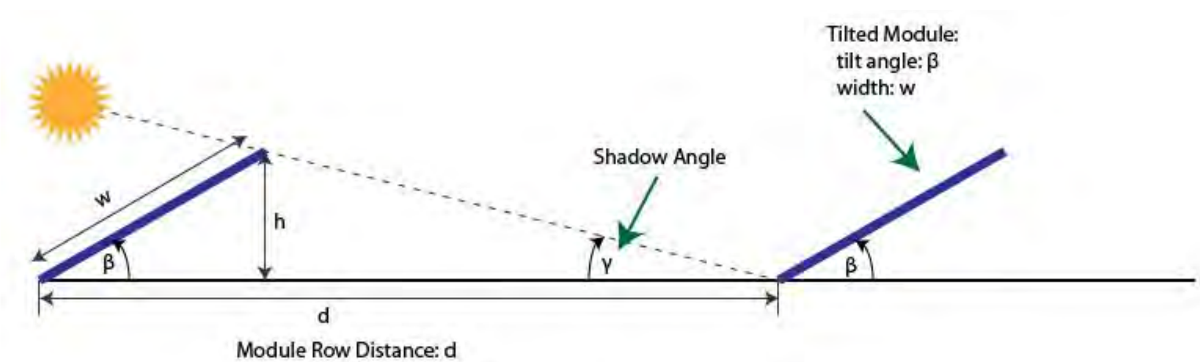

Figure 7.1: Row spacing, d, for an array using fixed tilt racking [http://www.greenrhinoenergy.com/].

The row-to-row distance, *x*, was varied to show the effect of increased shading on power production. Spacings of 5m, 10m, and 15m were used here. The row-to-row distance to ensure no shading at noon on 21 December was calculated to be 17.4m, for comparison.

Shading profiles

The shading profiles over the course of the year for the three different row spacings, as calculated by PVSyst, are shown in Figure 7.2.

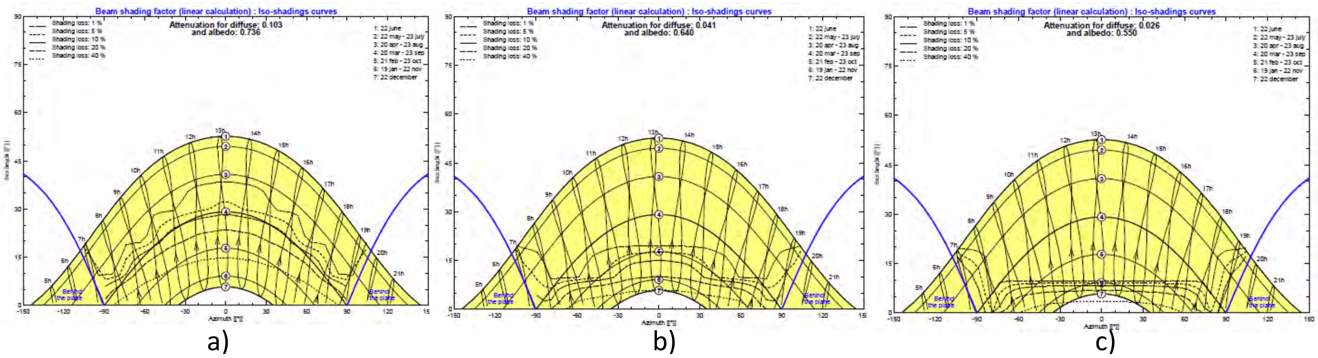

Figure 7.2: Shading profile for a) 5m row separation; b) 10m row separation, and c) 15m row separation

As expected, the less shaded the panels produce more energy. However, the extent to which this is a benefit is a trade-off with the increased area required for the array. A larger area requirement means more area needs to be cleared of brush, and longer wire lengths are needed to connect up the array, as well as larger wire diameters. This can add to the over-all up front costs of the project, and looking into how the finances are affected by the increases in energy yield are important in making a decision on the best array design.

Table 7.1 shows some key parameters for the 3 different row spacing designs: near shading %, energy yield, installation area, and estimated LCOE. LCOE calculations were based on a 30 year project lifetime.

Table 7.1: Effect of row spacing on energy yield and LCOE

Row Spacing	Near Shading (%)	Annual Energy Yield (MWh)	Installation Area (acres)	LCOE ($/kWh)
5 m	12.0	918.6	3.1	0.2680
10 m	5.2	1013	6.2	0.2442
15 m	3.3	1040	9.3	0.2398

While the benefit from moving from a 5m spacing to a 10m spacing is clear, there begins to be diminishing returns beyond that point. For the purpose of the simulations throughout this report, the near shadings value was attempted to be kept below 5% to provide a balance between maximizing energy and reducing area requirements, while maintaining a decent LCOE

8 Haines Junction Energy Analysis

In this section we look at the various options for a power plant at Haines Junction, and recommend what, for this location, makes the most sense. The following options have been modeled: different panel technologies, racking systems, tracking systems, and inverter setups.

8.1 Racking and Tracking Simulation Results

8.1.1 Fixed Tilt Racking

Simulations with the various panel types were run in PVSyst using fixed racking tilted at 45°. The results can be seen in Table 8.1.

Table 8.1: Annual energy production of PV power plants at Haines Junction using fixed racking and central inverters vs. string inverters

	Central	**String**	**Central**
Haines Junction	**1 MW (MWh/yr)**	**1 MW (MWh/yr)**	**5 MW (MWh/yr)**
Heliene 72P-320W	1168	1168	5603
CDN Solar CS6K-290MS	1103		5385
CDN Solar CS6X-320P	1163		5475
Sunpower SPR-440NE-WHT-D	1125	1106	5389
Panasonic VBHN330SJ47	1110		5319
Prism Bi60-343BSTC	1143	1124	5560

The installed capacity varied slightly depending on the string arrangements. As expected, the more efficient the solar panel, the fewer panels will be needed in order to get to the desired installed capacity. At the 1 MW size, area is not a critical characteristic yet, however, so lower efficiency modules, well spaced out may come in with the best price per watt.

8.1.2 Single Axis and Dual Axis Tracking

The energy modeling results from PVSyst for a PV plant using single axis and dual axis tracking, as well as central vs. string inverters, are detailed in Table 8.2.

Table 8.2: Annual energy production of PV power plants at Haines Junction using single axis and dual axis tracking, and central inverters vs. string inverters

	Single Axis	Single Axis	Dual Axis	Single Axis
	Central	String	Central	Central
Haines Junction	**1MW (MWh/yr)**	**1MW (MWh/yr)**	**1MW (MWh/yr)**	**5MW (MWh/yr)**
Heliene 72P-320W	1437	1360	1439	5751
CDN Solar CS6K-290MS	1461		1433	6750
CDN Solar CS6X-320P	1389		1356	6425
Sunpower SPR-440NE-WHT-D	1352	1294	1425	6723
Panasonic VBHN330SJ47	1435		1383	6526
Prism Bi60-343BSTC	1480		1423	6695

The increase in energy generated when going from fixed tilt racking to single axis tracking is significant – a nearly 30% increase (see Table 8.3). However, when moving from single axis to dual axis, the energy yield effects are not as impressive – only 5.6% for the Sunpower cells, and a negative impact on the Canadian Solar poly cells, possibly due to the increased shading from the way in which the panels orient themselves. The percent increase in energy production production between each type of module and tracking system is detailed in Table 8.3.

Table 8.3: Relative increase in annual energy production with each type of tracking system, for each module type, for a 1MW plant

Haines Junction	Fixed	Single	Increase from Fixed	Dual	Increase from Single
Heliene 72P-320W	1119	1403	25.4%	1405	0.1%
CDN Solar CS6K-290MS	1056	1399	32.5%	1373	-1.9%
CDN Solar CS6X-320P	1113	1413	27.0%	1379	-2.4%
Sunpower SPR-440NE-WHT-D	1109	1334	20.3%	1405	5.3%
Panasonic VBHN330SJ47	1112	1438	29.3%	1386	-3.6%
Prism Bi60-343BSTC	1111	1438	29.4%	1383	-3.8%

The increase in energy production from fixed tilt racking to single axis tracking is significant; once the financial analysis is taken into account, this may be the ideal system for Haines. However, the relative increase in production from single axis to dual axis tracking is much less pronounced, while the increase in complexity of the system is quite significant.

As the impact of having dual axis tracking is not necessarily beneficial, dual axis tracking was not simulated for the larger systems. Table 8.4 shows the increase in energy production when going from fixed tilt to single axis tracking for a 5 MW system at Haines Junction – about a 25% increase in annual energy yield.

Table 8.4: Increase in specific energy production for single axis trackers over fixed tilt for a 5MW system

Haines Junction - 5MW	Fixed	Single	Increase
Heliene 72P-320W	1029	1248	21.3%
CDN Solar CS6K-290MS	986	1238	25.6%
CDN Solar CS6X-320P	1002	1253	25.0%
Sunpower SPR-440NE-WHT-D	988	1240	25.5%
Panasonic VBHN330SJ47	1021	1272	24.6%
Prism Bi60-343BSTC	1036	1301	25.6%

8.2 Effect of inverters

Only a selection of the original eight panel types was modeled with string inverters, to show the trends and save on simulation time. A comparison of power production of central vs. string inverters can be seen in Table 8.5.

Table 8.5: Effect of string inverters on fixed and single-axis mounted 1MW arrays (specific energy production)

	Fixed			Single Axis		
	Central	String		Central	String	
Modules	Specific Production (kWh/kWp)	Specific Production (kWh/kWp)	% increase	Specific Production (kWh/kWp)	Specific Production (kWh/kWp)	% increase
Heliene 72P-320W	1110	1119	0.81%	1385	1402	1.23%
Sunpower SPR-440NE-WHT-D	1102	1084	-1.63%	1330	1296	-2.56%
Prism Bi60-343BSTC	1083	1090	0.65%	1405		-

In the case of the fixed tilt arrays, the string inverters can provide a modest energy benefit of 0.6% to 0.8%. For the single axis arrays, the string inverters can give a benefit up to 1.6%. A final assessment of whether the string inverters as worth it will come from the financial analysis.

8.3 Area Requirements

The types of panels used, and the type of racking or tracking, will determine the footprint required for the installation. Table 8.6 shows the area requirements for each module type studied, with each choice of racking.

Table 8.6: Area requirements for 1, 5 and 10 MW PV installations

	Area (acres) - Fixed Tilt			Area (acres) - Trackers		
Modules	1 MW	5 MW	10 MW	1 MW	5 MW	10 MW
Heliene Poly	13.6	45.7	91.4	39.5	74	148
CDN Solar Mono	9.9	49.9	99.8	35.6	66.7	133.4
CDN Solar Poly	10.9	53.6	107.2	38	71.2	142.4
Sunpower	8.5	40	80	28.4	53.4	106.8
Panasonic HIT	8.9	40.4	80.8	24.9	46.7	93.4
Prism Bi-facial	8.9	43.5	87	30	54	108

8.3.1 Haines Junction – 1 MW Array Footprints

Figures 8.1 and 8.2 illustrate the smallest and largest potential plant footprints for 1 MW arrays at Haines Junction.

Figure 8.1: 1 MW fixed tilt area requirements at Haines Junction. Left: Smallest (8.5 acres); Right: Largest (13.6 acres)

Figure 8.2: 1 MW single axis tracker area requirements at Haines Junction. Left: Smallest (25 acres); Right: Largest (40 acres)

8.3.2 Haines Junction – 5 MW Array Footprints

Figures 8.3 and 8.4 illustrate the smallest and largest potential plant footprints for 5 MW arrays at Haines Junction.

Figure 8.3: 5 MW fixed tilt area requirements at Haines Junction. Left: Smallest (40 acres); Right: Largest (53.6 acres)

Figure 8.4: 5 MW single axis tracker area requirements at Haines Junction. Smallest option only (40 acres). The installation options over 55 acres do not fit at this location.

From the footprints, it can be seen that as the array size increases at this location, space becomes much more of a premium. If a 5 MW installation is desired at Haines Junction, some of the less efficient panels may not be suitable. A 10 MW installation already cannot be accommodated at this location.

9 Whitehorse Quarry Energy Analysis

In this section we look at the various options for a power plant at the Copper Quarry site in Whitehorse, and recommend what, for this location, makes the most sense. The following options have been modeled: different panel technologies, racking systems, tracking systems, and inverter setups.

9.1 Racking and Tracking Simulation Results

9.1.1 Fixed Tilt Racking

Simulations with the various panel types were run in PVSyst using fixed racking tilted at 45°. The results can be seen in Table 9.1.

Table 9.1: Annual energy production of PV power plants at Haines Junction using fixed racking and central inverters

	Central	Central	Central
Whitehorse Quarry	**1 MW (MWh/yr)**	**5 MW (MWh/yr)**	**10 MW (MWh/yr)**
Heliene 72P-320W	1123	5647	11471
CDN Solar CS6K-290MS	1059	5435	*11067**
CDN Solar CS6X-320P	1107	5555	*11311**
Sunpower SPR-440NE-WHT-D	1189	5456	11136
Panasonic VBHN330SJ47	1151	5391	*10977**
Prism Bi6-343BSTC	1152	5634	*11472**

** Values in italics were calculated based on trends, not run through the simulation program, due to the long duration these large simulations take.*

String inverters were not modeled at the Whitehorse location, as it's expected that the trends will be similar to those seen at the Haines Junction location (Section 8.1.1). It was seen in that section that there is not a large difference in the energy harvested using either inverter set-up. Cost and maintenance concerns will play a larger role in inverter choice than energy expectations.

Monthly energy expectations for each design choice can be found in Appendix B.

9.1.2 Single Axis and Dual Axis Tracking

As dual axis tracking was seen to not be effective in the Haines Junction simulations, it was left out of the analysis at Whitehorse. The energy modeling results from PVSyst for a PV plant using single tracking and central inverters are detailed in Table 9.2.

Table 9.2: Annual energy production of PV power plants at Whitehorse Quarry using single axis tracking, and central inverters

	Central	Central	Central
Whitehorse	**1 MW (MWh/yr)**	**5 MW (MWh/yr)**	**10 MW (MWh/yr)**
Heliene 72P-320W	1344	6041	*13960**
CDN Solar CS6K-290MS	1366	6786	*13468**
CDN Solar CS6X-320P	1290	6447	*13765**
Sunpower SPR-440NE-WHT-D	1330	6757	13558
Panasonic VBHN330SJ47	1326	6555	*13359**
Prism Bi6-343BSTC	1483	6934	*13961**

** Values in italics were calculated based on trends, not run through the simulation program, due to the long duration these large simulations take.*

The increase in energy generated when going from fixed tilt racking to single axis tracking is significant – on average over 25% (see Table 9.3).

Table 9.3: Relative increase in annual energy production with each type of tracking system, for each module type, for a 1 MW plant

Whitehorse - 1MW	Fixed	Single	Increase
Heliene 72P-320W	1075	1313	22.1%
CDN Solar CS6K-290MS	1056	1309	24.0%
CDN Solar CS6X-320P	1059	1312	23.9%
Sunpower SPR-440NE-WHT-D	1074	1312	22.2%
Panasonic VBHN330SJ47	1101	1329	20.7%
Prism Bi60-343BSTC	1119	1441	28.8%

The increase in energy production from fixed tilt racking to single axis tracking is significant; once the financial analysis is taken into account, this may be the ideal system. Table 9.4 shows the increase in energy production when going from fixed tilt to single axis tracking for a 5 MW system at Whitehorse – an average 22.6% increase in annual energy yield.

Table 9.4: Increase in specific energy production when moving from fixed tilt tacking to single axis trackers for a 5 MW installation at Whitehorse Quarry

Whitehorse - 5MW	Fixed	Single	Increase
Heliene 72P-320W	1081	1311	21.3%
CDN Solar CS6K-290MS	1041	1300	24.9%
CDN Solar CS6X-320P	1064	1312	23.3%
Sunpower SPR-440NE-WHT-D	1076	1333	23.9%
Panasonic VBHN330SJ47	1080	1314	21.7%
Prism Bi60-343BSTC	1117	1348	20.7%

Table 9.5 shows the increase in energy production when going from fixed tilt to single axis tracking for a 10 MW system at Whitehorse. Only one data point is shown, due to the size of the simulations – Sunpower, requiring the least number of modules due to their high efficiency – was able to be modeled in a reasonable time frame. It's expected that the other types of modules would also experience about a 20% increase in energy yield by moving to single axis tracking.

Table 9.5: Increase in specific energy production when moving from fixed tilt tacking to single axis trackers for a 10 MW installation at Whitehorse Quarry

Whitehorse – 10 MW	Fixed	Single	Increase
Sunpower SPR-440NE-WHT-D	11,136	13,558	21.7%*

**This value was used to extrapolate the energy production of all the module types.*

9.2 Area Requirements

The types of panels used, and the type of racking or tracking, will determine the footprint required for the installation. Table 8.6, re-shown from the Haines Junction analysis, contains the area requirements for each module type studied with each choice of racking.

Table 8.6: Area requirements for 1, 5 and 10 MW PV installations

	Area (acres) - Fixed Tilt			Area (acres) - Trackers		
Modules	1 MW	5 MW	10 MW	1 MW	5 MW	10 MW
Heliene Poly	13.6	45.7	91.4	39.5	74	148
CDN Solar Mono	9.9	49.9	99.8	35.6	66.7	133.4
CDN Solar Poly	10.9	53.6	107.2	38	71.2	142.4
Sunpower	8.5	40	80	28.4	53.4	106.8
Panasonic HIT	8.9	40.4	80.8	24.9	46.7	93.4
Prism Bi-facial	8.9	43.5	87	30	54	108

9.2.2 Whitehorse – 1 MW Array Footprints

Figures 9.1 and 9.2 illustrate the smallest and largest potential plant footprints for 1 MW arrays at the Whitehorse Quarry.

Figure 9.1: 1 MW fixed tilt area requirements at Whitehorse. Left: Smallest (8.5 acres); Right: Largest (13.6 acres)

Figure 9.2: 1 MW single axis tracker area requirements at Whitehorse. Left: Smallest (25 acres); Right: Largest (40 acres)

9.2.3 Whitehorse – 5 MW Array Footprints

Figures 9.3 and 9.4 illustrate the smallest and largest potential plant footprints for 5 MW arrays at the Whitehorse Quarry.

Figure 9.3: 5 MW fixed tilt area requirements at Whitehorse. Left: Smallest (40 acres); Right: Largest (53.6 acres)

Figure 9.4: 5 MW single axis tracker area requirements at Whitehorse. Left: Smallest (46 acres); Right: Largest (74 acres)

From the footprints, it can be seen that there is ample space at the quarry for 5 MW arrays using any of the module or racking types available.

9.2.4 Whitehorse – 10 MW Array Footprints

Figures 9.5 and 9.6 illustrate the smallest and largest potential plant footprints for 10 MW arrays at the Whitehorse Quarry.

Figure 9.5: 10 MW fixed tilt area requirements at Whitehorse. Left: Smallest (80 acres); Right: Largest (107 acres)

Figure 9.6: 10 MW single axis trackers area requirements at Whitehorse. Only the smallest array options (less than 110 acres – 93 acres shown) will fit.

For the 10 MW array, any module option will work with fixed racking. However, when moving to single axis tracking, more space is required to ensure the modules don't become too shaded, and **only the three highest efficiency modules – Sunpower, Panasonic, and Prism Solar – will meet the area restrictions.**

10 Financial Analysis Methodology

The financial analyses for each size and location of power plant were approached in the same manner. Before getting into the details of the analyses, a few notes on the engineering expenses are explained.

10.1 Engineering Fees Explanation

At first glance the estimated engineering costs for the construction of the proposed solar arrays might seem quite low. This is due to the fact that much of the engineering costs associated with constructing a solar array are represented in the costs of various materials for the project.

Structural/Civil Engineering:

When constructing a utility scale solar power plant, developers will typically work with integrated racking companies such a Schletter or Sunlink. These companies have in-house structural, civil and geotechnical engineering teams that will fully engineer and stamp the racking design before manufacturing the racking according the specifications.

This approach ensures that clients receive racking that is designed for the geotechnical and climatic conditions on location, giving solar project developers peace of mind that their racking will last the entire operating life of the power plant.

Geotechnical Engineering:

When designing solar farms with ground mount racking/trackers, a geotechnical analysis of the site must be performed in order to determine the racking substructure design and piling layout/depths. While the racking supplier will typically analyze the geotechnical samples collected they do not provide the onsite engineering teams to collect the samples for analysis. The added cost of collecting the samples is represented in each budget with the analysis of the samples incorporated into the racking costs.

Electrical Engineering:

Typically, utility scale solar power plants use Central Inverter or String Inverter electrical architecture with all DC/AC electrical equipment provided by an integrated electrical supplier such a Schneider, ABB, or SMA.

In the case of central inverters this typically means central inverters are housed in pre-wired skids or containers along with step-up transformers and switch gear. These containers or skids are fully engineered by the supplier to the plant specifications, allow for direct grid connection to the primary bushings of the transformer in each container. As with the racking this engineering work is performed/stamped by the suppliers in house engineering team with the cost included in the materials cost.

When constructing solar power plants with string inverters, developers typically look to the inverter supplier to provide pre-wire substations containing step-up transformers and switch gear allowing for multiple string inverters to connect to the grid at one central location. These substations are pre-engineered to work with the specific string inverter used on location by the inverter supplier’s in-house engineering team with the engineering costs absorbed in the cost of the materials.

Environmental Engineering:

Typically, environmental engineering is not required for most utility scale solar projects unless constructed on previously contaminated sites or old landfills. However, it is advised that solar project developers pay for a basic third party baseline environmental assessment of any property being considered for a solar power plant to ensure that there are no pre-existing contaminants on location that could be disturbed as part of construction or lead to misplaced liability for the costs of cleaning the contamination at a later date. The cost of a baseline environmental assessment is represented in the budget for each proposed project in this report.

10.2 Capital Expenditures Examples

An example of the detailed capital expenditures is shown in Table 10.1. The breakdown for each individual technology choice can be found in the Excel spreadsheets accompanying this report. Table 10.1 shows a 1 MW installation at Haines Junction using central inverters.

Table 10.1: CapEx breakdown example – Heliene 72P modules using ABB central inverters and fixed tilt racking

	Price
Component	**$1,520,799.97**
Modules	**$844,168.77**
Heliene 72P	$844,168.77
Racking	**$354,631.20**
Schletter	$354,631.20
Inverter Centers (ABB Central Inverters)	**$225,000.00**
SCADA (included with inverters)	**$0.00**
Electrical Components	**$85,000.00**
Fencing	**$12,000.00**
Service	**$483,000.00**
Shipping	**$105,000.00**
Driving Piles	**$20,000.00**
Surveying	**$8,000.00**
Geo-Technical Assessment	**$15,000.00**
Environmental Quality Assessment	**$5,000.00**
Road Construction and Excavation	**$40,000.00**
Crane Services	**$4,000.00**
Tree/Brush Removal	**$60,000.00**
Fencing Installation	**$16,000.00**
System Design & Engineering	**$45,000.00**
Civil Engineering	**$25,000.00**
Electrical Engineering Review	**$35,000.00**
Electrical Installation	**$25,000.00**
Solar Installation	**$70,000.00**

Commissioning	**$10,000.00**
Project Management Costs	**$65,000.00**
OHS Management	**$5,000.00**
Project Management	**$50,000.00**
Logistics Management	**$10,000.00**
Other Costs	**$390,320.00**
Taxes	**$103,440.00**
Duty	
Permitting	**$80,000.00**
Land Purchase	
10% Contingency	**$206,880.00**
TOTAL:	**$2,459,119.97**

10.3 Operations and Maintenance Examples

Operations and maintenance costs were broken down in a similar manner. Full details can be found in the accompanying financial spreadsheets and two examples are shown in Tables 10.2 and 10.3 for reference. In addition to the annual maintenance costs, some increased expenses are included for once the product warranties on some of the components begin to expire. There is also a large inverter replacement cost at Year 20.

Table 10.2: Example of annual operations and maintenance costs for 1MW fixed tilt PV installation at Haines Junction

Repair	**Year 1**
Module cleaning	$1,000.00
Brushing and grounds upkeep	$2,000.00
Module hot spot monitoring	$2,000.00
DC wiring inspections	$1,000.00
Land use payments	$4,000.00
Inverter repairs after warranty expires	($2,000.00) Y6+
Inverter & combiner box inspections	$2,000.00
Possible inverter replacement - Y20	($147,945.00) Y20
HVAC maintenance	$500.00
24/7 monitoring	$10,000.00
Insurance	$7,000.00
Total Annual Costs:	**$29,500.00**

Table 10.3: Example of annual operations and maintenance costs for 10MW fixed tilt PV installation at Whitehorse Quarry

Maintenance/Repair	**Year 1**
HVAC maintenance	$5,000.00
Module cleaning	$10,000.00
Module hot spot monitoring	$20,000.00
DC wiring, combiner and inverter thermal inspections	$40,000.00
Energy storage maintenance	$20,000.00
Inverter repairs after warranty expires	($10,000.00) Y6+
Inverter consumables	$2,500.00
Possible inverter replacement	($1,125,000.00) Y20
Reserve Fund	$76,400.70
24/7 monitoring	$130,000.00
Total Annual Costs:	**$303,900.70**

10.4 Levelized Cost of Electricity (LCOE)

The Levelized Cost of Electricity (LCOE) was calculated for each generation option at Haines. These were calculated over 30 years, using the real Weighted Average Cost of Capital of 3.38% provided by YEC for YEC resource options. LCOE was calculated using the following equation:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where

- I = capital expenditures in year t
- M = operations and maintenance costs in year t
- F = fuel costs in year t
- E = energy generated in year t
- r = discount rate

For our purposes, the fuel costs of this project are zero.

11 Financial Analysis – Haines Junction

11.1 Capital Expenses at Haines Junction

The over-all capital expenses are summarized for the various Haines Junction projects. Here we will show average results to give a sense of the magnitude of the project expenses. Full details for each project can be found in the accompanying financial analysis spreadsheets.

Table 11.1: Average capital and operating expenses for PV power plant at Haines Junction using various racking options

	Capital Cost (2015$)			Annual Fixed O&M Costs (2015$)
	Plant Capital Cost	Transmission Capital Cost	Total Capital Cost	
	$000	**$000**	**$000**	**$000**
Fixed Tilt: 1 MW	$2,876,350	$0*	$2,876,350	$31,500
Fixed Tilt: 5 MW	$12,359,119	$460,000	$12,819,119	$142,600
Single Axis: 1 MW	$3,434,393	$0*	$3,434,393	$36,926
Single Axis: 5 MW	$12,994,800	$460,000	$13,454,800	$169,252

**For a 1 MW project at Haines, the existing power lines running nearby should be able to accommodate this amount of additional current generation*

This gives a sense of the expected over-all project costs. The value of each project in terms of levelized costs of electricity (LCOE) is better for comparing projects of different sizes, and are presented in the following sections.

11.2 Financial Trends Due to Module Cost

Full tables of LCOE data can be found in Appendix C. A subset of the data, as well as average results, is presented here for simplicity.

Table 11.2 shows the calculated LCOE results for a 1MW array using SMA inverters and fixed tilt racking at Haines Junction. In general, all the LCOE results for all simulations in all locations follow the general trend seen here. Heliene Poly, Prism, and Canadian Solar Mono fluctuate between providing the lowest LCOE, mostly due to differences in system sizing and the amount of racking required. Sunpower is always the most expensive option. At the 1MW level, there is ample area for the arrays using any technology, and a decision can be made entirely on price and the ease of maintenance.

Table 11.2: LCOE values for 1 MW fixed tilt PV installations at Haines Junction using SMA string inverters.

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 2: Heliene Poly	$0.166	$0.186	$0.262
Inverter Option 2: CDN Solar Mono	$0.198	$0.222	$0.315
Inverter Option 2: CDN Solar Poly	$0.200	$0.224	$0.318
Inverter Option 2: Sunpower	$0.238	$0.268	$0.384
Inverter Option 2: Panasonic HIT	$0.204	$0.229	$0.325
Inverter Option 2: Prism Bi-Facial	$0.184	$0.207	$0.292

11.3 Fixed Tilt Racking vs. Trackers

The average LCOE values for each type of installation was calculated for the Haines Junction location and can be seen in Table 11.3.

Table 11.3: Comparison of average LCOE values for different racking options at Haines Junction.

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Fixed Tilt: 1 MW	$0.189	$0.213	$0.302
Fixed Tilt: 5 MW	$0.173	$0.193	$0.272
Single Axis: 1 MW	$0.178	$0.200	$0.281
Single Axis: 5 MW	$0.165	$0.185	$0.261
Dual Axis: 1 MW	$0.192	$0.215	$0.304

Despite the fact that the capital and maintenance expenses are higher for single axis tracking projects, since the trackers allow for 22% to 25% more energy to be collected, the cost of the energy is much lower. As expected, dual axis tracking comes in as the most expensive option due to the limited energy benefit and increased cost and complexity.

11.4 Effect of Inverter Choice

The average LCOE values for each inverter option was calculated for the 5 MW, fixed tilt racking Haines Junction installation. The results can be seen in Figure 11.1. This graph is typical of what is seen in all the installations looked at in this report. Both Schneider and ABB have central inverter options, however one is the most expensive choice, and one is the least. The difference in energy collected between central and string inverters is only slight, not enough to have an impact one way or the other on the LCOE. As such, inverter choice should be made based on maintenance concerns and weather-resistance rather than on cost or energy.

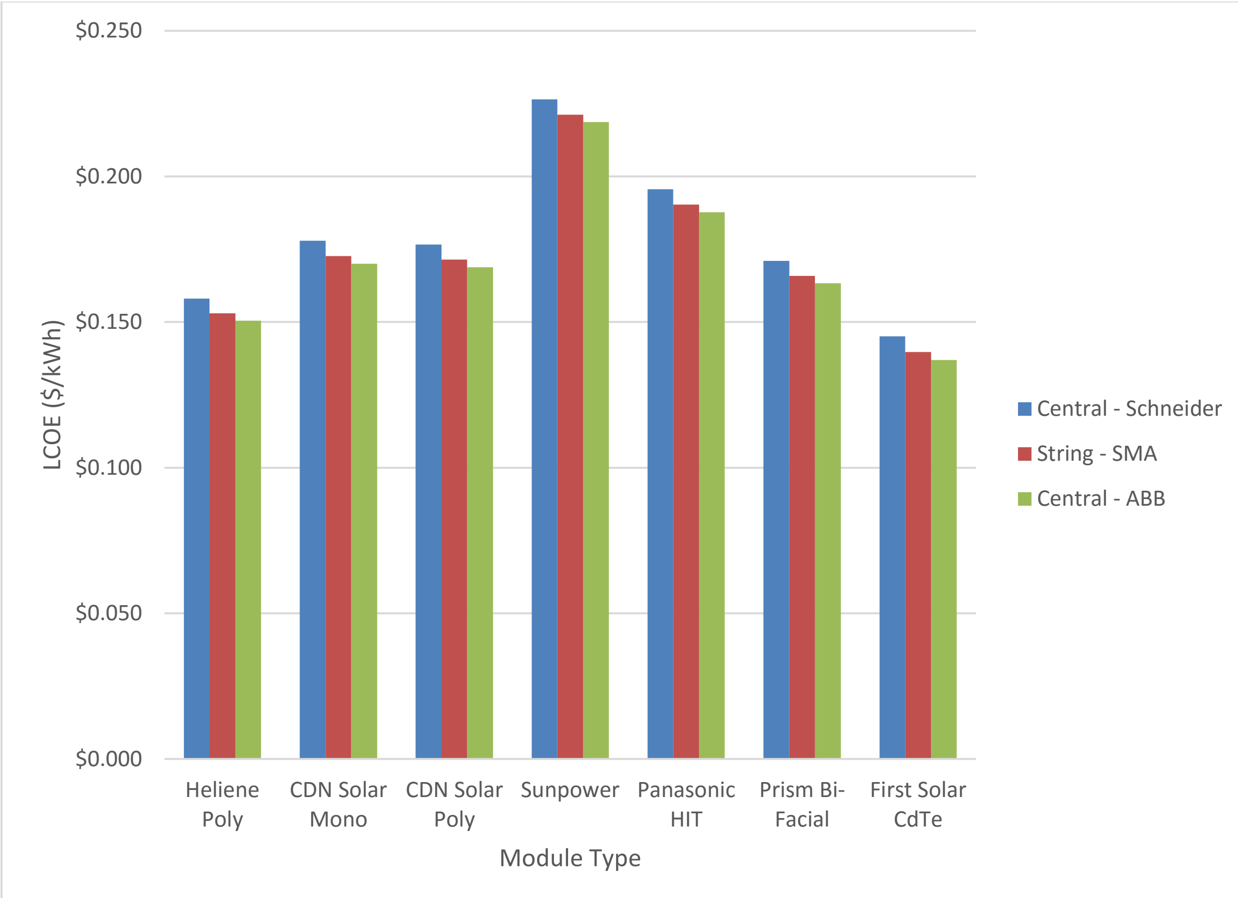

Figure 11.1: Comparison of average LCOE values for different inverter options at Haines Junction.

12 Financial Analysis – Whitehorse

12.1 Capital Expenses at Whitehorse

The over-all capital expenses are summarized for the various Whitehorse projects. Here we will show average results to give a sense of the magnitude of the project expenses. Full details for each project can be found in the accompanying financial analysis spreadsheets.

Table 12.1: Average capital and operating expenses for PV power plant at Whitehorse using various racking options

	Capital Cost (2015$)			Annual Fixed O&M Costs (2015$)
	Plant Capital Cost	Transmission Capital Cost	Total Capital Cost	
Fixed Tilt: 1 MW	$2,855,817	$460,000	$3,315,817	$31,500
Fixed Tilt: 5 MW	$12,225,363	$460,000	$12,685,363	$142,600
Fixed Tilt: 10 MW	$25,041,563	$460,000	$25,501,563	$307,384
Single Axis: 1 MW	$3,244,377	$460,000	$3,704,377	$36,926
Single Axis: 5 MW	$12,998,387	$460,000	$13,458,387	$167,346
Single Axis: 10 MW	$28,130,039	$460,000	$28,590,069	$352,346

This gives a sense of the expected over-all project costs. The value of each project in terms of levelized costs of electricity (LCOE) is better for comparing projects of different sizes, and are presented in the following sections.

12.2 Fixed Tilt Racking vs. Trackers

The average LCOE value for each type of installation was calculated for the Whitehorse location and can be seen in Table 12.2.

Table 12.2: Average LCOE comparison of the various installation types and sizes at Whitehorse

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Fixed Tilt: 1 MW	$0.200	$0.227	$0.333
Fixed Tilt: 5 MW	$0.157	$0.178	$0.259
Fixed Tilt: 10 MW	$0.172	$0.193	$0.272
Single Axis: 1 MW	$0.193	$0.219	$0.321
Single Axis: 5 MW	$0.140	$0.159	$0.233
Single Axis: 10 MW*	$0.163	$0.183	$0.258

***Sunpower, Prism Solar and Panasonic options only*

The same trends are seen here that were seen at Haines Junction – as you increase from 1 to 5 MW in size, the price drops due to economies of scale. There are also benefits in going from fixed racking to single axis tracking. While the trackers are more expensive to install and maintain, the added energy benefit out-weights the costs and the LCOE drops.

12.3 Comparison Against Haines Junction

To better see how the two sites stack up against each other, we compare their LCOE values. Tables 12.3 and 12.4 compare the fixed tilt installation costs and single axis tracker installation costs at the two sites.

Table 12.3: LCOE comparison of fixed tilt installations at Haines Junction and Whitehorse

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Haines: 1 MW	$0.178	$0.201	$0.293
Haines: 5 MW	$0.159	$0.180	$0.262
Whitehorse: 1 MW	$0.200	$0.227	$0.333
Whitehorse: 5 MW	$0.157	$0.178	$0.259
Whitehorse: 10 MW	$0.172	$0.193	$0.272

Table 12.4: LCOE comparison of single axis tracker installations at Haines Junction and Whitehorse

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Haines: 1 MW	$0.178	$0.200	$0.281
Haines: 5 MW	$0.165	$0.185	$0.261
Whitehorse: 1 MW	$0.193	$0.219	$0.321
Whitehorse: 5 MW	$0.140	$0.159	$0.233
Whitehorse: 10 MW*	$0.163	$0.183	$0.258

**Sunpower, Prism and Panasonic options only*

Interestingly, a 1 MW installation is more cost effective at Haines Junction than it is at Whitehorse. This is because, even though the land needs to be cleared at Haines, the site can make use of nearby low voltage lines as a connection point. As the size of the installation increases to 5 MW, better transmission lines are required to be installed to handle the current, and the cost increases. At Whitehorse, a transmission line will need to be built regardless of the size of the install, and so that cost is included in the price for the 1 MW option as well as the others.

At the 5 MW level, with the increased land clearing requirements at Haines as well as the transmission line installation, Whitehorse becomes the best option for the PV plant.

Only the Whitehorse location can accommodate a 10 MW PV plant. And it should be noted again that with trackers, only the three highest efficiency panels – Sunpower, Panasonic, and Prism Solar – will be able to be used.

12.4 Module Comparison

Once more, we quickly look at how the module performance stacks up in terms of cost. Table 12.5 shows the detailed LCOE breakdown for a 5 MW single axis tracker installation at Whitehorse using Schneider central inverters. Jumping to 10 MW, there would likely be an LCOE increase of about $0.015/kWh for the 3.38% real WACC case.

Table 12.5: Comparison of LCOE for various module options in a 5 MW single axis tracker installation at Whitehorse making use of Schneider central inverters

Photovoltaic Options	**3.38% Real WACC**	**4.61% Real WACC**	**8.82% Real WACC**
	LCOE (2015$)	**LCOE (2015$)**	**LCOE (2015$)**
	$/kW.h	**$/kW.h**	**$/kW.h**
Heliene Poly	$0.153	$0.170	$0.238
CDN Solar Mono	$0.151	$0.169	$0.239
CDN Solar Poly	$0.152	$0.170	$0.239
Sunpower	$0.190	$0.214	$0.305
Panasonic HIT	$0.168	$0.189	$0.267
Prism Bi-Facial	$0.165	$0.185	$0.263

While Sunpower modules certainly are more expensive, the Prism Solar and Panasonic options are reasonable. Of these, Prism bi-facial modules are the least expensive, and the Panasonic modules have the best weather characteristics and come from a highly bankable company. Either are a good option.

13 Summary and Recommendations

Site and Panel Recommendations

Two excellent sites were found as potential locations for future photovoltaic power plants: Haines Junction, near the airport and dump, and the old Copper Quarry site in Whitehorse.

For 1 MW installations, Haines Junction is the most cost effective site, with either Heliene Poly or Prism Bi-Facial modules and single axis trackers being recommended.

For 5 MW installations and larger, the Whitehorse site becomes the most cost effective option. Lower prices for electricity and capacity are achieved at the 5 MW level. For fixed tilt installations at both sites, any module can be used. For single axis trackers at Haines Junction, only the three highest efficiency panels – Sunpower, Panasonic, and Prism – will fit in the available space. Heliene and Prism solar panels again have the lowest LCOE.

For 10 MW installations, only the Whitehorse site has adequate space available. For fixed tilt racking installations, any modules can be used. For single axis tracking, only the three most efficient panels (Sunpower, Panasonic, and Prism Solar) will fit.

Racking and Inverter Recommendations

In general, we recommend the use of single axis trackers due to the large increase in energy collected (22% to 25%), even through they cost more to install and maintain. The gains out-weigh the costs.

The difference between central inverters and string inverters was found to have no significant effect on the energy generation. The cost between the two options is also very comparable. String inverters are recommended as maintenance and replacement could be done by local workers as opposed to waiting for servicing of central inverters by the manufacturer, however this should be weighed against the weather-resistance of the inverter choice, and the price and service contracts that can be negotiated with the suppliers.

Financial Summary

The LCOE for the 1MW systems ranged from \$0.16 to \$0.20/kWh.

The LCOE for the 5MW systems is quite attractive, ranging from \$0.14 to \$0.18 on average.

For the 10MW system, additional battery storage is needing for smoothing in case of power fluctuations, since the 10MW system will have a greater penetration of the electricity grid. For the 10MW system along with battery storage, the LCOE is about \$0.21/kWh. When the energy storage is taken out of the equation, the LCOE for a 10 MW solar plant becomes on average \$0.16/kWh to \$0.17/kWh.

Potential Show Stoppers

There are a several things to keep in mind when planning this project that could be potential show-stoppers:

1. YESAB assessment has an issue with the perceived environmental impact (mostly pertains to Haines Junction).
2. Archeological site is discovered during pre-construction (Only applies to Haines junction as the quarry is all old mine tailings that have been processed).
3. General Public does not want development at either location.
4. Mineral rights dispute (Whitehorse location only)
5. Rare/Endangered species discovered living on location (Haines Junction only).
6. Sudden collapse in the Canadian Dollar as all major components are provided by US based suppliers.
7. Aboriginal groups objecting/opposing the project.

Appendix A – Monthly Profile Data

Tables of monthly energy generation data for the PV array configurations looked at in this report.

1 MW Haines Junction Monthly Generation Data

January						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	23600	21800	12.21	11.29
Canadian Solar - Mono	Single Axis	Schneider - Central	29165	27295	13.72	12.84
Canadian Solar - Poly	Single Axis	Schneider - Central	28505	26728	13.41	12.57
Canadian Solar - Poly	Fixed	Schneider - Central	24400	21000	11.92	10.26
Canadian Solar - Mono	Dual Axis	Schneider - Central	33180	31270	13.08	12.33
Heliene - Poly	Fixed	Schneider - Central	30079	28219	13.43	12.6
Heliene - Poly	Single Axis	Schneider - Central	30100	28200	13.43	12.6
Heliene - Poly	Single Axis	SMA - String	20395	19153	8.93	8.38
Prism - Bi-facial	Fixed	Schneider - Central	24467	22638	14.94	13.82
Prism - Bi-facial	Single Axis	Schneider - Central	29522	27632	16.36	15.31
Prism - Bi-facial	Fixed	SMA - String	24035	22721	14.97	14.15
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	22925	19225	13.83	11.6
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	27186	25269	14.89	13.84
SunPower - Mono	Fixed	Schneider - Central	24125	22458	14.79	13.77
SunPower - Mono	Fixed	SMA - String	23595	22321	14.7	13.9
SunPower - Mono	Single Axis	Schneider - Central	21390	19807	11.9	11.02

February						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	67300	64600	13.57	13.03
Canadian Solar - Mono	Single Axis	Schneider - Central	81173	78182	13.96	13.44
Canadian Solar - Poly	Single Axis	Schneider - Central	78778	75983	13.54	13.06
Canadian Solar - Poly	Fixed	Schneider - Central	69500	66700	13.18	12.65
Canadian Solar - Mono	Dual Axis	Schneider - Central	90944	87664	13.85	13.35
Heliene - Poly	Fixed	Schneider - Central	83302	80311	13.59	13.11
Heliene - Poly	Single Axis	Schneider - Central	83300	80300	13.59	13.11
Heliene - Poly	Single Axis	SMA - String	76838	74475	12.39	12.01
Prism - Bi-facial	Fixed	Schneider - Central	69407	66614	16.47	15.81
Prism - Bi-facial	Single Axis	Schneider - Central	83067	79957	16.82	16.19
Prism - Bi-facial	Fixed	SMA - String	68070	65800	16.49	15.94
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	66239	63377	15.54	14.87
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	79246	76083	15.86	15.23

SunPower - Mono	Fixed	Schneider - Central	68418	65952	16.31	15.72
SunPower - Mono	Fixed	SMA - String	67391	65212	16.32	15.79
SunPower - Mono	Single Axis	Schneider - Central	74086	71520	15.24	14.71

March						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	111882	107818	13.21	12.73
Canadian Solar - Mono	Single Axis	Schneider - Central	144018	139140	13.65	13.19
Canadian Solar - Poly	Single Axis	Schneider - Central	137853	133351	13.17	12.74
Canadian Solar - Poly	Fixed	Schneider - Central	115100	110900	12.79	12.32
Canadian Solar - Mono	Dual Axis	Schneider - Central	147889	142846	13.65	13.19
Heliene - Poly	Fixed	Schneider - Central	146490	141603	13.28	12.84
Heliene - Poly	Single Axis	Schneider - Central	146500	141600	13.28	12.84
Heliene - Poly	Single Axis	SMA - String	141234	137197	12.84	12.47
Prism - Bi-facial	Fixed	Schneider - Central	115703	97565	16.09	13.57
Prism - Bi-facial	Single Axis	Schneider - Central	147102	141997	16.44	15.87
Prism - Bi-facial	Fixed	SMA - String	113476	96283	16.1	13.66
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	110857	106453	15.23	14.63
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	140499	135322	15.64	15.06
SunPower - Mono	Fixed	Schneider - Central	113528	109760	15.86	15.33
SunPower - Mono	Fixed	SMA - String	111831	108453	15.87	15.39
SunPower - Mono	Single Axis	Schneider - Central	135291	131006	15.76	15.26

April						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	175200	134500	15.87	12.89
Canadian Solar - Mono	Single Axis	Schneider - Central	233011	224995	16.36	15.8
Canadian Solar - Poly	Single Axis	Schneider - Central	218385	211394	15.49	14.99
Canadian Solar - Poly	Fixed	Schneider - Central	177700	171500	15.15	14.62
Canadian Solar - Mono	Dual Axis	Schneider - Central	214853	207195	16.4	15.82
Heliene - Poly	Fixed	Schneider - Central	232784	225047	15.67	15.15
Heliene - Poly	Single Axis	Schneider - Central	232800	225000	15.67	15.15
Heliene - Poly	Single Axis	SMA - String	221060	214698	15.16	14.72
Prism - Bi-facial	Fixed	Schneider - Central	178514	172208	19.05	18.37
Prism - Bi-facial	Single Axis	Schneider - Central	233367	225319	19.33	18.66
Prism - Bi-facial	Fixed	SMA - String	171739	166418	18.7	18.12
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	175148	154632	18.47	16.3

Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	228804	220329	18.92	18.22
SunPower - Mono	Fixed	Schneider - Central	176929	171293	18.96	18.36
SunPower - Mono	Fixed	SMA - String	170288	165207	18.54	17.99
SunPower - Mono	Single Axis	Schneider - Central	214139	207359	18.82	18.22

May						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	165900	159900	15.63	15.06
Canadian Solar - Mono	Single Axis	Schneider - Central	212334	204892	16	15.44
Canadian Solar - Poly	Single Axis	Schneider - Central	199706	193116	15.21	14.71
Canadian Solar - Poly	Fixed	Schneider - Central	169400	163300	15.01	14.47
Canadian Solar - Mono	Dual Axis	Schneider - Central	197190	190295	15.96	15.41
Heliene - Poly	Fixed	Schneider - Central	212689	205505	15.38	14.86
Heliene - Poly	Single Axis	Schneider - Central	212700	205500	15.38	14.86
Heliene - Poly	Single Axis	SMA - String	205663	199992	15.07	14.65
Prism - Bi-facial	Fixed	Schneider - Central	170480	164234	18.91	18.22
Prism - Bi-facial	Single Axis	Schneider - Central	214570	207016	19.08	18.41
Prism - Bi-facial	Fixed	SMA - String	165946	160970	18.78	18.22
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	167637	160947	18.38	17.64
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	210529	202442	18.69	17.97
SunPower - Mono	Fixed	Schneider - Central	168735	145745	18.8	16.24
SunPower - Mono	Fixed	SMA - String	164491	142893	18.62	16.17
SunPower - Mono	Single Axis	Schneider - Central	199136	192684	18.71	18.1

June						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	147300	141700	15.17	14.59
Canadian Solar - Mono	Single Axis	Schneider - Central	186042	179288	15.54	14.98
Canadian Solar - Poly	Single Axis	Schneider - Central	175519	169475	14.83	14.32
Canadian Solar - Poly	Fixed	Schneider - Central	151000	145300	14.63	14.08
Canadian Solar - Mono	Dual Axis	Schneider - Central	181718	175540	15.58	15.05
Heliene - Poly	Fixed	Schneider - Central	186890	164880	14.99	13.23
Heliene - Poly	Single Axis	Schneider - Central	186900	164900	14.99	13.23
Heliene - Poly	Single Axis	SMA - String	180720	160718	14.63	13.01
Prism - Bi-facial	Fixed	Schneider - Central	152270	146422	18.47	17.76
Prism - Bi-facial	Single Axis	Schneider - Central	188933	182052	18.62	17.95
Prism - Bi-facial	Fixed	SMA - String	148644	144250	18.4	17.86
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	150090	143779	17.99	17.24

Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	185813	178368	18.3	17.57
SunPower - Mono	Fixed	Schneider - Central	150548	145300	18.34	17.7
SunPower - Mono	Fixed	SMA - String	147321	143145	18.24	17.72
SunPower - Mono	Single Axis	Schneider - Central	175468	169531	18.21	17.6

July						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	142400	137000	15.06	14.48
Canadian Solar - Mono	Single Axis	Schneider - Central	181194	174621	15.44	14.88
Canadian Solar - Poly	Single Axis	Schneider - Central	170977	165099	14.74	14.23
Canadian Solar - Poly	Fixed	Schneider - Central	146100	140600	14.53	13.98
Canadian Solar - Mono	Dual Axis	Schneider - Central	175960	169907	15.45	14.91
Heliene - Poly	Fixed	Schneider - Central	182004	153223	14.9	12.54
Heliene - Poly	Single Axis	Schneider - Central	182000	153200	14.9	12.54
Heliene - Poly	Single Axis	SMA - String	175395	148739	14.52	12.32
Prism - Bi-facial	Fixed	Schneider - Central	147426	141738	18.35	17.65
Prism - Bi-facial	Single Axis	Schneider - Central	184185	177480	18.52	17.84
Prism - Bi-facial	Fixed	SMA - String	144407	140129	18.35	17.8
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	145489	139343	17.9	17.14
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	181302	174051	18.22	17.49
SunPower - Mono	Fixed	Schneider - Central	145727	140608	18.22	17.58
SunPower - Mono	Fixed	SMA - String	143224	139152	18.19	17.68
SunPower - Mono	Single Axis	Schneider - Central	170471	164704	18.1	17.49

August						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	137500	132500	15.3	14.73
Canadian Solar - Mono	Single Axis	Schneider - Central	175196	169052	15.66	15.11
Canadian Solar - Poly	Single Axis	Schneider - Central	165627	160121	14.94	14.45
Canadian Solar - Poly	Fixed	Schneider - Central	140800	135700	14.74	14.2
Canadian Solar - Mono	Dual Axis	Schneider - Central	163044	157098	15.64	15.07
Heliene - Poly	Fixed	Schneider - Central	176259	170298	15.1	14.59
Heliene - Poly	Single Axis	Schneider - Central	176300	170300	15.1	14.59
Heliene - Poly	Single Axis	SMA - String	170277	165629	14.78	14.38
Prism - Bi-facial	Fixed	Schneider - Central	141946	123129	18.59	16.13
Prism - Bi-facial	Single Axis	Schneider - Central	177988	171705	18.77	18.1
Prism - Bi-facial	Fixed	SMA - String	138556	121075	18.52	16.18
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	140103	134418	18.14	17.4

Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	175317	168548	18.45	17.74
SunPower - Mono	Fixed	Schneider - Central	140407	118766	18.47	15.63
SunPower - Mono	Fixed	SMA - String	137371	116957	18.36	15.63
SunPower - Mono	Single Axis	Schneider - Central	165309	159892	18.38	17.78

September						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	98300	89400	15.68	14.26
Canadian Solar - Mono	Single Axis	Schneider - Central	124704	120138	16.06	15.47
Canadian Solar - Poly	Single Axis	Schneider - Central	118838	114694	15.4	14.86
Canadian Solar - Poly	Fixed	Schneider - Central	101100	97200	15.17	14.58
Canadian Solar - Mono	Dual Axis	Schneider - Central	122471	117940	16.01	15.42
Heliene - Poly	Fixed	Schneider - Central	126454	121960	15.55	15
Heliene - Poly	Single Axis	Schneider - Central	126500	122000	15.55	15
Heliene - Poly	Single Axis	SMA - String	122390	118839	15.25	14.81
Prism - Bi-facial	Fixed	Schneider - Central	101924	97899	19.14	18.38
Prism - Bi-facial	Single Axis	Schneider - Central	127391	122665	19.34	18.62
Prism - Bi-facial	Fixed	SMA - String	99596	96429	19.08	18.47
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	99476	75501	18.46	14.01
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	124355	119345	18.79	18.03
SunPower - Mono	Fixed	Schneider - Central	100442	88791	18.94	16.74
SunPower - Mono	Fixed	SMA - String	98448	87420	18.86	16.75
SunPower - Mono	Single Axis	Schneider - Central	118410	114338	18.88	18.23

October						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	76200	73000	16.04	15.37
Canadian Solar - Mono	Single Axis	Schneider - Central	92411	88800	16.46	15.82
Canadian Solar - Poly	Single Axis	Schneider - Central	89004	85650	15.88	15.28
Canadian Solar - Poly	Fixed	Schneider - Central	78500	68300	15.54	13.53
Canadian Solar - Mono	Dual Axis	Schneider - Central	97781	93964	16.43	15.79
Heliene - Poly	Fixed	Schneider - Central	94662	91049	16.03	15.42
Heliene - Poly	Single Axis	Schneider - Central	94700	91000	16.03	15.42
Heliene - Poly	Single Axis	SMA - String	88364	85551	14.79	14.32
Prism - Bi-facial	Fixed	Schneider - Central	79071	67920	19.61	16.84
Prism - Bi-facial	Single Axis	Schneider - Central	94568	90817	19.84	19.05
Prism - Bi-facial	Fixed	SMA - String	77520	67197	19.61	17
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	76358	72863	18.71	17.86

Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	91250	87368	18.96	18.16
SunPower - Mono	Fixed	Schneider - Central	77652	74662	19.34	18.6
SunPower - Mono	Fixed	SMA - String	76451	73913	19.34	18.7
SunPower - Mono	Single Axis	Schneider - Central	86052	82855	18.38	17.7

November						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	29800	27700	12.73	11.87
Canadian Solar - Mono	Single Axis	Schneider - Central	36055	33896	13.81	12.99
Canadian Solar - Poly	Single Axis	Schneider - Central	35182	33128	13.48	12.69
Canadian Solar - Poly	Fixed	Schneider - Central	31000	28900	12.47	11.64
Canadian Solar - Mono	Dual Axis	Schneider - Central	39559	37389	12.86	12.16
Heliene - Poly	Fixed	Schneider - Central	37294	35128	13.56	12.77
Heliene - Poly	Single Axis	Schneider - Central	37300	35100	13.56	12.77
Heliene - Poly	Single Axis	SMA - String	26952	25586	9.61	9.12
Prism - Bi-facial	Fixed	Schneider - Central	31142	29059	15.69	14.64
Prism - Bi-facial	Single Axis	Schneider - Central	34754	32594	15.68	14.71
Prism - Bi-facial	Fixed	SMA - String	30479	29005	15.67	14.91
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	29153	27063	14.51	13.47
Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	32613	30448	14.54	13.58
SunPower - Mono	Fixed	Schneider - Central	30382	28491	15.37	14.42
SunPower - Mono	Fixed	SMA - String	14008	12960	10.94	10.12
SunPower - Mono	Single Axis	Schneider - Central	27533	25746	12.49	11.68

December						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	14100	12700	9.19	8.28
Canadian Solar - Mono	Single Axis	Schneider - Central	22130	20564	13.68	12.71
Canadian Solar - Poly	Single Axis	Schneider - Central	21644	20162	13.37	12.46
Canadian Solar - Poly	Fixed	Schneider - Central	14700	13200	8.96	8.09
Canadian Solar - Mono	Dual Axis	Schneider - Central	23584	22082	11.6	10.86
Heliene - Poly	Fixed	Schneider - Central	22826	19525	13.39	11.45
Heliene - Poly	Single Axis	Schneider - Central	22800	19500	13.39	11.45
Heliene - Poly	Single Axis	SMA - String	10929	8986	6.29	5.17
Prism - Bi-facial	Fixed	Schneider - Central	14733	13314	11.27	10.19
Prism - Bi-facial	Single Axis	Schneider - Central	22057	20499	16.06	14.92
Prism - Bi-facial	Fixed	SMA - String	14490	13411	11.32	10.47
Panasonic HIT - Bi-facial	Fixed	Schneider - Central	13902	12479	10.51	9.44

Panasonic HIT - Bi-facial	Single Axis	Schneider - Central	19369	17870	13.93	12.86
SunPower - Mono	Fixed	Schneider - Central	14135	12809	10.87	9.85
SunPower - Mono	Fixed	SMA - String	27533	25746	12.49	11.68
SunPower - Mono	Single Axis	Schneider - Central	14054	12745	10.28	9.32

5 MW Haines Junction Monthly Generation Data

January						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (KWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	78667	60715	8.16	6.29
Canadian Solar - Mono	Single Axis	Schneider - Central	95462	87211	8.98	8.21
Canadian Solar - Poly	Single Axis	Schneider - Central	82894	74380	8.09	7.26
Canadian Solar - Poly	Fixed	Schneider - Central	82900	74400	8.09	7.26
Heliene - Poly	Fixed	Schneider - Central	82454	73837	7.95	7.12
Heliene - Poly	Single Axis	Schneider - Central	94189	86871	9.34	8.62
Prism - Bi-facial	Fixed	Schneider - Central	119504	110128	14.89	13.72
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	73104	59159	8.82	7.14
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	107563	98871	9.59	8.81
SunPower - Mono	Fixed	Schneider - Central	77872	70037	9.55	8.59
SunPower - Mono	Single Axis	Schneider - Central	99912	92039	11.12	10.24

February						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	320528	278942	12.92	11.24
Canadian Solar - Mono	Single Axis	Schneider - Central	357325	343884	12.29	11.83
Canadian Solar - Poly	Single Axis	Schneider - Central	331112	317573	12.56	12.04
Canadian Solar - Poly	Fixed	Schneider - Central	331100	317600	12.56	12.04
Heliene - Poly	Fixed	Schneider - Central	335589	321656	12.59	12.06
Heliene - Poly	Single Axis	Schneider - Central	340566	328157	12.45	12
Prism - Bi-facial	Fixed	Schneider - Central	338818	324454	16.41	15.72
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	308831	295125	14.49	13.85
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	367892	353805	12.03	11.56
SunPower - Mono	Fixed	Schneider - Central	319225	307419	15.22	14.66
SunPower - Mono	Single Axis	Schneider - Central	364921	352216	15.01	14.49

March						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	547974	527963	12.94	12.47
Canadian Solar - Mono	Single Axis	Schneider - Central	681631	658272	13.1	12.65
Canadian Solar - Poly	Single Axis	Schneider - Central	564217	475495	12.54	10.56
Canadian Solar - Poly	Fixed	Schneider - Central	564200	475500	12.54	10.56
Heliene - Poly	Fixed	Schneider - Central	575339	553590	12.64	12.16
Heliene - Poly	Single Axis	Schneider - Central	623005	601944	12.84	12.4
Prism - Bi-facial	Fixed	Schneider - Central	563384	473974	15.99	13.45
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	541965	520272	14.9	14.3
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	672452	649111	12.35	11.92
SunPower - Mono	Fixed	Schneider - Central	556174	537629	15.54	15.02
SunPower - Mono	Single Axis	Schneider - Central	675673	654262	15.75	15.25

April						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	858399	828458	15.55	15.01
Canadian Solar - Mono	Single Axis	Schneider - Central	1096843	1059085	15.76	15.22
Canadian Solar - Poly	Single Axis	Schneider - Central	871671	841355	14.86	14.34
Canadian Solar - Poly	Fixed	Schneider - Central	871700	841400	14.86	14.34
Heliene - Poly	Fixed	Schneider - Central	890822	787160	15.02	13.27
Heliene - Poly	Single Axis	Schneider - Central	977209	944542	15.19	14.68
Prism - Bi-facial	Fixed	Schneider - Central	869528	837386	18.93	18.23
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	856889	756385	18.07	15.95
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	1062821	1026356	14.66	14.16
SunPower - Mono	Fixed	Schneider - Central	867310	839658	18.59	18
SunPower - Mono	Single Axis	Schneider - Central	1069584	1035721	18.8	18.2

May						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	818051	788170	15.41	14.85
Canadian Solar - Mono	Single Axis	Schneider - Central	1013639	977691	15.59	15.03
Canadian Solar - Poly	Single Axis	Schneider - Central	835479	805176	14.81	14.27

Canadian Solar - Poly	Fixed	Schneider - Central	835500	805200	14.81	14.27
Heliene - Poly	Fixed	Schneider - Central	853367	747844	14.96	13.11
Heliene - Poly	Single Axis	Schneider - Central	907500	876479	15.07	14.55
Prism - Bi-facial	Fixed	Schneider - Central	832360	800264	18.84	18.12
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	825032	791915	18.09	17.36
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	990553	955319	14.59	14.08
SunPower - Mono	Fixed	Schneider - Central	831739	717949	18.54	16
SunPower - Mono	Single Axis	Schneider - Central	995067	962819	18.7	18.09

June						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	724882	617534	14.93	12.72
Canadian Solar - Mono	Single Axis	Schneider - Central	885184	852451	15.09	14.53
Canadian Solar - Poly	Single Axis	Schneider - Central	743364	714982	14.41	13.86
Canadian Solar - Poly	Fixed	Schneider - Central	743400	715000	14.41	13.86
Heliene - Poly	Fixed	Schneider - Central	759115	729636	14.55	13.99
Heliene - Poly	Single Axis	Schneider - Central	798152	703676	14.65	12.91
Prism - Bi-facial	Fixed	Schneider - Central	743116	712968	18.4	17.65
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	737138	705877	17.67	16.92
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	872809	840305	14.24	13.71
SunPower - Mono	Fixed	Schneider - Central	740732	714668	18.05	17.42
SunPower - Mono	Single Axis	Schneider - Central	876725	847050	18.2	17.58

July						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	701017	673750	14.82	14.25
Canadian Solar - Mono	Single Axis	Schneider - Central	858930	827221	14.99	14.44
Canadian Solar - Poly	Single Axis	Schneider - Central	719546	691919	14.31	13.76
Canadian Solar - Poly	Fixed	Schneider - Central	719500	691900	14.31	13.76
Heliene - Poly	Fixed	Schneider - Central	734623	705921	14.45	13.89
Heliene - Poly	Single Axis	Schneider - Central	775440	651972	14.55	12.24
Prism - Bi-facial	Fixed	Schneider - Central	719494	690175	18.28	17.54
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	714574	684077	17.58	16.83
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	848615	817057	14.18	13.65
SunPower - Mono	Fixed	Schneider - Central	717062	691579	17.93	17.3
SunPower - Mono	Single Axis	Schneider - Central	851740	822915	18.09	17.48

August						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	678321	653086	15.09	14.53
Canadian Solar - Mono	Single Axis	Schneider - Central	835005	805212	15.27	14.72
Canadian Solar - Poly	Single Axis	Schneider - Central	694927	602926	14.54	12.62
Canadian Solar - Poly	Fixed	Schneider - Central	694900	602900	14.54	12.62
Heliene - Poly	Fixed	Schneider - Central	709415	682725	14.68	14.13
Heliene - Poly	Single Axis	Schneider - Central	751802	725936	14.79	14.28
Prism - Bi-facial	Fixed	Schneider - Central	693133	599974	18.53	16.04
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	689777	661570	17.86	17.13
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	822709	793132	14.39	13.87
SunPower - Mono	Fixed	Schneider - Central	692371	585114	18.22	15.4
SunPower - Mono	Single Axis	Schneider - Central	826022	798950	18.37	17.77

September						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	485385	466290	15.48	14.87
Canadian Solar - Mono	Single Axis	Schneider - Central	597402	575109	15.68	15.1
Canadian Solar - Poly	Single Axis	Schneider - Central	499326	479724	14.98	14.39
Canadian Solar - Poly	Fixed	Schneider - Central	499300	479700	14.98	14.39
Heliene - Poly	Fixed	Schneider - Central	509792	489391	15.12	14.52
Heliene - Poly	Single Axis	Schneider - Central	539938	520335	15.25	14.7
Prism - Bi-facial	Fixed	Schneider - Central	497835	477051	19.07	18.28
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	490198	371152	18.19	13.77
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	586853	564743	14.76	14.2
SunPower - Mono	Fixed	Schneider - Central	495700	438036	18.7	16.52
SunPower - Mono	Single Axis	Schneider - Central	591681	571329	18.86	18.22

October						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**

Canadian Solar - Mono	Fixed	Schneider - Central	368027	352228	15.5	14.83
Canadian Solar - Mono	Single Axis	Schneider - Central	421575	404552	15.11	14.5
Canadian Solar - Poly	Single Axis	Schneider - Central	379287	324994	15.03	12.88
Canadian Solar - Poly	Fixed	Schneider - Central	379300	325000	15.03	12.88
Heliene - Poly	Fixed	Schneider - Central	387048	370131	15.16	14.5
Heliene - Poly	Single Axis	Schneider - Central	394107	378715	14.96	14.37
Prism - Bi-facial	Fixed	Schneider - Central	385853	330565	19.53	16.73
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	366671	349523	17.97	17.13
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	427828	410487	14.56	13.97
SunPower - Mono	Fixed	Schneider - Central	373600	358875	18.61	17.88
SunPower - Mono	Single Axis	Schneider - Central	428255	412314	18.29	17.61

November						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	105488	96297	9.03	8.24
Canadian Solar - Mono	Single Axis	Schneider - Central	121945	112891	9.34	8.65
Canadian Solar - Poly	Single Axis	Schneider - Central	111118	101713	8.94	8.19
Canadian Solar - Poly	Fixed	Schneider - Central	111100	101700	8.94	8.19
Heliene - Poly	Fixed	Schneider - Central	111315	97272	8.86	7.74
Heliene - Poly	Single Axis	Schneider - Central	121470	113125	9.82	9.14
Prism - Bi-facial	Fixed	Schneider - Central	152432	141832	15.67	14.58
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	98294	88786	9.79	8.84
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	139866	130196	10.15	9.45
SunPower - Mono	Fixed	Schneider - Central	103318	94638	10.46	9.58
SunPower - Mono	Single Axis	Schneider - Central	128733	119935	11.68	10.88

December						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	48005	41444	6.24	5.39
Canadian Solar - Mono	Single Axis	Schneider - Central	52858	46058	6.53	5.69
Canadian Solar - Poly	Single Axis	Schneider - Central	51889	45246	6.35	5.53
Canadian Solar - Poly	Fixed	Schneider - Central	51900	45200	6.35	5.53
Heliene - Poly	Fixed	Schneider - Central	50961	44206	6.16	5.35
Heliene - Poly	Single Axis	Schneider - Central	48787	39375	6.36	5.13
Prism - Bi-facial	Fixed	Schneider - Central	68379	61369	10.68	9.58
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	41167	34915	6.23	5.28

Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	63529	56680	7.44	6.64
SunPower - Mono	Fixed	Schneider - Central	39586	33362	6.09	5.13
SunPower - Mono	Single Axis	Schneider - Central	60305	53891	8.82	7.88

1 MW Whitehorse Monthly Generation Data

January						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (KWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	21113	16286	10.15	7.83
Canadian Solar - Mono	Single Axis	Schneider - Central	22097	20373	9.32	8.59
Canadian Solar - Poly	Single Axis	Schneider - Central	18624	16881	8.09	7.33
Canadian Solar - Poly	Fixed	Schneider - Central	22946	21278	9.67	8.97
Heliene - Poly	Fixed	Schneider - Central	18528	16758	7.95	7.2
Heliene - Poly	Single Axis	Schneider - Central	23753	22034	9.5	8.82
Prism - Bi-facial	Fixed	Schneider - Central	27955	26026	15.19	14.14
Prism - Bi-facial	Single Axis	Schneider - Central	32438	30426	16.11	15.11
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	21563	18312	11.05	9.39
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	20492	18727	10.06	9.19
SunPower - Mono	Fixed	Schneider - Central	21663	19992	11.83	10.91
SunPower - Mono	Single Axis	Schneider - Central	24927	23233	12.43	11.59

February						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	65365	58048	13.28	11.8
Canadian Solar - Mono	Single Axis	Schneider - Central	75513	72685	12.6	12.13
Canadian Solar - Poly	Single Axis	Schneider - Central	68277	65491	12.53	12.02
Canadian Solar - Poly	Fixed	Schneider - Central	73887	71189	12.37	11.92
Heliene - Poly	Fixed	Schneider - Central	68974	66117	12.52	12
Heliene - Poly	Single Axis	Schneider - Central	77869	75001	12.38	11.92
Prism - Bi-facial	Fixed	Schneider - Central	71998	69104	16.54	15.88
Prism - Bi-facial	Single Axis	Schneider - Central	86161	82917	16.91	16.28
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	69752	66754	15.12	14.47
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	70954	68015	13.85	13.27
SunPower - Mono	Fixed	Schneider - Central	67673	65196	15.62	15.04
SunPower - Mono	Single Axis	Schneider - Central	76627	73952	15.23	14.69

March						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**

Canadian Solar - Mono	Fixed	Schneider - Central	107786	104114	13.18	12.73
Canadian Solar - Mono	Single Axis	Schneider - Central	138963	134127	13.33	12.87
Canadian Solar - Poly	Single Axis	Schneider - Central	114999	100425	12.7	11.09
Canadian Solar - Poly	Fixed	Schneider - Central	132124	127676	12.87	12.43
Heliene - Poly	Fixed	Schneider - Central	117553	113071	12.84	12.35
Heliene - Poly	Single Axis	Schneider - Central	140360	135547	12.98	12.53
Prism - Bi-facial	Fixed	Schneider - Central	117117	102253	16.19	14.13
Prism - Bi-facial	Single Axis	Schneider - Central	148610	143394	16.54	15.96
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	116607	111965	15.2	14.6
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	134318	129231	15.25	14.68
SunPower - Mono	Fixed	Schneider - Central	111880	108090	15.53	15.01
SunPower - Mono	Single Axis	Schneider - Central	137531	133109	15.94	15.42

April						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	166971	161639	15.86	15.35
Canadian Solar - Mono	Single Axis	Schneider - Central	222253	214571	16.09	15.53
Canadian Solar - Poly	Single Axis	Schneider - Central	175955	169835	15.1	14.57
Canadian Solar - Poly	Fixed	Schneider - Central	204867	198248	15.23	14.74
Heliene - Poly	Fixed	Schneider - Central	180470	157991	15.31	13.41
Heliene - Poly	Single Axis	Schneider - Central	218338	211027	15.41	14.9
Prism - Bi-facial	Fixed	Schneider - Central	178906	172579	19.21	18.53
Prism - Bi-facial	Single Axis	Schneider - Central	233270	225200	19.51	18.84
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	182427	164462	18.48	16.66
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	214328	206315	18.61	17.91
SunPower - Mono	Fixed	Schneider - Central	172545	167055	18.61	18.02
SunPower - Mono	Single Axis	Schneider - Central	215233	208408	19.09	18.49

May						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	159212	153866	15.48	14.96
Canadian Solar - Mono	Single Axis	Schneider - Central	207284	199952	15.67	15.12
Canadian Solar - Poly	Single Axis	Schneider - Central	168722	162652	14.81	14.28
Canadian Solar - Poly	Fixed	Schneider - Central	192595	186170	14.93	14.43
Heliene - Poly	Fixed	Schneider - Central	172885	154315	15.01	13.4
Heliene - Poly	Single Axis	Schneider - Central	205098	198115	15.09	14.58
Prism - Bi-facial	Fixed	Schneider - Central	171820	165568	18.88	18.19
Prism - Bi-facial	Single Axis	Schneider - Central	218429	210754	19.12	18.45

Panisonic HIT - Bi-facial	Fixed	Schneider - Central	175781	168874	18.22	17.51
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	202315	194464	18.31	17.6
SunPower - Mono	Fixed	Schneider - Central	165550	145793	18.27	16.09
SunPower - Mono	Single Axis	Schneider - Central	202283	195749	18.72	18.12

June						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	140998	124771	15.01	13.28
Canadian Solar - Mono	Single Axis	Schneider - Central	178886	172174	15.17	14.6
Canadian Solar - Poly	Single Axis	Schneider - Central	149683	143936	14.39	13.84
Canadian Solar - Poly	Fixed	Schneider - Central	167483	161531	14.49	13.97
Heliene - Poly	Fixed	Schneider - Central	153379	147385	14.58	14.01
Heliene - Poly	Single Axis	Schneider - Central	178370	158772	14.65	13.04
Prism - Bi-facial	Fixed	Schneider - Central	152942	147030	18.41	17.69
Prism - Bi-facial	Single Axis	Schneider - Central	189689	182685	18.63	17.94
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	157036	150450	17.83	17.08
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	176966	169650	17.88	17.14
SunPower - Mono	Fixed	Schneider - Central	147296	142058	17.8	17.17
SunPower - Mono	Single Axis	Schneider - Central	176441	170394	18.21	17.59

July						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	137128	132299	14.91	14.38
Canadian Solar - Mono	Single Axis	Schneider - Central	175383	169123	15.07	14.53
Canadian Solar - Poly	Single Axis	Schneider - Central	146323	140891	14.37	13.83
Canadian Solar - Poly	Fixed	Schneider - Central	164940	159321	14.49	13.99
Heliene - Poly	Fixed	Schneider - Central	149710	144054	14.54	13.99
Heliene - Poly	Single Axis	Schneider - Central	175406	157067	14.63	13.1
Prism - Bi-facial	Fixed	Schneider - Central	149686	144086	18.4	17.71
Prism - Bi-facial	Single Axis	Schneider - Central	187452	180832	18.65	17.99
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	153269	147066	17.77	17.05
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	173675	166816	17.81	17.11
SunPower - Mono	Fixed	Schneider - Central	143690	138743	17.74	17.13
SunPower - Mono	Single Axis	Schneider - Central	173159	167477	18.15	17.55

August						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**

Canadian Solar - Mono	Fixed	Schneider - Central	126702	122374	15.09	14.58
Canadian Solar - Mono	Single Axis	Schneider - Central	163584	157819	15.28	14.74
Canadian Solar - Poly	Single Axis	Schneider - Central	134955	118615	14.52	12.76
Canadian Solar - Poly	Fixed	Schneider - Central	152900	147791	14.64	14.15
Heliene - Poly	Fixed	Schneider - Central	138152	133012	14.7	14.15
Heliene - Poly	Single Axis	Schneider - Central	162677	157146	14.79	14.28
Prism - Bi-facial	Fixed	Schneider - Central	137776	120993	18.55	16.29
Prism - Bi-facial	Single Axis	Schneider - Central	174014	167923	18.81	18.15
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	141162	135525	17.93	17.22
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	161024	154734	18	17.3
SunPower - Mono	Fixed	Schneider - Central	132468	114336	17.92	15.47
SunPower - Mono	Single Axis	Schneider - Central	160605	155409	18.35	17.75

September						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	92266	88844	15.56	14.99
Canadian Solar - Mono	Single Axis	Schneider - Central	116560	112156	15.73	15.13
Canadian Solar - Poly	Single Axis	Schneider - Central	98517	94612	15.01	14.41
Canadian Solar - Poly	Fixed	Schneider - Central	110171	106172	15.13	14.58
Heliene - Poly	Fixed	Schneider - Central	100839	96767	15.19	14.58
Heliene - Poly	Single Axis	Schneider - Central	117206	112882	15.28	14.72
Prism - Bi-facial	Fixed	Schneider - Central	100493	96475	19.16	18.4
Prism - Bi-facial	Single Axis	Schneider - Central	124140	119453	19.42	18.68
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	101876	83977	18.33	15.11
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	114677	109916	18.37	17.61
SunPower - Mono	Fixed	Schneider - Central	96368	87097	18.46	16.68
SunPower - Mono	Single Axis	Schneider - Central	115552	111507	18.88	18.22

October						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	68030	65304	15.87	15.24
Canadian Solar - Mono	Single Axis	Schneider - Central	82959	79668	15.59	14.97
Canadian Solar - Poly	Single Axis	Schneider - Central	72305	63913	15.24	13.47
Canadian Solar - Poly	Fixed	Schneider - Central	79882	76809	15.16	14.58
Heliene - Poly	Fixed	Schneider - Central	73916	70672	15.41	14.73
Heliene - Poly	Single Axis	Schneider - Central	84777	81490	15.27	14.68
Prism - Bi-facial	Fixed	Schneider - Central	74643	65987	19.69	17.41
Prism - Bi-facial	Single Axis	Schneider - Central	91454	87855	20.05	19.26

Panisonic HIT - Bi-facial	Fixed	Schneider - Central	74342	70924	18.5	17.65
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	80579	77039	17.83	17.05
SunPower - Mono	Fixed	Schneider - Central	71021	68218	18.82	18.08
SunPower - Mono	Single Axis	Schneider - Central	83344	80272	18.82	18.13

November						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	24196	22446	10.51	9.75
Canadian Solar - Mono	Single Axis	Schneider - Central	26271	24476	9.93	9.25
Canadian Solar - Poly	Single Axis	Schneider - Central	22409	20571	8.79	8.07
Canadian Solar - Poly	Fixed	Schneider - Central	26559	24800	10.03	9.37
Heliene - Poly	Fixed	Schneider - Central	22634	19675	8.78	7.63
Heliene - Poly	Single Axis	Schneider - Central	27947	26113	10.02	9.36
Prism - Bi-facial	Fixed	Schneider - Central	31752	29696	15.59	14.58
Prism - Bi-facial	Single Axis	Schneider - Central	36446	34296	16.22	15.26
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	25308	23320	11.72	10.8
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	23469	21638	10.32	9.52
SunPower - Mono	Fixed	Schneider - Central	24902	23141	12.28	11.41
SunPower - Mono	Single Axis	Schneider - Central	28389	26612	12.69	11.9

December						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	9857	8514	7.72	6.67
Canadian Solar - Mono	Single Axis	Schneider - Central	10592	9176	7.57	6.56
Canadian Solar - Poly	Single Axis	Schneider - Central	10169	8744	7.2	6.19
Canadian Solar - Poly	Fixed	Schneider - Central	10274	8951	7.34	6.4
Heliene - Poly	Fixed	Schneider - Central	10213	8769	7.15	6.14
Heliene - Poly	Single Axis	Schneider - Central	10549	9128	7.16	6.19
Prism - Bi-facial	Fixed	Schneider - Central	13617	12137	12.06	10.75
Prism - Bi-facial	Single Axis	Schneider - Central	19143	17533	16.11	14.76
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	10380	8891	8.67	7.43
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	10792	9393	8.98	7.81
SunPower - Mono	Fixed	Schneider - Central	10493	9137	9.34	8.13
SunPower - Mono	Single Axis	Schneider - Central	12664	11316	10.71	9.57

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January

Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (KWh)	Array Efficiency (%)	System Efficiency (%)
Canadian Solar - Mono	Fixed	Schneider - Central	89326	67291	8.24	6.21
Canadian Solar - Mono	Single Axis	Schneider - Central	108042	99359	9.11	8.38
Canadian Solar - Poly	Single Axis	Schneider - Central	95276	86385	8.27	7.5
Canadian Solar - Poly	Fixed	Schneider - Central	115658	107180	9.75	9.04
Heliene - Poly	Fixed	Schneider - Central	94033	85026	8.07	7.3
Heliene - Poly	Single Axis	Schneider - Central	105356	97603	9.37	8.68
Prism - Bi-facial	Fixed	Schneider - Central	136945	127044	15.19	14.09
Prism - Bi-facial	Single Axis	Schneider - Central	109685	100971	10.89	10.03
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	81737	66960	8.78	7.19
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	105356	97603	9.37	8.68
SunPower - Mono	Fixed	Schneider - Central	86933	78767	9.49	8.6
SunPower - Mono	Single Axis	Schneider - Central	116012	107651	11.57	10.74

February						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	329963	291256	12.87	11.36
Canadian Solar - Mono	Single Axis	Schneider - Central	371568	357550	12.4	11.94
Canadian Solar - Poly	Single Axis	Schneider - Central	342759	328701	12.58	12.07
Canadian Solar - Poly	Fixed	Schneider - Central	369163	355682	12.36	11.91
Heliene - Poly	Fixed	Schneider - Central	346700	332242	12.59	12.06
Heliene - Poly	Single Axis	Schneider - Central	348888	336017	12.32	11.87
Prism - Bi-facial	Fixed	Schneider - Central	351993	337050	16.5	15.8
Prism - Bi-facial	Single Axis	Schneider - Central	385860	371137	15.17	14.6
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	316544	302492	14.37	13.74
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	348888	336017	12.32	11.87
SunPower - Mono	Fixed	Schneider - Central	328224	315961	15.15	14.58
SunPower - Mono	Single Axis	Schneider - Central	377705	364458	15.01	14.48

March						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	561225	540483	12.97	12.49
Canadian Solar - Mono	Single Axis	Schneider - Central	690969	666944	13.26	12.8
Canadian Solar - Poly	Single Axis	Schneider - Central	578127	504890	12.57	10.98
Canadian Solar - Poly	Fixed	Schneider - Central	660565	638322	12.86	12.43
Heliene - Poly	Fixed	Schneider - Central	589189	566739	12.67	12.18
Heliene - Poly	Single Axis	Schneider - Central	631592	609931	12.98	12.53
Prism - Bi-facial	Fixed	Schneider - Central	575894	501821	15.99	13.93

Prism - Bi-facial	Single Axis	Schneider - Central	710086	684891	16.09	15.52
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	554799	532445	14.92	14.32
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	631592	609931	12.98	12.53
SunPower - Mono	Fixed	Schneider - Central	569239	550001	15.56	15.03
SunPower - Mono	Single Axis	Schneider - Central	687558	665449	15.93	15.42

April						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	872644	842172	15.59	15.04
Canadian Solar - Mono	Single Axis	Schneider - Central	1106558	1068307	16.02	15.47
Canadian Solar - Poly	Single Axis	Schneider - Central	886797	855947	14.9	14.38
Canadian Solar - Poly	Fixed	Schneider - Central	1024351	991254	15.23	14.74
Heliene - Poly	Fixed	Schneider - Central	905846	793043	15.05	13.18
Heliene - Poly	Single Axis	Schneider - Central	982447	949551	15.41	14.89
Prism - Bi-facial	Fixed	Schneider - Central	882613	849999	18.94	18.24
Prism - Bi-facial	Single Axis	Schneider - Central	1112688	1074009	19.06	18.39
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	870516	784779	18.1	16.31
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	982447	949551	15.41	14.89
SunPower - Mono	Fixed	Schneider - Central	881244	853111	18.62	18.03
SunPower - Mono	Single Axis	Schneider - Central	1076530	1042390	19.1	18.49

May						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	826980	796994	15.43	14.87
Canadian Solar - Mono	Single Axis	Schneider - Central	1032096	995547	15.61	15.05
Canadian Solar - Poly	Single Axis	Schneider - Central	845783	815343	14.85	14.32
Canadian Solar - Poly	Fixed	Schneider - Central	962932	930806	14.93	14.43
Heliene - Poly	Fixed	Schneider - Central	863407	770661	14.99	13.38
Heliene - Poly	Single Axis	Schneider - Central	922940	891510	15.09	14.58
Prism - Bi-facial	Fixed	Schneider - Central	841052	808866	18.86	18.14
Prism - Bi-facial	Single Axis	Schneider - Central	1047852	1010658	18.71	18.04
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	833675	800439	18.11	17.39
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	922940	891510	15.09	14.58
SunPower - Mono	Fixed	Schneider - Central	840691	740282	18.56	16.34
SunPower - Mono	Single Axis	Schneider - Central	1011878	979184	18.73	18.12

June

Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Canadian Solar - Mono	Fixed	Schneider - Central	731655	645949	14.95	13.2
Canadian Solar - Mono	Single Axis	Schneider - Central	890359	856872	15.1	14.53
Canadian Solar - Poly	Single Axis	Schneider - Central	750294	721482	14.43	13.87
Canadian Solar - Poly	Fixed	Schneider - Central	837411	807648	14.49	13.97
Heliene - Poly	Fixed	Schneider - Central	765898	735949	14.56	13.99
Heliene - Poly	Single Axis	Schneider - Central	802607	714415	14.65	13.04
Prism - Bi-facial	Fixed	Schneider - Central	748357	717837	18.38	17.63
Prism - Bi-facial	Single Axis	Schneider - Central	909054	874960	18.18	17.5
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	743949	712127	17.7	16.94
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	802607	714415	14.65	13.04
SunPower - Mono	Fixed	Schneider - Central	747124	720557	18.06	17.42
SunPower - Mono	Single Axis	Schneider - Central	882505	852251	18.22	17.59

July						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	710842	684167	14.84	14.28
Canadian Solar - Mono	Single Axis	Schneider - Central	872673	841459	15	14.46
Canadian Solar - Poly	Single Axis	Schneider - Central	733223	706001	14.4	13.87
Canadian Solar - Poly	Fixed	Schneider - Central	824680	796577	14.49	13.99
Heliene - Poly	Fixed	Schneider - Central	747564	719304	14.52	13.97
Heliene - Poly	Single Axis	Schneider - Central	789280	706753	14.62	13.1
Prism - Bi-facial	Fixed	Schneider - Central	732155	703226	18.37	17.64
Prism - Bi-facial	Single Axis	Schneider - Central	896841	864657	18.19	17.54
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	725479	695547	17.62	16.9
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	789280	706753	14.62	13.1
SunPower - Mono	Fixed	Schneider - Central	728081	703042	17.98	17.36
SunPower - Mono	Single Axis	Schneider - Central	865987	837568	18.15	17.56

August						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	657497	633397	15.04	14.49
Canadian Solar - Mono	Single Axis	Schneider - Central	814538	785784	15.22	14.68
Canadian Solar - Poly	Single Axis	Schneider - Central	676394	594521	14.55	12.79
Canadian Solar - Poly	Fixed	Schneider - Central	764493	738944	14.64	14.15
Heliene - Poly	Fixed	Schneider - Central	689950	664262	14.68	14.13

Heliene - Poly	Single Axis	Schneider - Central	732001	707107	14.79	14.28
Prism - Bi-facial	Fixed	Schneider - Central	674239	590891	18.53	16.24
Prism - Bi-facial	Single Axis	Schneider - Central	833008	803433	18.39	17.73
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	668901	641779	17.8	17.08
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	732001	707107	14.79	14.28
SunPower - Mono	Fixed	Schneider - Central	671979	580028	18.18	15.69
SunPower - Mono	Single Axis	Schneider - Central	803263	777269	18.35	17.76

September						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	478683	459673	15.5	14.89
Canadian Solar - Mono	Single Axis	Schneider - Central	580447	558489	15.66	15.07
Canadian Solar - Poly	Single Axis	Schneider - Central	493676	474107	15.04	14.45
Canadian Solar - Poly	Fixed	Schneider - Central	550874	530874	15.13	14.58
Heliene - Poly	Fixed	Schneider - Central	503663	483312	15.18	14.56
Heliene - Poly	Single Axis	Schneider - Central	527361	507900	15.28	14.71
Prism - Bi-facial	Fixed	Schneider - Central	491787	471034	19.14	18.33
Prism - Bi-facial	Single Axis	Schneider - Central	596125	573262	19	18.27
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	482706	397439	18.19	14.98
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	527361	507900	15.28	14.71
SunPower - Mono	Fixed	Schneider - Central	488817	441921	18.73	16.93
SunPower - Mono	Single Axis	Schneider - Central	577864	557635	18.89	18.22

October						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	351217	336112	15.5	14.84
Canadian Solar - Mono	Single Axis	Schneider - Central	411697	395271	15.47	14.86
Canadian Solar - Poly	Single Axis	Schneider - Central	363848	321664	15.11	13.36
Canadian Solar - Poly	Fixed	Schneider - Central	399393	384017	15.16	14.58
Heliene - Poly	Fixed	Schneider - Central	370991	354712	15.24	14.57
Heliene - Poly	Single Axis	Schneider - Central	380883	366099	15.25	14.66
Prism - Bi-facial	Fixed	Schneider - Central	367441	324029	19.49	17.19
Prism - Bi-facial	Single Axis	Schneider - Central	427181	410004	18.94	18.18
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	349699	333226	17.97	17.12
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	380883	366099	15.25	14.66
SunPower - Mono	Fixed	Schneider - Central	357044	342905	18.64	17.9
SunPower - Mono	Single Axis	Schneider - Central	414550	399250	18.72	18.03

November						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	107993	98861	9.01	8.25
Canadian Solar - Mono	Single Axis	Schneider - Central	126745	117762	9.58	8.9
Canadian Solar - Poly	Single Axis	Schneider - Central	113479	104104	8.9	8.17
Canadian Solar - Poly	Fixed	Schneider - Central	132078	123169	9.98	9.31
Heliene - Poly	Fixed	Schneider - Central	114502	99821	8.88	7.75
Heliene - Poly	Single Axis	Schneider - Central	123922	115699	9.88	9.22
Prism - Bi-facial	Fixed	Schneider - Central	156071	145490	15.64	14.58
Prism - Bi-facial	Single Axis	Schneider - Central	132103	122993	11.76	10.95
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	99213	89904	9.63	8.73
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	123922	115699	9.88	9.22
SunPower - Mono	Fixed	Schneider - Central	103641	95163	10.22	9.39
SunPower - Mono	Single Axis	Schneider - Central	133730	124987	11.96	11.17

December						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Canadian Solar - Mono	Fixed	Schneider - Central	45785	38798	6.89	5.84
Canadian Solar - Mono	Single Axis	Schneider - Central	49541	42483	7.08	6.07
Canadian Solar - Poly	Single Axis	Schneider - Central	49204	42079	6.97	5.96
Canadian Solar - Poly	Fixed	Schneider - Central	49175	42508	7.03	6.07
Heliene - Poly	Fixed	Schneider - Central	48979	41811	6.86	5.85
Heliene - Poly	Single Axis	Schneider - Central	44857	38494	6.76	5.8
Prism - Bi-facial	Fixed	Schneider - Central	63923	56534	11.56	10.22
Prism - Bi-facial	Single Axis	Schneider - Central	49854	42787	8.39	7.2
Panisonic HIT - Bi-facial	Fixed	Schneider - Central	40218	33422	7.04	5.85
Panisonic HIT - Bi-facial	Single Axis	Schneider - Central	44857	38494	6.76	5.8
SunPower - Mono	Fixed	Schneider - Central	41041	34535	7.3	6.15
SunPower - Mono	Single Axis	Schneider - Central	55932	49298	9.46	8.34

10 MW Whitehorse Monthly Generation Data

January						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (KWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	234898	215872	10.09	9.27

SunPower - Mono	Fixed	Schneider - Central	220385	203572	12.03	11.11
SunPower - Mono	Single Axis	Schneider - Central	230669	213976	11.51	10.67

February						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	716940	687452	13.01	12.48
SunPower - Mono	Fixed	Schneider - Central	690657	665488	15.94	15.36
SunPower - Mono	Single Axis	Schneider - Central	756936	730430	15.04	14.51

March						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	1184201	1139160	12.73	12.25
SunPower - Mono	Fixed	Schneider - Central	1146526	1107888	15.67	15.14
SunPower - Mono	Single Axis	Schneider - Central	1381590	1337027	16.01	15.49

April						
Module	**Racking**	**Inverter**	**Array Energy (kWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	1820400	1593869	15.13	13.24
SunPower - Mono	Fixed	Schneider - Central	1774482	1717921	18.75	18.15
SunPower - Mono	Single Axis	Schneider - Central	2161262	2092710	19.17	18.56

May						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	1734685	1548335	15.06	13.44
SunPower - Mono	Fixed	Schneider - Central	1692234	1490330	18.68	16.45
SunPower - Mono	Single Axis	Schneider - Central	2030504	1964927	18.79	18.19

June						
Module	**Racking**	**Inverter**	**Array Energy (KWh)**	**Energy to Grid (kWh)**	**Array Efficiency (%)**	**System Efficiency (%)**
Heliene - Poly	Fixed	Schneider - Central	1539655	1479652	14.64	14.07
SunPower - Mono	Fixed	Schneider - Central	1505078	1451847	18.19	17.55
SunPower - Mono	Single Axis	Schneider - Central	1771384	1710724	18.28	17.66

July						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	1503266	1446631	14.6	14.05
SunPower - Mono	Fixed	Schneider - Central	1467386	1417187	18.12	17.5
SunPower - Mono	Single Axis	Schneider - Central	1738614	1681618	18.22	17.62

August						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	1386726	1335237	14.75	14.21
SunPower - Mono	Fixed	Schneider - Central	1353442	1168416	18.31	15.8
SunPower - Mono	Single Axis	Schneider - Central	1612174	1560058	18.42	17.82

September						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	1012318	971534	15.25	14.64
SunPower - Mono	Fixed	Schneider - Central	984466	890052	18.86	17.05
SunPower - Mono	Single Axis	Schneider - Central	1159755	1119224	18.95	18.29

October						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	752653	719879	15.46	14.78
SunPower - Mono	Fixed	Schneider - Central	728460	699990	19.02	18.27
SunPower - Mono	Single Axis	Schneider - Central	831688	801086	18.78	18.09

November						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	274255	243669	10.64	9.45
SunPower - Mono	Fixed	Schneider - Central	254571	236819	12.56	11.68
SunPower - Mono	Single Axis	Schneider - Central	266650	249187	11.92	11.14

December						
Module	Racking	Inverter	Array Energy (KWh)	Energy to Grid (kWh)	Array Efficiency (%)	System Efficiency (%)
Heliene - Poly	Fixed	Schneider - Central	104768	90153	7.33	6.31

SunPower - Mono	Fixed	Schneider - Central	100047	86552	8.9	7.7
SunPower - Mono	Single Axis	Schneider - Central	110267	97045	9.32	8.2

Appendix B – Additional Energy Simulations Results

Haines Junction – 1 MW, Fixed Tilt, Central Inverters

Table B.1: Properties and performance of 1MW nominal power installations at Haines Junction using fixed racking and central inverters

Modules	Number of Modules	Installed Capacity (MW)	Annual Production (MWh)	Specific Production (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	3264	1.044	1168	1119	82.3	-3
CDN Solar CS6K-290MS	3600	1.044	1103	1056	77.7	-3.1
CDN Solar CS6X-320P	3264	1.044	1163	1113	81.9	-3.1
Sunpower SPR-440NE-WHT-D	2304	1.014	1125	1109	81.6	-3.1
Panasonic VBHN330SJ47	3024	0.998	1110	1112	81.9	-3.2
Prism Bi60-343BSTC	3000	1.029	1143	1111	81.7	-3

Haines Junction – 1 MW, Single Axis, Central Inverters

Table 8.2: Properties and performance of 1MW power installations at Haines Junction using single-axis trackers

Modules	Number of Modules	Installed Capacity (MW)	Annual Production (MWh)	Specific Production (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	3200	1.024	1437	1403	84.6	-1.1
CDN Solar CS6K-290MS	3600	1.044	1461	1399	83.7	-1.7
CDN Solar CS6X-320P	3264	0.938	1389	1413	85.2	-1.1
Sunpower SPR-440NE-WHT-D	2304	1.014	1352	1334	83.2	-4.7
Panasonic VBHN330SJ47	3024	0.998	1435	1438	86.9	-1.8
Prism Bi6-343BSTC	3000	1.029	1480	1438	86.1	-1.6

Haines Junction – 1 MW, Dual Axis, Central Inverters

Table 8.3: Properties and performance of 1MW power installations at Haines Junction using dual-axis trackers

Modules	Number of Modules	Installed Capacity (MW)	Annual Production (MWh)	Specific Production (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	3200	1.024	1439	1405	86.3	-1.7
CDN Solar CS6K-290MS	3600	1.044	1433	1373	82.9	-2.1
CDN Solar CS6X-320P	3072	0.983	1356	1379	84.7	-1.7
Sunpower SPR-440NE-WHT-D	2304	1.014	1425	1405	86.7	-1.9
Panasonic VBHN330SJ47	3024	0.998	1383	1386	85.8	-2.5
Prism Bi6-343BSTC	3000	1.029	1423	1383	83.9	-2.1

Haines Junction – 5 MW, Fixed Tilt, Central Inverters

Table 9.1: Properties and performance of 5MW nominal power installations at Haines Junction

Modules	# modules	Installed Capacity (MW)	Annual Production (MWh)	Spec. Production (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	16320	5.222	5372	1029	76.1	-5.6
CDN Solar CS6K-290MS	18000	5.22	5145	986	72.9	-5.6
CDN Solar CS6X-320P	16320	5.222	5230	1002	74.1	-5.6
Sunpower SPR-440NE-WHT-D	11520	5.069	5006	988	73.1	-5.8
Panasonic VBHN330SJ47	15120	4.99	5096	1021	75.6	-6.2
Prism Bi60-343BSTC	14700	5.042	5226	1036	76.7	-3.2

Haines Junction – 5 MW, Single Axis Trackers, Central Inverters

Table 9.2: Properties and performance of 5MW power installations at Haines Junction using single-axis trackers

Modules	# modules	Installed Capacity (MW)	Annual Production (MWh)	Spec. Production (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	14400	4.608	5751	1248	77.8	-4.3
CDN Solar CS6K-290MS	18000	5.22	6462	1238	75.8	-5.4
CDN Solar CS6X-320P	15360	4.915	6157	1253	78.1	-4.3
Sunpower SPR-440NE-WHT-D	11520	5.069	6287	1240	77.8	-4.7
Panasonic VBHN330SJ47	15120	4.99	6348	1272	79.5	-6.1
Prism Bi6-343BSTC	15000	5.145	6695	1301	79.5	-4.9

Whitehorse – 1 MW, Fixed Tilt Racking, Central Inverters

Table 12.1: Properties and performance of 1MW nominal power installations at the Whitehorse Quarry. Central inverters and fixed tilt racking used.

Modules	# modules	Installed Capacity (MW)	Annual Production	Spec. Production	Performance Ratio	Near Shading
Heliene 72P-320W	3264	1.044	1123	1075	79.2	-5.5
CDN Solar CS6K-290MS	3456	1.002	1059	1056	77.8	-4.1
CDN Solar CS6X-320P	3264	1.044	1107	1059	78.1	-5.3
Sunpower SPR-440NE-WHT-D	2304	1.014	1189	1074	79.1	-4.1
Panasonic VBHN330SJ47	3168	1.045	1151	1101	81.1	-4.3
Prism Bi6-343BSTC	3000	1.029	1152	1119	82.5	-2.8

Whitehorse – 1 MW, Single Axis Tracking, Central Inverters

Table 12.2: Properties and performance of 1MW power installations at the Whitehorse Quarry site using single-axis trackers

Modules	# modules	Installed Capacity (MW)	Annual Production	Spec. Production	Performance Ratio	Near Shading
Heliene 72P-320W	3200	1.024	1344	1313	81.5	-4.3
CDN Solar CS6K-290MS	3600	1.044	1366	1309	79.7	-4.6
CDN Solar CS6X-320P	3072	0.983	1290	1312	81.5	-4.2
Sunpower SPR-440NE-WHT-D	2304	1.014	1330	1312	82	-4.5
Panasonic VBHN330SJ47	3024	0.998	1326	1329	82.7	-5.5
Prism Bi6-343BSTC	3000	1.029	1483	1441	86.5	-1.6

Whitehorse – 5 MW, Fixed Tilt Racking, Central Inverters

Table 13.1: Performance of 5MW PV plant at Whitehorse Quarry using fixed tilt racking and central inverters

Modules	# modules	Installed Capacity (MW)	Annual Production	Spec. Production	Performance Ratio	Near Shading
Heliene 72P-320W	16320	5.222	5396	1033	76.1	-5.6
CDN Solar CS6K-290MS	18000	5.22	5170	990	73	-5.7
CDN Solar CS6X-320P	16320	5.222	5286	1012	74.6	-5.5
Sunpower SPR-440NE-WHT-D	11520	5.069	5047	996	73.4	-6
Panasonic VBHN330SJ47	15120	4.99	5153	1033	76.7	-6.1
Prism Bi6-343BSTC	14700	5.042	5406	1072	79	-3.2

Whitehorse – 5 MW, Single Axis Tracking, Central Inverters

Table 13.2: Annual energy production and other characteristics of 5MW single axis tracker PV plants at Whitehorse

Modules	# modules	Installed Capacity (MW)	Annual Production	Spec. Production	Performance Ratio	Near Shading
Heliene 72P-320W	14400	4.608	5832	1266	78.6	-4.4
CDN Solar CS6K-290MS	18000	5.22	6509	1247	76	-5.3
CDN Solar CS6X-320P	15360	4.915	6193	1260	78.2	-4.3
Sunpower SPR-440NE-WHT-D	11520	5.069	6333	1249	78.1	-4.8
Panasonic VBHN330SJ47	15120	4.99	6386	1280	79.6	-6.2
Prism Bi6-343BSTC	15000	5.145	6695	1301	79.5	-4.9

Whitehorse – 10 MW, Fixed Tilt Racking, Central Inverters

Table 14.1: Energy production characteristics of 10MW PV arrays with fixed tilt racking and central inverters at Whitehorse

Modules	# modules	Installed Capacity (MW)	Annual Production (MWh)	Spec. Prod. (kWh/kWp)	Performance Ratio (%)	Near Shading (%)
Heliene 72P-320W	32640	10.445	10372	993	73.2	-4.4
Sunpower SPR-440NE-WHT-D	23040	10.138	9614	948	69.9	-4.6

Appendix C – Complete LCOE Tables

Haines Junction – 1 MW Fixed Tilt

Table C.1: LCOE for 1 MW installations at Haines Junction (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.179	$0.201	$0.285
Inverter Option 1: CDN Solar Mono	$0.203	$0.228	$0.324
Inverter Option 1: CDN Solar Poly	$0.194	$0.218	$0.310
Inverter Option 1: Sunpower	$0.247	$0.279	$0.401
Inverter Option 1: Panasonic HIT	$0.216	$0.243	$0.347
Inverter Option 1: Prism Bi-Facial	$0.196	$0.220	$0.313
Inverter Option 2: Heliene Poly	$0.166	$0.186	$0.262
Inverter Option 2: CDN Solar Mono	$0.198	$0.222	$0.315
Inverter Option 2: CDN Solar Poly	$0.200	$0.224	$0.318
Inverter Option 2: Sunpower	$0.238	$0.268	$0.384
Inverter Option 2: Panasonic HIT	$0.204	$0.229	$0.325
Inverter Option 2: Prism Bi-Facial	$0.184	$0.207	$0.292
Inverter Option 3: Heliene Poly	$0.161	$0.181	$0.254
Inverter Option 3: CDN Solar Mono	$0.184	$0.206	$0.292
Inverter Option 3: CDN Solar Poly	$0.176	$0.197	$0.279
Inverter Option 3: Sunpower	$0.229	$0.258	$0.369
Inverter Option 3: Panasonic HIT	$0.198	$0.222	$0.315
Inverter Option 3: Prism Bi-Facial	$0.178	$0.199	$0.282

Haines Junction – 1 MW Single Axis Trackers

Table C.1: LCOE for 1 MW installations at Haines Junction (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.171	$0.191	$0.268
Inverter Option 1: CDN Solar Mono	$0.177	$0.199	$0.280
Inverter Option 1: CDN Solar Poly	$0.188	$0.211	$0.297
Inverter Option 1: Sunpower	$0.231	$0.260	$0.370
Inverter Option 1: Panasonic HIT	$0.191	$0.214	$0.303
Inverter Option 1: Prism Bi-Facial	$0.172	$0.192	$0.271
Inverter Option 2: Heliene Poly	$0.170	$0.189	$0.265
Inverter Option 2: CDN Solar Mono	$0.169	$0.189	$0.266
Inverter Option 2: CDN Solar Poly	$0.171	$0.191	$0.269
Inverter Option 2: Sunpower	$0.229	$0.257	$0.365
Inverter Option 2: Panasonic HIT	$0.179	$0.200	$0.281
Inverter Option 2: Prism Bi-Facial	$0.166	$0.186	$0.260
Inverter Option 3: Heliene Poly	$0.156	$0.174	$0.243
Inverter Option 3: CDN Solar Mono	$0.163	$0.182	$0.256
Inverter Option 3: CDN Solar Poly	$0.173	$0.194	$0.272
Inverter Option 3: Sunpower	$0.216	$0.242	$0.344
Inverter Option 3: Panasonic HIT	$0.175	$0.196	$0.276
Inverter Option 3: Prism Bi-Facial	$0.158	$0.176	$0.247

Haines Junction – 1 MW Dual Axis Trackers

Table C.1: LCOE for 1 MW installations at Haines Junction (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaics Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.191	$0.214	$0.302
Inverter Option 1: CDN Solar Mono	$0.199	$0.223	$0.316
Inverter Option 1: CDN Solar Poly	$0.213	$0.239	$0.339
Inverter Option 1: Sunpower	$0.234	$0.263	$0.376
Inverter Option 1: Panasonic HIT	$0.209	$0.234	$0.333
Inverter Option 1: Prism Bi-Facial	$0.183	$0.205	$0.289
Inverter Option 2: Heliene Poly	$0.180	$0.202	$0.284
Inverter Option 2: CDN Solar Mono	$0.188	$0.211	$0.298
Inverter Option 2: CDN Solar Poly	$0.202	$0.226	$0.319
Inverter Option 2: Sunpower	$0.223	$0.251	$0.357
Inverter Option 2: Panasonic HIT	$0.196	$0.220	$0.311
Inverter Option 2: Prism Bi-Facial	$0.172	$0.193	$0.271
Inverter Option 3: Heliene Poly	$0.176	$0.197	$0.278
Inverter Option 3: CDN Solar Mono	$0.184	$0.206	$0.291
Inverter Option 3: CDN Solar Poly	$0.197	$0.221	$0.312
Inverter Option 3: Sunpower	$0.219	$0.246	$0.351
Inverter Option 3: Panasonic HIT	$0.192	$0.215	$0.304
Inverter Option 3: Prism Bi-Facial	$0.169	$0.188	$0.264

Haines Junction – 5 MW Fixed Tilt Racking

Table C.1: LCOE for 5 MW installations at Haines Junction (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.162	$0.182	$0.255
Inverter Option 1: CDN Solar Mono	$0.182	$0.204	$0.289
Inverter Option 1: CDN Solar Poly	$0.181	$0.203	$0.287
Inverter Option 1: Sunpower	$0.231	$0.260	$0.372
Inverter Option 1: Panasonic HIT	$0.200	$0.225	$0.319
Inverter Option 1: Prism Bi-Facial	$0.175	$0.196	$0.278
Inverter Option 2: Heliene Poly	$0.157	$0.176	$0.246
Inverter Option 2: CDN Solar Mono	$0.177	$0.198	$0.280
Inverter Option 2: CDN Solar Poly	$0.176	$0.197	$0.278
Inverter Option 2: Sunpower	$0.226	$0.254	$0.363
Inverter Option 2: Panasonic HIT	$0.195	$0.218	$0.310
Inverter Option 2: Prism Bi-Facial	$0.170	$0.190	$0.269
Inverter Option 3: Heliene Poly	$0.155	$0.173	$0.243
Inverter Option 3: CDN Solar Mono	$0.175	$0.196	$0.276
Inverter Option 3: CDN Solar Poly	$0.174	$0.194	$0.274
Inverter Option 3: Sunpower	$0.223	$0.251	$0.359
Inverter Option 3: Panasonic HIT	$0.192	$0.216	$0.306
Inverter Option 3: Prism Bi-Facial	$0.168	$0.188	$0.265

Haines Junction – 5 MW Single Axis Tracking

Table C.1: LCOE for 5 MW installations at Haines Junction (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.167	$0.186	$0.261
Inverter Option 1: CDN Solar Mono	$0.158	$0.177	$0.250
Inverter Option 1: CDN Solar Poly	$0.159	$0.178	$0.251
Inverter Option 1: Sunpower	$0.192	$0.216	$0.308
Inverter Option 1: Panasonic HIT	$0.173	$0.194	$0.275
Inverter Option 1: Prism Bi-Facial	$0.175	$0.196	$0.278
Inverter Option 2: Heliene Poly	$0.168	$0.188	$0.264
Inverter Option 2: CDN Solar Mono	$0.154	$0.173	$0.244
Inverter Option 2: CDN Solar Poly	$0.159	$0.178	$0.250
Inverter Option 2: Sunpower	$0.188	$0.212	$0.302
Inverter Option 2: Panasonic HIT	$0.169	$0.190	$0.268
Inverter Option 2: Prism Bi-Facial	$0.171	$0.192	$0.272
Inverter Option 3: Heliene Poly	$0.166	$0.186	$0.260
Inverter Option 3: CDN Solar Mono	$0.153	$0.171	$0.241
Inverter Option 3: CDN Solar Poly	$0.157	$0.176	$0.247
Inverter Option 3: Sunpower	$0.187	$0.210	$0.299
Inverter Option 3: Panasonic HIT	$0.167	$0.188	$0.265
Inverter Option 3: Prism Bi-Facial	$0.169	$0.190	$0.269

Whitehorse – 1 MW Fixed Tilt Racking

Table C.1: LCOE for 1 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.208	$0.234	$0.333
Inverter Option 1: CDN Solar Mono	$0.234	$0.264	$0.377
Inverter Option 1: CDN Solar Poly	$0.226	$0.254	$0.363
Inverter Option 1: Sunpower	$0.255	$0.287	$0.414
Inverter Option 1: Panasonic HIT	$0.230	$0.259	$0.371
Inverter Option 1: Prism Bi-Facial	$0.234	$0.263	$0.378
Inverter Option 2: Heliene Poly	$0.194	$0.218	$0.310
Inverter Option 2: CDN Solar Mono	$0.220	$0.247	$0.352
Inverter Option 2: CDN Solar Poly	$0.212	$0.238	$0.339
Inverter Option 2: Sunpower	$0.242	$0.273	$0.392
Inverter Option 2: Panasonic HIT	$0.217	$0.244	$0.348
Inverter Option 2: Prism Bi-Facial	$0.219	$0.246	$0.352
Inverter Option 3: Heliene Poly	$0.190	$0.213	$0.301
Inverter Option 3: CDN Solar Mono	$0.215	$0.241	$0.343
Inverter Option 3: CDN Solar Poly	$0.207	$0.233	$0.331
Inverter Option 3: Sunpower	$0.237	$0.268	$0.384
Inverter Option 3: Panasonic HIT	$0.212	$0.238	$0.340
Inverter Option 3: Prism Bi-Facial	$0.216	$0.243	$0.347

Whitehorse – 1 MW Single Axis Tracking

Table C.1: LCOE for 1 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.191	$0.214	$0.301
Inverter Option 1: CDN Solar Mono	$0.198	$0.222	$0.314
Inverter Option 1: CDN Solar Poly	$0.212	$0.237	$0.335
Inverter Option 1: Sunpower	$0.244	$0.274	$0.391
Inverter Option 1: Panasonic HIT	$0.209	$0.234	$0.331
Inverter Option 1: Prism Bi-Facial	$0.190	$0.213	$0.301
Inverter Option 2: Heliene Poly	$0.226	$0.254	$0.361
Inverter Option 2: CDN Solar Mono	$0.187	$0.209	$0.295
Inverter Option 2: CDN Solar Poly	$0.200	$0.224	$0.315
Inverter Option 2: Sunpower	$0.232	$0.261	$0.371
Inverter Option 2: Panasonic HIT	$0.197	$0.221	$0.311
Inverter Option 2: Prism Bi-Facial	$0.178	$0.199	$0.282
Inverter Option 3: Heliene Poly	$0.176	$0.196	$0.274
Inverter Option 3: CDN Solar Mono	$0.183	$0.205	$0.288
Inverter Option 3: CDN Solar Poly	$0.195	$0.219	$0.308
Inverter Option 3: Sunpower	$0.228	$0.256	$0.364
Inverter Option 3: Panasonic HIT	$0.193	$0.216	$0.304
Inverter Option 3: Prism Bi-Facial	$0.176	$0.197	$0.277

Whitehorse – 5 MW Fixed Tilt Racking

Table C.1: LCOE for 5 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	**3.38% Real WACC**	**4.61% Real WACC**	**8.82% Real WACC**
	LCOE (2015$)	**LCOE (2015$)**	**LCOE (2015$)**
	$/kW.h	**$/kW.h**	**$/kW.h**
Inverter Option 1: Heliene Poly	$0.160	$0.179	$0.252
Inverter Option 1: CDN Solar Mono	$0.180	$0.201	$0.285
Inverter Option 1: CDN Solar Poly	$0.178	$0.199	$0.281
Inverter Option 1: Sunpower	$0.227	$0.256	$0.366
Inverter Option 1: Panasonic HIT	$0.197	$0.221	$0.313
Inverter Option 1: Prism Bi-Facial	$0.172	$0.193	$0.272
Inverter Option 2: Heliene Poly	$0.155	$0.173	$0.242
Inverter Option 2: CDN Solar Mono	$0.174	$0.195	$0.275
Inverter Option 2: CDN Solar Poly	$0.172	$0.192	$0.272
Inverter Option 2: Sunpower	$0.216	$0.242	$0.346
Inverter Option 2: Panasonic HIT	$0.191	$0.214	$0.303
Inverter Option 2: Prism Bi-Facial	$0.167	$0.186	$0.263
Inverter Option 3: Heliene Poly	$0.153	$0.171	$0.240
Inverter Option 3: CDN Solar Mono	$0.173	$0.193	$0.272
Inverter Option 3: CDN Solar Poly	$0.170	$0.191	$0.269
Inverter Option 3: Sunpower	$0.214	$0.241	$0.344
Inverter Option 3: Panasonic HIT	$0.189	$0.212	$0.301
Inverter Option 3: Prism Bi-Facial	$0.165	$0.185	$0.260

Whitehorse – 5 MW Single Axis Tracking

Table C.1: LCOE for 5 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB)

Photovoltaic Options	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.153	$0.170	$0.238
Inverter Option 1: CDN Solar Mono	$0.151	$0.169	$0.239
Inverter Option 1: CDN Solar Poly	$0.152	$0.170	$0.239
Inverter Option 1: Sunpower	$0.190	$0.214	$0.305
Inverter Option 1: Panasonic HIT	$0.168	$0.189	$0.267
Inverter Option 1: Prism Bi-Facial	$0.165	$0.185	$0.263
Inverter Option 2: Heliene Poly	$0.154	$0.172	$0.241
Inverter Option 2: CDN Solar Mono	$0.148	$0.165	$0.232
Inverter Option 2: CDN Solar Poly	$0.152	$0.169	$0.238
Inverter Option 2: Sunpower	$0.186	$0.209	$0.298
Inverter Option 2: Panasonic HIT	$0.165	$0.184	$0.260
Inverter Option 2: Prism Bi-Facial	$0.162	$0.181	$0.257
Inverter Option 3: Heliene Poly	$0.152	$0.169	$0.237
Inverter Option 3: CDN Solar Mono	$0.146	$0.163	$0.229
Inverter Option 3: CDN Solar Poly	$0.149	$0.167	$0.234
Inverter Option 3: Sunpower	$0.184	$0.207	$0.295
Inverter Option 3: Panasonic HIT	$0.162	$0.182	$0.257
Inverter Option 3: Prism Bi-Facial	$0.159	$0.179	$0.253

Whitehorse – 10 MW Fixed Tilt Racking

Table C.1: LCOE for 10 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB). NOTE: the cost of energy storage is NOT included in these cost estimates!

	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.153	$0.171	$0.239
Inverter Option 1: CDN Solar Mono	$0.171	$0.191	$0.270
Inverter Option 1: CDN Solar Poly	$0.170	$0.190	$0.268
Inverter Option 1: Sunpower	$0.203	$0.228	$0.325
Inverter Option 1: Panasonic HIT	$0.188	$0.210	$0.298
Inverter Option 1: Prism Bi-Facial	$0.164	$0.183	$0.258
Inverter Option 2: Heliene Poly	$0.150	$0.167	$0.234
Inverter Option 2: CDN Solar Mono	$0.168	$0.188	$0.265
Inverter Option 2: CDN Solar Poly	$0.167	$0.186	$0.263
Inverter Option 2: Sunpower	$0.200	$0.224	$0.319
Inverter Option 2: Panasonic HIT	$0.185	$0.207	$0.293
Inverter Option 2: Prism Bi-Facial	$0.161	$0.180	$0.253
Inverter Option 3: Heliene Poly	$0.148	$0.165	$0.231
Inverter Option 3: CDN Solar Mono	$0.166	$0.186	$0.262
Inverter Option 3: CDN Solar Poly	$0.165	$0.184	$0.260
Inverter Option 3: Sunpower	$0.198	$0.223	$0.316
Inverter Option 3: Panasonic HIT	$0.183	$0.205	$0.290
Inverter Option 3: Prism Bi-Facial	$0.159	$0.178	$0.250

Whitehorse – 10 MW Single Axis Tracking

Table C.1: LCOE for 10 MW installations at Whitehorse (Option 1: Schneider; Option 2: SMA; Option 3: ABB). NOTE: the cost of energy storage is NOT included in these cost estimates!

	3.38% Real WACC	4.61% Real WACC	8.82% Real WACC
	LCOE (2015$)	LCOE (2015$)	LCOE (2015$)
	$/kW.h	$/kW.h	$/kW.h
Inverter Option 1: Heliene Poly	$0.147	$0.164	$0.231
Inverter Option 1: CDN Solar Mono	$0.162	$0.181	$0.256
Inverter Option 1: CDN Solar Poly	$0.162	$0.181	$0.256
Inverter Option 1: Sunpower	$0.170	$0.190	$0.270
Inverter Option 1: Panasonic HIT	$0.172	$0.193	$0.273
Inverter Option 1: Prism Bi-Facial	$0.154	$0.172	$0.242
Inverter Option 2: Heliene Poly	$0.145	$0.161	$0.227
Inverter Option 2: CDN Solar Mono	$0.159	$0.178	$0.251
Inverter Option 2: CDN Solar Poly	$0.160	$0.179	$0.252
Inverter Option 2: Sunpower	$0.167	$0.188	$0.265
Inverter Option 2: Panasonic HIT	$0.170	$0.190	$0.268

Inverter Option 2: Prism Bi-Facial	$0.151	$0.169	$0.238
Inverter Option 3: Heliene Poly	$0.143	$0.160	$0.224
Inverter Option 3: CDN Solar Mono	$0.158	$0.177	$0.249
Inverter Option 3: CDN Solar Poly	$0.158	$0.177	$0.249
Inverter Option 3: Sunpower	$0.166	$0.186	$0.263
Inverter Option 3: Panasonic HIT	$0.168	$0.188	$0.266
Inverter Option 3: Prism Bi-Facial	$0.150	$0.168	$0.236