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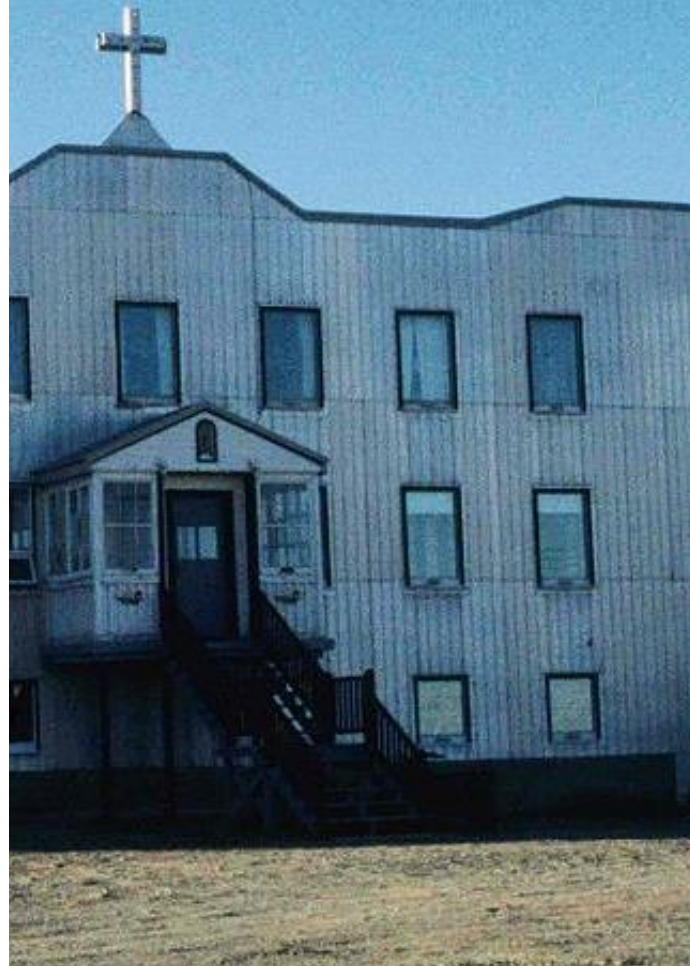
# Igluligaarjuk Midnight Sun Pre-Feasibility Study

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iSolara Solar Power

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## 2 Overview

### 2.1 Introduction

iSolara Solar Power is Canada's Solar Expert. iSolara Energy Services was incorporated in 2003 and has been delivering quality Solar Projects under the trade name iSolara Solar Power for more than fifteen years. iSolara Solar Power has installed over 700 solar projects as large as 440 kW for a total of 15 MW of solar PV systems as of Dec. 2018. We follow strict internal processes to assure our customers can depend on us to complete their projects on time and on budget.

Through our reputation for integrity and system delivery we have grown to be the number one solar company in Eastern Ontario and we are the largest solar company in Canada east of Toronto. We set-up monitoring for all our in-service systems and know what works and what does not. We have our own in-house Engineering staff for layouts and electrical design.

iSolara is a proud member of the Canadian Solar Industry Association (CanSIA) since 2010, has chaired several committees and attends regulatory meetings on behalf of CanSIA. iSolara has an A+ with the Better Business Bureau and has been a member since 2011. iSolara Solar Power is a registered Renewable Energy Technology vendor with the IESO. Our RET Vendor registration number is YR3-DJC.

### 2.2 Objective

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*The objective of this pre-feasibility report is to determine an approximate system size of a photovoltaic ground-mounted solar array paired with lithium ion battery storage for the hamlet of Chesterfield Inlet.*

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### 2.3 Structure

This report will provide some brief context to the energy infrastructure in the northern territories, an overview of the electric utility in Nunavut, a description of the Hamlet of Chesterfield Inlet and how Natural Resources Canada's Clean Energy for Remote and Rural Communities Demonstration Stream can support this project.

A description of the technology alternatives to the existing diesel generator plant will be provided. Including an overview of the innovative Canadian Solar bifacial solar modules, iSolara Solar Power's two-position ground mounted racking system and Tesla's Powerpack energy storage solution.

An overview of the approach to determine the system sizing, simulation tools, including model parameters and assumptions will be provided. This report will conclude with a discussion on the simulation results as well as recommendations for future work.

### 2.4 Scope

The scope of this report is limited to exploring the simulated results for a small photovoltaic energy system paired with energy storage operating as an independent power producer on the Chesterfield Inlet distribution grid. This report does not investigate other technologies such as wind or a detailed economic study such as a cost benefit analysis. This work along with future fine tuning of system sizing is reserved for a future report.

## 3 Context

### 3.1 Energy in the North

The electricity system in the north is aging, underperforming and at capacity. The utilities and territorial governments are not able to pursue major infrastructure projects as they rely on a small dispersed population for revenues. 90% of Nunavut's territorial revenues stem from the Federal Government. Due to these challenges residents in the north face the highest electricity rates in the country. To keep the cost of living affordable, the territories rely on substantial subsidization. [1]

All of the communities in the territories are considered remote as they are not connected to the North American power grid. These communities are highly dependent on diesel generation. Diesel generation is simple to install, easy to maintain and has low upfront capital costs. It is also highly scalable to meet a growing community. Diesel generators are also flexible and extremely reliable. However, it has very high operating costs due to a constant need for fuel consumption as well as the volatility of fuel prices. There is an additional cost as the fuel must be transported to remote locations by sea or air. There is an environmental impact as generators emit greenhouse gas emissions, air pollution, noise pollution and the fuel tank has a risk of spills. [1]

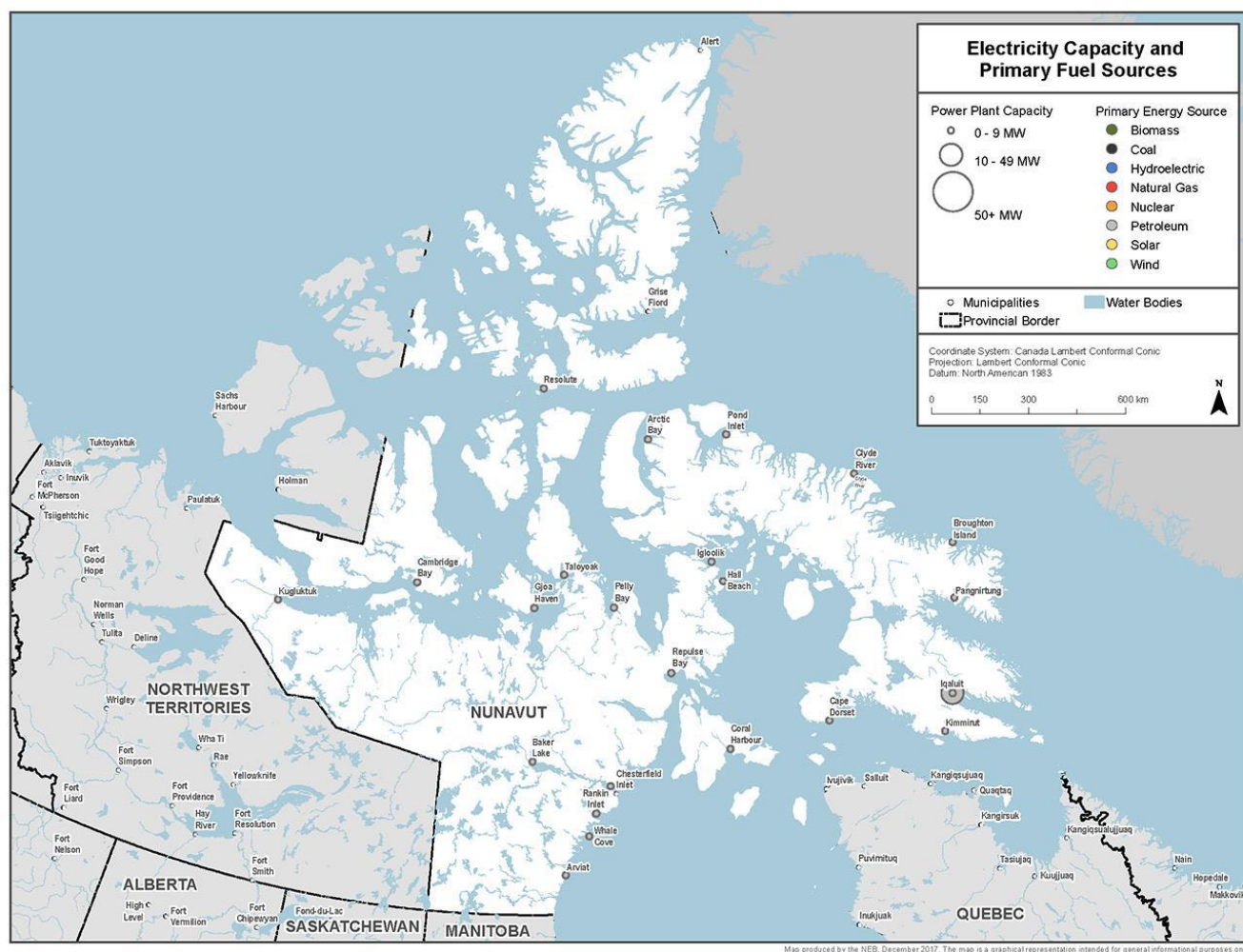


Figure 1: Electricity generation facilities in Nunavut [2]



### 3.2 Qulliq Energy Corporation

Qulliq Energy Corporation (QEC) is the only supplier of electricity to communities in the territory as of April 1<sup>st</sup>, 2001 (renamed from Nunavut Power Corporation in 2003). QEC is 100% owned by the territorial government, it has an independent board which allows it to operate at arm's length from the government that reports to the territorial minister. [3]



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Qulliq Energy Corporation  
Société d'énergie Qulliq  
Qulliq Alruyaktuqtunik Ikumatjutiit

QEC operates 25 stand-alone diesel power plants with a total installed capacity of 76 MW serving 15,000 customers. Each community has its own generation and distribution system that is entirely reliant on imported diesel fuel. [3]

In April 2018, QEC released *QEC Energy Framework: The Cost of Generating Electricity in Nunavut* which includes financial considerations when evaluating renewable energy alternatives. 55 million liters of diesel are consumed annually for electricity generation across the territory and diesel generators will remain the primary source for generating electricity into the future. However, QEC wants to incorporate renewable energy where it is possible. [4]

One of the ways QEC is considering incorporating renewable energy into their grids is through an Independent Power Producers (IPP) program. This program would allow IPPs to own and operate facilities that generate electricity for the purpose of selling this energy to QEC. An IPP ownership model alleviates QEC's upfront financial burden for these projects as well as the risk and operations and maintenance costs associated with the project. [4]

QEC is in the process of establishing its procurement policy for IPPs which will include detailed contracts outlining technical and commercial conditions as well as inter connection guidelines. The program is expected to launch in the spring of 2019. [5]



Figure 2: Rankin Inlet Diesel Power Station [18]

### 3.3 Chesterfield Inlet

The Hamlet of Chesterfield Inlet is located on the west coast of Hudson Bay in the Kivalliq region of Nunavut. Its traditional name is Igluigaarjuk which translates to “place with a few igloos”. It is considered the “oldest” Arctic community and has a population of 390. Chesterfield Inlet has a daily average in January of -30.9°C and a record low of -49.0°C. [6]

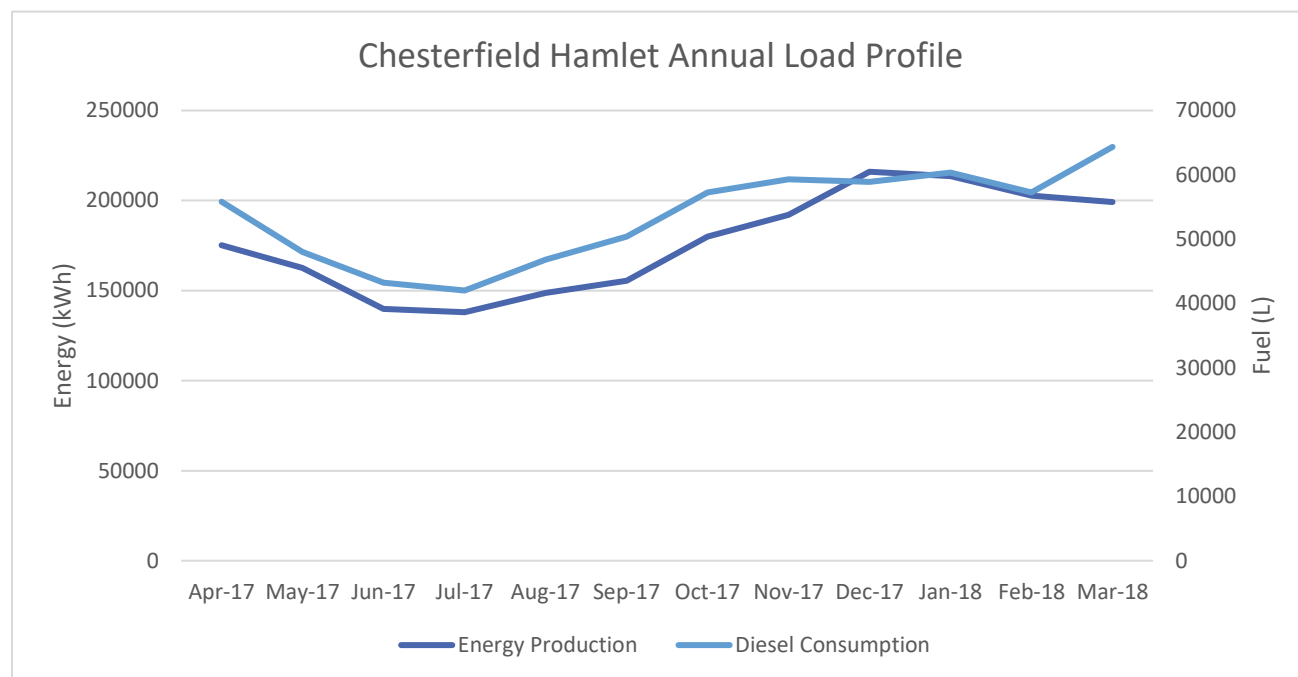


Figure 3: Monthly energy and fuel consumption for Chesterfield Inlet April 2017 to March 2018 [7]

The Hamlet consumes 2,123 MWh per year in electricity with a peak load of 400 kW (see Figure 3: Monthly energy and fuel consumption for Chesterfield Inlet April 2017 to March 2018 ). This is forecasted to grow to 2,169 MWh per year with a peak load of 412 kW by 2025. Power is entirely supplied by diesel generators which consumed over 640,000 liters last year. The power plant has passed its 40 year design life and consists of two 320 kW generators and one 400 kW generator for a total plant capacity of 1.04 MW (see Table 1). [7]

The fuel efficiency of the current plant is 3.46 kWh/L of diesel fuel at a fuel cost of \$0.9341/L [8]. The current commercial electricity rate in Chesterfield Hamlet is \$0.8556/kWh [9]. The variable component of this rate that is solely associated with the cost of diesel is \$0.37/kWh [4].

GEN Set No	Model	Rating (kW)
G1	Detroit Series 60	320
G2	Detroit Series 60	320
G3	CAT D 379	400
<b>Total</b>		<b>1040</b>

Table 1: Chesterfield Inlet Power Plant Equipment Ratings [7]

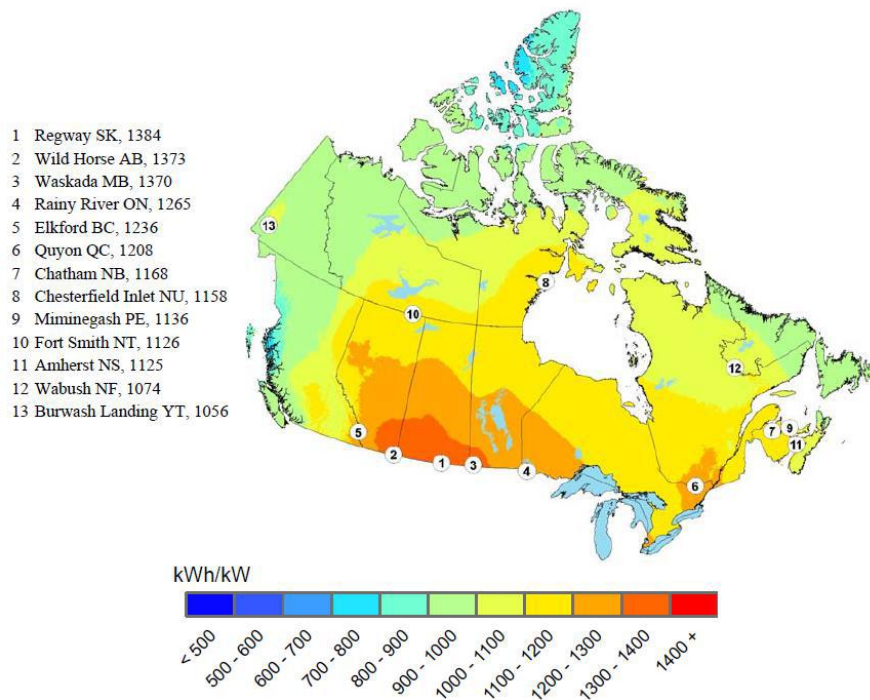


Figure 4 Yearly PV potential map for latitude tilt and 13 "PV hotspots" in each province and territory. [12]

The Hamlet of Chesterfield Inlet is eager to investigate renewable energy alternatives for the community [10]. With its location on the coast of the Hudson Bay, Chesterfield Inlet is one of the sunniest communities in Nunavut with an annual solar irradiance of 1.2 MWh/kW which rivals that of Ontario which has a vibrant solar industry [11].

Chesterfield Inlet is listed as the best location in Nunavut for solar energy generation potential. Due to the long summer days, the period from March to June is considered the best in the country. [12]

### 3.4 Clean Energy in Remote and Rural Communities

In 2018 Natural Resources Canada launched the Clean Energy for Rural and Remote Communities program. This program aims to reduce remote and rural communities' reliance on diesel fuel for heat and power. This program will provide \$220 million in funding over six years to support clean energy infrastructure projects. This program has streams that will provide funding for projects that demonstrate innovative technologies, deploy renewable energy technologies and building capacity to support communities. [13]

This program is an excellent opportunity to provide funding for a demonstration sized solar energy system in Chesterfield Inlet. This program has the potential to provide funding for the entire cost of the system under the demonstration stream as well as fund future projects under the deployment stream.

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## 4 Technology Alternatives

### 4.1 Bifacial Solar Modules

Canadian Solar's innovative bifacial modules will facilitate the deployment of solar energy systems in the Arctic by increasing energy production per module and lowering installation costs.

The BiHiKu super high power bifacial poly perc modules can produce up to 30% more extra power from the back of the module. As well, the front side can produce 24% more power than conventional modules. This means a 400W module has the potential to operate as a 520W module. These modules are rugged as they can withstand a heavy snow load of up to 5400 Pa and wind loads up to 2400 Pa.



*Figure 5: Canadian Solar BiHiKu Super High Power Bifacial Poly PERC Module.*

Bifacial modules have a transparent rear glass which makes them particularly well suited for the arctic as they can take full advantage of the albedo effect. Albedo is an expression of the ability of surfaces to reflect sunlight. Ice and snow covered areas have high albedo as they reflect a large portion of the incoming sunlight [14]. Bifacial solar modules are able to harness the solar irradiance directly in line with the modules as well as any solar irradiance that is reflected from the ground. A snow covered surface can have an albedo value 6 times greater than a grassy field [15].

Canadian Solar's modules, with a standard 30 year power output warranty and 10 year product warranty, will ensure their products are supported for the lifetime of this demonstration system and beyond. These warranties are much longer than the standard 1 year parts warranty on diesel generators.

Canadian Solar's commitment to lowering the cost of solar energy will expedite the date when solar and storage systems are cheaper than diesel generators. Their commitment to quality will increase the reliability of solar energy systems to help ensure they are more reliable than conventional diesel generators.

### 4.2 QuickTrack Racking System

iSolara Solar Power's two-position QuickTrack racking system has been deployed all over Ontario as a proven reliable system. There are no motors, no controllers, no sensors and no actuators which significantly reduces system downtime. This system is ideal for remote communities as there are no special order parts and specialists are not required for system repairs.

This system has been optimized to provide an ideal summer tilt angle and an ideal winter tilt angle which results in 12% more production over a fixed rack system. A single maintenance worker can perform this adjustment twice a year. There is no requirement for system inspections, greasing motors, changing oils, etc.

This novel application of a two-position racking system in the Arctic will demonstrate the simplicity of installing this system in the Arctic. The components of the system are simple aluminum and stainless steel rails connected together with standard hardware pieces. The system is adaptable to a variety of mounting



configurations such as ballast blocks (see Figure 6), ground piles, or ballast pans with local fill. This product is also linearly scalable in sizes from a small residential 10 kW system to a large community scale 500 kW system.

Changes to the Quick Track design will be required to ensure it will be compatible with the harsh Arctic environment. These design changes will be patented in a new Arctic variant of the Quick Track racking system as a result of this project.



*Figure 6: iSolara's Quick Track mounting system deployed at a project in Eastern Ontario.*

### 4.3 Powerpack Energy Storage

Tesla's Powerpack systems provide remote communities with greater control, reliability and security when paired with solar energy systems. Tesla has successfully deployed these systems in American Samoa to offset their diesel consumption through the use of a renewable energy micro grid.

Including a Powerpack energy storage system in this system will smooth and firm the output of the solar energy system thereby mitigating the risks associated with integrating variable energy sources on a remote grid. Excess energy from the solar energy system will be stored in a Powerpack for later use. As well, during the dark winter months when the community will largely be dependent on the generators for power, the system can maintain some energy storage in case of a generator outage or regular maintenance.



*Figure 7: Tesla's Powerpack Energy Storage System.*

This state of the art battery system is designed for efficiency and a 10 year product lifetime. Powerpacks use a very reliable architecture that has already been tested over one billion miles in their electric vehicles.

Powerpacks use a thermal control system with internal liquid cooling and heating that allows for pinpoint temperature control. This ensures maximum performance in all climates with better efficiency than air cooling. Powerpacks can operate with ambient temperatures as low as -30°C. Heat Mode is a built-in feature that allows the battery to maintain rated power and energy capabilities across the system's operating temperature range.

Powerpack's enclosure is outdoor rated for all environments. No additional structures or covers are required, simplifying installation and lowering site preparation expenses. This application will demonstrate that the Powerpack System can operate in the Arctic.

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## 5 Approach

### 5.1 Methodology

A wide range of factors were considered in the design method for this pre-feasibility report such practical deployment considerations and right sizing this system.

In order to ensure this project would results in a significant diesel reduction for the community a constraint was placed on the system model requiring a minimum renewable fraction<sup>1</sup> of 25%.

Chesterfield Inlet's power plant currently has a peak rating of 1.04 MW and the community has a peak load of 400 kW [7]. In order to minimize the impact the variable renewable energy source will have on the local distribution grid an operating reserve of 75% of solar power output was set. This means that the system must provide enough spare capacity operating in case output from the PV array suddenly decreases by 75%.

In order to determine the right size to meet these requirements and simulate the performance of this system, HOMER (Hybrid Optimization Model for Multiple Energy Resources) Pro microgrid software was utilized. This program is the global standard for optimizing microgrid design across all sectors. HOMER simulates the operation of a microgrid system for an entire year in one hour time steps.

### 5.2 Assumptions

In order to complete the simulation some assumptions were made based on the evidence available at the time of this report:

- **Discount Rate – 8%.** As recommended by Treasury Board of Canada for evaluating publicly funded projects. [16]
- **Load Profile – Community load at 5.8 MWh/day with a peak in January.** This assumption utilizes HOMER's template for a community load with the modification that the annual peak occurs in January the coldest month of the year. [1]
  - **Day-to-day Variability – 3%**
  - **60 minute Timestep Variability – 3%**
- **Sell Rate - \$0.37/kWh.** Based on the variable rate cost of diesel in Chesterfield Inlet which is assumed to be the rate offered to IPPs from QEC. [4]
- **Diesel Fuel Price - \$0.934 / L [8].**
- **Generator Replacement Cost - \$12,077/kW.** Based on QEC's project plan for a new 2.6 MW Kugluktuk Power Plant. [17]
- **Generator Emissions.** Based on current specification sheet for Caterpillar Diesel Generators:
  - **CO<sub>2</sub> – 751 g/kWh**
  - **NO<sub>x</sub> – 6.654 g/kWh**
  - **CO – 0.492 g/kWh**
  - **HC – 0.045 g/kWh**
  - **PM – 0.058 g/kWh**

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<sup>1</sup> Renewable fraction is the percentage of annual energy consumed in the community provided by the solar energy system.

- **SO – 0.001 g/kWh**
- **Carbon Tax.** \$50 per tonne.

In a future feasibility report these values should be replaced with the true sell rate expected from the IPP contract with QEC, the true generator replacement costs for the Chesterfield Inlet power plant from QEC and the recorded emissions from the power plant from QEC.

### 5.3 Model Parameters

Table 2 displays the inputs that were used for the HOMER Pro simulation:

Table 2: Model input for HOMER Pro Simulation

Component	Name	Size	Unit
<b>Solar Array</b>	CS3W-400PB-AG	400	W
<b>Storage</b>	Tesla Powerpack 2	210	kWh
<b>Dispatch Strategy</b>	HOMER Load Following		
<b>Load</b>	Community Profile	5817	kWh/day
	January Peak	400	kW
<b>Generator</b>	CAT-D379	400	kW
	Detroit Diesel Series 60	320	kW
	Detroit Diesel Series 60	320	kW

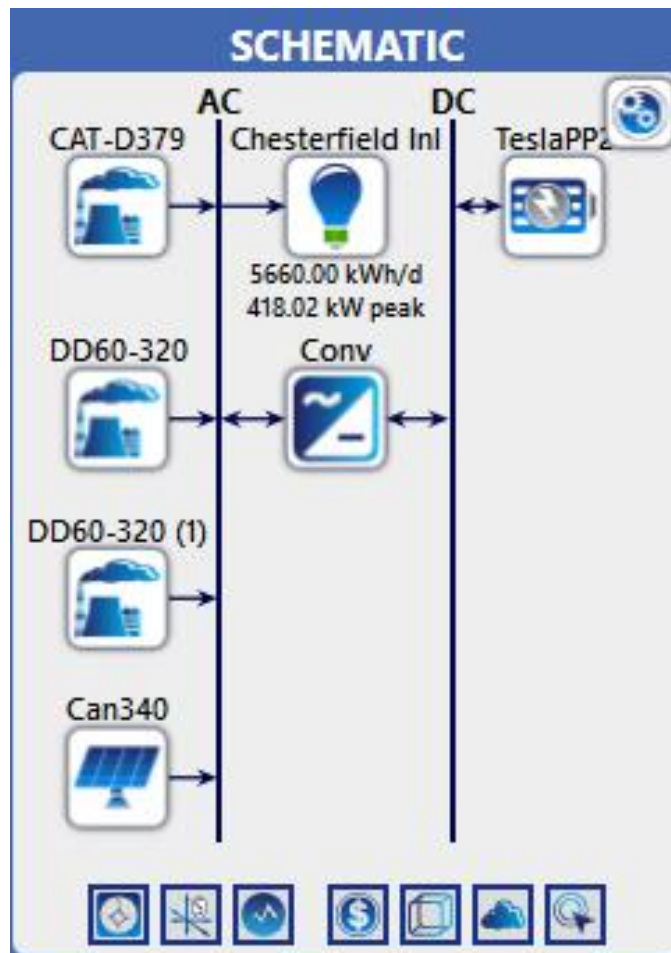


Figure 8: Schematic of the system model in HOMER Pro.

## 6 Results

### 6.1 Optimization Results

Component	Optimized Size
<b>Solar</b>	609 kW
<b>Energy Storage</b>	636 kWh

Table 3: Optimized sizing results from HOMER Pro

HOMER Pro evaluated 396 simulations spanning 44 optimization cases and 9 sensitivity cases. The results from the sensitivity cases range in size for the solar system from 588 kW for a low price of diesel and low community load scenario to 743 kW in a higher community load scenario. For the energy storage system the opposite was true, 420 kWh of energy

storage was required for scenarios with a high community energy load but these systems did have a risk of grid stability problems. The prevalent energy storage system size across a wide range of sensitivity case was 630 kWh of storage. In the end for the scenario with a diesel fuel price of \$0.934/L and a community load of 5.8 MWh/day the optimized system size is 609 kW of solar power paired with 636 kWh of energy storage (Table 3).

### 6.2 Simulation Results

The simulation results demonstrate that a system of this size could produce 720 MWh per year which represents 31% of Chesterfield Inlet's electricity needs. As expected, the majority of this production would occur in the summer months, where most of the hamlet's electricity will come from clean reliable solar energy. The winter months will still be largely reliant on QEC's generators for electricity.

As well, the energy storage system is able to utilize excess energy generated from the solar array to provide this additional energy in the evening when the community hits its peak power requirement. Figure 12 displays the peak charge and discharge power of the energy storage system for each month of the year. As expected, this energy storage is utilized the most during the summer months and the least during the

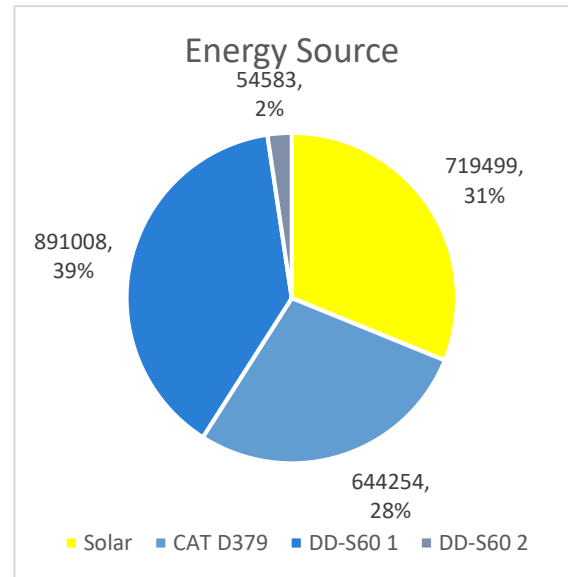


Figure 10: Annual electrical energy production (kWh) by source.

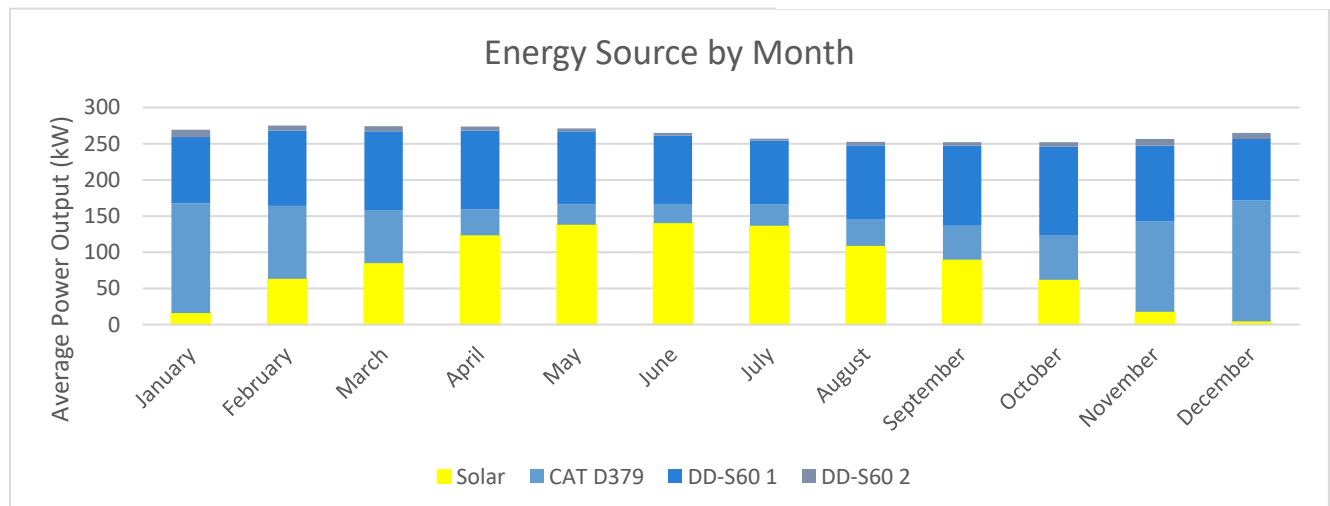


Figure 9: Monthly average electric production by energy source.

winter months. This allows the energy storage system to remain at a high state of charge throughout the winter in order to act as a back-up power supply if generator maintenance is required or if there is a generator failure.

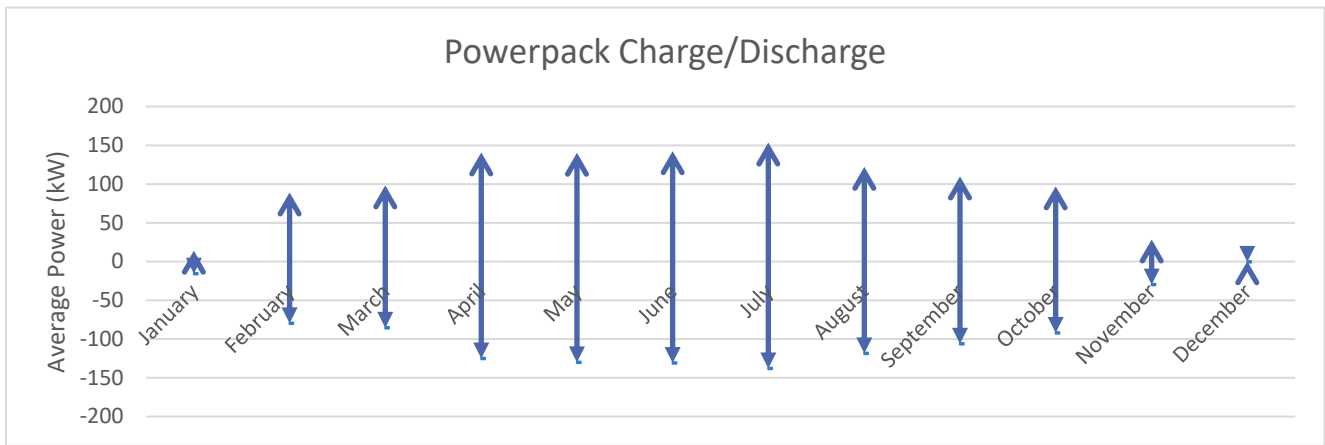


Figure 12: Average monthly peak charge and discharge rates for Tesla Powerpack energy storage system.

Figure 11 displays how the system will operate on a typical summer day. The purple line represents the electricity needs of the community, the yellow line represents the energy generation from the solar array, the black line represents the electricity provided by the Detroit Diesel Series 60 Generator 1, the orange line represents electricity provided by the CAT D379 generator and the red line represents the charging (positive) and discharging (negative) of the Powerpack.

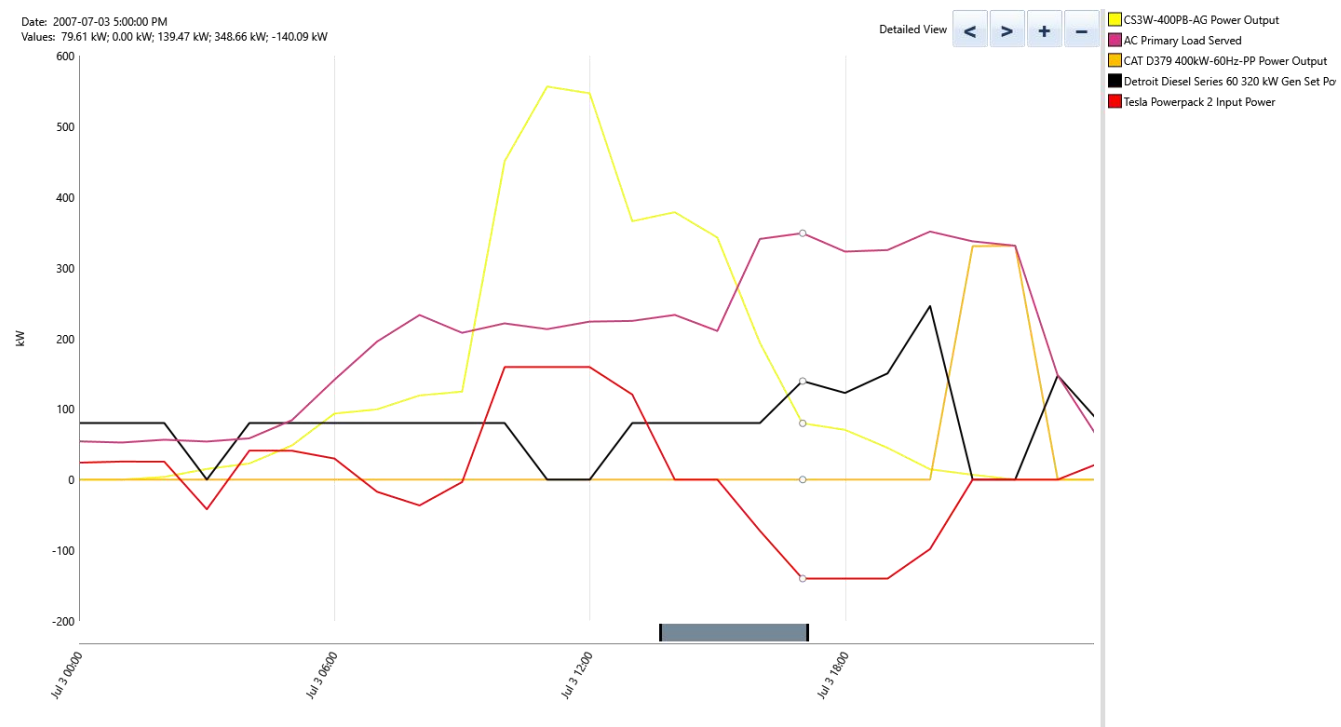


Figure 11: Typical summer day hourly system profile.

Due to the long arctic summer days, the solar array is able to provide power for nearly 20 hours out of the day. The solar array and grid provide power to the community in the morning while the Powerpack charges/discharges to handle any sudden changes in load or solar irradiance. By 11 AM the solar array is



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providing all of the community's energy needs as well as charging the Powerpack. This provides the opportunity for all generators to be turned off. Throughout the year at its highest point the solar system has a maximum penetration rate of 510 kW AC, providing 284% of the community load (i.e. powering the entire community load and charging the energy storage system). At 3 PM when the evening load in the community begins, the Powerpack discharges to allow QEC's generators to start back up and continuing to provide electricity to meet the load through the evening.

### 6.3 Conclusion

This report has determined that the ideal size for the Igluligaarjuk Midnight Sun demonstration project is a 609 kW DC photovoltaic ground-mounted solar array paired with a 636 kWh Powerpack system. This system will produce 720 MWh per year in clean electricity. Using the current plant efficiency of 3.46 kWh/L, this will provide an annual diesel reduction of over 208,000 liters of fuel. This reduction in diesel fuel corresponds to 541 tonnes in carbon dioxide emission reductions. This does not include the additional diesel fuel associated with transporting the fuel to site.

Using the expected QEC sell rate for the IPP program of \$0.37/kWh this represents an annual revenue stream of \$266k a year or \$2.6 million over initial 10 year lifetime of the project. It is expected this will lead to a demonstration project that will provide a detailed framework and cost estimate for future deployments that can be repeated in Nunavut's 24 other remote communities.

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