JANUARY 2022

DIESEL REDUCTION IMPLEMENTATION PLAN

CORAL HARBOUR, NUNAVUT

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Nunavut

NORTHERN
ENERGY
CAPITAL

Sakku Investments Corporation
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ACKNOWLEDGEMENTS

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Glossary & List of Acronyms

BESS	Battery Energy Storage System
Bifacial array	Solar PV panels that capture the sun's energy on both sides, allowing energy to also be collected from the underside of the panel when light is reflected up from the ground surface.
Brownfield Site	A decommissioned site that has known contamination in the surface or subsurface
CEP	Community Energy Plan
Curtailment	The deliberate restriction of excess electricity production to maintain stability of grid infrastructure, or due to an inability to store or use it. Excess energy is usually released as heat.
CIPP	Commercial and Institutional Power Producer policy
CIRNAC	Crown Indigenous Relations and Northern Affairs Canada
CGS	Community and Government Services Department, Government of Nunavut
Energy	The capacity to do work, such as moving or heating
GHG	Greenhouse gases: gases that trap heat in the atmosphere
GN	Government of Nunavut
IODI	Indigenous Off Diesel Initiative
IPP	Independent Power Producer Policy
KRLUP	Keewatin Regional Land Use Plan
kW	kiloWatt; a unit of power equivalent to 1000 Watts
MW	MegaWatt; a unit of power equivalent to 1,000,000 Watts
MWh	Megawatt hour; a unit of energy capable of generating 1 MW for 1 hour
NIRB	Nunavut Impact Review Board
NPC	Nunavut Planning Commision
PPA	Power Purchase Agreement
Project Team	The team of individuals leading development and implementation activities, especially the solar project.
Proponent	The company that will be the ultimate owner and operator of the project, Kivalliq Alternative Energy
QEC	Qulliq Energy Corporation, Nunavut's electricity Utility provider
Utility	An organization that maintains infrastructure for a public service, like electricity, typically in a monopoly or quasi-monopoly arrangement.

Executive Summary

This Implementation Plan is intended to support the development and implementation of Phase 3 activities for the Indigenous Off Diesel Initiative in the community of Salliq (Coral Harbour), NU, and will outline the plans of the Project Team over the next one to two years. Phase 3 activities were planned following on the results of the Community Energy Plan (CEP) for Salliq, which provided an in-depth investigation of possible diesel reduction projects that could be pursued by the community over the short and long term. Ultimately, the CEP for Salliq pointed the Project Team towards the creation of a 5 year diesel reduction plan, which includes several key activities as outlined below:

- Development and construction of a medium penetration renewable energy + battery facility, to offset electricity produced from diesel
- Identification of a leader to implement an LED lighting campaign in public buildings
- Distribution of self-install home energy kits to local residents
- Continued planning to implement building retrofits based on the results of a building energy audit completed in one building in the community, plus the pursuit of funding for additional building energy audits and retrofits
- Development of a biomass pilot project in either Naujaat or Salliq, to test feasibility of biomass energy in a remote northern community
- Recruitment of a Regional Energy Manager based in Rankin Inlet, to support clean energy planning in the Kivalliq region

Following the conclusions of the CEP, the Project Team conducted a further technical review of the medium penetration renewable energy project in order to determine the most appropriate size and type of project for the local grid and energy setting. Project options were narrowed down to solar and wind energy, at which point both the Hamlet and Proponent were engaged to determine the final project selection. Ultimately, a 960kW solar energy + 1MWh battery facility was selected to be the best project for Salliq to focus their energy on in Phase 3.

The remainder of this Implementation Plan provides details on the activities required to develop a solar energy project in Salliq. Requirements of the project as a whole are considered, but with a focus on those activities to be completed next during Phase 3 of the IODI program. A detailed timeline and schedule of activities is provided at the end of the document.

First, candidate sites are described and compared based on data collected during a site visit in July of 2021. Sites were considered based on topography, proximity to infrastructure including roads and electrical, and environmental and traditional land use impacts. An area 3km to the NE of the airport was requested by the Hamlet to be investigated, and was ultimately selected as the preferred site for development. Activities to initiate land use approvals and a lease at this location are currently underway.

Following site selection, the technical team completed a solar energy technology review to determine the optimal orientation and type of solar array to be used. This indicated that south facing, fixed tilt, bifacial arrays oriented at 45° will produce the most energy. Additionally, an energy yield analysis of the solar resource potential at the site, and a preliminary concept design of the site layout were also completed. Expected energy yield from the site is in the range of 1596 MWh/year, with the majority of production occurring in the summer months from March - August. Preliminary design and energy yeild will be used to inform further design work in Phase 3, as well as procurement options, communication with the territorial Utility, Qulliq Energy Corporation (QEC), and the project budget, business case and proforma.

Next steps planned for early in Phase 3 include the acquisition of a lease for the project, initiating the environmental permitting process by applying for a Conformity Determination with the Nunavut Planning Commission, and collecting additional data at the site to inform design and engineering. Data to be collected includes a ground survey of the site area, and a geotechnical assessment. Requests for Fee Proposals for these two services have already been issued, with activities planned to take place in summer, 2022.

At this stage, the Project Team has initiated conversations with the Nunavut Planning Commission, NAV CANADA, and the Land Administration Team at the government of Nunavut's Community and Government Services. An application for Conformity Determination will be prepared early in Phase 3, concurrently with a lease application. The Project Team has also applied for aeronautical approvals through NAV CANADA and Transport Canada, as the project site is within the airport zoning regulations radius of the Salliq Airport.

Activities to follow will include work on advanced design and engineering for the project, pricing from qualified contractors including a solar supply and install contractor, and commissioning of an interconnection study with QEC. At present the Utility has not yet released their anticipated Independent Power Producer Policy (IPP), which will be instrumental to the project's ability to proceed. As such, this interconnection study is planned for later in Phase 3, and there is a risk that it may occur even later if the IPP policy is delayed. An interconnection study will be important to understand the requirements of QEC for the project to safely interconnect with the grid. This study will also inform the project's interconnection budget.

After Phase 3, project activities will include final design and engineering work, late stage negotiations with contractors to bring the project to financial close, logistics and construction, local training to support operations, and project testing and commissioning. The project will then enter the operations and maintenance phase, with an expected lifespan of 30 years or more.

Once in operation (anticipated in 2024-25) this project is expected to displace up to 31% of Salliq's current electricity demand, an equivalent of 360 thousand litres of diesel each year. Over the life of the project, this would amount to 10.8 million litres of diesel displaced, saving 28,500 tonnes of CO_2. Overall, this amounts to 10% of Salliq's total diesel consumption for all uses.

1. Introduction and Project Background

1.1. PROJECT OVERVIEW AND BENEFITS

1.1.1 PROJECT OVERVIEW

Renewable energy has become an area of growing interest in northern Canada. Rising oil prices, along with mounting concerns related to climate change and greenhouse gas emissions have played a key role in the desire for remote northern communities to move away from their present reliance on diesel generated power. On a global scale, technologies are improving rapidly, driven by the desire to shift to greener energy production. Innovation has led to improved efficiencies and reliability in renewable energy generation, even in cold climates. And despite the unique logistics and supply challenges faced by northern communities, a global trend towards decreasing capital costs of renewable technologies is underway. For these reasons, clean energy is more attainable than ever before.

Faced with a climate emergency, the federal government has created a number of funding programs directed at developing clean energy potential in Canada, with many targeted specifically towards rural and northern communities. One such funding program, the Indigenous Off Diesel Initiative, has kickstarted the path towards renewable energy within the community of Coral Harbour (known in the local language as Salliq).

Through this program, a Community Energy Plan (CEP) was created to identify potential pathways towards reduced diesel consumption, and to help the community plan its energy future. Ultimately, the CEP process identified a variety of project opportunities and resulted in several actionable, short term goals. Foremost among them is the development of a utility scale solar energy facility in Salliq, which will be the focus of near term planning for Phase 3 of the IODI program. Such a project will allow Salliq to make significant strides towards their goal to displace local diesel consumption within just a few years.

Beyond Phase 3 and following the completion of the solar energy project, the CEP has identified longer term projects and goals to focus on, which will be revisited at a later date. An overview of Salliq's near term and future energy plans are discussed in the subsections to follow.

The remaining sections of this implementation plan will describe how a solar energy generation project was selected, and present the path forward to the development and construction of a 960kW solar energy facility with accompanying 1MWh energy storage in the community of Salliq, Nunavut. The plan will review details of the project setting and background, including a summary of work done to date. The plan will also provide an overview of the local solar resource potential, an analysis of shortlisted project sites and recommendation for the final project site, and an overview of what is expected during the development, design, and implementation stages of the project. Finally, the plan will recommend a detailed series of next steps to advance the project.

1.1.2 PROJECT BENEFITS

The development and construction of a solar energy project in Salliq would have significant benefits, both locally and across Canada. In total, the project is expected to meet over 31% of the community's annual electricity demand, and displace over 360 thousand litres of diesel each year. Over the life of the project, this would amount to 10.8 million litres of diesel displaced, saving 28,500 tonnes of CO_2. This reduction in GHG emissions will allow Salliq to play a role in the fight against climate change, a global issue already having noticeable effects in the arctic. Furthermore, reduced local diesel requirements means less of the fuel will need to be transported by ship into Salliq and stored each year, thus reducing the likelihood of environmentally damaging marine and terrestrial spills.

In addition to environmental benefits, a solar project of this size will present both short and long term local economic benefits. A project of this type would bring a limited number of contract opportunities during development and construction, as well as opportunities for skills training within the community to support long term facility maintenance and operations. As a project that aims to operate as an Independent Power Producer (IPP), this project also represents a new public-private-sector infrastructure investment for the community.

Finally, because the IPP framework is a newly emerging program in Nunavut, this solar project is poised to be a groundbreaking undertaking within the territory, and will set the stage for additional similar projects within the region and across northern Canada.

Salliq will become a clean energy leader, contributing to improved capacity, experience, and industry supply chains that will reduce barriers to entry for subsequent clean energy projects in northern Canada.

1.2. INDIGENOUS OFF DIESEL INITIATIVE

This project implementation plan is being developed as part of the federal funding program known as the Indigenous Off Diesel Initiative (IODI). The IODI is a three phase funding program, with each phase containing specific tasks and related funding, as follows[1]:

The IODI kicked off in spring of 2019 with the selection and training of local Energy Champions to lead their communities in the creation of a diesel reduction initiative. Led by their Champion, communities received funding and expert support to develop and build a Community Energy Plan. CEPs are intended to assess the current energy situation within a community, review possible clean energy solutions and areas for improvement in energy efficiency or reduced environmental impact, and narrow in on viable solutions that can be implemented over the short and long term.

Following the outcomes of the CEP, each community then identifies a project (or projects) and creates a detailed project implementation plan. Ultimately, the IODI external Indigenous jury will review all CEPs and implementation plans to determine who is eligible for additional funding to begin pursuing their development plans in Phase 3. Successful communities may then be selected to receive additional follow-up funding after the wrap up of IODI phase 3, which is to be used for the continued implementation of their project(s).

The community of Salliq's participation in the IODI program has been supported by the following team:

- Salliq Community Energy Champion, Blaine Chislett
- Government of Nunavut (GN) Climate Change Secretariat,
    - Andreane Lussier, Climate Change Mitigation Manager
    - Jordan Blake, Energy Advisor
    - Hyacinthe Djouaka, Climate Change Mitigation Specialist

1 *Impact Canada. (2021). Indigenous Off-diesel Initiative.* https://impact.canada.ca/en/challenges/off-diesel/process

- Sakku Investments Corporation, development corporation and business arm of the Kivalliq Inuit Association, in the Kivalliq region of Nunavut
    - Jean Conrad, Director of Operations
    - Cassandra Hargrave, Project Manager
    - Guillaume Guida, Vice President
    - Dino Bruce, Chairperson of the Board
- Northern Energy Capital, renewable energy project development expert and project manager
    - James Griffiths, Development Manager, CEP lead author
    - Dana May, Project Coordinator, Implementation Plan lead author
    - Malek Tawashy, CEO
- Green Cat Renewables, renewable energy technical expertise, engineering, and design support

At present, the Salliq Project Team is in Phase 2 of the program. With the completion of this Implementation Plan, the CEP, and accompanying training and capacity building, Salliq will have fulfilled the requirements of Phase 1 and 2 of the program, and will be submitting their application for Phase 3 of the program.

1.3. PROJECT SETTING

1.3.1 LOCATION

The community of Salliq (known in the local language as Salliq) is a small, remote coastal town situated on the southern side of Shugliaq Island (also known as Southampton Island). Shugliaq Island is a large landmass at the northern mouth of Hudson Bay, and is one of the most southerly islands in Nunavut. A map of the community's location is included in FIGURE 1.

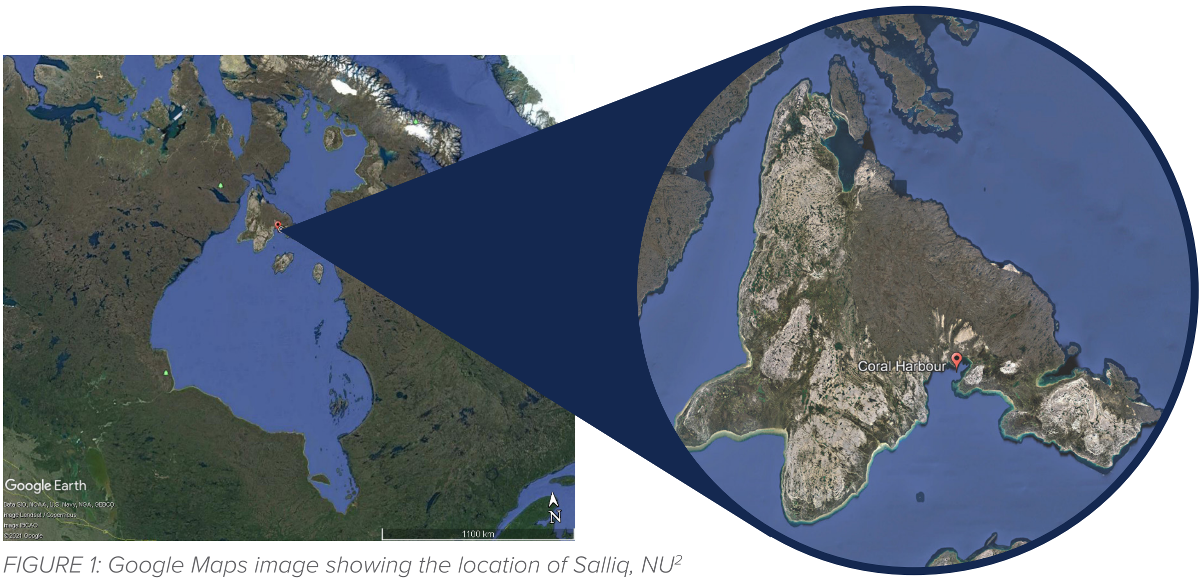

FIGURE 1: Google Maps image showing the location of Salliq, NU[2]

2 Google Maps: https://www.google.ca/maps/place/Coral+Harbour,+NU/@62.8543967,-84.0437669,6z/data=!4m5!3m4!1s0x4def62c2e842db7b:0x6a74a228b2240d29!8m2!3d64.138834!4d-83.169897

As of the most recent census in 2016, Salliq was home to 891 people. Over 96% of the population identify as having Indigenous ancestry, and the community has a strong base in the local language, Inuktitut. Historically, the people of Salliq were the Sallirmiut, believed to be some of the last of the Thule Inuit of the arctic. Today, the people of the region have varied histories, and the Inuit of the region are represented by the Kivalliq Inuit Association (KIA).

Ecotourism is strong in Salliq, as it is a well loved location for tourists seeking sights of wildlife such as polar bears, walrus, caribou, beluga whales, and migratory arctic birds[3]. Residents' livelihoods within the community vary, with the most common industries being public administration, retail trade, educational services, and healthcare and social assistance. A small proportion of residents report livelihoods in agriculture/forestry/fishing/hunting, but no stats are available for residents that take part in traditional unpaid activities like hunting, whaling, and fishing[4].

A complete, detailed community and geographic profile for the town of Salliq can be found in Section 2 of the Salliq Community Energy Plan[5].

Salliq is located in the southern arctic ecozone of Canada, within the ecoregion subcategory of the Southampton Island Plain. FIGURE 2 shows the ecozones of the Kivalliq region of Nunavut. The region is characterized by predominantly low elevation plains, with frequent bedrock outcroppings, and is bounded by continuous permafrost with medium ice content. The region experiences seasonal cycles which rotate through very cold temperatures and long periods of darkness in the winter, to mild temperatures and long sunny days in the summer. From November until June, the ocean is covered in sea ice, and much of the land is blanketed in snow. When the sea ice is melted, the region often experiences fog, and coastal ice is persistent[6].

Being north of the latitudinal treeline, local flora and fauna in the region consists of low shrub tundra vegetation such as dwarf willow and birch, sedges, mosses, and grasses, as well as wildflowers. As mentioned above, the wildlife in the region is rich, with a wealth of migratory birds and marine life such as seals, walrus, and whales. The island is also host to polar bears, caribou, wolf, weasel, arctic hare and fox, among others[7]. Flora and fauna of the region are well adapted to the climatic conditions and seasonal cycles, as are the people who live in the region.

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3 Nunavut Planning Commission (2021). Salliq. https://www.nunavut.ca/coral-harbour

4 Statistics Canada. (2016). Census Profile, Salliq. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=6205014&Geo2=CD&Code2=6205&SearchText=coral%20harbour&SearchType=Begins&SearchPR=01&B1=All&TABID=1&type=0

5 Griffiths, J. et al. (2021). Community Energy Plan for the Hamlet of Salliq, Nunavut. pp. 22-40

6 GN Department of Environment. (ND). Kivalliq Ecological Land Classifications Map Atlas.

7 GN Department of Environment. (ND). Kivalliq Ecological Land Classifications Map Atlas.

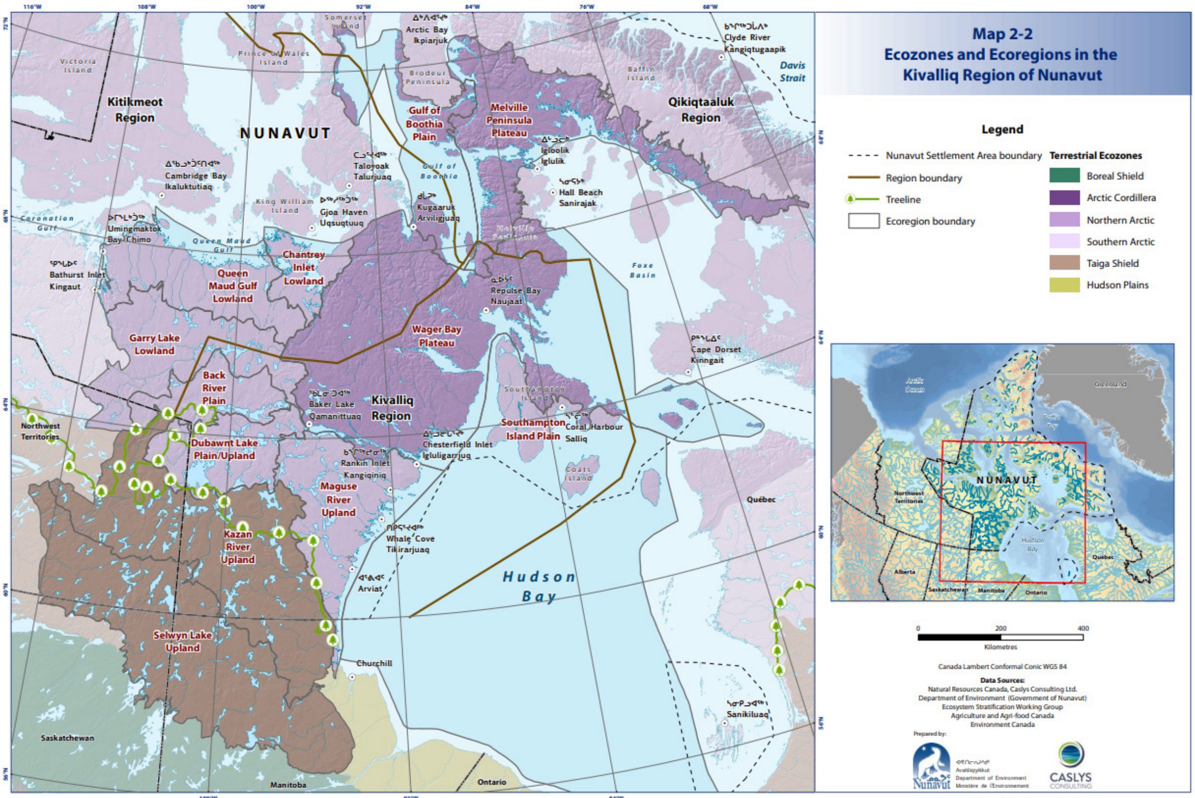

FIGURE 2: Ecozones of the Kivalliq Region of Nunavut. Salliq is located in the Southern Arctic Ecozone, indicated in light purple[8]

The harsh climate and remote location of Salliq present special challenges to any would-be developer of a renewable energy project. As an island community over 300km from the next nearest town, virtually all transportation into and out of Salliq occurs via ship in the summer, or by plane year round. There is a small local airport 12 kilometers northwest of town which transports primarily people and some smaller goods into and out of the area. With the ocean frozen for a large percentage of the year, there is only a short summer window for the delivery of the majority of goods via ship. This is an important consideration for any infrastructure project of moderate size which must bring in equipment and materials.

Projects will benefit from the local capacity, as industry within Salliq is well equipped to handle all the general needs of the community. However, since local industry is specific to the day-to-day needs of the community, highly specialised or non-locally available goods and services must be brought in from larger municipalities to the south. This often includes specialized industrial services and equipment. As a result of these challenges, the cost of living in Salliq is high, and many residents supplement their needs with traditional activities like hunting, fishing, whaling, and sealing.

1.3.2 LOCAL GRID AND ENERGY SETTING

The energy infrastructure in Nunavut is made up of local microgrids run by the territorial Utility, which supplies electricity needs to residents of each town. A microgrid is defined as a localized network of electrical services that serves a small number of customers, and which is supplied by its own power source[9]. Microgrids are able to operate autonomously from the larger national grid,

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8 GN Department of Environment. (ND). Kivalliq Ecological Land Classifications Map Atlas. https://www.gov.nu.ca/sites/default/files/kivalliq_ecological_land_classification_map_atlas_section_2.pdf

9 US Department of Energy. (2014). How Microgrids Work. https://www.energy.gov/articles/how-microgrids-work and may be either entirely separate from the national grid, or in some cases may be connected but able to disconnect and operate independently if desired. Microgrids can be quite small, servicing only a single home or business, or they can be larger, servicing a single small town or neighbourhood.

Due to their small size, microgrids face different challenges than those experienced by a large national grid. A national grid will have many different sources of power and extend over an expansive network of electrical cable, allowing it to absorb fluctuations in supplied energy. Large grids also have many customers, resulting in an averaged-out energy demand profile that follows a predictable diurnal pattern. Fluctuations in energy supply and demand are thus handled relatively easily by the grid infrastructure.

Microgrids, on the other hand, can experience instability when large jumps or drops in energy supply occur, causing surges of power or blackouts if not properly regulated. For this reason, microgrids must employ technological control systems like software programs, and may often include energy storage systems to level out supply and demand. Energy storage systems – such as batteries – will absorb and store excess energy when production is high and/or demand is low, and will release that stored energy when production is low and/or demand is high. Many microgrids also prefer to rely on stable, controllable energy sources such as fossil fuel based generators. These types of generators can be held at a steady level of energy production, and can reliably increase or decrease power within its operating range to meet changes in demand. However, fossil fuel based energy production comes with environmental costs, including air pollution, GHG emissions, human health impacts, and damage to terrestrial and marine ecosystems from fuel spills.

Renewable energy sources such as solar, wind, hydro, geothermal, and biomass, are all possible sources of energy with lower environmental impact that can be used on a microgrid. Some of these renewable sources are quite stable, while others are more intermittent and may require more stabilizing infrastructure. All have varying costs and requirements to build, and were considered and analysed for viability in Salliq within the CEP. A summary of the results of the CEP analyses and the resulting recommendations will be provided in Section 1.4 of this report. Regardless of the type of renewable energy chosen, the proper control technologies and energy storage systems must be incorporated for a project to successfully integrate within a microgrid setting.

In Nunavut, the territorial Utility is Qulliq Energy Corporation (or QEC), which owns and operates microgrids for each of the 25 communities within the territory[10]. All of the local grids operate independent of one another, and are separate from the national grid system that serves much of the rest of North America.

All of the electrical grids run by QEC are currently dependent on fossil fuels, specifically diesel generators. Most communities require between 3-5 generators to match the size of the town's energy needs, though some larger communities require more[11]. Diesel fuel is supplied by the GN's Petroleum Products Division[12], and is shipped into Salliq via barge and stored within QEC facilities. Both the shipping and storage of fuel presents environmental risks, as fuel may be spilled during transport, or can be accidently released to the environment during use or when stored improperly. Any reduction in the amount of diesel fuel required by the community would decrease this environmental risk by lowering the volume of fuel needing to be transported and stored each year.

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10 CIPP Technical Interconnection Requirements, QEC, 2021
11 CIPP Technical Interconnection Requirements, QEC, 2021
12 GN (no date). Petroleum Products Division. https://www.gov.nu.ca/petroleum-products-division

In Salliq, the town's energy needs are met by three 1,200RPM diesel generators, with capacities of 720kW, 300kW, and 540kW[13].These three generators give the community a maximum generating capacity of 1,320kW. According to QEC, Salliq uses 3,609 MWh of electricity each year (as of FY2018-19), with the average consumption being 406kW, and the peak consumption occurring at 731 kW. QEC projects for this consumption to increase to 3,915 MWh by 2025[14]. A detailed overview of the energy baseline in Salliq, including the uses, cost, and rate structure of different fuels, is provided in Section 4 of the CEP[15].

The current energy setting within Nunavut as a whole, and within Salliq specifically, leaves a large area of opportunity for the integration of renewables into the Utility's operations. At present, there is very little renewable energy penetration on any of QEC's remote community grids. Projects that do exist are typically at a very small scale through QEC's net metering program, such as rooftop solar panel installations, as well as a solar energy demonstration project in Iqaluit[16]. As such, any renewable energy project of moderate or larger scale will have a big impact as far as a reduction of overall fossil fuel use, improved environmental performance, and reduced pollution and emissions. Additionally, given that many of the microgrids under QEC's care serve small communities, a moderately sized renewable energy project will have a significant impact on the community's energy supply, causing a sizable portion of the local annual energy demand to be produced locally.

Also of note is the fact that much of QEC's electrical infrastructure is aging, and updates and replacements can be challenging due to the remoteness of the communities QEC serves. The development of a novel clean energy project will inject much needed new electrical infrastructure into the grid. As a result, it is the belief of the Project Team that any kind of renewable energy project at a commercial or utility scale will be beneficial for the community of Salliq. Thus, it is a matter of finding the type of project which is the best fit for the community's geographic and climatic setting, and which makes the most economic sense over the short and long term for both the Hamlet, and the Proponent.

1.3.3 ECONOMIC CONSIDERATIONS

The CEP for Salliq outlines currently available government programs aimed at supporting the clean energy transition in Nunavut. These programs target a number of different areas including heating, building energy efficiency, energy retrofits, and incentivizing renewable energy projects. Of the programs reviewed, those applicable specifically to the development of a renewable energy project were limited, and include QECs Net Metering Program, their Commercial and Institutional Power Producer program (CIPP), and an upcoming Independent Power Producer program (IPP).

The Net Metering Program is targeted towards residential customers interested in installing small-scalerenewable power on their homes, and only allows one municipal government account per community[17]. As such, it is not a good fit for a project of larger size. The CIPP, while targeted more towards the commercial side, would likely be able to support only small-scale rooftop solar in Salliq, due to limitations and restrictions set by the program on installation size, ownership, and location[18].

13 QEC. (2019). Salliq SLD, Rev. G.
14 CIPP Technical Interconnection Requirements, QEC, 2021
15 Griffiths, J. et al (2021). Salliq CEP. pp 54-62
16 QEC. (2021). Solar. https://www.qec.nu.ca/node/167
17 QEC. (2018). Net Metering Program. https://www.qec.nu.ca/node/759
*18 QEC. (ND) CIPP Frequently Asked Questions. https://www.qec.nu.ca/sites/default/files/cipp_*

While the Utility's IPP program has not yet been released, this program has been under development for several years, and the Utility has stated that it is finalizing details of the program[19]. An IPP program would be the most desirable candidate for the development of a meaningful renewable energy project in Salliq, as it presents a number of benefits for the project. Such a program would allow non-Utility producers to generate clean electricity at Utility scale, without the restrictions related to location and ownership faced by the CIPP. The pursuit of an IPP project does, however, present some risk to the project timeline because the policy has not yet been finalized or released by QEC.

IPP frameworks are used globally to allow independent developers and operators to build renewable energy projects that benefit both the Utility and its customers, as well as the private business owners who operate them. While QEC has the experience of owning and operating power generating facilities in Nunavut, it is not necessarily the best positioned to make the large upfront capital and human resource investment required to design, build and operate a new renewable power generating facility[20]. Independent organizations may be able to help fill this gap, with increased flexibility to obtain funding or other sources of investment. Through QEC's IPP program, independent project owners can undertake the development and construction of a renewable energy facility, while QEC gains the additional power generation capacity for its grids. Project owners will then benefit from revenues through the sale of electricity.

Under an IPP program, the project Proponent will have more flexibility with regards to project size and location. Projects can be developed in the most suitable location for the type of energy being generated, rather than being restricted to the existing property of QEC customers, as they would be under the CIPP or Net Metering Program. IPP projects generally have size restrictions to ensure the local grid is not overloaded, however, these size limitations are at the utility scale and intended to allow electricity generation that would serve multiple customers. As such, an IPP project in Salliq could be scaled to the most appropriate size for the local grid, while also maximizing the diesel reduction opportunities for the community.

It is not yet known what structure QEC will provide for its IPP program, though information from QEC to date indicates it will likely be a "Standing Offer" type program, which sets a fixed price for energy based on location and accepts project Proponents that come forward with a project that can deliver energy at that price. QEC currently sets its rates using a combination of a fixed rate component, and a variable component, as described below[21]:

Total electricity rate = Fixed Component + Variable Component

where

Variable Component = QEC Diesel Cost

and

Fixed Component = Infrastructure, Investment and Operations Costs

The variable component is different for each community, and was adopted from the pricing structure of QECs predecessor, Northwest Territories Power Corporation. QEC has indicated that the maximum amount it will be able to pay for renewable power is the variable cost component,

faqs_18feb2021_eng.pdf

19 QEC. (ND). Independent Power Producer Program. https://www.qec.nu.ca/customer-care/generating-power/independent-power-producer-program

20 QEC. (2018). QEC Energy Framework: The cost of generating electricity in Nunavut. https://www.qec.nu.ca/sites/default/files/qec_energy_framework_-_generation_-_april_18_eng.pdf

21 QEC. (2018). QEC Energy Framework: The cost of generating electricity in Nunavut.

without risking raising the cost of electricity for customers. Customer rates for electricity are already subsidized in Nunavut, to make it more affordable for customers that have a very high cost of living[22]. These factors make the cost of electricity inflexible and artificially cheap, and is a challenge faced by Proponents of renewable energy projects that wish to sell electricity.

An IPP project is thus also desirable because a larger, utility scale project is the most economically beneficial option for the project owner as a business opportunity. While this project has many social and environmental benefits, it is also a business venture, and must be approached with the intent to create a financially sound, economically feasible project with a good overall business case. The challenges presented by Salliq's remote location and limited access to specialized industry and services will result in an unavoidably higher capital cost to build and operate a renewable energy project. In combination with the funding opportunities available for renewable energy projects in northern Canada, and the proposed pricing structure from QEC, a larger project in Salliq will present the economies of scale necessary to make this project worthwhile and sound from a business perspective.

A detailed business case for the project is presented in section 5.0 of this document.

1.4. COMMUNITY ENERGY PLAN SUMMARY AND RECOMMENDATIONS

The CEP for Salliq presents a thorough and detailed look at the energy landscape within Salliq, including the challenges and opportunities available, and an assessment of their viability for implementation. A summary of the areas considered in the CEP are included below:

- Detailed community profile, including location, climate, demographics, history, governance and community/regional land use planning
- Current energy efficiency and energy improvement initiatives
- Local capacity and existing energy program opportunities
- Energy baseline for the community, including current sources of electricity and heat, energy uses, pollution and GHG status, building stock, and waste

Energy efficiency opportunities:

- Building efficiency improvements
- Self install home energy kits
- Building code and standards compliance
- LED lighting
- Heat pumps and geo exchange
- Tiny homes

22 *Griffiths, J. et al. (2021). Salliq CEP*

Clean energy project opportunities:

- Solar energy
- Wind energy
- Biomass energy
- Hydroelectric and run-of-river energy
- Ocean based energy (tidal, wave)
- Geothermal energy
- Energy storage assessment

Other energy transformation opportunities:

- Waste to energy
- Waste heat capture
- Electric thermal storage
- Electric vehicles
- Greenhouses

Following a review of the above, the CEP team then categorised these opportunities based on how viable they would be for the community, and the timescale over which they could be implemented, if at all.

1.4.1 NEAR TERM CEP ACTIVITIES

A key output of the CEP process was a 5-year plan for Salliq. The 5-year plan outlines major deliverables for the community over the short term to help Salliq reach its diesel reduction goals. A summary of the 5-year plan can be found in the CEP in Section 8.5, and is also included in FIGURE 3. Sections 1.4.1 - 1.4.3 of this report, provide additional details and rationale for this plan, as well as how it fits within Phase 3 of the IODI program and beyond.

Of the opportunities presented in the CEP, several were identified as readily actionable, or "low hanging fruit". Steps towards starting these activities have already been initiated within the community. The first of these tasks is the distribution of self-install home energy efficiency kits to local residents. These kits will be distributed early in 2022 during a planned community visit in February, and will be accompanied by instructional videos to aid residents with proper installation. Kits include low-cost, easy to install changes that residents can make on their own within their homes to save on energy use or water use.

Another activity with a short term outlook is to implement an LED lighting campaign to replace incandescent bulbs with LED bulbs in all public buildings. This activity has not yet been started, but the Project Team will take on the role of identifying a leader for this project during Phase 3. The CEP Team partners envision that this project could be led by a representative from within the Government of Nunavut, such as Community and Government Services, in collaboration with the

YEAR 1 - 2022

- Completion of the community engagement work that was delayed during the CEP. Community engagement work will continue through year 1 and beyond.
- Distribute self-install energy kits and associated videos.
- Inform local homeowners regarding the potential for rooftop solar under net metering.
- Develop and hire a "Regional Energy Manager", to assist with coordination of energy planning and act as a liaison on projects.
- Seek funding to implement energy efficiency upgrades to buildings that have been audited, and to audit additional buildings.
- Seek funding (IODI Phase 3) to complete development work on a clean energy project (wind or solar plus battery).
- Initiate environmental permitting, design, and engineering work to progress clean energy project.
- Engage with QEC to conduct a grid impact study for clean energy project.
- Work with the GN and Hamlet to ensure that LEDs are installed in commercial/community buildings.

YEAR 2 - 2023

- Continued community engagement work towards one or more clean energy project.
- Final stages of development work to progress selected clean energy project (solar+battery) to "shovel-ready".
- Work with the GN to advance a biomass heating pilot project, including pursuit of funding.
- Implement energy efficiency upgrades to buildings that have been audited.
- Conduct energy efficiency audits on additional buildings.
- Work with NHC and homeowners to encourage energy efficiency solutions in residential buildings.
- Develop a longer-term plan for maintenance and updates to the self install energy kit program.

YEAR 3 - 2024

- Construction of selected clean energy project (solar) under QECs IPP program.
- Continued implementation of energy efficiency upgrades to buildings.
- Revisit planning for additional clean energy projects, such as wind, and begin planning for wind resource assessment.
- Continued work with GN to advance biomass heating pilot project.

YEAR 4 - 2025

- Completion of construction on clean energy project (solar) and beginning of project operations.
- Target date for implementation of the biomass heating pilot project.
- Hiring/training for maintenance work to support the new clean energy project.

YEAR 5 - 2026

- Review of literature to learn the current status of emerging technologies including waste heat capture, electric thermal storage, electric vehicles, greenhouses, and geo-exchange / heat pumps.
- Hamlet to organize a team to revisit the CEP, to review progress to date, and to set new goals for the next 5 years.
- Begin collecting data from the biomass heating pilot project, solar project, and wind resource.

Figure 3: Summary of the 5-year Community Energy plan for Salliq

Hamlet, with an opportunity for local training and capacity building during the project. The CEP Team has also been instrumental in organizing a building audit for one public building within Salliq. This audit was conducted in July of 2021, and included an in person inspection of the selected building to collect energy information and photos. This information was reviewed at a desktop level by SES Consulting, who specializes in building energy efficiency audits. The audit will be used to help the team understand what kinds of building retrofits could have the biggest impact on energy use and efficiency. Details on the outcomes of the audits can be found in the CEP, section 5.1.

Following the results of the building audit, building renovations and retrofitting will be pursued in the audited building over the short to medium term. An opportunity also exists to identify and audit additional buildings as part of an ongoing building upgrade program. Building upgrades, if applied to key facilities that are large energy users, could have a large impact on energy use within the community. During Phase 3, the Project Team intends to support planning for a building upgrade program, as well as to pursue project partners that could work with the Hamlet to lead such a program. In addition to planning work, funding that could support such a program will also be sought.

To support the activities described above during Phase 3, as well as energy planning over the longer term, the Project Team envisions a Regional Energy Manager role, positioned within Sakku Investments Corporation. This role would be based in Rankin Inlet, and would provide support to sustainability and clean energy initiatives across the region, including both Salliq and Naujaat. Members of the Project Team have already applied to NRCan's Smart Renewables and Electrification Pathways (SREP) program for funding to support this role, through the Capacity Building Stream. This funding has not yet been approved, therefore, planning for this role to be supported by IODI Phase 3 funding has also been put in place, in case the other funding is unsuccessful (if SREP funding is successful, these IODI funds will be used elsewhere). Once a source of funding is confirmed, development of a job description and recruitment can begin.

In addition to the above activities, the Project Team committed to selecting a single larger project to advance during Phase 3 and 4.

Wind energy, solar energy, and a biomass pilot project stood out as the most viable, high impact options for Salliq to consider in the short to medium term.

These projects are more complex, cost more to build, and take longer to implement, but would have a bigger impact on offsetting GHG emissions and displacing local fossil-fuel based energy use. Such a project would be owned and operated by Kivalliq Alternative Energy (the Proponent), a majority Inuit owned organization and partnership between Sakku Investments Corporation and Northern Energy Capital.

1.4.2 COMMUNITY ENGAGEMENT AND PHASE 3 PROJECT SELECTION

Based on the recommendations of the CEP, the Salliq Project Team assessed the list of viable, larger impact clean energy projects, with the goal of selecting the best single project to be the focus of implementation in the community during Phase 3 of the IODI program.

Ultimately, the biomass pilot project has been postponed over the short term, but will be revisited by the CEP Team in 1-2 years. While biomass technology is well developed in other parts of the world, uncertainties related to shipping and the ability to store wood pellets in a completely dry state for long periods of time in the community give the project a higher level of risk, and a pilot project will help test feasibility ahead of local use on a larger scale. Over the medium term, the Project Team intends to work with the Government of Nunavut to advance planning for a biomass pilot project in the Kivalliq region (either in Naujaat or Salliq). If the pilot project is successful, full scale biomass projects could be more confidently implemented throughout the region. Biomass is of special interest for its ability to generate both electricity and heat, something that most other renewable energy sources do not offer. However, as a pilot, the biomass project would not have a large upfront impact due to its intentionally small scale, and thus will not be the focus of Phase 3 IODI activities.

Of the remaining two projects which would be viable for the short term (and ultimately for Phase 3 IODI activities), solar and wind energy remained as very feasible and promising options. Both types of renewable energy were widely supported by residents in the community survey conducted during the CEP phase. Wind and solar technologies are well developed and proven in cold climates, and could be implemented at full scale in a few years. This means the impact of such projects would be significant even over the short term.

The CEP proposed several sizes of solar and wind projects that could be implemented. To better understand which type and size of project would be most suitable for the community, the engineering and design team modelled and analyzed a range of solar, wind, and mixed wind and solar options, both with and without energy storage. Modelling was first reviewed in consultation with the Project Team partners and the Proponent. Factors considered in this process included:

- Energy resource potential, based on desktop solar and wind data available for the region.
- Suitability of topography, land cover, and climate for various sizes of installation.
- A system integration study, in collaboration with QEC, to determine the most suitable size and type of project that could be integrated with the local grid without causing adverse impacts. This study can be found in Appendix 1, and looked at the following:
    - Analysis of total energy use by the community, hourly, daily, and annually.
    - Estimated energy output from various sizes of solar or wind project compared against seasonal demand profile.
    - Grid stability at various levels of renewable energy penetration based on project type and size, and the role of an energy storage system in stabilization and grid performance.
    - Cost analysis for the development and installation of each type and size.

Following this technical analysis, the Project Team put together informational community handouts to facilitate discussions with the Hamlet during a site visit undertaken in July. Handouts were provided in Inuktitut and English, and described each of the clean energy technologies under consideration. Also included was a cost benefit analysis to inform hamlet representatives, answer general questions, and aid in project selection. A copy of this handout can be found in Appendix 2. Ultimately, the intention was to select a project that was in alignment with the goals, values, and business plans of the Proponent and the Hamlet, in terms of complexity, cost, and time to develop and construct.

Community engagement throughout the project selection process has been a priority for the Project Team. Unfortunately, however, engagement has been an ongoing challenge due to the COVID-19 pandemic, resulting travel restrictions, and a shortage of resources. The Project Team made a continued effort throughout Phase 2 to organize meetings and arrange community visits, and despite early delays, were able to successfully complete a visit in July of 2021. This visit was important to achieve initial communication with community members, and to visit candidate sites for a clean energy project.

Beyond the visit to Salliq in July, the team have faced ongoing difficulties with engagement, primarily related to the time and resource availability of the Hamlet and the Project Team. A second visit was planned for November of 2021 to host much more extensive community engagement, including an open house for the general public to attend and ask questions, and a meeting with the Hamlet to progress community energy planning. Unfortunately, due to pandemic travel restrictions and resource challenges, this visit had to be postponed to early 2022. Input and communication from the 2022 trip will be used to confirm siting and development plans for the solar project, and to further inform and align community energy planning for the short and long term.

Following the above technical assessment and initial consultation with the Hamlet, the Salliq Project Team determined that a 960kW_{AC} solar energy project with an accompanying 1MWh battery for grid stability would be the highest impact project for Salliq to pursue in their short term energy planning. Such a project is attainable, will have a big impact on diesel reduction, and can be progressed considerably during Phase 3 of the IODI program. As such, this solar project will be the focus of Phase 3 work within the IODI program.

1.4.3 FUTURE ENERGY PLANNING

Once the solar energy project is completed, the community of Salliq will have the opportunity to revisit other projects identified in the CEP over the medium to long term. Through the CEP process, remaining projects and activities under review were categorized into a future consideration, or rejected list.

Several projects noted for future consideration are not viable for the community at the present time based on current infrastructure and availability, or because the technologies are not yet mature enough to be implemented successfully in a remote location such as Salliq. Other projects could be implemented sooner, but require additional time and resources to plan, and have therefore been earmarked for review at a later time. All of these projects could become promising options for Salliq in the future, and should remain under consideration in the community's long term energy plan.

Projects of interest that should be revisited include:

- Implementation and maintenance of the building retrofit program, including additional energy audits and building upgrades, and ongoing building maintenance.
- Planning for a long term renewal or maintenance program for the self-install home energy kits, to enable residents to keep homes up to the most current energy efficiency standards.
- Following completion of the biomass pilot project, consideration of results and determination of feasibility for full scale biomass projects.
- Clean solutions to heating, including heat pumps or geoexchange systems, electric thermal storage, or increased electrification of heating systems
- Further penetration of the electrical grid with additional renewable energy sources, such as wind energy. Wind energy may better support winter electricity needs.

- Waste heat capture opportunities using heat from the diesel generators. Heat could be used to warm a pool, greenhouse, or other facility built nearby to the powerhouse.
- An electric vehicle program, if the local grid reaches a point where renewable energy provides the majority of the electricity generation.

Rejected projects identified in the CEP were deemed to be not suitable for implementation in Salliq at any time, and included the following: tiny homes, hydroelectric and run-of-river energy, ocean based energy, geothermal energy, and waste-to-energy. A detailed overview of the strategic goals and recommendations that came out of community energy planning for Salliq can be found in section 8 of the CEP

The remaining sections of this report will discuss the implementation plan for the proposed solar energy project in Salliq. Topics will include proposed site locations, analysis of the resource potential for a solar project, and the road map for the design, development, and construction of a solar project in Salliq.

2. Solar Energy Resource Assessment

In this section, an overview of solar energy is provided, along with an analysis of several proposed locations for the installation of a solar energy generating facility. A desktop review of the energy generating potential of the sites is also presented, followed by a review of the energy storage system component.

2.1. SOLAR ENERGY

Solar energy technologies capture light energy from the sun and convert it to electricity using solar photovoltaics (solar PV). Solar PVs consist of thin membranes made from semi-conductor metals (eg. silicon), mounted on self-contained glass panels. These membranes absorb light in a way that energizes electrons to create an electrical current.

Solar PV systems generate electricity in DC (direct current), which then needs to be converted into AC (alternating current), the type of electricity typically used in homes and businesses. This conversion is done with an inverter, thus allowing power to be transmitted to the grid.

At the scale of interest for this project (960kW_{AC}), solar energy projects typically include the following features:

- **Solar panels:** solar panels are made of solar PV cells grouped together in units onto glass modules. At a minimum, installations will include two or more solar panels linked together. For a 960kW project, the installation would span 2.6ha (6.5 acres), and include many hundreds of panels.
- **Mounting system:** Mounting systems are typically made up of frames attached to the ground with pile driven concrete footings
- **Inverters:** These are contained electrical units which convert energy produced in direct current (DC) to alternating current (AC), to match the local grid. A 960kW project will require several inverters, which are sized to match the capacity of the PV array.
- **Roads:** Access roads to and from the solar site

- **Electrical infrastructure:** Electrical lines and cables, which collect energy from the panels and deliver it to the grid. Depending on the distance of the site from existing infrastructure, new power lines and poles may need to be installed to connect to the nearest substation or electrical line.
- **Battery:** Not all solar projects require a battery for energy storage, however, on a microgrid an energy storage system of some kind is often required to ensure grid stability.

2.2. SITE SELECTION CRITERIA

The following technical factors should be considered when selecting a site for a commercial scale solar PV project.

- **Solar Resource:** Computer modeling can predict the solar irradiance level based on geographic latitude and cloud cover statistics with a high degree of accuracy. No direct measurement of the solar resource is needed.
- **Ground Conditions:** Much of the installation cost of a solar PV project depends on the local ground conditions. Flat, solid ground will allow for easy movement of the construction crew, as well as affordable racking and anchoring equipment. Ground that is uneven, rocky, or permafrost can lead to higher equipment and labour costs.
- **Road Access:** A site that lies closer to existing, usable roads will have lower costs than a site requiring construction or upgrades of roads.
- **Interconnection Costs:** A site that lies closer to a suitable interconnection point on the electrical grid will be cheapest. A larger project may be able to connect into an existing power line if it is of a suitable voltage. Often, larger projects need to build new electrical lines to interconnect at the nearest substation, meaning farther away locations experience higher electrical losses and higher costs.
- **Visual Impact:** Visual impacts are very subjective. Ground-mounted arrays will introduce a new structure into the landscape, which is typically low-lying and not visible from a distance.
- **Footprint:** Commercial scale solar PV projects take up a lot of land compared to most other energy technologies. In order to maximize efficiency, it is important for the design engineers to lay out the rows of PV panels so that they are optimally oriented toward the path of the sun. In northern communities these panels are often oriented close to vertical so that they capture as much winter sun as possible, when the sun is low in the sky. This requires spacing between long rows of panels.
- **Noise:** Solar panels themselves do not generate any noise, however the electrical components (e.g. inverter, transformer) can create noise. For a larger solar PV system, noise should be considered when selecting a site.
- **Glare:** Solar PV technology is specifically designed to absorb as much sunlight as possible, however, occasionally reflected light can cause a glare effect. Solar arrays should therefore be designed and sited to ensure there are no adverse glare impacts, such as to a nearby airport runway.
- **Environmental Impacts:** Environmental impacts from solar PV projects are typically very low, and limited to land use displacement and construction. Nevertheless, sites with the potential to cause unacceptable environmental impacts, or impacts on traditional land use, should be identified and avoided.

2.3. PROPOSED PROJECT LOCATIONS

The Salliq Project Team has conducted a screening of various potential solar energy sites within the vicinity of Salliq, and compared candidate sites against the criteria described above. Following an initial desktop review, five sites were shortlisted for more detailed evaluation, including a site visit which was conducted in July, 2021. A map of the five sites under consideration is included in FIGURE 4.

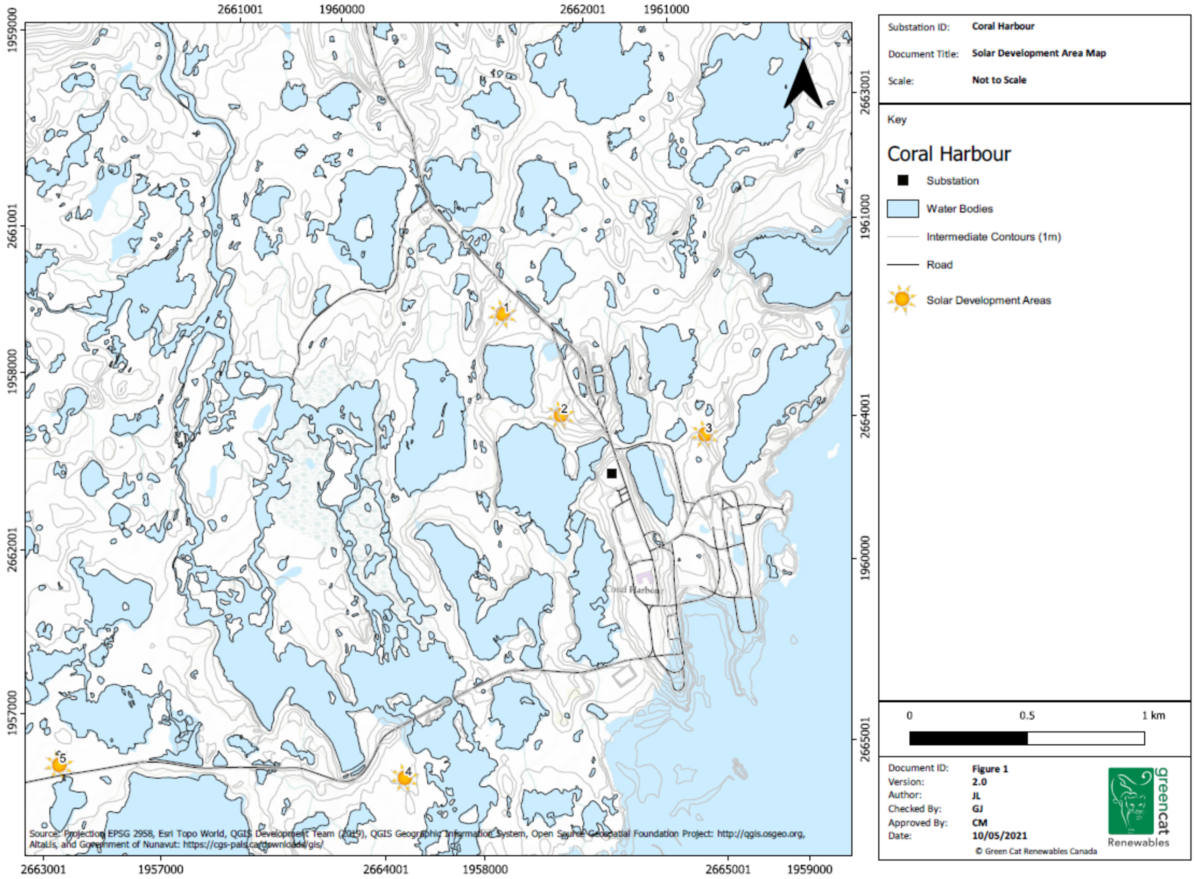


FIGURE 4: Solar energy development sites at Salliq, NU. Solar sites are indicated by the sun symbols, and the hamlet's substation is indicated by a black square.

Following the site visits in July, Site 4 and Site 5 were immediately removed from consideration due to clear site constraints that would not allow a solar project to continue. Site 4 was removed from consideration due to its close proximity to the local cemetery and the presence of several Inukshuks which likely indicate heritage resources in the area. Site 5 was extremely wet and marshy, and was therefore removed from consideration due to unfavorable environmental conditions. Such conditions would not only be difficult to build on, but also present a higher likelihood of use as habitat by wildlife such as birds.

In addition to the originally proposed sites listed above, the Hamlet council of Salliq has also proposed a preferred site for the development of a solar energy project. This site is considered in the following sections as a new Site 4, following the removal of the originally proposed Site 4.

All four sites are discussed in further detail in the following sections.

2.3.1 SITE 1

Site 1 is located to the north of the hamlet, approximately 1.3km northwest of the community centre, on a wide, flat grassy area. Solar panels could be installed at the approximate coordinates 64°08'47.65" N, 83°10'51.91' W. A simulated image of the site from Google Earth is included in FIGURE 5.

FIGURE 5: Simulated image of Site 1 from Google Earth, looking north

The site boasts favorable topography for the installation of a solar energy project. Site 1 is fairly flat, is mostly free of large boulders and bedrock outcroppings, and is quite large in area, at approximately 3.5ha (8.6 acres). If the entirety of the proposed area is suitable for development, this would be a sufficient size to host a 960kW solar installation. However, further investigation of the area would be required to determine if all of the site can be developed. If additional development space were needed, there could be the potential to expand the project area to the west or northwest of the site.

Site 1 is bounded to the south by a moderately sized water body, and by a well maintained access road along the northeast edge. From photos collected at the site visit, there appears to be an existing powerline to the west of the site which the project could potentially connect into if it is of suitable voltage and capacity. If this existing electrical line is not suitable for interconnection, approximately 750m of new electrical line would be required to connect the site to Salliq's diesel power station.

FIGURE 6: Site 1, looking southeast towards the community

FIGURE 7: Site 1, looking west. An electrical powerline can be seen in the background just past the rock outcropping

Due to the wide swath of grassland at Site 1 and the nearby waterbody, there is a possibility that this site could serve as habitat to wildlife or plant species of note. As such, additional investigation into possible adverse environmental or traditional land use effects would need to be undertaken before developing this site.

Anecdotal evidence indicates that Site 1 may be the location of the community's old landfill. The Project Team has requested additional information about this site from the GN to learn more about whether it is classified as a contaminated site. If Site 1 is pursued for this project, further research into the implications of developing on a possible brownfield site will need to be undertaken.

2.3.2 SITE 2

Site 2 is located fairly close to the community, approximately 800m northwest of the community centre, on a flat grassy area. Solar panels could be installed at the approximate coordinates 64^{0}08'34.04" N, 83^{0}10'32.60' W. A simulated image of the proposed site area from Google Earth is included in FIGURE 8.

FIGURE 8: Simulated Image of Site 2 from Google Earth, looking towards the north.

The site is fairly small, bounded on much of the south and west by water bodies, and to the north east by buildings and a road. The entire site area is approximately 1.57ha (3.9 acres), which is only about half the size of the required area for a 960kW solar installation. Additionally, there is little room for expansion in any direction due to the water bodies and buildings on all sides. While the site itself is fairly flat and mostly free of large rock outcroppings, the presence of a lot of bodies of water could indicate a higher incidence of wildlife. There is also some uncertainty about the rise and fall of water levels in these adjacent water bodies. Seasonal changes could be a regular risk, and the longer term risk of sea level rise due to climate change must also be considered. With the ground level being quite low and flat, flooding or water level rise could impact the installation.

Site 2 is located nearby to an access road, as well as existing electrical infrastructure. However, the site visit photos show that the electrical line may run right through the site, which could pose a challenge during construction, and/or limit the usable area of the site. If this site were to be explored further, more detailed mapping of the route of existing power lines would need to be reviewed. Additionally, despite the close proximity to an access road, the site itself is located in a low lying area, with a steep drop down from the road level of 2-3m. An indication of the height difference between the road and the site area can be seen in FIGURE 10. It is therefore likely that alterations to the road would be needed to accommodate access to the site.

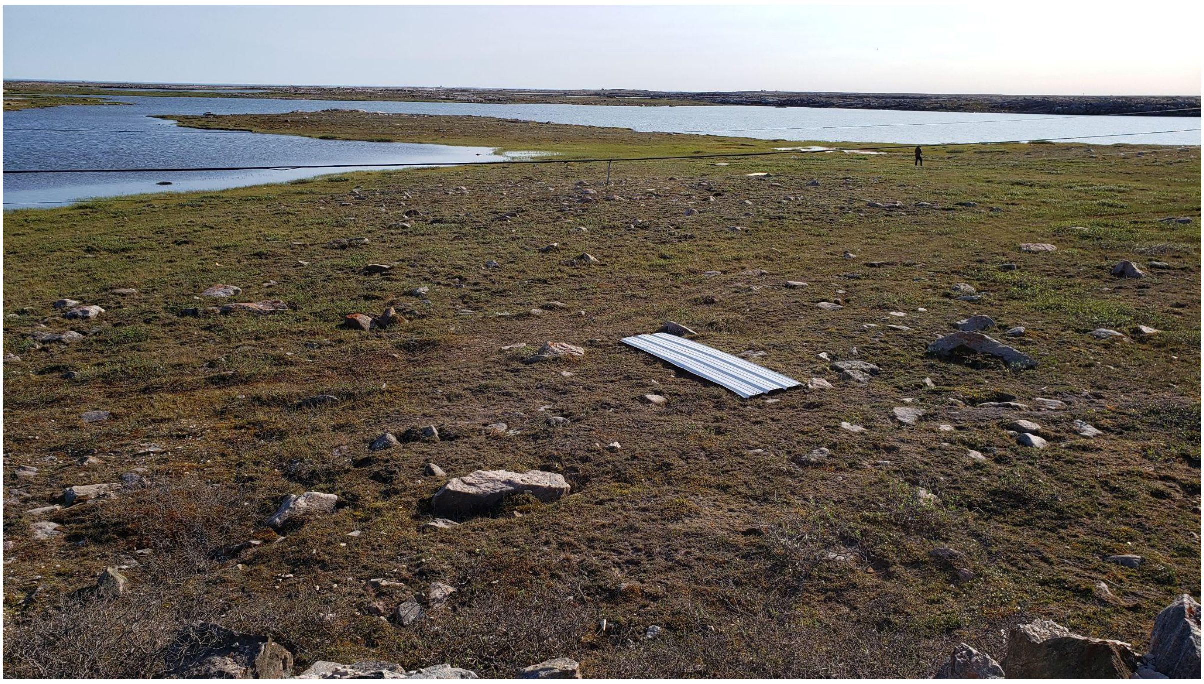


FIGURE 9: Site 2, looking south towards the large body of water

FIGURE 10: View of Site 2, looking towards the west along the edge of the existing buildings. The power line running through the site can be seen.

FIGURE 11: Site 2, looking southeast towards the community. The existing power line can be seen cutting through the site.

2.3.3 SITE 3

Site 3 is the closest site to Salliq. It is located within about 150m of the northern edge of the community and is approximately 500m from the hamlet centre. Solar panels could be installed at the approximate coordinates 64⁰08'32.07" N, 83⁰09'47.01' W. A simulated image of the proposed site area from Google Earth is included in FIGURE 12.

FIGURE 12: Simulated image of Site 3 from Google Earth, looking north away from the community

The topography of Site 3 is rougher than Sites 1 and 2, and consists of a mixture of grassland, moss, and low shrubs, along with moderate rockiness and clusters of bedrock outcroppings, as well as sections of gravel covering the ground. To the east of the site is a large body of water and then the bay, with some smaller areas of standing water or ponds along the western side. To the south are hamlet buildings and what appears to be an industrial area, with a large pile of boulders between the site and the hamlet.

FIGURE 13: Site 3, looking east towards the bay

FIGURE 14: Site 3, looking southeast towards the community, showing the bedrock outcroppings and boulders between the site and the community

Site 3 is quite close to existing electrical infrastructure due to its proximity to the hamlet. Existing electrical lines are located nearby that could potentially be interconnected into, or alternatively the hamlet's power station is approximately 500m away and could be connected via new electrical line. The road accessing the site is in poor condition and partly under standing water, so upgrades would be required. However, this segment of road is short, and upgrades costs should be minimal. The positioning of Site 3 may also block an existing access to the eastern water body, thus it would need to be determined if the project would have adverse effects on existing land use.

FIGURE 15: View from Site 3, facing southwest along the access road

In total, Site 3 is approximately 1.3ha (3.2 acres), which is not large enough to accommodate the desired size of the project. Unfortunately, there are only limited possibilities for expanding this site, with restrictions on the south, east, and west sides. There may be potential for expansion in the northerly direction, however it is uncertain how accessible that area would be. At minimum, additional road would likely need to be built to access it, adding cost to the project.

FIGURE 16: View from Site 3 to the north, where possible expansion could be considered.

2.3.4 SITE 4

Site 4 is the Hamlet's preferred development site, and is located the furthest from the community. This site is approximately 12km northwest of the community itself, and can be accessed via a well maintained road to the airport, which continues past the airport to the northeast where the site is located. Solar panels could be installed at the approximate coordinates 64^{0}12'12.65" N, 83^{0}18'12.52' W. The location of Site 4 in relation to the community can be seen in FIGURE 17. The airport runway can be seen to the left of the project site as a small gravel strip. A more zoomed in simulated image of the proposed site area from Google Earth is included in FIGURE 18.

FIGURE 17: Simulated Google Earth Image of Site 4 in relation to the location of the community. Salliq is located in the bottom right corner, while the site is in the upper left corner.

FIGURE 18: Simulated Google Earth Image of Site 4, looking southwest towards the airport

Site 4 is located on a large, open expanse of flat terrain that looks to be made of mud or crumbled rock. There are no visible bedrock outcroppings within the vicinity of the site area. The ground cover has only a small amount of plant life visible from the site photos, and appears to be mostly barren, however there do appear to be grasses or sedges in the distance. The lack of vegetation visible at the site likely means that construction would have minimal environmental impact to local flora. Additionally, the flat and even nature of the terrain would be well suited to the installation of a solar energy facility, with lots of flexibility to design the most efficient project layout. The site area does not pose any major limitations to sizing, and could easily accommodate a 2.6ha (6.5 acre) project layout.

FIGURE 19: View of Site 4 showing the flat, even, mostly barren terrain that dominates the site. Small clumps of vegetation can be seen scattered throughout, as well as a patch of vegetation in the distance.

While the terrain of Site 4 is ideal for building a solar project, there is one concern related to the location that could increase the cost of the project which is due to the nature of the electrical infrastructure servicing the site. The site is situated near an existing 12.5kV electrical powerline that runs to the airport, and then further north to the radio tower. The length of this powerline is 13.5km. The Project Team has reached out to QEC to learn more about the capacity of this electrical line, as the ability of the project to interconnect on this line without the need for significant upgrades will be instrumental to its feasibility. If substantial upgrades are required, this could be prohibitively expensive.

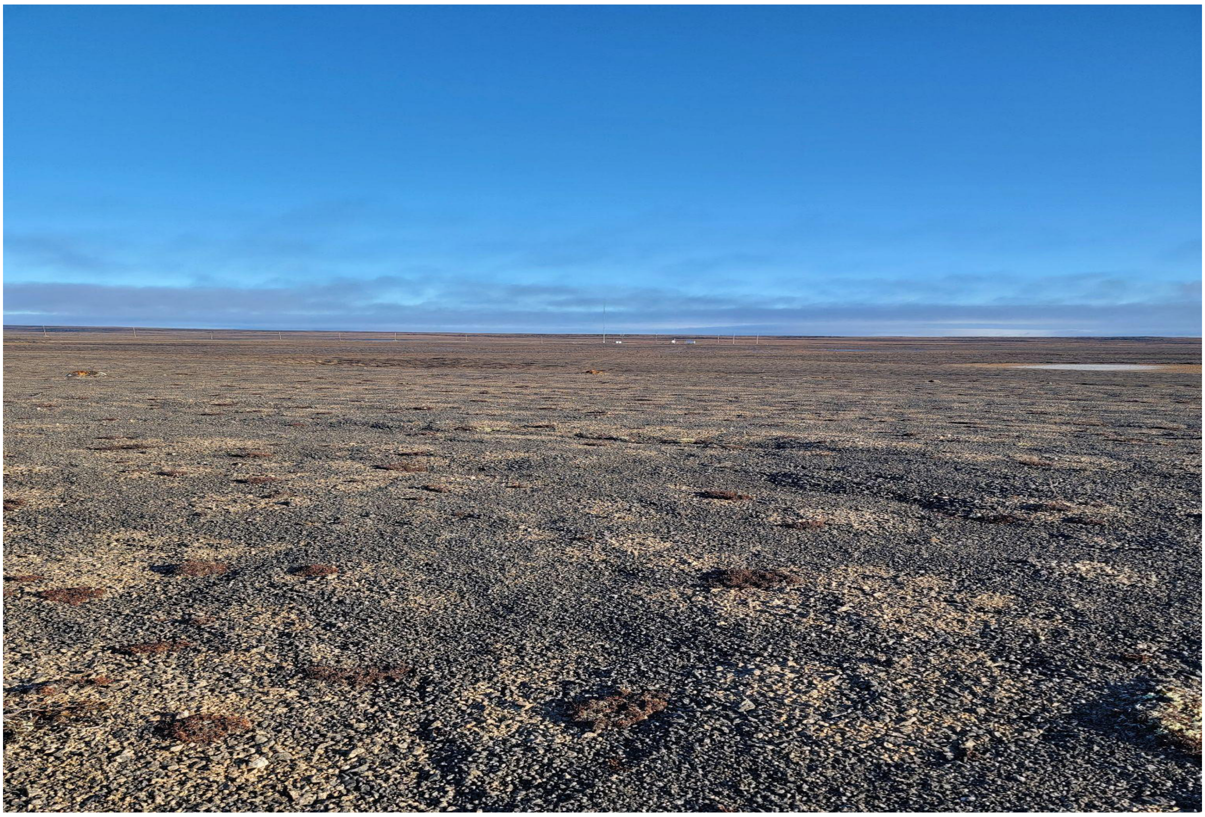


FIGURE 20: View of Site 4, looking northeast towards the road and a nearby radio tower. An electrical line can be seen in the distance running parallel to the road

2.3.5 SITE SUMMARY AND RECOMMENDATIONS

Overall, four sites around Salliq were selected for site visits and were further analysed through photographs and field notes. Following this more in depth review, it is the recommendation of the Project Team that Site 4 is the best candidate for the installation of a solar project. This recommendation is based on the following observations:

- Suitable, very flat topography with minimal prevalence of bedrock and no visible standing water which is ideal for building a large solar installation
- Strong desire expressed by the Hamlet to develop a clean energy project at this site
- Proximity to a well maintained access road
- Low risk of adverse environmental impacts at the site, which is mostly barren ground

The advantages noted above make Site 4 the best candidate for advancing development of a solar energy project. In particular, the Project Team has a strong desire to advance the preferred site of the Hamlet. However, it should be noted that there is still some significant uncertainty around the interconnection requirements at this site. The Project Team is pursuing a resolution to these issues with the assistance of QEC, the Hamlet, and the project's design and engineering team.

If for any reason Site 4 is determined to be unsuitable for the development of a solar project, the Project Team recommends Site 1 as a back-up option. Site 1 is quite large, has suitable topography for a utility scale solar installation, and is in close proximity to road and electrical infrastructure. If Site 1 were ultimately selected for a project site, further investigation into the presence of an old landfill at that location and resulting implications on development would need to be undertaken.

2.4. SOLAR RESOURCE POTENTIAL

Solar energy resource potential is expected to be similar across all of the four proposed sites. A technology comparison was completed by the project engineering team to assess different types of solar panel configurations at the site location. Three configurations were analysed:

- Fixed tilt, south facing array
- E-W split, fixed tilt array
- An east/west tracking array

In all cases, spacing between rows of solar panels was determined to be 20m to minimize losses from shading. Additionally, for both of the fixed tilt arrays, which remain stationary in the same orientation throughout the year, a tilt of 45°-55° was found to be optimal for energy production at this latitude.

The technology comparison results showed that an east-west tracking system will produce the most energy, however these systems are typically less robust and will cost more. By comparison, a south facing fixed tilt array will produce the next highest amount of energy, with the E-W split producing the least amount. Fixed tilt systems are likely to be more cost effective, longer lasting, and will require less maintenance. In all cases, the use of a bi-facial array[23] will increase energy yields by approximately 7%. Results from the analysis are shown in FIGURE 21, and the complete results from the technology analyses can be found in Appendix 3.

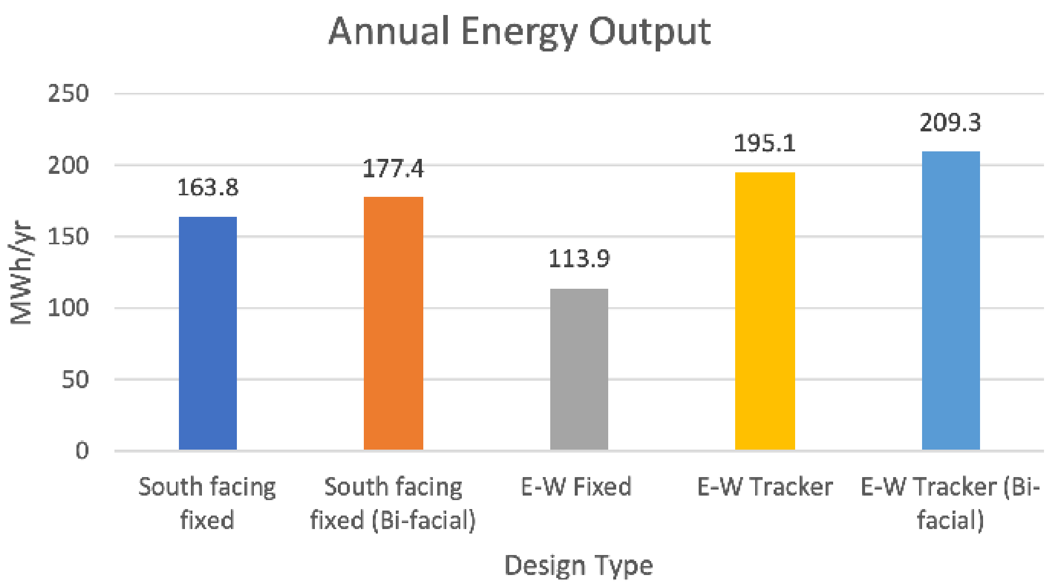


FIGURE 21: Estimated annual energy yield for different PV designs, based on a 100kW system.

Following confirmation of the specific site location and size, a more detailed energy yield assessment was completed for the recommended site (Site 4) to predict the expected annual energy production of the project. The energy yield was conducted for a 960kW project, spanning 2.63 ha (6.5 acres) in the layout provided in Section 3.2. A summary of the predicted system production of the 960kW project at Site 4 is included in FIGURE 22, and a complete copy of the Energy Yield Assessment Report can be found in Appendix 4.

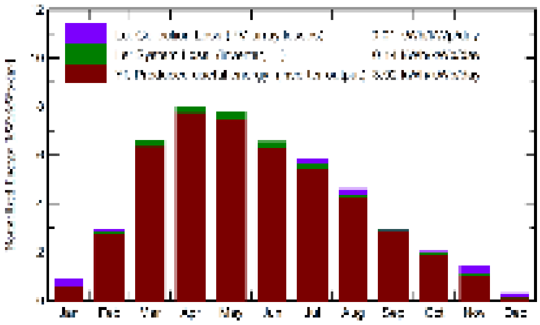
23 Bi-facial arrays capture the sun's energy on both sides of the panel, allowing energy to also be collected from the underside of the panel when light is reflected up from the ground surface.

Main results

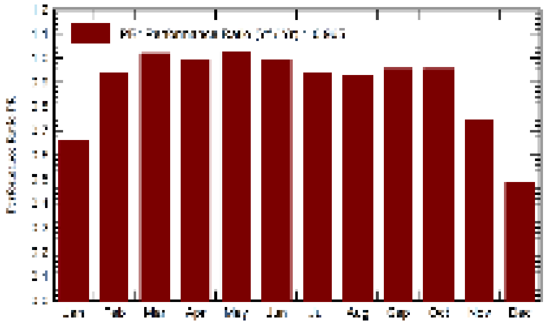
System Production

Produced Energy 1596 MWh/year | Specific production 1492 kWh/kWp/year
Performance Ratio PR 98.53 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	5.9	3.57	-28.77	28.5	16.7	22.3	21.0	0.860
February	25.1	8.77	-28.42	82.3	72.1	66.5	65.7	0.934
March	85.6	15.66	-24.75	193.8	182.7	227.5	220.2	1.018
April	146.5	25.11	-15.80	234.2	222.0	268.2	259.6	0.966
May	191.1	58.56	-5.80	227.3	217.1	267.8	259.3	1.024
June	183.8	68.56	3.57	190.8	181.7	218.8	211.7	0.966
July	173.3	73.70	11.85	178.8	171.1	144.8	165.7	0.941
August	118.8	58.78	8.34	142.5	135.8	152.8	147.8	0.978
September	60.7	33.16	2.32	89.0	84.8	86.2	84.7	0.956
October	28.9	18.69	-4.87	52.8	56.8	84.2	83.7	0.958
November	10.2	5.73	-14.84	43.8	31.8	37.8	38.2	0.741
December	2.1	1.70	-23.16	6.7	4.7	5.8	4.7	0.468
Year	1030.0	371.68	-0.85	1468.5	1378.8	1651.4	1596.1	0.966

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

FIGURE 22: Main results of the energy yield analysis conducted for Salliq's 1MW solar array at Site 4[24]

Annual energy production of the 960kW project is estimated to be 1596 MWh/year, with the majority of production occurring in the summer months from March - August. Energy production drops significantly from September - February, with production during November, December, and January being under 1 kWh/KW/day35. This is compared to a production potential of 6-8 kWh/KW/day in the summer months.

FIGURE 23 shows an estimation of how energy demand could be met in Salliq with a combination of 960kW solar energy, existing diesel powered energy generation, and a 1 MWh Battery Energy Storage System (BESS) over the course of a typical year. While the model results shown below used a 1MW system, the capacity is similar enough to give a good approximation of the results that would be seen with an 960kW system. The red line along the top of the graph in FIGURE

24 *Greencat Renewables. (2021). PVsyst Simulation Report for Salliq Solar Project*

23 indicates the total annual energy demand of the community, the orange sections represent the proportion met by solar energy generation, and the blue sections represent the proportion met by diesel energy generation. A combination of the two power sources will provide sufficient energy to meet the community's needs. The grey sections at bottom represent solar energy that must be spilled in order to maintain stability of the electrical grid.

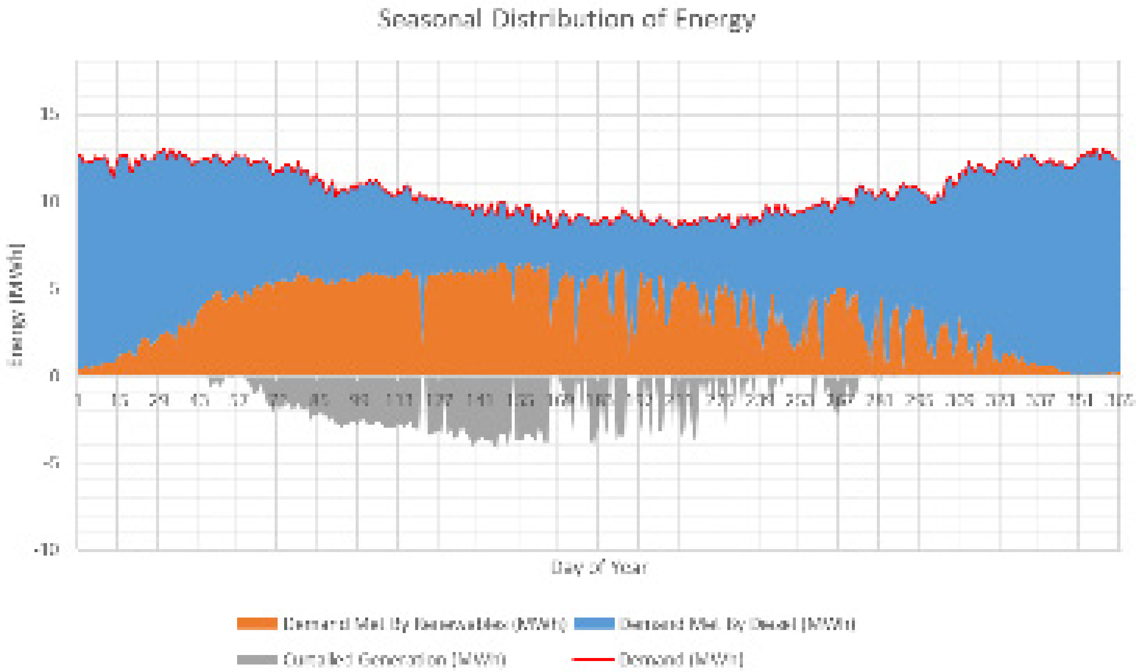


FIGURE 23: Seasonal distribution of demand met by renewables (a 1000kW solar energy system with 1MW BESS) and diesel, with curtailed renewable generation where required.

Salliq is located in a remote, arctic ecoregion, and therefore the community needs the most energy (electricity and heat) during the winter months, when temperatures are cold and nights are long. Regardless of the time of year, the community meets nearly 100% of its energy demand with fossil fuels. A solar energy project will offset some of the electricity component of this annual energy usage.

While the annual electricity production profile of a solar project is not a perfect match with the electricity demand profile of Salliq, FIGURE 23 demonstrates that any penetration of the local grid by renewable energy will have a meaningful impact. Renewable energy generation during the summer will still displace a significant amount of the fossil fuels that would normally be used for electricity production during this time of year. While wind energy was considered for this project, the lower cost, time, and complexity of a solar project, along with the similarly impactful annual diesel displacement projections, made solar the best choice for Salliq's first renewable energy project.

Future projects in Salliq, however, should consider complementary renewable energy sources that can provide more electricity in the winter months, such as wind energy. Following the successful implementation of a solar energy project, future energy planning in Salliq will likely also focus more on energy sources used for heating, which is presently provided by heating oil and natural gas. Increased electrification of heating systems across the community could improve the overall penetration of clean energy on the local grid. Additionally, more sustainable, cleaner sources of heat such as biomass or geo-exchange will be considered for projects over the long term.

2.5. ENERGY STORAGE ASSESSMENT

Energy storage systems are typically required when renewable energy is added to small isolated micro-grids, such as Salliq's. Renewable energy sources such as wind and solar will experience fluctuations in their generating capacity over time. Solar energy can experience intermittency when clouds cover the sun, and during periods of rain or snow. Energy storage on a micro-grid can serve both as a sink for excess energy when generation is high, and as a reserve bank of energy when renewable generation is low. This helps balance the grid and ensure users have a reliable source of energy when they need it.

Today's chemical batteries are generally considered to be the optimal choice for utility-scale energy storage, and some battery technologies have recently become commercially competitive. A BESS is typically characterized by its maximum output capacity (in kW) and by how long a period it can supply this output (in hours).

Modern energy generating facilities with BESS can be equipped with smart software systems that manage energy input from various generation sources for charging and discharging of the battery, as well as curtailment[25]. These systems, known as microgrid controllers, use algorithmic logic systems to monitor various inputs and outputs and ensure all involved components work in an optimized manner. A simple illustration of how the logic in a microgrid control system with BESS could work is shown in FIGURE 24.

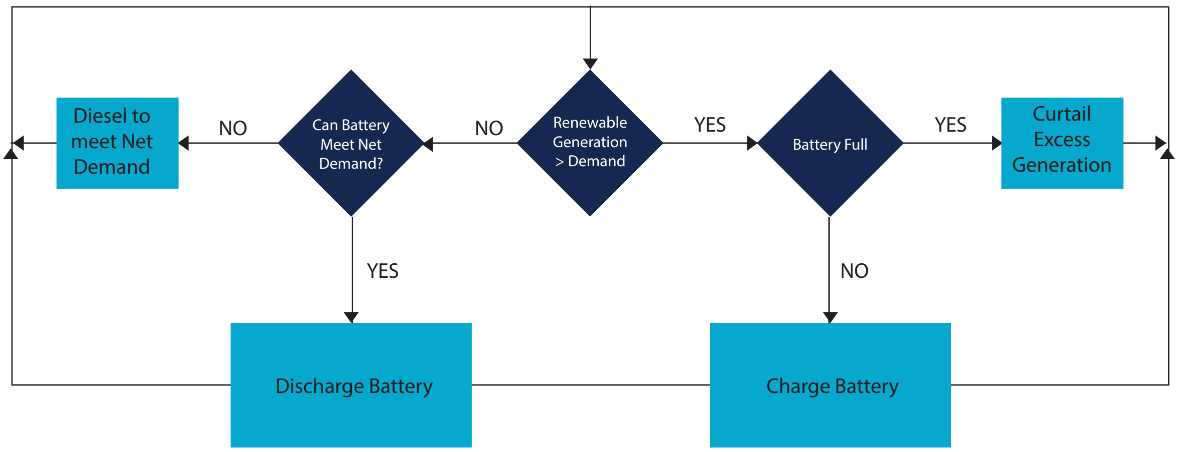


FIGURE 24: Simple Illustration of the hourly simulation logic for a system with BESS[26]

Based on the results of the system integration study conducted for Salliq, excess energy generation is expected during the summer months, when the sun is up for long periods of time, and overall energy demand in the community is lower. Energy production is anticipated to be high enough in the mid summer months to require some curtailment even with a BESS (for example, when the BESS is fully charged, or power production is in excess of the BESS rated power). However, a BESS will be crucial to capture some of this excess energy generation and to reduce the amount of curtailment needed. Energy stored in the battery during these periods of excess generation can then be accessed later(i.e. at night), further reducing the need for the diesel generators to run. A BESS will also help balance short term periods of intermittency or peaks in generation and demand.

25 Curtailment is the deliberate restriction of excess electricity production to maintain stability of grid infrastructure, or due to an inability to store or use it. Excess energy is usually released as heat.

26 Green Cat Renewables. (2021). Salliq System Integration Study.

Several sizes of BESS were modelled for this project, as well as a project without a BESS (see Appendix 1). While larger BESS will typically have greater benefits with regards to curtailment, grid stability, and stored reserves of energy, a larger system is also significantly more costly. In a remote community such as Salliq, the benefits of a BESS must be weighed against the added costs and logistical challenges of installing a larger system. For this project, a 1000kW battery with 1 hour of storage (i.e. a 1MWh BESS) is of sufficient size to meet peak demand in the event of a sudden drop in renewable energy generation, ensuring the grid remains stable while the diesel generators ramp up to the required capacity. This size of battery will also provide some benefits in terms of stored energy, while still balancing cost considerations.

In total, excess generation requiring curtailment from a 900kW[27] solar project in Salliq would be approximately 586MWh annually without any form of energy storage. The addition of a 1MWh BESS would reduce this curtailment requirement by half, to approximately 290MWh annually. In addition to reducing curtailment, the Project Team anticipates that QEC is likely to require that the project include a BESS to ensure grid stability. Such a requirement would ensure that the size of project being recommended integrates smoothly and maintains the reliability and service standards required for its customers.

The Project Team has initiated conversations with QEC for this project in relation to the system integration study, in order to collect information required for studying the impact of different types of renewable energy systems. As part of the next steps for development, the Project Team would work with QEC to begin an interconnection study for the project. This involves disclosing design details of the proposed project plan, such as size and energy storage, for analysis by QEC. An interconnection study ensures all of the Utility's requirements for project success are met, and will outline expected upgrades and costs to safely and effectively connect to the grid.

27 Grid integration modelling completed for this project provided estimates of curtailment in project increments of 100kW only, therefore curtailment has been estimated from a 900kW project, rather than a 960kW project

3. Solar Energy: Project Development and Implementation

3.1. LAND, PERMITTING AND APPROVALS

Following selection of the project site, the Salliq IODI team completed a preliminary project layout to delineate all lands required for project construction and operations. The project layout sets the stage for the Project Team to begin the necessary approval process with respect to environmental assessments and land use, as well as confirming zoning (or rezoning), land rights, easements, leases and permits. Details of the preliminary design are discussed in Section 3.2.

3.1.1 LAND LEASE

Land sales are prohibited in Nunavut, therefore a lease for the project will be required, and would be pursued for a length of time equivalent to the expected life of the Project (eg. a 30 year term). The location of the project on either municipal land, Inuit Owned Land (IOL), or Crown land impacts whether lease arrangements are pursued with the Hamlet, the Kivalliq Inuit Association, the Government of Nunavut, or the Federal Government.

For lands within the municipal boundaries of a community, leases are typically approved by the Hamlet, with the assistance of the Government of Nunavut, Community and Government Services department (CGS). For projects leasing IOL, which in some cases may be within the boundaries of the municipality, a land use permit from the appropriate Inuit association will be required before a lease can be issued. In Salliq, IOL is administered by the Kivalliq Inuit Association. For projects located on land deemed to be Commissioners Land or Federal Land, the lease is signed and administered by either the Government of Nunavut, CGS, or by Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), respectively. In smaller communities where the Government of Nunavut does not have representation, leases pursued on Commissioner's Land will go through the Hamlet to obtain CGS approval.

Initial conversations with CGS indicate that the preferred project site is located on Federal Lands, and not within the municipal boundary of the Hamlet. As such, the Project Team will need to engage with CIRNAC to obtain a lease. At present, the Project Team is in communication with a representative from CIRNAC in order to better understand the process of obtaining a lease with the Crown. Once the lease application process has been confirmed with the federal government, the team intends to begin preparing a preliminary proposal for the lease application. While the site under consideration was recommended by the Hamlet, the Project Team nonetheless intends to confirm micro adjustments to the final site location with the Hamlet ahead of submitting any lease documents. This will take place in the upcoming February 2022 community visit.

Applications for land leases typically follow a standard agreement template and can take a month or more to process, however, unique clauses specific to the type of project may be required for more complex land uses. More complex projects may also require additional time for processing, so this should be planned for in advance. All land leases in Nunavut have property taxes, which are usually paid to and administered by the Government of Nunavut[28]. Conversations with CIRNAC will help clarify whether property taxes will be payable to the territorial or federal government in the case of this project.

Once the lease process has been initiated, the project can then proceed through the regulatory process, which includes conformity with appropriate land use plans, and an environmental assessment if applicable. The issuance of a lease ahead of the environmental approval process can be given under condition that the project receives approvals from the NPC and NIRB. In some cases, these two processes happen concurrently. The environmental and regulatory process is described further in the following section.

3.1.2 CONFORMITY WITH LAND USE PLAN

Under the Nunavut Land Claims Agreement, the Nunavut Planning Commission (NPC) has the authority to review proposed projects and developments to ensure they conform with the terms and conditions of the land use plan for that region[29]. As Salliq is located within the boundaries of the Keewatin Regional Land Use Plan (KRLUP), the project will be required to submit the project to the NPC for a Conformity Determination.

To initiate the Conformity Determination process, the Proponent submits a complete Project Proposal to the NPC using its online application portal. Once received, the NPC has 45 days to review information provided and determine if a project conforms to the land use plan[30]. If the project is found to conform to the land use plan, the NPC will then determine whether the project is exempt from additional screening by the Nunavut Impact Review Board (NIRB). The NIRB oversees all environmental impact assessments for development projects within the territory. Additionally, the NPC may request the NIRB's opinion on project exemptions, and will consider cumulative impacts that could result from the project. All of this information will then inform the final determination for the project. FIGURE 25 shows a flowchart of the Conformity Determination process.

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28 Pers. comm Randy Mercer, Regional Lands Administrator, GN.

29 Nunavut Planning Commission. (2000). Keewatin Regional Land Use Plan. https://www.nunavut.ca/land-use-plans/keewatin-regional-land-use-plan

30 Nunavut Planning Commission. (2020). Nunavut Planning Commission Internal Procedure: Conformity Determination. Image adapted from: https://www.nunavut.ca/sites/default/files/2020-10-23_revised_conformity_determination_internal_procedure.pdf

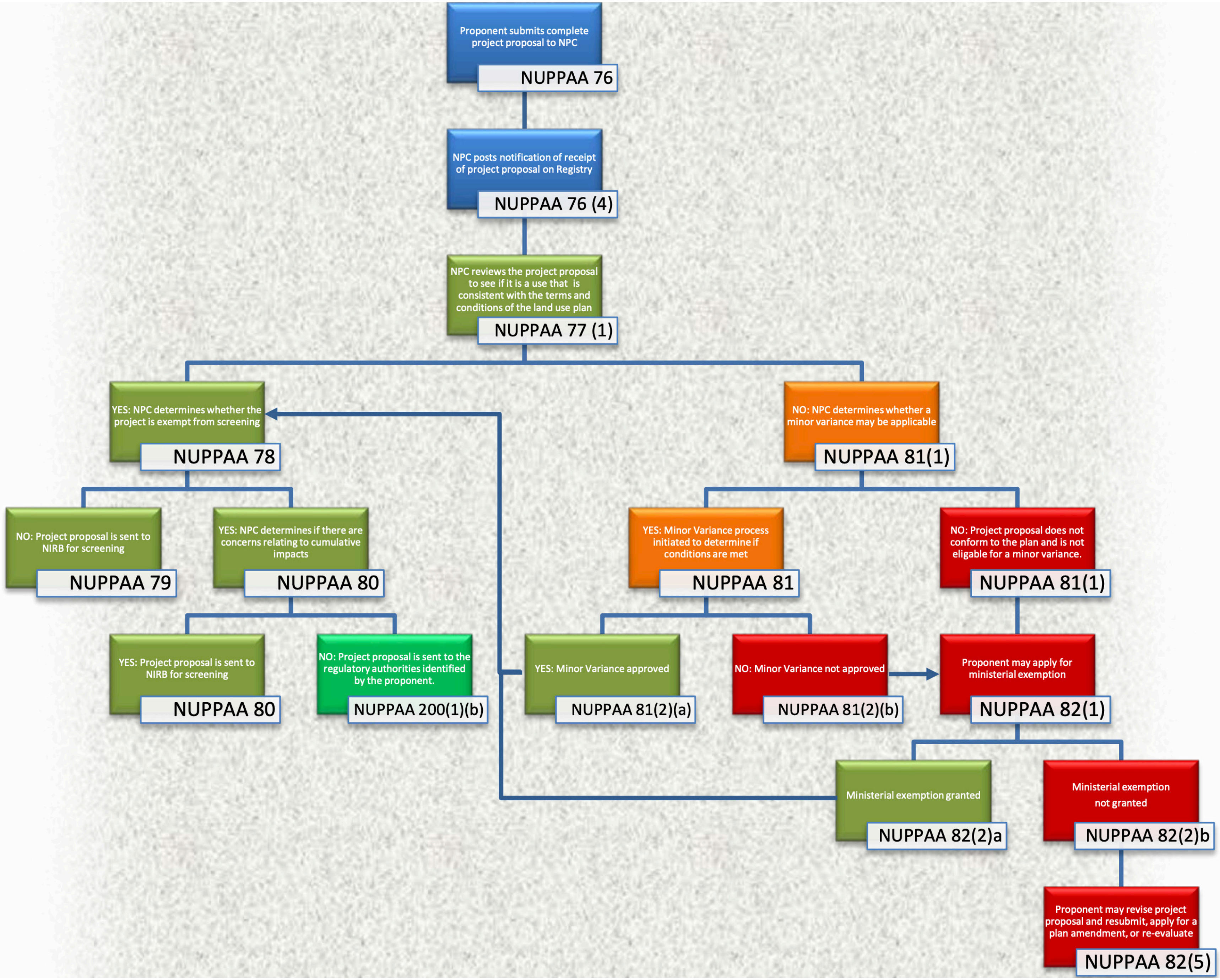

FIGURE 25: Flowchart of the conformity determination process through the Nunavut Planning Commision[1]

1 Nunavut Planning Commission. (2020). Nunavut Planning Commission Internal Procedure: Conformity Determination. Image adapted from: https://www.nunavut.ca/sites/default/files/2020-10-23_revised_conformity_determination_internal_procedure.pdf

An initial screening of the KRLUP was completed as part of the CEP. It is not anticipated that a utility scale solar project in Salliq would be at odds with the KRLUP. The plan emphasizes the importance of sustainable development, and strives to strike "a balance between industrial development and other human activities in order to guarantee the long-term preservation and conservation of the land, wildlife and wildlife habitat"[31]. As a renewable resource with a long project lifetime, and minimal impact during construction and operation, solar energy seems like a good fit with the region's goals. However, the completion of the conformity determination process will ensure that is the case.

3.1.3 ENVIRONMENTAL IMPACT ASSESSMENT

Completion of the Conformity Determination will trigger the impact assessment process for the project, if required. The NPC will decide whether a project should be submitted for screening by NIRB. If a screening is needed, NIRB will take 45 days to review project information and receive public comments on the project[32]. This information will inform the Board's decision as to whether the project may proceed. There are four possible outcomes following the screening process, as shown in FIGURE 26.

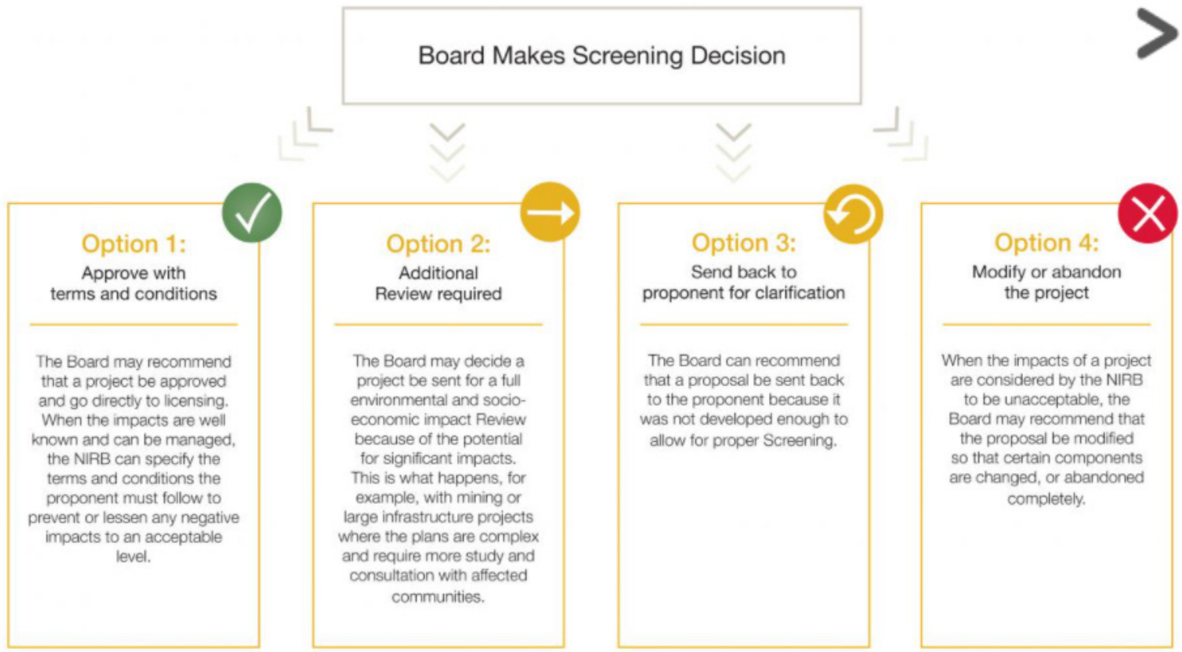

FIGURE 26: Possible outcomes of NIRB Screening Process[33]

In some cases, NIRB may recommend that the project undergo a full environmental impact assessment. In that case, Proponents must develop an impact statement and may have to complete additional environmental studies. The project would then also be required to go through a public hearing. Typically, full environmental assessments are only required for large, complex development projects with a high potential to cause adverse impacts[34].

31 Nunavut Planning Commission. (2000). Keewatin Regional Land Use Plan. https://www.nunavut.ca/land-use-plans/keewatin-regional-land-use-plan
32 Nunavut Impact Review Board. (n.d.). NIRBs Processes. Retrieved from: https://www.nirb.ca/nirb-processes
33 Nunavut Impact Review Board. (n.d.). NIRBs Processes. Retrieved from: https://www.nirb.ca/nirb-processes
34 Nunavut Impact Review Board. (n.d.). NIRBs Processes. Retrieved from: https://www.nirb.ca/nirb-processes

Projects that are approved through screening or following a full impact assessment will then move to the licensing stage, and may proceed with construction. Often, approvals will come with terms and conditions that the projects must comply with. Some projects may also be subject to monitoring programs.

The NPC may determine that a project is exempt from NIRB screening, and will not refer the project for screening. Exempt projects can then proceed directly to development and construction. Exemptions are defined in Schedule 12-1 of the Nunavut Land Claims Agreement[35]. Upon initial review of the exemptions, no clauses were found that would immediately indicate the project is exempt from screening

Given the large size of the proposed project, the novelty of utility scale solar projects in Nunavut, and the nature of the operation as a commercial endeavor, it is likely that the NPC will request a NIRB screening of the project. However, it is not likely that a full impact assessment will be required. In the experience of the Project Team, solar projects elsewhere in Canada are not typically required to undergo a full environmental impact assessment to proceed, due to their low impact nature.

3.1.4 OTHER PERMITS AND APPROVALS

In Salliq, the airport is located some distance from the community (approximately 12 km). All airport authorities will have a 3-dimensional zone of exclusion around the airport and runway to ensure safety of incoming and outgoing aircraft. The exclusion zone is described in the municipality's Airport Zoning Regulations, and dictates the distance at which structures of certain heights can be built relative to the runway.

Solar projects are typically low to the ground and so should not pose a risk in relation to standard airport zones of exclusion, unless they are built very close by. The recommended site for the project (Site 4) is the only proposed project site near to the airport, being within 3km of the runway. According to the Salliq Airport Zoning regulations, the exclusion zone applies in a 4km radius around the centre of the airport, and exists as an incline plane that extends upwards and outwards from the runway edges[36]. Based on this description, it is not anticipated that there will be a conflict between the project and the airport, as the distance between the site and the runway is large enough that a structure would have to be quite tall to violate the regulations (such as a utility scale wind turbine). However, since the project is within the 4km regulation zone, a survey submitted to Transport Canada may be required to show compliance with the regulations.

Additionally, solar projects can cause glare that may adversely impact the safety of aircraft. NAV CANADA requires that solar projects submit an application form for project review, along with a reflectivity study and details of the project height and location[37]. NAV CANADA will then engage with the airport to determine possible impacts. An approval from NAV CANADA will be required for this project to proceed.

At the time of writing, the Project Team has established communication with the Nunavut Department of Economic Development and Transportation, Transport Canada, and NAV CANADA,

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35 Nunavut Land Claims Agreement, The Inuit of the Nunavut Settlement Area-Canada, May 25, 1993, S.C. 1993 c. 29.https://www.gov.nu.ca/sites/default/files/Nunavut_Land_Claims_Agreement.pdf

36 Salliq Airport Zoning Regulations, SOR/92-68, 1992-01-23. https://laws-lois.justice.gc.ca/eng/regulations/SOR-92-68/page-1.html#docCont

37 NAV CANADA. (2021). Detailed Land Use Proposal Guidelines. https://www.NAV CANADA.ca/en/w-ldu-102-detailed-land-use-proposal-guidelines-en.pdf

and has commissioned a reflectivity study for the project. The application and accompanying study will be submitted to NAV CANADA for review before the end of Phase 2.
Finally, the project is proposed for operation under Nunavut's upcoming IPP policy. Typically, an IPP policy would require the execution of a Power Purchase Agreement (PPA) between the Proponent and the regional utility operator for the commercial sale of electricity produced by the project. However, because Nunavut has not yet finalized their IPP policy, specific requirements for establishing a PPA are not yet outlined by the territory. The Project Team has therefore drawn on our experience developing similar projects in other provinces and territories for an indication of what to expect.

A suitable example for guidance is the Yukon's recently established IPP policy, which includes a Standing Offer Program through which project Proponents can apply for their project to sell electricity to the territorial utility at an agreed upon rate. The Yukon's IPP requires that project proponents progress through a series of eligibility and assessment steps during the application process for a PPA. The application process includes the following steps[38]:

- Pre-Application Phase;
- Preliminary Feasibility Assessment Phase;
- Application Phase; and
- EPA Execution Phase.

Presently, the Salliq Project would be in the Pre-Application Phase. The submission of an application form to the Utility by the Proponent would trigger the start of the process. Work at this stage would include early engagement meetings with the Utility to review potential eligibility and interconnection requirements. The Utility would then assess the project at increasing levels of detail as it progresses through each of the phases. Typically, this process includes interconnection studies by the Utility, and collaboration with the territorial impact review board.

Ultimately, the Utility would then draft a PPA to offer to the project Proponent. Acceptance and signing of a PPA is often considered an important step towards securing construction financing to begin building the project, though it is not always mandatory that a PPA is signed before construction can begin. Such a decision will be unique to the circumstances in which the project is being developed.

For this project, next steps would be to engage further with QEC regarding an interconnection study, and to express the Project Team's interest in a PPA through their upcoming IPP program. However, a PPA will not be pursued until the IPP program is rolled out.

3.2. PLANNING AND DESIGN

In consideration of all information collected about the site to date (environmental considerations, factors such as ground type and roughness, proximity to key infrastructure, available space, etc.), the project engineering team has developed a preliminary conceptual design layout of Site 4. The concept layout location relative to the Salliq airport is included in FIGURE 26, and a detailed view of the layout components is included in FIGURE 27. This design will further inform engineering and construction considerations for a solar PV installation at this site

38 YEC. (2019). Standing Offer Program Rules; Yukon Government. (2018). Yukon's Independent Power Production Policy. https://yukon.ca/sites/yukon.ca/files/emr/emr-yukon-independent-power-production-policy.pdf

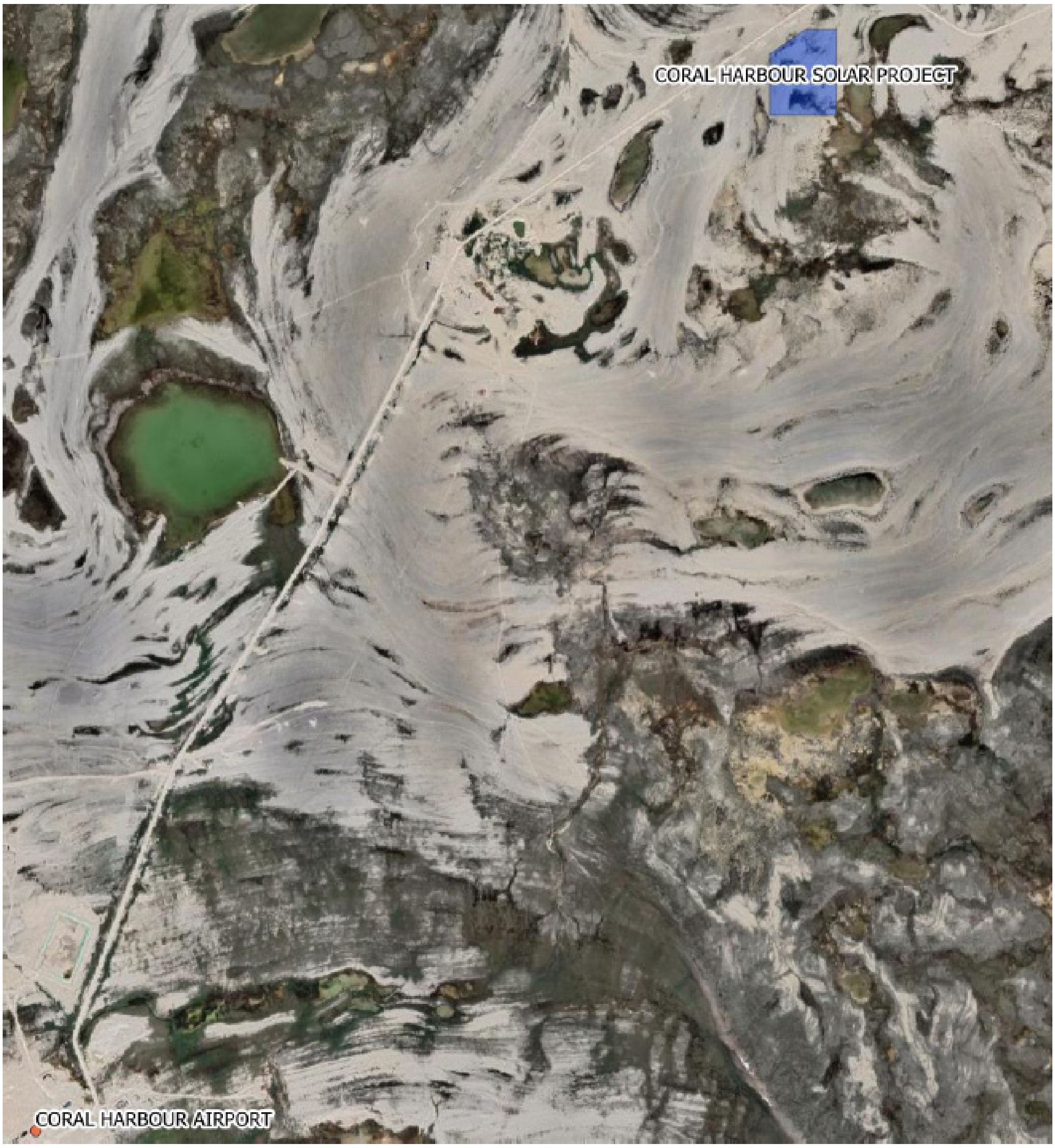

FIGURE 26: Location and size of proposed Site 4 solar project layout, relative to the airport

The layout schematic in FIGURE 27 includes 960kW spaced over a single block approximately 2.5ha (6.5) acres in size. The design is suited to the topography of the site with the highest degree of accuracy possible using a combination of data collected at the site and publicly available topographical and mapping data. Ultimately, south facing fixed tilt, bi-facial arrays were chosen for the project. This type of array is better suited to a remote site with extreme climatic conditions, as the fixed frame is more robust and will require less maintenance than a tracking system. Additionally, the fixed array is the more cost effective option.

The site was configured to maximise the energy generation of the plant with a 1115 kW_{DC} (960kW_{AC}) maximum installed capacity. To do this, a balance was struck between optimum inclination of the modules as well as inter-row spacing. As noted previously in Section 2.4, inclination angles of 45 degrees and inter-row spacing of 20m resulted in the greatest annual output, striking a balance between energy generation and inter-row shading losses. Increasing the module inclination angle or decreasing the inter-row spacing (or both) results in less generation per annum.

The system array was modelled using Longi Solar LR5-72 HBD 540 M Bifacial modules, with each unit having a nominal power of 540W. The entire system includes 2064 modules, arranged in 86 strings of 24 modules in series. In addition to the solar modules themselves, the modelled system also includes three, 320kW$_{AC}$ Sungrow inverters, with a total power capacity of 960kW. A complete list of the array configurations modelled for this project can be found in Appendix 3 - Salliq Solar Project EYA Report.

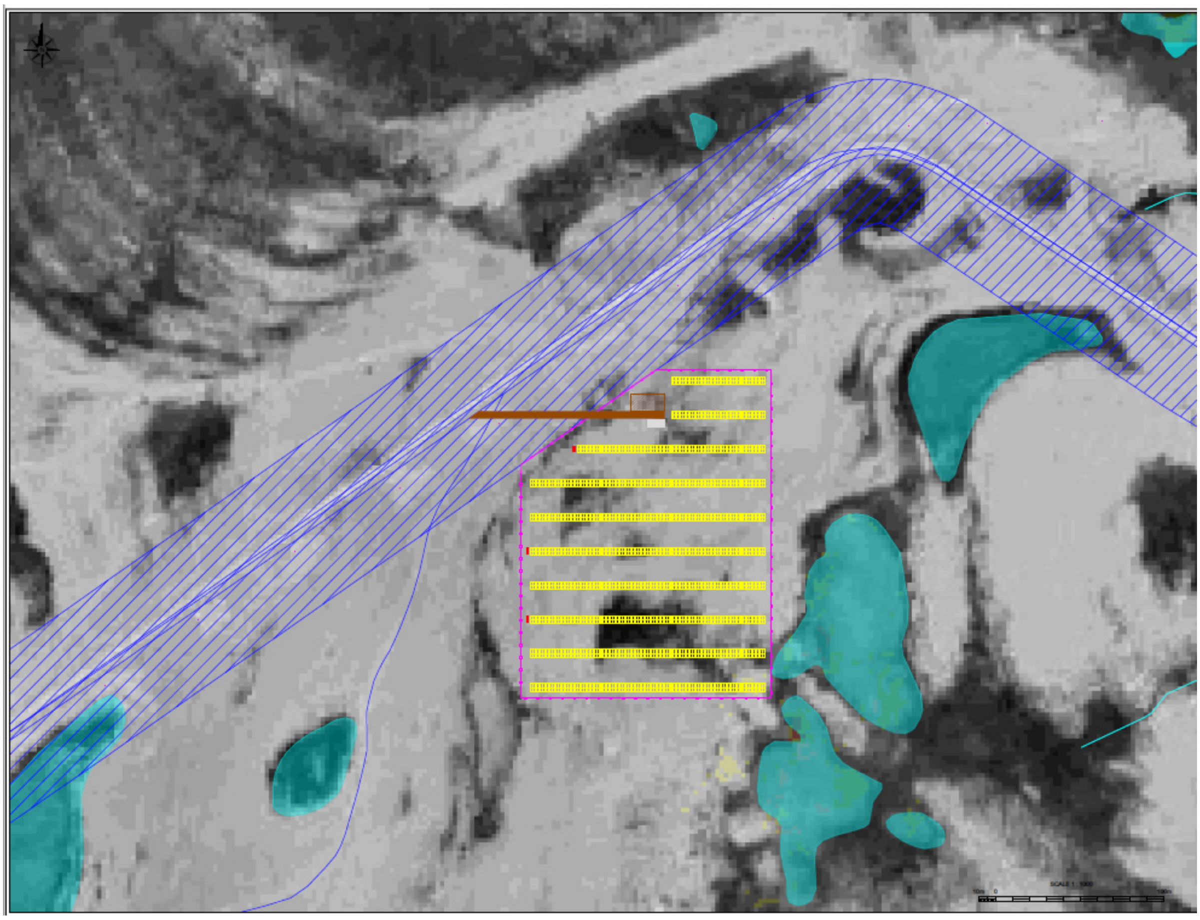

FIGURE 27: Closer view of the conceptual site layout design for a 960kW solar array in Salliq at Site 4. Panels are indicated in yellow, and new road is indicated in brown[39]

One of the next steps required to further the design of the project site is a topographical land survey of the proposed location. At present, the proposed site layout is based on high level data from a preliminary site visit, in conjunction with satellite and GIS mapping data. Available mapping data is typically at a lower resolution than what is needed for detailed design and engineering work. As a result, higher resolution data acquired through a physical land survey would be needed to progress design to the required level of detail for construction planning.

In addition to a topographical survey, a geotechnical assessment is also recommended to advance design and engineering for the project. Geotechnical data will inform the project design team about the suitability of the ground type, whether there is bedrock beneath the surface and at

39 *Greencat Renewables. (2021).*

what depth, and the competency of the soil or bedrock (if present) for foundation anchors. A geotechnical assessment would also provide insight with regards to the impact of permafrost on the project, to inform design plans for mitigating any potential impacts to structural integrity.

Once more information is known about the topography and geology of the site, further steps would include looking at the capacity of the site within the realms of the proposed IPP program, to ensure generating capacity is maximized without overstepping the suitability of the project size relative to community needs. This step can be taken once the details of the IPP program are released, which would include information about caps on project sizing. This step may include oversizing the installed capacity in order to maximize the output of the site, or could involve downsizing the project to meet QEC capacity restrictions. The next stage would also look at designing the most efficient site layout by optimizing string lengths and row sizing, and also optimizing the siting of the electrical infrastructure. This optimization will be informed by the ground survey and by system interconnection studies with QEC to ensure the grid is able to safely accept the energy produced by the project. Finally, rapidly changing technology is also likely to result in small tweaks to project sizing and specifications ahead of construction. The inclusion of cutting edge technology in the project design will ensure the project is as efficient as possible and will reduce costs over time.

3.3. LOGISTICS

This section outlines key considerations for the logistics approach for the project. The logistics process includes the planning, implementing and controlling of the most efficient and cost-effective transport and flow of materials and equipment required for the Project's construction. Logistical considerations span from early engineering and design, procurement activities, all the way to project site and final demobilization.

Logistic management will be required for each of the project's major components, including data collection for design and engineering during the development phase, system upgrades/interconnection, delivery of specialized equipment and materials to site for construction, and the installation and testing of the foundations, racking system, and solar PV array. Each of the major contractors on the project will assign an internal logistics manager who handles the procurement, transport and delivery, scheduling, and overall materials management for their aspect of the project. Major contractors may include a general contractor, the Utility for the system upgrades, and the solar PV system supplier. These individuals will report to the Project's development manager or technical project manager.

Individuals in charge of logistics will work with the project development team to handle delivery of required materials, many of which are not available locally and will need to be transported a significant distance to the site. During the development and design phase, it is anticipated that the following specialized equipment may need to be brought to site:

- Topographical land survey equipment and personnel
- Small drill rig for core sampling during geotechnical assessment

Once construction begins, the complexity of logistics will increase significantly, as considerably more materials and equipment are required at the site. Table 1 lists the specialized equipment and materials that will be required for construction at a minimum, with other equipment and materials not listed likely to be identified as the project progresses:

Table 1: Preliminary Construction Equipment List

Civil materials	Electrical materials	Equipment
Gravel/fill material	Switchgear or extensions	Excavators
Steel frames	Electrical housing	Drill rig
Concrete batch plant & trucks for foundations	Transformers	Pile driver
Wood for formworks, shoring	Overhead line, power cable, connectors & joints	Hauling trucks
Power poles, if required	Control panels/Site management system	Comms equipment
	Inverter	
	BESS, housing, and components	

Components of the solar array itself will include the following, to be provided by the solar system supplier:

- Pilings/posts of various predetermined lengths
- Frame components and brackets
- Solar PV panels in steel and glass frames
- Electrical wiring and wire housing

In addition to specific materials and equipment needed to install the solar energy system, other general items required for the construction site will include:

- Site trailers and site office, portable outhouses, storage facilities for site staging area
- Water source
- Generator and fuel
- Safety equipment, PPE
- Site vehicles
- Tools, ladders, and related assembly equipment

Organization and planning for items to be brought to site should begin well ahead of the start of construction. Logistics personnel must understand lead times on various components requiring manufacturing, as well as how much time is required to transport components from their source location to the site. Ships visit Salliq several times per year, therefore, the project construction schedules should be planned around these delivery times as much as possible. This type of planning will minimize the need for on-site laydown or storage prior to installation, which can add costs. If needed, a dedicated visit from a cargo ship can be arranged for a diversion fee, which typically costs around $50,000[40].

Most equipment and materials will be delivered in sea-cans, with the possible exception of some larger equipment. Sea-cans come in various sizes, typically 20ft or 40ft. Salliq does not have a deep water port, therefore ships must anchor in the bay and transfer cargo to a barge using the ship's crane. This transfer imposes an 11 tonne weight limit on the sea-can. Once transferred to

40 *Arctic Buying Co. as quoted in Griffiths, J. et al. (2021). Salliq CEP.*

the barge, sea-cans are then brought to shore and can be unloaded onto trucks using a forklift. A small crane or large forklift may be required to unload the sea can from the truck onto the site laydown area.

3.4. INTERCONNECTION

QEC owns and operates the distribution network that serves the community of Salliq. As a small local grid, network lines do not have to travel long distances, so high voltage transmission lines are not present in the community. QEC has noted in their Technical Interconnection Guidelines for the CIPP program that distribution lines in Salliq are in the 4.16 - 12.5kV range[41]. It is known that a 12.5kV line services the airport to the northwest of the community, and it is anticipated that shorter local lines servicing the community itself are mostly 4.16kV.

The power generation substation houses the three generators and is located on the northern edge of the community, at approximate coordinates 64°08'25.78" N, 83°10'15.84" W. All three generators run in parallel and feed power into a common switchgear, which then passes power into three main feeder lines. Feeder lines #1 and #3 supply the town, while feeder line #2 supplies the airport. On the airport line, power is stepped up to 12.5kV for the longer distance transmission, via a 500kVA transformer bank[42]. On feeder lines #1 and #3, power is stepped up to 4.15kVA, however the specification of the transformers on these two lines is unknown at this time. A single line diagram provided by QEC is included in FIGURE 28.

Site 4 is 9.7km from the power plant as the crow flies, or approximately 14.4km from the power plant along the existing road route. Feeder Line #2 runs 12.65km along the road to where it serves the airport. Additional electrical line runs to a telecommunications tower beyond the airport, but no information is known about this part of the line. While the voltage of feeder line #2 to the airport is known (12.5kV), more information is needed to inform the feasibility of building the project at this site.

In communication with QEC, the Project Team has learned that the capacity of the physical line itself is sufficiently high to serve the project, however, the capacity of the system servicing the airport overall is limited by other equipment, including the transformers. No information is currently available from QEC about the type of equipment facilitating the step-down at the airport, which is where the project would most likely interconnect. Additionally, information is needed about the demand load at the airport and its impact on line availability. Until this information can be obtained, it is uncertain what the costs associated with electrical upgrades would be.

41 QEC. (2021). CIPP Technical Interconnection Requirements.

42 QEC. (2018). Repulse Bay SLD, Rev. F.

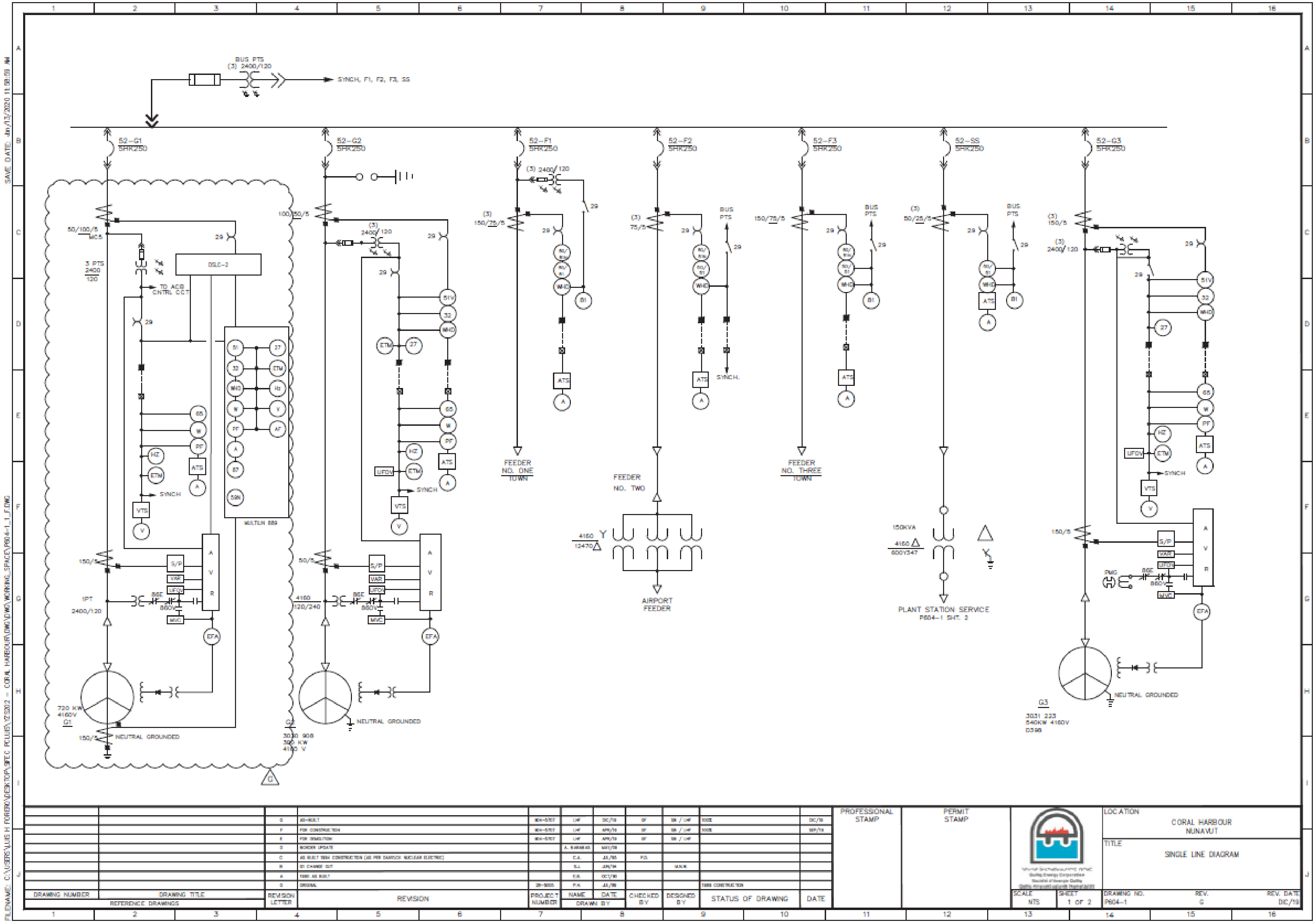

FIGURE 28: Single Line Diagram of the electrical grid at Salliq, provided by QEC

The Project Team is currently in conversations with QEC, the GN Department of Economic Development and Transportation, and the Hamlet to pursue additional information as described above. Furthermore, the team hopes to learn more about the electrical infrastructure via a visit to the airport to collect photos, facilitated by a member of Sakku Investments Corporation who lives locally.

Next steps will include further analysis of the information obtained about the airport by the Project Team to assess the feasibility of Site 4 from an interconnection standpoint. If the Hamlet's preferred site is deemed to be feasible by the Project Team, steps to follow will include formal, technical system interconnection studies with QEC at the site to further review feasibility, and to determine specifics of the required electrical infrastructure and associated costs from QEC. These interconnection studies are integral to ensuring a safe and reliable interconnection with the grid, as well as understanding the role of Utility in the project over the short and long term.

3.5. CONSTRUCTION

The steps that will be involved in constructing the solar energy project are described in the following section. Construction will commence once the project has completed all planning and design, all relevant permits and approvals are in place, and the project has acquired the needed capital investment, bringing the project to financial close. Ideally, capital investment will be provided primarily through government funding programs, with the possibility of some private investment and/or financing making up any gaps.

The first step in construction will be to establish the site boundaries and ensure adequate access for construction vehicles and equipment. As such, prior to commencing construction on the solar panels themselves, any required road improvements must first be made. At the chosen site in Salliq, a well maintained road services the site location, so road improvements will likely be minimal. However, some new road will need to be built to access the site from the existing road, and for movement around and through the site. Based on preliminary design work, approximately 110m of new road will be built from the existing road to access the site area. A staging area will also be established, which will house equipment, sea-cans containing materials for the project, vehicles, and a site office.

As mentioned in previous sections, a geotechnical report will inform the appropriate approach to installing foundations for the racking system. This information will be used in combination with the land survey to inform the positioning of the foundations and pilings. Piling length and locations are carefully planned to ensure the panels themselves are level and oriented in the correct direction for maximum energy capture.

Once road construction is complete, piling locations will be marked within the site area. If needed, any earthworks around the foundation will be completed concurrently with road improvements. A pile driver will be used to install each post into the ground in its designated location, to a depth of at least 8 ft. Pilings are set up in rows, across which horizontal frames are mounted. Exact configurations of the frames will vary between manufacturers, and also on the type of array chosen, but typically a steel beam is secured at an angle to the posts, along which horizontal frame pieces will be mounted and secured.

FIGURE 29: Solar framing at another site being installed prior to mounting the panels[43]

Panels are then installed within the frames, and each individual panel is secured using mounting brackets. The mounting brackets are typically tightened with bolts to hold the panel securely within the frame.

Panels are mounted individually in series, and are then wired together by electricians. Often, a series of panels will contain around 26 panels wired together, though this will vary to suit the configurations of the site[44]. Wires are run along the back of the panels in protected housing to connect to the inverters, which collect all of the electricity and convert the DC power generated by the panels into AC power. Inverters have varying capacities which should be matched to the power generating capacity of the panels. For Salliq's 960kW installation, three inverters will be needed.

43 *Reproduced with the permission of Green Cat Renewables*

44 *Centre for Energy Education. (2021). Phases of Solar Project Installation [video]. https://www.youtube.com/watch?v=Sj81Q4qd9cU*

FIGURE 30: An example of fully installed south facing, bi-facial, fixed tilt solar arrays. This view from the back shows the framing typically used for these types of panels[45]

Concurrent to the installation of the solar components, upgrades to the electrical infrastructure serving the project will be made where required. It is unlikely that the existing line running north from the airport is suitable for interconnection, therefore the project will plan to interconnect at the airport substation. This may require the installation of new power poles and electrical conduit from the site to the airport, or running new lines along the existing power poles.

On-site electrical collection systems will also be required and include the installation of new conduit, power cables, switchgear and transformers to suit the project size and technical specifications. The point of interconnection will be located on site and will house the installation of the requisite revenue meters and communications systems for the Utility. Electrical components therefore make up the on-site electrical infrastructure required to operate the Project and support the connection of the Project to existing, extended or upgraded transmission systems servicing the community. These facilities may be installed by the Utility at a cost to the project Proponent, or may be installed by an electrical engineering team under contract to the Project and then handed over to the Utility for operation.

Once construction is complete, the project will then undergo a period of testing to ensure safety and quality control. During this time, key members of the Project Team will work with the Utility and an electrical inspector to ensure the project is operating correctly and meets all the technical and safety specifications required by law.

Concurrently with testing, a period of commissioning will also take place, which ensures that the project and all associated systems and components are operating according to the requirements of the owner and operator. If required, troubleshooting and adjustments may be undertaken. During this time, electrification of the solar PV array will be completed, so that interconnection with the grid and successful generation of power can be tested.

45 *Reproduced with the permission of Green Cat Renewables*

4. Operations and Maintenance

In this section, a general overview of the expected operations and maintenance (O&M) scope for a solar energy facility are considered. Operations costs have been estimated and are included in the business case section of this report.

A typical solar energy facility will have an operational lifespan of 30 years or more. During this time, both regularly scheduled maintenance, unscheduled maintenance, and site visits are required to maintain the solar panels in optimal condition. While overall maintenance for a fixed tilt solar energy project is typically low, regular maintenance is important as a preventative measure against larger and more costly maintenance issues. Maintenance tasks should include regular inspections of all electrical components, as well as any manufacturer recommended regular maintenance tasks. Modern utility-scale solar energy facilities typically include monitoring systems to help identify issues remotely and in real time.

In addition to regular maintenance, it is expected that larger maintenance events such as repair or replacement of parts will inevitably occur as the Project ages. A budget should be established from the start of operation, with funds set aside for larger maintenance requirements that will be needed towards the later part of the project life. Typically, larger components like the inverters and the BESS will decrease in efficiency over time, and will need to be replaced once or twice during the project lifetime. The solar arrays themselves have a very long life span and are not anticipated to require replacement, except in the event of accidental damage.

Depending on the manufacturer chosen for this Project, a service and maintenance package may or may not be included with the purchase of the solar PV system. The inclusion of a service and maintenance package would guarantee service for all scheduled and unscheduled maintenance needs, creating a more hands-off approach for the Project owner. Such a package would de-risk the operations component of the Project, but may create a missed opportunity for capacity and skills building within the local community.

On the other hand, if no service and maintenance package is purchased an opportunity would arise for local capacity building in order to fulfil the need for trained personnel who can provide scheduled and unscheduled maintenance. A more detailed assessment of this component should be considered by the project ownership group.

Additional O&M scope must also be considered for aspects of the project not directly related to the electricity generating components themselves. Generally, this would include any materials or personnel required to operate and maintain other components of the facility, such as roads, administration, and software programs. Scope may include:

- Road maintenance, repairs, and snow clearing,
- Clearing of snow from the solar panels,
- Operations and maintenance of any electrical facilities on site up to the point of interconnection where responsibility is transferred to the Utility. Inclusive of:
    - Metering equipment at connection point of facility to Utility owned assets,
    - Underground or overhead collection lines and conduit built for the project,
    - Transformer and switchgear
- Administrative costs (land lease, property taxes, legal fees, regulatory compliance with environmental permits),
- Insurance,
- Software and hardware service, updates, or fixes,
- Remote engineering services,
- Travel and lodging for site visits by non-local personnel

In producing this report and the business case that follows, a desktop study was completed to estimate operating costs using a comparison of similar projects, and information gathered from available sources and service providers.

5. Preliminary Business Case

A high level desktop financial model was created for this Project that considers the capital costs, operational costs, and projected revenue from the sale of generated energy for a solar energy project in Salliq. The output of the financial model at this stage presents a projected return on investment for the project, as well as an indication of the level of funding needed to pursue for the most successful business case.

It should be noted that the financial projections are, at this stage, very preliminary. The business case for this project would serve to be refined as the project develops and further resources are committed to project design and engineering. Advancing project design and engineering will create the opportunity for more accurate construction costing projections as the project progresses.

The financial modelling scenario presented below is based on the following assumptions:

- Capital costs estimates includes a 15% construction contingency allowance
- Capital cost estimates include a 7.5% escalation cost allowance with 2020 as a base year for construction unit rates (2.5% per annum for three years, based on similar industry projects), assuming the project would commence construction in 2023
- Capital costs for solar are assumed to be funded 75% using federal grant funding sources aimed at fossil fuel displacement, and the remainder using private equity investment.
- Operating costs are modelled to increase at full CPI, which using the Iqaluit average over the last 10 years is 1.7% annually.
- Revenue estimates are based on a proposed rate for the avoided variable cost component of thermal energy generation, at $0.40/ kWh, received through recent communication with QEC . This PPA rate is modeled to increase at 50% of CPI for five (5) years to 2025 when it is assumed the first full calendar year of operations would commence.
- Property taxes have been modelled at a nominal amount observed for similar projects. Actual rates will be refined as the Project Team learns more.

5.1. CAPITAL COSTS

The estimated capital costs presented in Table 2 includes supply and installation of physical assets, such as the solar PV modules, framing and foundations, electrical collector systems, inverters, and battery. Accompanying infrastructure costs are also included, specifically road upgrades and distribution line upgrades. An estimate is included for the Utility's interconnection costs, as well as soft costs such as engineering, permitting, and project management costs. It should be noted at this stage that the estimated cost for utility interconnection is very preliminary, and subject to change following further conversations with QEC.

Table 2: Estimated capital costs for a 800kW solar PV installation

Scope Item	Est. Capital Cost	% of Total
EPC (GC+Solar Install+Battery)	$4,784,230	52%
Grid Int.	$800,000	9%
Rearch./Expl/Perm	$334,400	4%
Dev./Eng./Soft Costs	$1,638,108	18%
Escalation (3yrs@2.5%/yr)	$526,675	6%
Contingency @15%	$1,053,351	12%
Total Capital Cost	**$9,136,764**	**100%**

5.2. OPERATING COSTS

The estimated operating costs are presented in Table 3. These costs include items such as scheduled and unscheduled maintenance, estimated replacement of large components such as the battery and inverters amortized over the life of the project, as well as administrative and land costs. Further information about land and property tax costs is being pursued by the Project Team at present from the GN, therefore estimates are currently in place for these lines.

Table 3: Estimated operating costs for 800kW solar PV installation

Item No.	Total Operating Budget	Unit Cost	Units	No. Units	2021	Projected 2025
	Solar Direct Operating Costs					
1	Solar Array, TX, Switch Gear Maintenance and Services	$ 25.000	$/kW	1040	$ 26,000	$ 27,704
2	Battery Maintenance and Operation	$ 7,000	$/battery pk	4	$ 28,000	$ 29,835
3	Electricity Consumption					
4	Amortized Inverter Replacement	$ 12,885		1	$ 12,885	$ 13,730
5	Amortized Battery	$ 5,014		4	$ 20,056	$ 21,371
						$ 92,640
	Land, Access, Permits, Taxes and Lease					
6	Land Access Agreements	$ -	$/year	1	$ -	$ -
7	Property Tax Estimate	$ 4,500	$/year	1	$ 4,500	$ 4,795
8	Property Lease	$ 2,400	$/year	1	$ 2,400	$ 2,557
						$ 7,352
	Site Management, 3rd Party Contractors, Travel and Comms and Contingency					
9	Local Site Maintenance/Response Manager	$ 1,250	$/mo.	12	$ 15,000	$ 15,983
10	Snow Clearing + Road Maintenance	$ 5,500	$/clearing	2	$ 11,000	$ 11,721
11	Communications/Data Costs (assumes satellite)	$ 2,000	$/mo.	12	$ 24,000	$ 25,573
12	Operations Contract Management + Reporting to Shareholders	$ 1,000	$/mo.	12	$ 12,000	$ 12,787
13	Owner's Costs	$ 2,000	$/mo.	12	$ 24,000	$ 25,573
14	Travel Budget (flight+2nights hotel/meals)	$ 5,500	$/trip	2	$ 11,000	$ 11,721
15	Meetings and Misc Budget	$ 350	$/mo.	12	$ 4,200	$ 4,475
16	Bookkeeping, Accounting, Audits, Misc. Legal	$ 10,900	$/year	1	$ 10,900	$ 11,615
						$ 119,448
	Contingency and Insurance					
17	Property insurance due to losses not wear and tear				$ 25,000	$ 26,639
18	Contingency				$ 23,094	$ 24,608
	Sub Total (pre contingency)				$ 230,941	$ 246,080
	Total Operating Budget				**$ 254,035**	**$ 270,688**

5.3. REVENUES AND RETURN ON INVESTMENT

This project is projected to generate around $650-750 K dollars a year in gross energy sales. Revenues are estimated based on the desktop production summary estimates provided by Green Cat Renewables for a 960kW solar energy project, and a base PPA rate of $0.40/kWh. This electricity rate is a projection based on current conversations with QEC, but is not a confirmed rate. Final rates will be released with the release of the Utility's IPP program.

A sample table of net operating income for the first five (5) years of operations using a P50 estimate could look similar to the scenario included in Table 4, with similar trends extending for the full life of the Project, 30 years or more. With no moving parts, solar energy installations have a very long lifespan and could operate indefinitely, however, efficiency losses over time become significant enough to warrant replacement beyond 30 years.

Table 4: Salliq Proforma for 960MW solar PV installation, first 5 years

Coral Harbour Project Proforma 960 kW SOLAR

SCENARIO MODELED	P50	2025	2026	2027	2028	2029
Energy Check (net revenues / epa rate)		*1,596,000*	*1,596,000*	*1,596,000*	*1,596,000*	*1,596,000*
Energy Rate ($/kWh)		0.4000	0.4034	0.4069	0.4103	0.4138
Projected Gross Revenues		$638,400	$643,855	$649,357	$654,907	$660,503
Base Corrections & Losses For P50 Scenario						
Additional P-factor Adjustments (P75-99)	P50	$0	$0	$0	$0	$0
Projected Net Revenues		**$638,400**	**$643,855**	**$649,357**	**$654,907**	**$660,503**
Operating Budget						
Solar Direct Operating Costs		$92,640	$94,224	$95,834	$97,472	$99,138
Land, Access, Permits, Taxes and Lease		$7,352	$7,478	$7,606	$7,736	$7,868
Site Management, 3rd Party Contractors, Comms and Travel		$93,875	$95,480	$97,111	$98,771	$100,459
Owner Costs		$25,573	$26,010	$26,455	$26,907	$27,367
Insurance		$26,639	$27,094	$27,557	$28,028	$28,507
Contingency		$24,608	$25,029	$25,456	$25,891	$26,334
Total Operating Budget		**$270,688**	**$275,314**	**$280,019**	**$284,805**	**$289,673**
Projected Net Operating Income	**-2,284,191**	**$367,712**	**$368,541**	**$369,338**	**$370,101**	**$370,830**
Simple IRR	**15.5%**					

Considering a Project delivery model that is able to secure up to 75% federally grant funded capital costs, this project is modeled to provide annual net operating income cash flows in the range of $350-400K, which returns an estimated 15.8% IRR on the equity investment of approximately $2.25M as presented below:

Grants (75%)	6,852,573
Equity (25%)	2,284,191
Total Capital Cost	9,136,764

6. Next Steps

The Project Team has completed a comprehensive review of available information, and has initiated some key steps in the development process for a solar energy project. These key steps include a site visit, initial conversations with the Utility and the hamlet, determination of the appropriate project size and type, and preliminary conceptual design work. These steps have enabled the Project Team to build a detailed plan for implementing this project, and start moving this plan towards realization.

6.1. GOVERNMENT FUNDING

To keep the project moving forward, the Project Team recommends the following next steps in the path towards realizing a solar energy project in Salliq. Because of the clean energy nature of the project, as well as its Indigenous ownership, the majority of the proposed project development work could be eligible for government grant funding. Funding for initial work is being sought through the IODI program in Phase 3, and the Project Team also hopes to receive additional funding for project implementation and construction through the same program in Phase 4. However, stacking of funding will also be pursued and will create viability for the overall business case.

The Project Team has already begun to engage the government in conversations about possible additional funding streams for the project, and is exploring a grant to support the Project Team's apacity to carry out additional funding research and application writing. Preliminary conversations related to this grant are being initiated with Indigneous Clean Energy at present.

Currently, the Project Team has registered for NRCan's Smart Renewables and Electrification Pathways program (Technology Stream) and is ready to begin work on the formal application for this program. Other programs that are of interest for Salliq's future energy planning include:

- Government of Nunavut, Municipal Green Infrastructure Fund
- NRCan, Smart Renewables and Electrification Pathways program, Capacity Building Stream
- NRCan, Clean Energy in Rural and Remote Communities
- Investing in Canada's Infrastructure Program
- Canadian Northern Economic Development Agency programs

Support for funding research and writing would be beneficial in providing additional resources to better understand funding opportunities that would benefit Salliq over both the short and long term. This would serve to support the short term goal of completing the solar energy project, as well as providing continued benefits in supporting longer term projects and energy planning within Salliq.

6.2. PROJECT SCHEDULE

In total, the Project Team estimates that the project could be developed and delivered in 2-3 years, with a commercial operation date in 2024 or 2024. IODI Phase 3 work for the project will include continued work on Steps 2 and 3 below, as well as beginning work on Steps 5 - 10. Phase 3 work is expected to continue over the duration of 2022, and into early 2023. Consultation with key stakeholders (Step 4) should continue throughout the duration of the project. Steps 11 - 13, as well as the wrap up of steps occurring later in Phase 3 (eg. steps 9 and 10), are expected to take place into Phase 4 of the IODI program and beyond. FIGURE 31 and the table to follow present a summary of recommended next steps, along with a potential schedule for project completion.

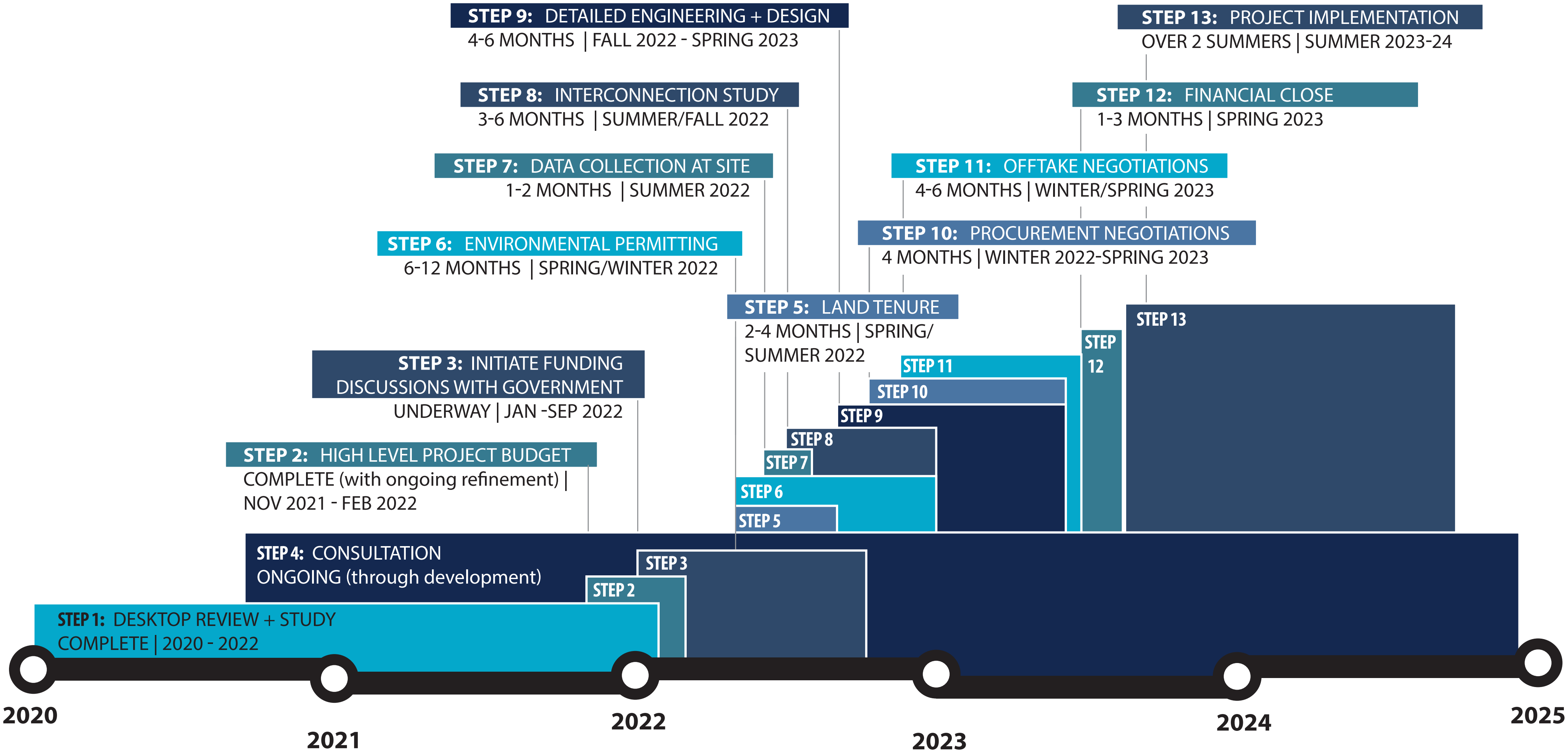

FIGURE 31: Planned next steps in the Salliq Solar Energy Project's implementation

Key Tasks	Deliverables	Duration (approx.)
STEP 1: Desktop review and study		
• Review of available information (market, mapping, infrastructure, technology)	• Community Energy Plan • This report • Project size and type • Site location • Preliminary business case	COMPLETE 2020-21
STEP 2: High level project budget		
• Engage with vendors and gather information to add more detail to the project financial model • Continued refinement and improvement to budget through project development	• High level project budget which will be continually refined as the project progresses • Initial quotes from vendors needed for the project • Local involvement in project where available	COMPLETE, with ongoing refinement Nov 2021 - Feb 2022
STEP 3: Initiate funding discussions with government		
• Engage with government and prepare applications for additional funding programs	• Strategy for obtaining funding to implement the project • Completed applications for appropriate program streams • Complementary funding opportunities to IODI	UNDERWAY Jan -Sep 2022
STEP 4: Consultation		
• Communication and engagement with key stakeholders about the project ○ Hamlet, Inuit organization, public, government agencies, other land users • Provide ongoing opportunities for input throughout project process • Response to questions about the project and potential impacts or opportunities	• Community investment in project selection and project success • Improved energy literacy and education on clean, sustainable energy solutions • Mitigation measures are often identified during consultation • Compliance with environmental assessment requirements	Ongoing throughout development

STEP 5: Land tenure		
• Early engagement discussions with appropriate entity regarding project lease request • Preparation of lease application • Submit lease application documents • Collaborate with NPC and NIRB regarding terms of land use	• Site lease for project area • Initiation of environmental permitting process	2-4 Months Spring/summer 2022 Phase 3
STEP 6: Environmental permitting		
• Compilation of information and submission of Conformity Determination application • Submission by NPC of project for NIRB screening, with support from Project Team • Dialogue with NPC and NIRB throughout the approval process • Pursuit of any further approvals identified via the NIRB process	• Conformity Determination approval for the project • NIRB screening approval for the project • Approval to begin obtaining required licenses and permits for construction	6-12 months Spring - Winter 2022 Phase 3
STEP 7: Data collection at site		
• Site visit to the final project location with a select team of technical professionals • Topographical survey • Geotechnical assessment	• Technical data collection to inform project design and engineering • Examination of finalized site area for environmental and heritage resources • Identification of any engineering issues requiring further study • Continued work on community engagement	1-2 months Summer 2022 Phase 3
STEP 8: Interconnection Study		
• Early engagement with QEC about project feasibility • Preparation and submission of supporting materials for QEC's interconnection study process. • Dialogue with QEC to arrive at the optimal interconnection solution	• Interconnection study reports • Optimized project size • Budget for interconnection facilities required by QEC	3-6 months Summer/Fall 2022 Phase 3

STEP 9: Detailed engineering and design		
• Civil design for roads and site layout • Structural design for solar array foundation and framing • Electrical design for transmission lines and interconnection facilities • Sharpening of budget based on contractor bids	• Engineering drawings to support tendering • Contractor bids	4-6 months Fall 2022 - Spring 2023 Phase 3 and 4
STEP 10: Procurement negotiations		
• Negotiation with solar suppliers to arrive at workable commercial terms for purchase and installation of Solar PV array • Negotiation with other suppliers/ contractors	• Solar PV Supply Agreement • Maintenance and Service Agreement (if pursuing) • Other contracts for delivery of materials and services • Finalizing of detailed project budget	4 months Winter/Spring 2023 Phase 3 and 4
STEP 11: Offtake negotiations		
• Negotiation with QEC regarding the terms of their PPA	• PPA with QEC under their IPP program	4-6 months Winter/Spring 2023 Phase 4
STEP 12: Financial close		
• Establishment of the legal entity to own and operate the project • Review of all project information • Sharpening/filling info gaps as needed to satisfy funders/lenders • Finalization of contingency plans for foreseeable risks	• Final agreements with government funders • Final agreement with debt lender (if needed) • Flow of funds to allow implementation of the project • Execution of contracts with key project vendors	2-3 months Spring/ Summer 2023 Phase 4

STEP 13: Project implementation		
• Communications with key stakeholders • Site preparation • Construction • Commissioning • Training for maintenance staff • Start of operations	• A 960kW solar energy facility in Salliq, owned by Kivalliq Alternative Energy	This project could be delivered over 1-2 summer building seasons. Summer 2023-2024 Phase 4 and beyond
STEP 14: Operations + Maintenance		
• Operation of a 960kW solar energy and energy storage project in Salliq • Administration of project operations • Training of local operators to maintain project facilities	• Displacement of up to 31% of Salliq's diesel generated electricity (or 10% of total diesel use)	30 years or more, starting 2024/25

Appendix 1 - System Integration Study

CORAL HARBOUR

PRELIMINARY SYSTEM INTEGRATION STUDY

August 2021

Prepared By:

Green Cat Renewables Canada Corporation

Prepared For:

Northern Energy Capital & Sakku Investment Corporation

Revision	Date	Author	Checked By	Approved By
0.1 Client Draft Issued for Review	May 31st, 2021	GR	GJ	CM
1.0 Final Issue	June 28th, 2021	GR	GJ	CM
2.0 Second Issue	July 28th, 2021	GR	GJ	CM
3.0 Third Issue	August 16th, 2021	GR	GJ	CM

CONTENTS

1. INTRODUCTION

Green Cat Renewables (herein GCR) have been retained by Northern Energy Capital (NEC) on behalf of Sakku Investment Corporation (herein 'SIC' and the 'Developer') to conduct a preliminary renewable energy system integration study for the community of Coral Harbour, Nunavut. Coral Harbour currently relies on diesel generators to meet the local electricity demand. The community is currently powered by three (2 x 500kW – derated to 480KW max and 1 x 720kW) diesel generators, with a fourth 500kW generator reserved for emergencies. Qulliq Energy Corporation (QEC), who are the local utility for the community, have provided monthly generation totals spanning four years for the community of Coral Harbour. Unfortunately, detailed daily data files, containing 10 second power generation data for each of the generators, were not available for this community due to the equipment installed. Therefore, for the purposes of this assessment, a number of daily data files measured at the community of Naujaat will be used and adjusted accordingly. These daily files for the community of Naujaat contain 10 second power generation data from each of the three generators installed there, as well as the total load. It is assumed that the load data provided by QEC are equivalent to the demand for the Naujaat community (under the assumption that no additional generators produce power for the local grid).

The following study considers the use of wind, solar and battery energy storage systems (BESS), and how renewable energy systems of different sizes might interact with the demand in order to offset the diesel generation. This study follows on from part 1 of the feasibility study: Coral Harbour Technology Comparison Analysis, issued to the Developer in September 2020[1]. A fixed tilt, bi-facial south facing solar array is the recommended solar configuration for this site and has been included as such in this study. Additionally, and for comparison, a single EWT wind turbine was considered. GCR has assumed a 1MW DW61 wind turbine with a 46m hub height for this purpose.

[1] Coral Harbour Technology Comparison Analysis v1.0 (2020.09.04).pdf

2. ANALYSIS OF ELECTRICITY GENERATION DATA PROVIDED

QEC provided monthly total electricity demand (in kWh) and diesel consumption (in litres)[2] for the Coral Harbour community, as tabulated in **Table 2-1**. The average seasonal profile of consumption over the four-year period is shown on **Figure 1**, on the following page. Unfortunately, QEC were unable to provide detailed daily data for the Coral Harbour community. Therefore, in the absence of this detailed daily data, GCR have compared the Coral Harbour data against the community of Naujaat data, in order to evaluate the correlation between the two communities. This would then allow the detailed daily data for Naujaat to be adjusted and utilised for the Coral Harbour community. The monthly total electricity demand (in kWh) and diesel consumption (in litres)[3] for the Naujaat community is tabulated in **Table 2-2** below. **Figure 1**, on the following page, illustrates the demand profile of the two communities.

Table 2-1 Monthly electricity demand and oil consumption data provided for Coral Harbour.

Month/Year	2015/2016		2016/2017		2017/2018		2018/2019	
	Electricity Demand (kWh)	Oil Consumption (l)	Electricity Demand (kWh)	Oil Consumption (l)	Electricity Demand (kWh)	Oil Consumption (l)	Electricity Demand (kWh)	Oil Consumption (l)
April	293,600	89,160	293,000	90,099	292,200	84,387	288,400	83,621
May	270,800	80,073	278,200	84,743	278,400	78,845	279,600	85,949
June	244,600	70,880	251,000	77,883	252,200	72,214	245,600	73,546
July	253,000	73,532	248,600	74,479	249,800	70,569	250,200	74,067
August	256,200	74,019	259,600	75,575	264,600	74,913	264,400	74,805
September	264,800	77,466	266,600	77,530	273,400	76,538	269,600	79,211
October	304,400	89,513	301,400	88,536	302,000	88,394	299,200	87,317
November	313,600	84,645	308,200	90,400	315,000	90,950	319,400	92,227
December	349,000	109,782	343,200	98,924	345,800	98,714	388,200	99,477
January	333,000	98,800	344,800	100,977	361,000	103,426	330,600	109,180
February	322,000	95,683	315,200	90,677	270,800	92,978	328,000	94,188
March	320,200	95,809	331,000	95,615	321,200	93,580	345,400	88,605

Table 2-2 Monthly electricity demand and oil consumption data provided for Naujaat

Month/Year	2015/2016		2016/2017		2017/2018		2018/2019	
	Electricity Demand (kWh)	Oil Consumptio n (l)	Electricity Demand (kWh)	Oil Consumptio n (l)	Electricity Demand (kWh)	Oil Consumptio n (l)	Electricity Demand (kWh)	Oil Consumptio n (l)
April	358,298	93,046	372,583	97,313	364,615	97,140	380,600	105,262
May	339,637	92,584	353,647	94,555	342,562	87,612	366,543	101,205
June	292,935	77,013	306,094	75,330	312,787	83,645	326,494	90,573
July	271,034	80,761	309,704	80,188	305,283	81,029	329,166	91,282
August	256,712	80,972	330,015	85,441	330,770	88,636	333,680	110,394
September	311,815	89,910	334,709	85,982	325,666	89,810	349,233	79,513
October	359,451	96,438	362,485	92,816	362,620	96,643	392,127	106,974
November	368,974	99,322	372,760	96,200	392,850	105,704	395,743	107,912
December	388,425	104,967	404,454	105,048	422,000	111,175	444,799	121,215
January	386,147	104,149	405,647	107,362	413,991	113,458	456,849	111,924
February	384,681	100,205	363,000	90,896	399,570	111,940	419,314	109,648
March	397,096	104,605	399,684	111,630	413,411	111,064	442,142	118,530

[2] Coral Harbour & Naujjat data.docx, provided by email to GCR by NEC on 22-07-2020

[3] Coral Harbour & Naujjat data.docx, provided by email to GCR by NEC on 22-07-2020

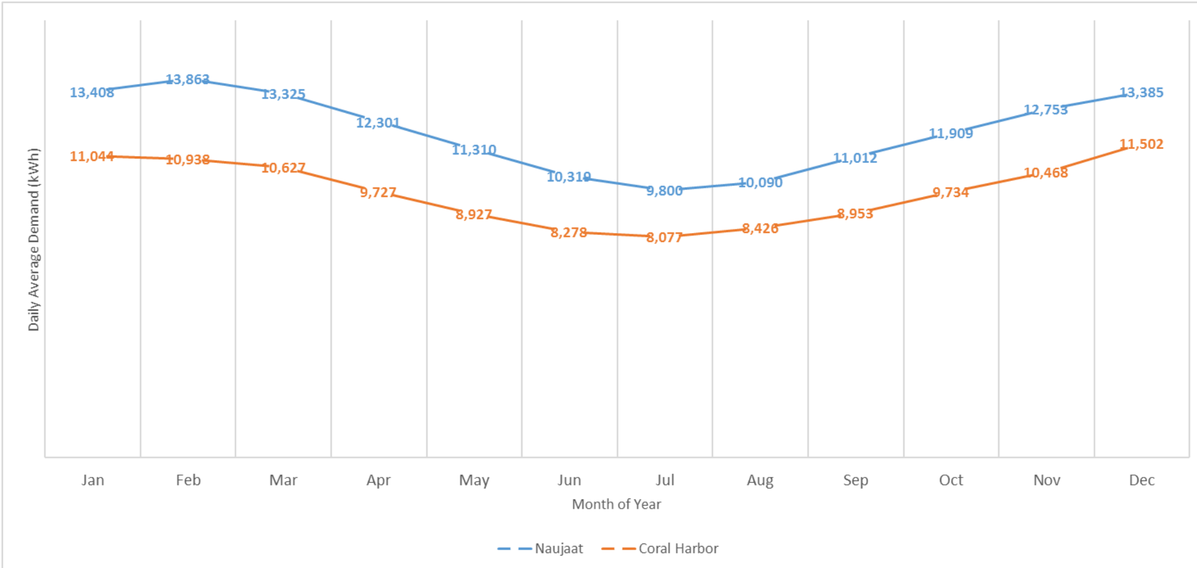

Figure 1 – Naujaat & Coral Harbour: seasonal distribution of demand (April 2015 to March 2019), according to the monthly data provided for review.

As can be seen above, in both communities the demand is highest in the winter months, reducing in the summer months. The annual demand is reasonably consistent, with a detectable upward trend in the annual demand over the four years. Within the same document, an indication of the forecast demand was provided: 3,915MWh per annum at Coral Harbour by 2025.

While the monthly energy consumption records provide useful context, the resolution is not adequate to inform the Preliminary Integration Study. GCR therefore requested detailed demand/production data from QEC. As noted, unfortunately QEC were unable to provide detailed data for Coral Harbour. As can be seen in **Figure 1,** above, the seasonal distribution of demand at Coral Harbour is comparable to that of Naujaat (albeit at a lower average daily demand). GCR therefore adopted the detailed data provided for Naujaat for the use in the current assessment for Coral Harbour. One potential limitation of this approach is that the diurnal variation may differ slightly between the two sites. On balance, it is considered preferable to adopt this data than to derive a synthetic demand profile for Coral Harbour. The remainder of this section describes the data provided for Naujaat in detail and the approach taken to scaling that data for use as a representative dataset at Coral Harbour.

2.1. NAUJAAT DEMAND DATA

On the 22nd February 2021, QEC provided a zip file containing 697 individual files in .csv format for Naujaat[4]. QEC indicated that these records are gathered by a programmable logic controller (PLC) installed on the site of the diesel generators. All available records have been provided where QEC have been able to do so. The file titled '2019 02 25 0000 (Tagname).csv' contained the following information:

Table 2-3 Contents of the tagname header file provided for Naujaat

;Tagname	TTagIndex	TagType	TagDataTyp
REPULSE_BAY\GEN1\G1_REAL_POWER	0	2	1
REPULSE_BAY\GEN2\G2_REAL_POWER	1	2	1
REPULSE_BAY\GEN3\G3_REAL_POWER	2	2	1
REPULSE_BAY\MISC\TOTAL_LOAD	3	2	1

The remaining files contained 10 second readings from each of the three generators, as well as the total load. The records provided are structured as follows:

Table 2-4 Header and first eight lines of data from the file '2018 03 28 0000 (Float).csv', provided for Naujaat.

Date	Time	Millitm	TagIndex	Value	Status	Marker	Internal
28/05/2020	00:00:02	532	0	0		B	-1
28/05/2020	00:00:02	532	1	0		B	-1
28/05/2020	00:00:02	532	2	131		B	-1
28/05/2020	00:00:02	532	3	479		B	-1
28/05/2020	00:00:09	419	0	0			0
28/05/2020	00:00:09	419	1	0			1
28/05/2020	00:00:09	419	2	128			2
28/05/2020	00:00:09	419	3	485			3

QEC indicated in a telephone conversation with GCR that the 'Value' column represents the instantaneous power reading in kW, taken at ~10 second intervals. A number of occurrences of 'E' in the status field were noted, often corresponding with a value of 0 in the value field. QEC indicated that occurrences of 'E' represent errors in the data in the data recording or communications systems. In has been inferred from the data provided that the timestamps are recorded in local time throughout (GMT-6 in the winter months and GMT-5 in the summer months).

After removing duplicate files and the tagname file, 485 files remain. A number of these files are incomplete however, with less than the full 34,560 lines of data. The records span the time interval 27/03/2018 to 28/05/2020 inclusive, with a number of prolonged gaps.

[4] NAUJAAT DATA.zip, provided to GCR by QEC in a shared Dropbox folder 22-02-2021

Due to the volume of data provided, GCR developed a VBA macro to process the 10 second values into a useable time series. The macro recorded the half-hourly average 'Value' for each: G1, G2, G3 and TOTAL_LOAD, alongside the max and min TOTAL_LOAD. The number of occurrences of 'E' in the marker field were also extracted from the data for each of the four tag indices, along with the observation count for each half hour long period. QEC indicated that the 'TOTAL_LOAD' measures the combined output of G1, G2 and G3, plus the emergency generator (which is not independently measured).

The data were then subject to quality control and validation using Windographer software. Any half hourly period with an 'E' count of greater than 0 were discarded. Similarly, periods adjacent to 'E' counts of greater than 0 were visually inspected and discarded if the corresponding 'Value' data were observed to be erratic or spurious e.g. significant differences in the max and min, large changes in readings from one half hour to the next or otherwise off-trend data points. It was observed that the G1, G2 and G3 readings are less reliable than the TOTAL_LOAD, with higher error counts and longer periods of missing data. Further, a number of instances where G1+G2+G3 is less than the TOTAL_LOAD were identified. This is presumably due to periods where the emergency generator is providing part of the load. Since detailed data for the individual generators is not required for this assessment, subsequent analysis will consider only the TOTAL_LOAD data.

The diurnal pattern of the quality-controlled data is shown in the following figure. As can be seen, the daily profile follows a fairly typical pattern, with high levels of consumption around lunch time and in the evening, and low levels of consumption during the night.

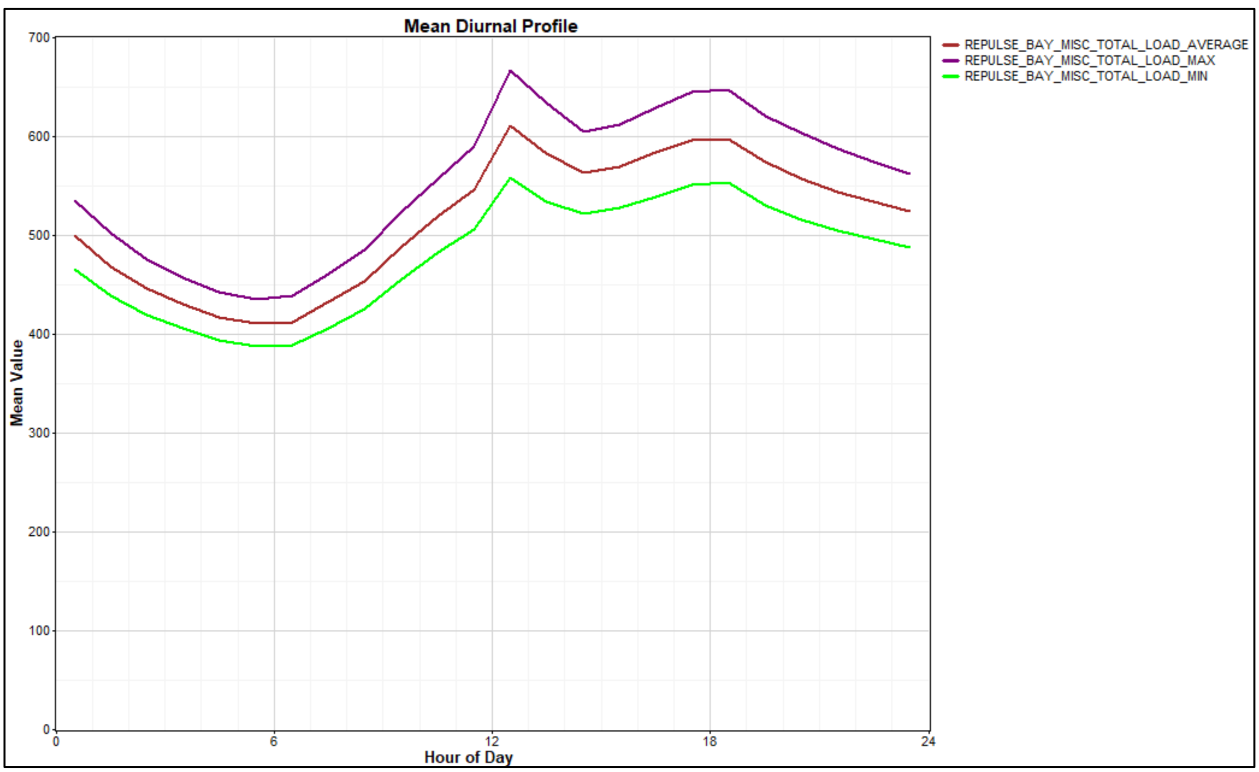

Figure 2 – Diurnal profile of generation at Naujaat.

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The following histogram illustrates the frequency of power output in kW. As can be seen, the power output of the diesel generators is never less than 300kW at Naujaat. These low demand periods tend to occur at night or in the early hours of the morning.

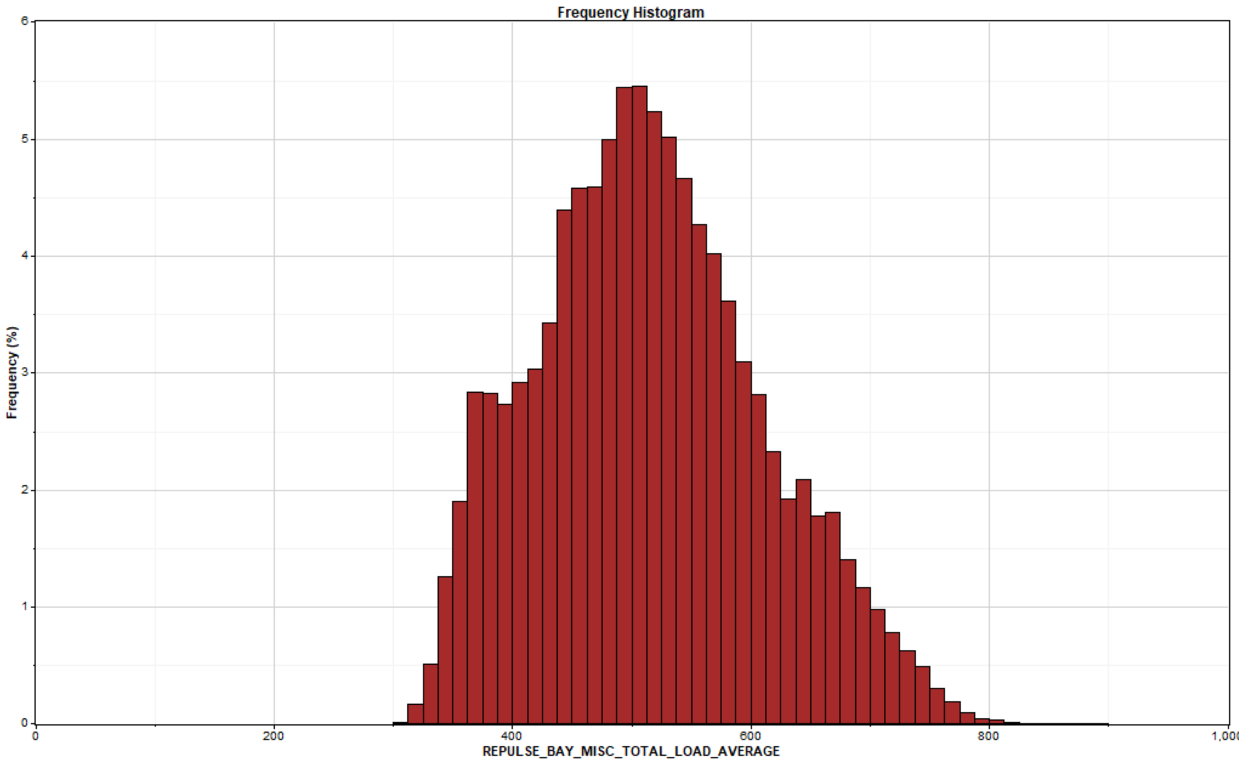

Figure 3 – Frequency histogram of generator output at Naujaat.

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The data daily and monthly data recovery of this quality-controlled dataset is shown in the following table:

Table 2-5 Naujaat data recovery for each day and month expressed as the number of retained half hourly data points after quality control.

Month/day of month	1	2	3	4	5	6	7	8	9	10	11	12
1	0	46	42	39	48	12	48	48	0	0	1	0
2	0	46	47	48	48	45	47	48	0	0	28	0
3	16	44	13	48	48	42	47	48	0	0	47	12
4	48	28	25	48	48	31	47	48	0	15	48	42
5	48	46	41	48	48	14	47	48	24	39	48	48
6	48	43	45	48	47	36	48	47	45	45	26	46
7	48	46	45	48	47	47	48	48	48	48	0	48
8	48	47	44	47	48	48	47	48	48	47	0	47
9	48	44	47	48	48	25	47	48	48	47	0	48
10	48	45	46	48	48	0	28	47	48	47	0	47
11	48	47	47	48	48	0	46	48	48	47	0	47
12	48	40	46	48	48	0	18	48	48	46	0	48
13	48	25	0	48	48	24	48	48	48	47	0	47
14	48	45	15	48	47	45	48	48	47	47	0	25
15	48	47	36	48	44	48	48	48	40	47	0	0
16	48	40	47	48	48	48	45	48	48	46	0	0
17	48	48	48	48	48	48	23	48	42	47	0	0
18	47	47	48	48	48	48	28	46	44	48	0	0
19	47	46	47	48	48	48	47	45	35	26	0	0
20	48	48	47	48	48	48	48	48	45	0	0	0
21	48	48	43	48	48	47	48	47	48	0	0	0
22	45	41	47	48	48	48	48	48	44	17	0	0
23	47	41	3	48	43	33	48	48	37	48	0	0
24	46	38	13	48	48	40	48	48	45	48	0	0
25	48	33	0	48	48	48	48	48	48	48	0	0
26	45	42	0	48	48	48	48	48	47	48	0	0
27	6	42	45	48	48	48	48	48	48	48	0	0
28	23	44	48	48	42	48	48	46	8	48	0	0
29	29	-	46	48	44	47	48	36	6	48	0	0
30	35	-	45	48	47	47	48	0	0	28	0	0
31	48	-	48	-	16	-	48	0	0	0	-	0

The overall data recovery is poor at around 75% of the year, with significant, prolonged gaps in the records, particularly in the months of November and December. Using this data as is will lead to a bias in the results due to the seasonal nature of both the renewable energy generation and the demand profile. Fortunately, the load profile follows a reasonably consistent diurnal and seasonal pattern. GCR has identified a degree of symmetry centred around mid-July:mid-January, that is to say: the generation for June is comparable with that of August, May is similar to September, and so on. This pattern is also observed in the monthly data provided for review.

GCR has derived a years' worth of demand data using the following data substitution methodology:

1. The quality-controlled data were exported from Windographer;
2. A fictitious 'representative year' half hourly time series was created. For each half hourly period, data were extracted from the records in the following order 2018, 2019 (when no values are available from 2018), 2020 (when no values are available from 2018 or 2019);
3. Half hour long gaps were interpolated from adjacent timestamps (~0.9% of data);

4. Remaining gaps (mainly long periods of time) were then filled using data from alternative dates, based on a line of symmetry through the 14th July e.g. data from the 15th July could be sourced from the 13thJuly, and so on. (~19.7% of data);
5. Any residual gaps were then filled according to the following data substitution scheme:
    a. Take data from 1 day ahead (~3.4% of data);
    b. Take data from 1 day behind (~1.1% of data);
    c. Take data from 2 days ahead (~0.2% of data);
    d. Take data from 2 days behind (<0.1% of data).

The resulting time series contains data for each 48-hour period, 365 days per year. The total annual energy demand in the Naujaat time series is 4,675MWh. For comparison: the demand in the last full twelve months of monthly data provided for Naujaat (April 2018 to March 2019 inclusive) was 4,637MWh – a difference of around 0.8%.

2.2. WEIGHTING OF NAUJAAT DATA

The 2025 annual demand forecast for Coral Harbour was given as 3,915MWh, 16.3% less than the data provided for Naujaat. GCR has therefore scaled the half hourly time series derived for Naujaat to this figure by applying a scaling factor of 83.7%. This is a reasonable approximation assuming the seasonal and daily distribution of demand at Coral harbour is similar to Naujaat. While the seasonal profile is a reasonably good match, as evidenced in **Figure 1**, the diurnal variation in the Coral Harbour demand is not well understood. While this is a limitation with the current study, the profile used is considered to be far more realistic than the next best alternative – using a fully synthetic profile for Coral Harbour. To allow this to be further evaluated in the future, a request has been submitted to QEC for the installation of the appropriate monitoring equipment at the Coral Harbour power station in order to collect detailed demand data.

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3. SYSTEM INTEGRATION TIME SERIES MODELLING

The scaled half hourly time series demand data derived above has been converted into an hourly time series for direct comparison with the wind and solar time series output (which are limited to hourly resolution). The average demand is compared with the net wind[5] and net solar AC power output for each hour for a full year (8760 hours).

The solar time series is based on the following configuration: 130kWp (DC), 100kW AC fixed tilt, bi-facial array. Full details can be found in the September 2020 technology comparison study. A scaling factor is used to scale the solar generation data from 0kW to 2000kW (AC), in 100kW increments. This is a reasonable approximation assuming the characteristics of the system remain constant regardless of the size. In practice, the larger systems might employ a smaller number of large inverters, for example.

The wind power time series is based on ERA-5[6] wind speed, temperature and pressure data for the node nearest the site (64.250N, 83.250W). The ERA-5 wind speed has been scaled to match the AWS wind speed estimate at 40m AGL of 5.85m/s (as provided by the Developer). The wind speed in each hour has also been modified by the air density (calculated from ERA-5 temperature and pressure data) in order to better capture the impact of changes in air density throughout the year (which is significant in this case). Sales power curve data for the EWT DW61 1MW[7] have been used to estimate the gross power production for each hour. Technical losses have been incorporated to produce an estimate of the net wind[5] power output for each hour. It is assumed that the turbine is equipped with anti-icing and de-icing options and includes a 'cold weather' package. There may be times when these systems consume power – this has not been modelled in this high-level study. The time series of wind power output for the year 2013 has been added to the timeseries. 2013 was found to be closest to average conditions at this site. It is important to highlight high levels of uncertainty in the wind power time series data.

A summary of the seasonal variation in daily average demand and wind and solar production is provided in Figure 4. As can be seen, the seasonal profile of wind generation is a closer match with the demand at this site when compared against the solar generation profile.

[5] Please refer to Appendix A – Wind Power Technical Losses
[6] ERA-5 reanalysis data, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF)
[7] EWT Document reference: S-1209901, revision 00, dated 13-04-2017

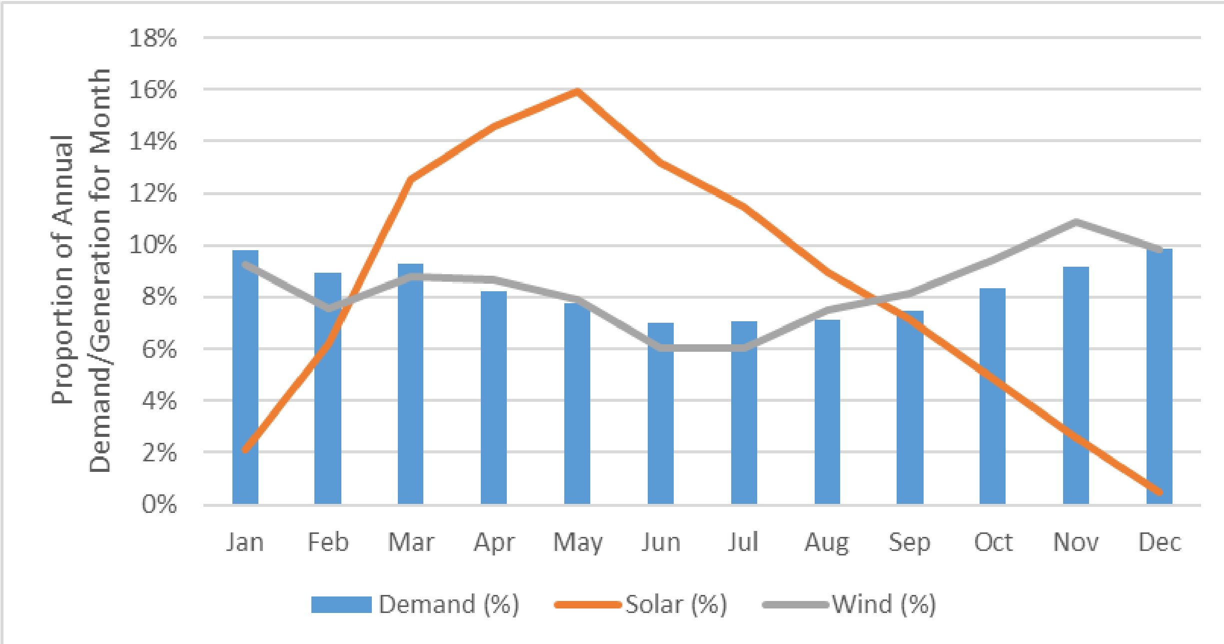

Figure 4 – Seasonal distribution of demand (derived from Naujaat and scaled to match the annual net demand of Coral Harbour) and wind and solar power generation. Solar based on Typical Meteorological Year (TMY). Wind based on long term period 1979 to 2020 inclusive.

The net demand and generation was calculated for each hour. Where there is excess generation, and where a BESS is modelled, the BESS has the opportunity to absorb the power for later use. Where the demand exceeds the renewable generation, the BESS will release the stored energy at a rate not greater than the net demand (after contributions from the wind turbine and/or solar array). The energy flow to and from the BESS is also limited by the rated power and energy capacity of the BESS. For the purpose of modelling, the specifications below have been assumed for the BESS modelling:

1. It is assumed that 80% of the BESS installed capacity will be available for use e.g. 800kWh for a 1000kWh system. This a reasonable assumption for a lithium-ion type BESS where a sensible strategy would be to limit the state of charge to between 10% and 90% to prolong the service life of the cells.
2. A charge and discharge efficiency of 95% is assumed, with a further 1% electrical loss assumed between the renewable generators to the BESS, and 1% loss from the BESS to the network. This results in a round trip efficiency of approximately 88%.
3. In this preliminary model, self-discharge, parasitic consumption[8] and battery performance degradation are not considered.

A series of BESS sizes have been modelled: 0kW (no BESS), and 1000kW, with 1, 2, 3 and 4 hours of storage (1000kWh, 2000kWh, 3000kWh and 4000kWh). A battery size of 1000kW has been selected as this will be

[8] The parasitic load is a more major consideration during when there is low generation and inclement weather conditions (e.g. a solar only system during the winter months, when the system may not charge for months and will be dormant for that period)

capable of covering the peak demand in the event of a sudden drop in renewable output e.g. renewable generator downtime at a time when the diesel generators are switched off. It is assumed that the renewable generators and BESS have priority over the diesel generators in this model. In the model with no battery (0kWh): the diesel generator is assumed to be able to produce either 0kW, or from 260kW[9] (minimum load assumed) to the net demand; the diesel generator is switched off if the renewable energy production exceeds the demand, otherwise, the diesel output is between 260kW and the net demand. In the model that includes the BESS: it is assumed that if required, that the average hourly output of the diesel could be less than the minimum assumed load (of 260KW). This could be achieved by running the diesel for part of the hour to charge the BESS sufficiently to meet the net demand for that hour.

Systems with high levels of renewable energy penetration may lead to instability in the local grid, especially in scenarios where no BESS is included. It may be possible to mitigate these effects by incorporating a short duration energy storage system. Such a system would need to be able to absorb short timescale fluctuations in renewable energy output and demand, and have a duration that is at least sufficient to bring the diesel generator(s) online in the event of a sudden drop in renewable power output e.g. wind and/or solar downtime, sudden cloud cover. The range of viable system configurations therefore depends on the stability of the system and the ramping capabilities of the generators and energy storage systems incorporated. An engineered solution should be investigated in conjunction with discussion with QEC as part of the detailed design, but it is expected that installing a suitably sized battery with the chosen renewable energy technology will provide the required stability required by QEC.

[9] QEC indicated in a meeting with GCR that a preferred minimum diesel load of 60% per generator would be desirable (300kW in this case). The minimum in the scaled demand data is around 260kW however. A minimum diesel load of 260KW has been adopted in this assessment.

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Figure 5 and **Figure 6** illustrate the logic used in the hourly simulation. These flow charts are not intended to be used as a live microgrid control algorithm.

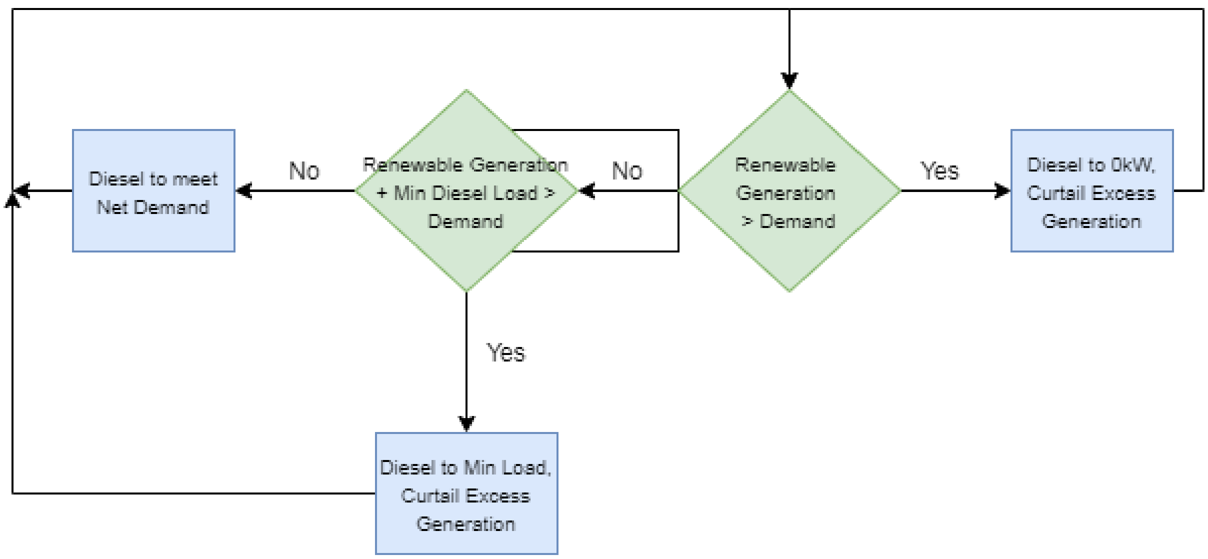

Figure 5 – Simple illustration of the hourly simulation logic for systems without BESS.

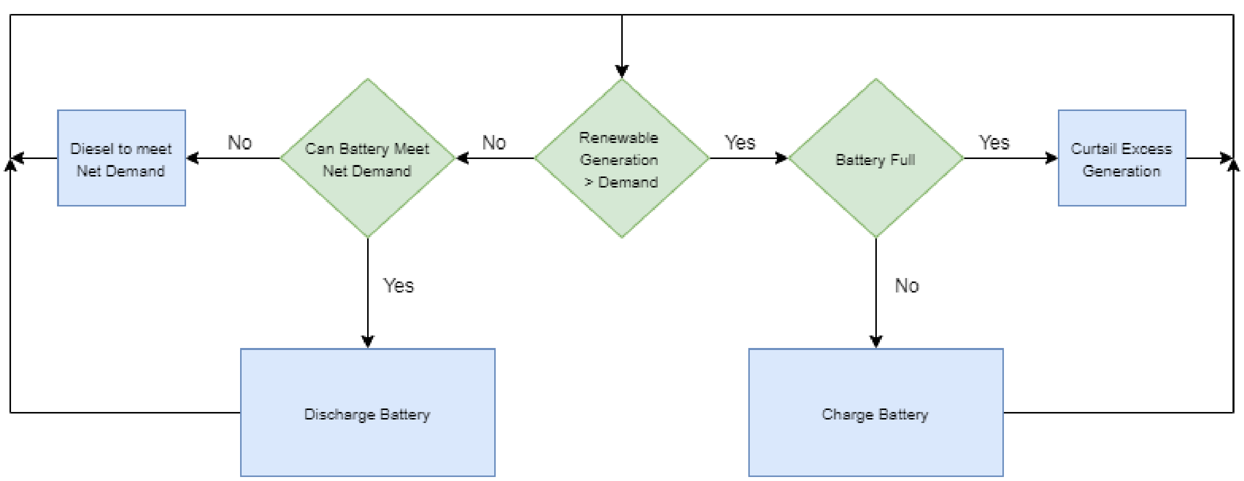

Figure 6 – Simple illustration of the hourly simulation logic for systems with BESS.

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4. RESULTS

Table 4-1, **Table 4-2** and **Table 4-3** on the following pages present the results for the range of wind, solar and BESS system configurations modelled. The demand profile is based on the 8760-hour long time series derived from measurement at the settlement of Naujaat and scaled to the 2025 annual demand forecast of 3,915MWh for Coral Harbour:

1. **Demand Met.** This is the annual demand met by the renewable generation and BESS in MWh.
2. **Fraction of Total Demand Met.** This is the above measure divided by the total demand of 3,915MWh per annum.
3. **Excess Generation.** The annual excess generation in MWh that is not utilised directly by the demand or by the BESS and later released to the demand e.g. due to a lack of BESS, a fully charged BESS at times when the renewable generation exceeds the demand, excess power in exceedance of the BESS rated power. Excess generation would need to be curtailed in some way or otherwise utilised in order to balance the electrical system. Solar could be curtailed by using the inverters Maximum Power Point Trackers (MPPT's) to control the output. The wind turbine could be curtailed in real time using via the SCADA system. A dump load could also be used to absorb excess generation.

Some selected examples from the results for illustration purposes:

1. A system with a wind turbine, 1 hour BESS and 0kW solar capacity could provide 1,626MWh (41.5% of demand) with an excess generation of 354MWh.
2. A system with 1,000kW AC of solar, no wind turbine and a 1 hour BESS could provide 1,346MWh (34.4% of demand) with an excess generation of 408MWh.

Graphs illustrating the seasonal distribution of energy for these two scenarios are provided in **Figure 7** and **Figure 8**, on the following page.

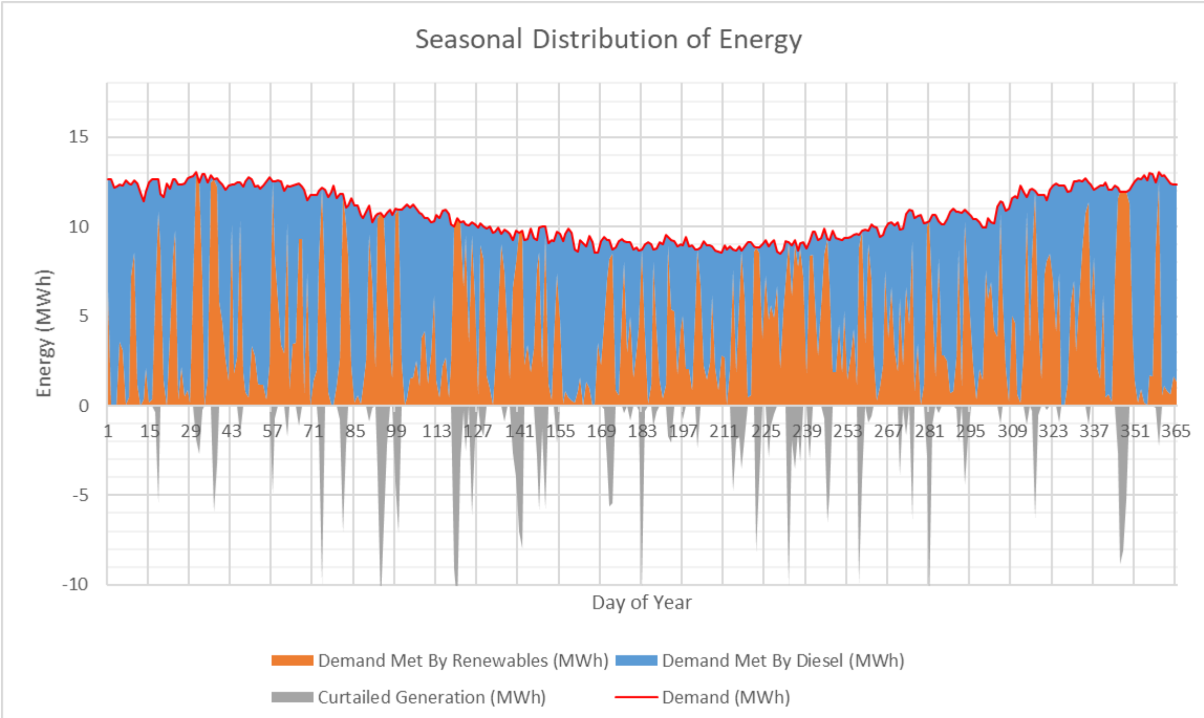

Figure 7 – Seasonal distribution of demand met by renewables and diesel, along with curtailed renewable generation. Results presented for an EWT DW61 1MW 46mHH and a one-hour, 1MW BESS.

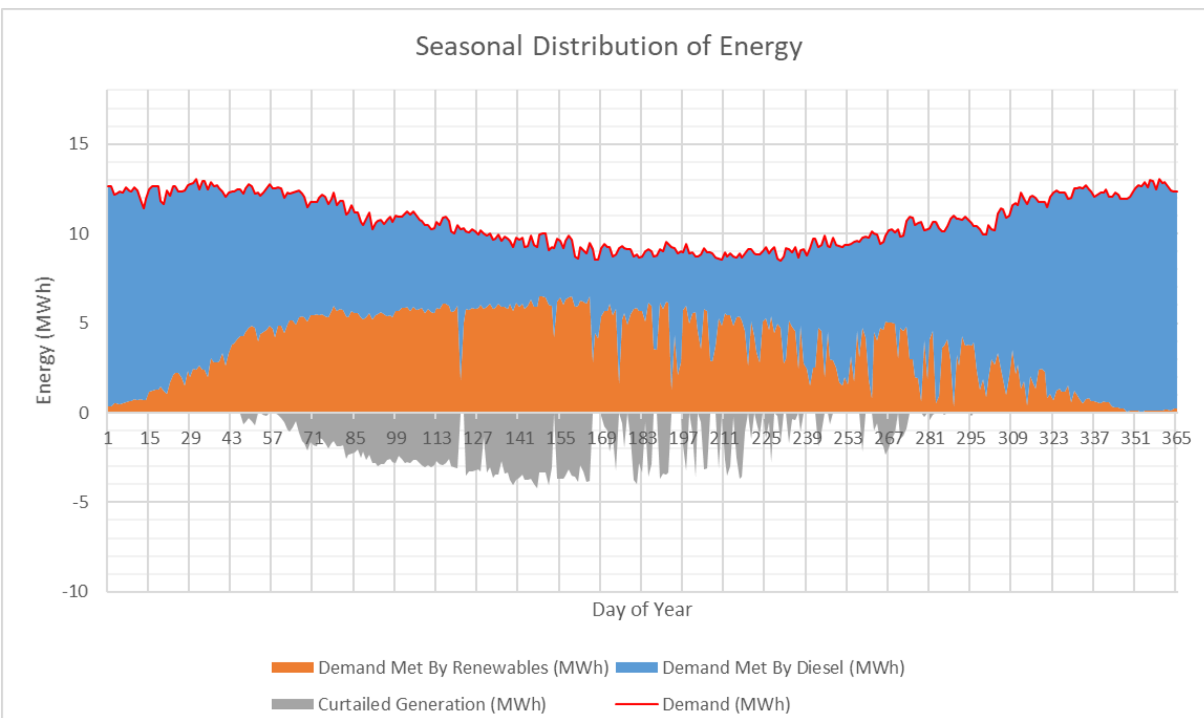

Figure 8 – Seasonal distribution of demand met by renewables and diesel, along with curtailed renewable generation. Results presented for 1000kW solar and a one-hour, 1MW BESS. [10]

10 In a typical summer day, the solar will charge the BESS during the day, discharge in the evening and the system would switch to diesel once the battery is depleted.

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Table 4-1 Coral Harbour Demand Met

Excluding Wind						
Demand Met (MWh)		BESS System Size (kWh)				
		0	1000	2000	3000	4000
Solar System Size (kW AC)	0	0	0	0	0	0
	100	176	177	177	177	177
	200	324	355	355	355	355
	300	415	532	532	532	532
	400	499	710	710	710	710
	500	672	883	883	883	883
	600	803	1,037	1,052	1,052	1,052
	700	886	1,143	1,207	1,218	1,218
	800	954	1,222	1,317	1,373	1,382
	900	1,012	1,289	1,400	1,485	1,536
	1000	1,056	1,346	1,469	1,571	1,650
	1100	1,103	1,394	1,530	1,642	1,738
	1200	1,140	1,435	1,582	1,704	1,811
	1300	1,168	1,471	1,627	1,761	1,875
	1400	1,193	1,504	1,667	1,811	1,933
	1500	1,219	1,535	1,702	1,854	1,986
	1600	1,242	1,562	1,735	1,893	2,034
	1700	1,262	1,587	1,766	1,928	2,076
	1800	1,281	1,610	1,794	1,960	2,112
	1900	1,297	1,630	1,820	1,990	2,146
	2000	1,313	1,649	1,844	2,019	2,176

Including Wind						
Demand Met (MWh)		BESS System Size (kWh)				
		0	1000	2000	3000	4000
Solar System Size (kW AC)	0	1,333	1,626	1,672	1,708	1,736
	100	1,460	1,766	1,814	1,851	1,881
	200	1,559	1,901	1,951	1,989	2,020
	300	1,634	2,030	2,081	2,120	2,154
	400	1,714	2,147	2,202	2,243	2,279
	500	1,834	2,254	2,314	2,358	2,396
	600	1,917	2,340	2,415	2,464	2,504
	700	1,973	2,399	2,497	2,557	2,600
	800	2,019	2,443	2,554	2,635	2,686
	900	2,057	2,479	2,598	2,690	2,757
	1000	2,088	2,510	2,635	2,733	2,809
	1100	2,117	2,535	2,666	2,769	2,851
	1200	2,139	2,557	2,693	2,800	2,885
	1300	2,157	2,577	2,716	2,829	2,916
	1400	2,172	2,594	2,736	2,854	2,945
	1500	2,188	2,611	2,755	2,875	2,970
	1600	2,204	2,625	2,772	2,894	2,991
	1700	2,214	2,638	2,788	2,911	3,011
	1800	2,227	2,649	2,803	2,928	3,028
	1900	2,238	2,660	2,816	2,943	3,044
	2000	2,246	2,670	2,829	2,958	3,058

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Table 4-2 Coral Harbour Fraction of Total Demand Met

	Excluding Wind						Including Wind				
Fraction of Total Demand Met (%)	BESS System Size (kWh)					Fraction of Total Demand Met (%)	BESS System Size (kWh)				
Solar System Size (kW AC)	0	1000	2000	3000	4000	Solar System Size (kW AC)	0	1000	2000	3000	4000
0	0.0%	0.0%	0.0%	0.0%	0.0%	0	34.1%	41.5%	42.7%	43.6%	44.3%
100	4.5%	4.5%	4.5%	4.5%	4.5%	100	37.3%	45.1%	46.3%	47.3%	48.0%
200	8.3%	9.1%	9.1%	9.1%	9.1%	200	39.8%	48.6%	49.8%	50.8%	51.6%
300	10.6%	13.6%	13.6%	13.6%	13.6%	300	41.7%	51.8%	53.1%	54.2%	55.0%
400	12.7%	18.1%	18.1%	18.1%	18.1%	400	43.8%	54.9%	56.2%	57.3%	58.2%
500	17.2%	22.6%	22.6%	22.6%	22.6%	500	46.8%	57.6%	59.1%	60.2%	61.2%
600	20.5%	26.5%	26.9%	26.9%	26.9%	600	49.0%	59.8%	61.7%	62.9%	64.0%
700	22.6%	29.2%	30.8%	31.1%	31.1%	700	50.4%	61.3%	63.8%	65.3%	66.4%
800	24.4%	31.2%	33.6%	35.1%	35.3%	800	51.6%	62.4%	65.2%	67.3%	68.6%
900	25.8%	32.9%	35.8%	37.9%	39.2%	900	52.5%	63.3%	66.4%	68.7%	70.4%
1000	27.0%	34.4%	37.5%	40.1%	42.2%	1000	53.3%	64.1%	67.3%	69.8%	71.7%
1100	28.2%	35.6%	39.1%	41.9%	44.4%	1100	54.1%	64.8%	68.1%	70.7%	72.8%
1200	29.1%	36.6%	40.4%	43.5%	46.3%	1200	54.6%	65.3%	68.8%	71.5%	73.7%
1300	29.8%	37.6%	41.6%	45.0%	47.9%	1300	55.1%	65.8%	69.4%	72.3%	74.5%
1400	30.5%	38.4%	42.6%	46.3%	49.4%	1400	55.5%	66.3%	69.9%	72.9%	75.2%
1500	31.1%	39.2%	43.5%	47.4%	50.7%	1500	55.9%	66.7%	70.4%	73.4%	75.9%
1600	31.7%	39.9%	44.3%	48.3%	52.0%	1600	56.3%	67.0%	70.8%	73.9%	76.4%
1700	32.2%	40.5%	45.1%	49.2%	53.0%	1700	56.6%	67.4%	71.2%	74.4%	76.9%
1800	32.7%	41.1%	45.8%	50.1%	54.0%	1800	56.9%	67.7%	71.6%	74.8%	77.4%
1900	33.1%	41.6%	46.5%	50.8%	54.8%	1900	57.2%	67.9%	71.9%	75.2%	77.8%
2000	33.5%	42.1%	47.1%	51.6%	55.6%	2000	57.4%	68.2%	72.3%	75.6%	78.1%

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Table 4-3 Coral Harbour Excess Generation

Excluding Wind

Excess Generation (MWh) — Solar System Size (kW AC)	BESS System Size (kWh): 0	1000	2000	3000	4000
0	0	0	0	0	0
100	1	0	0	0	0
200	31	0	0	0	0
300	118	0	0	0	0
400	211	0	0	0	0
500	215	0	0	0	0
600	262	17	0	0	0
700	357	85	12	0	0
800	466	180	74	10	0
900	586	290	164	68	10
1000	719	408	269	154	64
1100	850	537	383	256	148
1200	990	672	505	367	246
1300	1,139	812	636	485	355
1400	1,291	956	772	609	471
1500	1,443	1,102	912	741	591
1600	1,598	1,251	1,056	878	717
1700	1,755	1,404	1,201	1,018	850
1800	1,914	1,558	1,349	1,162	989
1900	2,075	1,714	1,499	1,307	1,131
2000	2,237	1,872	1,651	1,454	1,277

Including Wind

Excess Generation (MWh) — Solar System Size (kW AC)	BESS System Size (kWh): 0	1000	2000	3000	4000
0	655	354	301	260	228
100	706	390	336	294	261
200	784	432	376	333	298
300	887	481	423	378	341
400	985	540	478	431	391
500	1,042	608	540	490	447
600	1,136	696	611	555	510
700	1,258	812	701	633	585
800	1,390	944	818	727	669
900	1,529	1,084	950	847	771
1000	1,675	1,230	1,089	978	892
1100	1,824	1,382	1,234	1,118	1,025
1200	1,980	1,537	1,383	1,262	1,166
1300	2,139	1,694	1,537	1,409	1,310
1400	2,302	1,854	1,693	1,560	1,457
1500	2,463	2,014	1,851	1,716	1,608
1600	2,625	2,177	2,010	1,873	1,763
1700	2,792	2,342	2,171	2,032	1,920
1800	2,956	2,507	2,333	2,192	2,078
1900	3,123	2,674	2,497	2,353	2,239
2000	3,293	2,841	2,661	2,516	2,402

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5. LOWEST COST OF ENERGY

Capital Expenditure (CAPEX) costs for each respective system configurations and annual "Demand Met" figures from **Table 4-1** above were utilized to provide a normalized dataset highlighting cost competitiveness (per useful unit of energy generated) of each configuration.[11]

Table 5-1, on the following page, presents the normalized comparative costs of each configuration. The percentages are cost/MWh divided by the average of the maximum and minimum costs/MWh across the whole table. The lowest percentage represents the most cost-effective system and the highest percentage represents the least cost-effective project.[12]

[11] CAPEX cost included known and foreseeable hard and soft development costs, site specific variances and QEC requirements have the potential to influence assessment findings.

[12] $CAD/MWh, based on year 1 generation, as such findings do not represent a formal LCOE.

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Table 5-1 Coral Harbour Normalized Comparative Cost

Excluding Wind

Normalised Cost/MWh of Demand Met	BESS System Size (kWh)				
Solar System Size (kW AC)	0	1000	2000	3000	4000
0	-	-	-	-	-
100	51.1%	91.6%	124.8%	152.9%	175.9%
200	39.8%	56.8%	73.4%	87.4%	98.9%
300	38.7%	43.8%	54.8%	64.2%	71.8%
400	37.4%	36.5%	44.8%	51.9%	57.6%
500	31.3%	32.0%	38.7%	44.3%	48.9%
600	29.2%	29.6%	34.8%	39.5%	43.4%
700	29.0%	28.8%	32.1%	36.0%	39.3%
800	29.1%	28.6%	31.1%	33.4%	36.2%
900	29.3%	28.7%	30.6%	32.2%	33.8%
1000	29.8%	28.7%	30.4%	31.6%	32.5%
1100	30.2%	29.1%	30.4%	31.3%	32.0%
1200	30.8%	29.5%	30.5%	31.3%	31.7%
1300	31.6%	30.0%	30.7%	31.3%	31.5%
1400	32.3%	30.5%	31.0%	31.3%	31.4%
1500	33.0%	30.9%	31.3%	31.5%	31.4%
1600	33.7%	31.4%	31.7%	31.7%	31.5%
1700	34.3%	31.9%	32.0%	31.9%	31.6%
1800	34.9%	32.3%	32.3%	32.1%	31.7%
1900	35.6%	32.8%	32.6%	32.3%	31.9%
2000	36.2%	33.2%	32.9%	32.5%	32.0%

Including Wind

Normalised Cost/MWh of Demand Met	BESS System Size (kWh)				
Solar System Size (kW AC)	0	1000	2000	3000	4000
0	25.6%	25.4%	28.3%	30.6%	32.4%
100	26.3%	25.8%	28.4%	30.5%	32.2%
200	26.4%	25.4%	27.8%	29.8%	31.4%
300	26.4%	24.9%	27.1%	28.9%	30.4%
400	26.5%	24.5%	26.6%	28.3%	29.6%
500	25.8%	24.2%	26.1%	27.7%	29.0%
600	25.7%	24.1%	25.8%	27.3%	28.5%
700	25.9%	24.3%	25.7%	27.0%	28.2%
800	26.1%	24.5%	25.8%	26.9%	27.9%
900	26.3%	24.8%	25.9%	26.9%	27.7%
1000	26.6%	25.0%	26.0%	26.9%	27.6%
1100	27.0%	25.4%	26.4%	27.2%	27.8%
1200	27.4%	25.8%	26.7%	27.4%	28.0%
1300	27.9%	26.2%	27.0%	27.7%	28.3%
1400	28.4%	26.6%	27.4%	28.0%	28.5%
1500	28.9%	27.0%	27.7%	28.3%	28.7%
1600	29.3%	27.3%	28.0%	28.6%	29.0%
1700	29.7%	27.7%	28.3%	28.8%	29.2%
1800	30.1%	28.0%	28.6%	29.1%	29.5%
1900	30.5%	28.4%	28.9%	29.3%	29.7%
2000	30.9%	28.7%	29.1%	29.6%	29.9%

Utilizing the findings above, Table 5-1 indicates that:

1. A 1000 kW wind project is, conceptually, more cost competitive ($/MWh) than any solar solution.
2. A 800 kW solar project combined with 1MWh battery is predicted to be the most cost-effective scale ($/MWh) for solar only generation.
3. The most cost competitive project ($/MWh) appears to be 1000 kW of wind energy plus 600 kW of solar energy with a 1000 kWh battery.

It should be noted that it is expected that a battery will be required to maintain grid stability, while reaching a high level of renewable energy penetration.

6. CONCLUSIONS & RECCOMENDATIONS

Detailed 10 second generation data was not available from QEC for Coral Harbour. Therefore, the data that was available for Coral Harbour was correlated with the data that was available for the Naujaat community. This process confirmed the validity of scaling the Naujaat 10 second generation data as representative of the Coral Harbour community.

The detailed 10 second generation data provided for the community of Naujaat have been processed into a years' worth of demand data and scaled to the 2025 forecast demand for Coral Harbour. This has been directly compared with an hourly wind and solar power output time series produced for the Coral Harbour site specifically. The interaction between the demand, renewable generation and a BESS has been modelled for a range of wind, solar and BESS configurations to allow the Developer to understand how system sizing impacts the results.

GCR provide the following conclusions and recommendations:

1. Relatively high levels of renewable penetration are possible while avoiding significant levels of excess generation. This is thanks to the relatively high minimum demand and continuous nature of the demand.
2. A BESS and/or alternatively, a short duration energy storage system may be required in order to maintain stability of the grid. Grid stability of the scenarios presented should be determined as part of the preliminary and detailed design stages in conjunction with discussions with QEC. An engineered control system will be required.
3. The BESS system has been modelled using 'demand following' logic in this study. This maximises renewable energy penetration for a given BESS size. A BESS system could also operate in cycle charging mode, whereby the diesel generators operate at maximum efficiency in order to charge the BESS, before shutting down and handing over to the BESS. Cycle charging may result in a reduction in diesel consumption (due to higher efficiency) but may lead to additional degradation of the BESS. A combination of demand following, and cycle charging logic could also be used.
4. Due to higher levels of uncertainty in the wind power time series data, systems that include wind power are less certain than solar systems. If wind power is deemed a desirable option, it is recommended that a more detailed wind power time series is developed based on measured data. Measurements should be gathered for a period no less than 12 months and a detailed wind resource assessment should be undertaken thereafter.
5. This study could be refined based on site specific, high resolution demand data – the current study is based on demand data for Naujaat scaled to match the annual demand for Coral Harbour.
6. Modelling outcomes indicate that the most-cost effective ($/MWh) single technology project is a 1000 kW wind project. The addition of a battery to the wind project decreases the cost per MWh of demand met slightly. It should be noted that it is expected that a battery will be required to maintain grid stability. A 800 kW solar project, with a 1 MWh battery, is predicted to be the most

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cost-effective scale ($/MWh) for solar only. The most cost competitive project overall ($/MWh) appears to be 1000 kW of wind energy plus 600 kW of solar energy with a 1000 kWh battery. Discussions with QEC should be undertaken to help define the best solution for integration onto the existing micro-grid.

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APPENDIX A – WIND POWER TECHNICAL LOSSES

GCR has adopted the losses categories outlined by DNV KEMA in 2013.

1 Availability – An allowance of 5% has been included to account for turbine downtime. This is in keeping with a typical EWT warranty for a single turbine site. A further 0.5% has been included to allow for turbine maintenance.

A nominal allowance of 0.5% each for balance of plant and grid downtime has been included here. This assumption could be revisited based on data from the grid operator at a later date.

2 Wake effects – As the site consists of a single turbine without any neighbouring third party turbines, wake losses have not been included here.

3 Turbine performance – It is assumed that the turbine will perform according to the sales power curve data provided by EWT. It is recommended that power curve warranty is obtained along with a warranted power curve.

4 Electrical – A nominal allowance of 2% has been included to account for electrical losses from the point of generation to the point of use. A further 1% has been included to account for facility parasitic consumption. Facility parasitic consumption will depend on the icing and cold weather options installed on the site and will vary according to the climatic conditions on the site. It is recommended that this is revisited in the future based on an in-depth study utilising site specific measurements.

5 Environmental – It has been assumed that the wind turbine's performance will be reduced due to the following external factors:

- Aerodynamic degradation not due to Icing – Assumed 0.5% over a typical 10 year financing period.
- Icing – In the absence of measured data at this site, GCR has adopted a nominal icing loss of 5% to account for icing losses. This is based on information provided in the following reference [1], which designates the site as IEA ice class II, with a corresponding estimated production loss range of 0.5% to 5%.

  Icing losses have been factored in by setting the hourly production to 0kW when the temperature is near zero degrees Celsius. This is a conservative treatment in this case as a proportion of the icing losses will take the form of performance degradation losses i.e. the power output would reduce for a given wind speed.

  Icing losses may be higher or lower in practise, and the impact on overall energy yield and the distribution of losses will depend on the performance of the icing package installed on the turbine. It is recommended that this category is revised based on detailed site measurements and an assessment of the performance of EWT's icing packages.

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- Temperature threshold – It is understood that EWT turbines will shut down if the temperature is below the minimum operating temperature. It is assumed that the turbine installed at this site will be a 'cold climate' type (not standard). The minimum operating temperature for a cold climate type EWT is -40 degrees Celsius. Hours where the temperature is below this threshold has been assigned a power output of 0kW in the time series. The impact is relatively modest at <0.1%.

- Force majeure – An allowance of 2% has been included to account for force majeure events - this is approximately equivalent to one week per year. This assumption could be refined based on a more detailed study of weather delays affecting transport between the site and the relevant EWT service centre(s).

- Tree cover changes – Assumed to have a neutral effect over the long term period; there are no significant areas of woodland or forestry close to the site.

6 Curtailment – Various curtailment losses are possible:

- Wind sector management – Assumed none required – this is usually only applicable to larger developments that also have issues with turbine spacing.

- Grid & offtaker curtailment – These are modelled in time series depending on the scenario modelled.

- Planning restrictions – Curtailment losses attributable to planning restrictions (e.g. noise or shadow flicker) have not been considered in this assessment.

7 Other – No other losses have been accounted for.

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Table AA-0-1 – Definition of Technical Loss Categories in accordance wind DNV KEMA (2013)

Category Number	Category Name	Sub Category Number	Sub Category Name	Definition
1	**Availability**	1a	Turbine	Includes lost energy due to routine maintenance, faults, and component failures over the project lifetime.
		1b	Balance of plant	Losses due to downtime in components between the turbine main circuit breaker to and including project substation transformer and project-specific transmission line.
		1c	Grid	Losses due to downtime of power grid external to the wind power facility.
2	**Wake effects**	2a	Internal wake effects	Losses within the turbine array that is the subject of the energy assessment.
		2b	External wake effects	Losses on the turbines that are the subject of the energy assessment, from identified turbines that are not the subject of the energy assessment, which either already operate or which are expected to operate at commissioning of the facility being studied.
		2c	Future wake effects	Losses due to additional development in the vicinity of the turbines being studied, but which would occur after commissioning of the turbines being studied.
3	**Turbine performance**	3a	Power curve	Losses due to the turbine not producing to its reference power curve within test specifications (for which the turbines typically perform most favourably).
		3b	Wind flow	Losses due to turbulence, off-yaw axis winds, inclined flow, high shear, etc. These represent losses due to differences between turbine power curve test conditions and actual conditions at the site.
		3c	High wind hysteresis	Losses due to shutdown between high-wind cut-out and subsequent cut-back-in.
4	**Electrical**	4a	Electrical losses	Losses to the point of revenue metering, including, as applicable, transformers, collection wiring, substation, transmission.
		4b	Facility parasitic consumption	Losses due to parasitic consumption (heaters, transformer no-load losses, etc.) within the facility. This factor is not intended to cover facility power purchase costs, but does include the reduction of sold energy due to consumption "behind the meter."
5	**Environmental**	5a	Performance degradation not due to icing	Losses due to blade degradation over time (which typically gets worse over time, but may be repaired periodically), and blade soiling (which may be mitigated om time to time with precipitation or blade cleaning).
		5b	Performance degradation due to icing	Losses due to temporary ice accumulation on blades, reducing their aerodynamic performance.
		5c	Shutdown due to icing, lightning, hail, etc.	Losses due to turbine shutdowns (whether by the local turbine controller, project-wide control system, or by an operator) due to ice accumulation on blades, lightning, hail, and other similar events.
		5d	High and low temperature	Losses due to ambient temperatures outside the turbine's operating range. (Faults due to overheating of components that occur when

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Category Number	Category Name	Sub Category Number	Sub Category Name	Definition
				ambient conditions are within the turbine design envelope would be covered under turbine availability category above.)
		5e	Site access and other force majeure events	Losses due to difficult site access (for example: snow, ice, or remote project location). Note that this environmental loss and some other environmental losses may be covered under the availability definition, above. However, these “environmental” losses are intended to cover factors outside the control of turbine manufacturers.
		5f	Tree growth or felling	Losses due to growth of trees in the facility vicinity. This loss may be a gain in certain cases where trees are expected to be felled.
6	**Curtailment**	6a	Wind sector management	Losses due to commanded shutdown of closely spaced turbines to reduce physical loads on the turbines.
		6b	Grid and ramp-rate	Losses due to limitations on the grid external to the wind power facility, both due to limitations on the amount of power delivered at a given time, as well as limitations of the rate of change of power deliveries. This can be ongoing control of the Wind Turbine output over the project lifetime or temporary curtailment until grid reinforcements are carried out early in the project.
		6c	Offtaker curtailment	Losses due to the power purchaser electing to not take power generated by the facility.
		6d	Environmental (noise, visual, bird/bat)	Losses due to shutdowns or altered operations to reduce noise and shadow impacts, and for bird or bat mitigation This would include use of a low-noise power curve versus a standard one from time to time.
7	**Other**	7a	Other	Losses due to; the non-linear relationship of wind speed to energy, Air density correction if treated downstream of gross energy calculation,

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Appendix 2 - Community Handout for Salliq

SALLIQ (CORAL HARBOUR) CLEAN ENERGY PROJECT IMPLEMENTATION

Clean Energy Comparison: **Wind Energy vs. Solar Energy**

NORTHERN ENERGY CAPITAL

Sakku Investments Corporation

Nunavut

INTRODUCTION

The clean energy future in Nunavut is bright. Both wind and solar energy present opportunities for a groundbreaking project in the northern community of Salliq (Coral Harbour), which could be among the first in the territory to generate its own electricity with a clean and sustainable energy project. This project could empower Salliq to begin moving away from a reliance on fossil fuels like diesel and towards independent, clean energy production.

Over the past year, Sakku Investments Corporation, the Government of Nunavut's Climate Secretariat, and Northern Energy Capital have collaborated on the creation of a Community Energy Plan for the hamlet of Salliq. Through this plan, both wind energy and solar energy technologies have been identified as promising candidates for a clean energy project in the community. Wind and solar energy technologies both have good energy generation potential within the local area. While both small and large scale projects were analysed by the design team, a larger scale project has been identified as the most economical option for Salliq.

This informational package describes the process of wind and solar energy generation, what goes into each type of project, and the advantages and disadvantages of each. The design team is looking forward to hearing feedback from the community members of Salliq on this content.

PROJECT BENEFITS

Regardless of the type of project chosen, benefits to the community will be realized:

- Displacement of a portion of the communities' current diesel based energy consumption with electricity from a renewable source
- Reduction in greenhouse gas and carbon emissions, which is important in the fight against climate change
- A new private-sector infrastructure investment in the community
- A reduction in the quantity of diesel being shipped in, reducing costs and the likelihood of environmentally damaging spills
- Opportunities for skills training within the community to support facility maintenance and operations
- Opportunity for local contractor jobs during project construction

WIND ENERGY

Wind energy technologies capture the energy of the wind by using it to turn large rotating blades on a wind turbine. The rotational (or kinetic) energy of the blades is then converted into electricity within the turbine and passed into the grid where it can be used to power homes.

At a community scale, wind energy facilities typically include the following features:

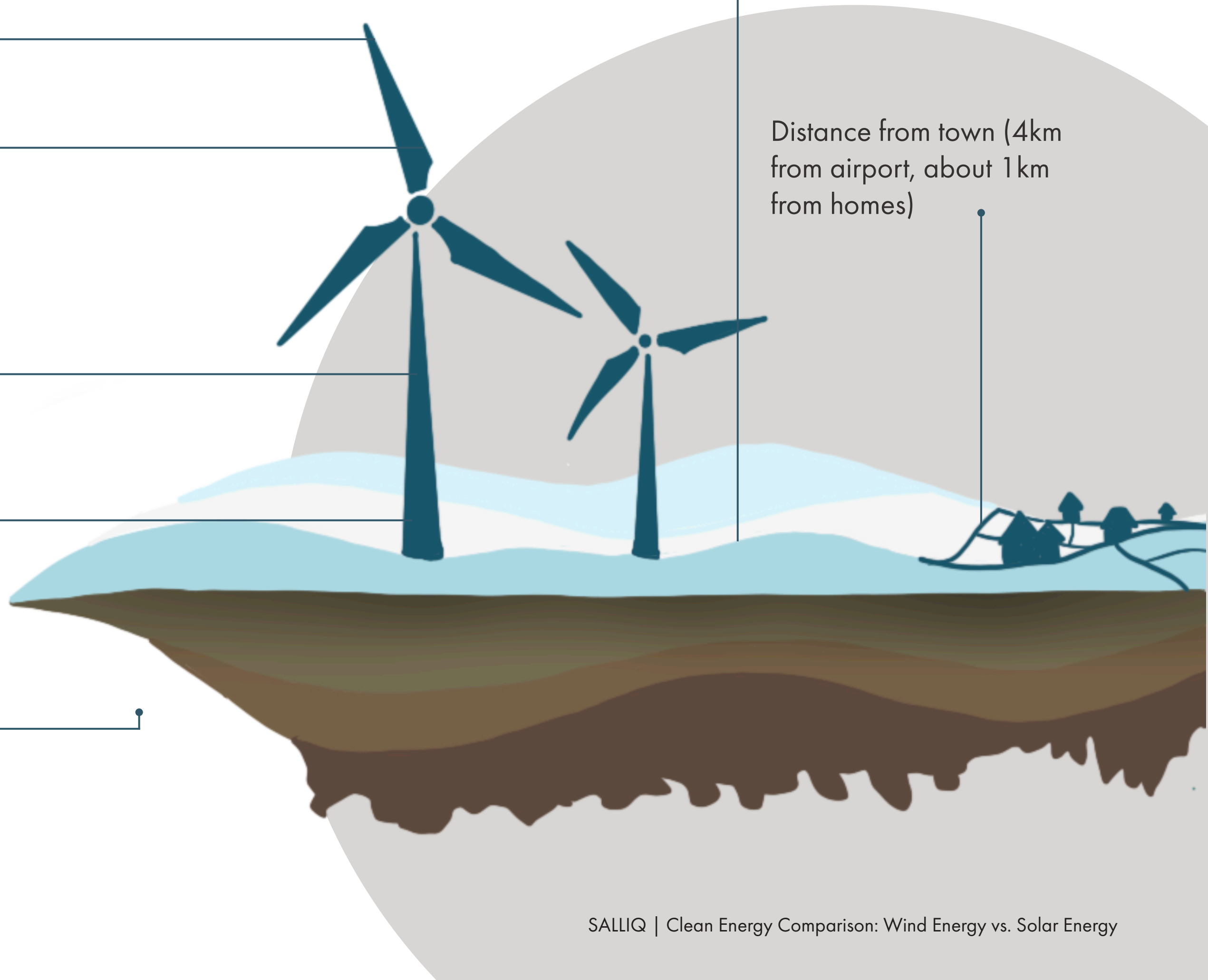
- One or more wind turbines, which can vary in size from small (15m tall) to very large (80m tall or more)
- A foundation suitable to the size of the turbine and the local ground conditions, usually made of concrete, rebar, and ground anchors
- Access roads to and from the wind turbine location
- A transformer to convert the electricity from the turbine(s) to a voltage that matches the grid
- Electrical infrastructure like electrical lines and cables, which collect energy from the turbines and deliver it to the grid
- A substation or switchgear to enable safe operation of the facility on the local grid

When determining the best size and location for a wind turbine on a microgrid, the following factors should be considered:

- Average wind speed, wind direction, and consistency
- Total energy use by the community, including seasonal highs and lows
- Whether a battery is needed to stabilize the grid, as wind energy is highly variable
- Accessibility of the site for maintenance and operations
- Local capacity to provide operations and maintenance personnel
- Impacts to the local environment such as birds, bats, plants, and migratory animals
- Ensuring the turbines are far enough away from homes and the airport
- Cost to install and operate the project, compared to the amount of energy and revenue it will create

WIND ENERGY

Siting criteria for building a wind energy project



SOLAR ENERGY

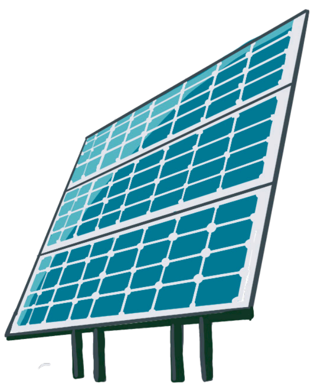
Solar energy technologies capture light energy from the sun and convert it to electricity using solar photovoltaics (solar PVs). Solar PVs consist of thin membranes made from special metals called semi-conductors (eg. silicon), mounted on self-contained glass panels. These membranes absorb light in a way that energizes electrons to create an electrical current, which can then be transmitted to the grid to power homes.

At a community scale, solar energy projects typically include the following features:

- Solar panels, which are made of solar PV cells grouped together in units onto glass panels. Usually, installations include two or more solar panels linked together, and can be small (on a single home), to very large (commercial operations spanning 1000s of acres)
- A mounting system, which could fix the system to a roof, or frames attached to the ground with pile driven concrete footings
- Inverters, which convert energy produced in direct current (DC) to alternating current (AC), to match the local grid
- Access roads to and from the solar site
- Electrical infrastructure like electrical lines and cables, which collect energy from the panels and deliver it to the grid

When selecting the appropriate size of solar system for a community project on a local microgrid, developers should consider the following factors:

- Seasonal fluctuations in daylight and average cloud cover
- Total energy use by the community, including seasonal highs and lows
- Whether a battery is needed to stabilize the grid. Solar energy is less variable than wind, but larger systems need somewhere to store excess energy
- Accessibility of the site for maintenance and operations
- Local capacity to provide operations and maintenance personnel
- Impacts to the local environment such as sensitive plant species or migratory animals
- Cost to install and operate the project, compared to the amount of energy and revenue it will create



Siting criteria for solar energy

Proximity to existing roads and electrical lines (closer = reduced cost)

Away from environmentally sensitive areas, traditional land use areas and archeological sites

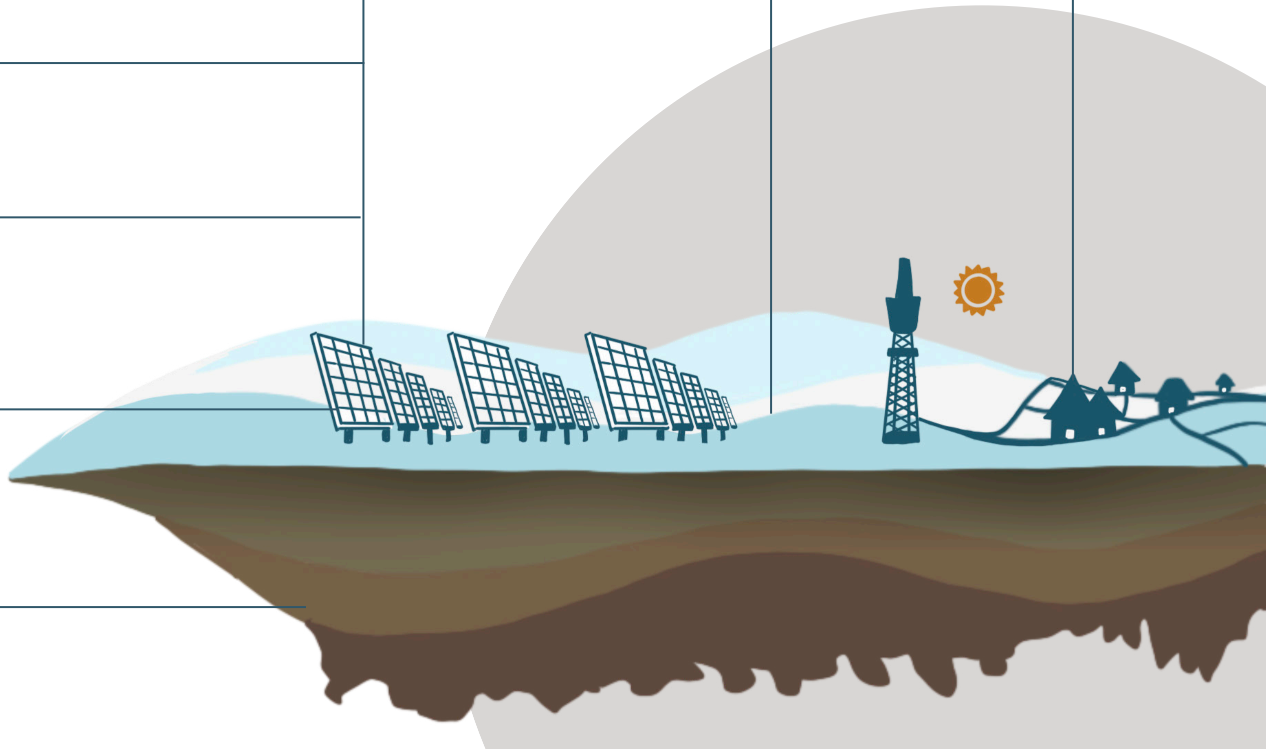
Close enough to town for ease of maintenance access

No shading from nearby tall objects, buildings or rock outcroppings

Topography/roughness (more level ground is better)

Stable type of land cover (bedrock, soil, gravel, etc)

Sufficient space for desired number of solar panels



ENERGY TECHNOLOGY COMPARISON

Annual energy demand in Salliq, forecasted out to 2025, is anticipated to be 3,915 MWh

	WIND	SOLAR
	For this scenario, a 1MW EWT wind turbine with a 1 MWh battery energy storage system is recommended for consideration	For this scenario, a 1 MW-AC ground mounted solar array with a 1 MWh battery energy storage system is recommended for consideration
Amount of usable energy produced	**1,700 MWh/Yr**	**1,300 MWh/Yr**
Match to seasonal demand profile	★★★★☆ **Very Good**	★☆☆☆☆ **Poor**
% of annual demand met	**42% - 45%**	**32% - 35%**
Cost competitiveness	★★★★☆ **Very Good**	★★★☆☆ **Good**
Capital cost	**$ $ $** **High**	**$ $** **Medium**
Development and construction time	365 365 365 365 **3 - 4 Years**	365 365 365 **2 - 3 Years**
Logistics complexity	* * * **High**	* * **Medium**
Required maintenance	* * **Medium**	* **Low**
Distance from town	**1-2 KM**	**<1 KM**

FREQUENTLY ASKED QUESTIONS

How much does it cost to build a solar project? A wind project?

The cost of solar and wind energy projects depends on many factors, including their size and location. Initial estimates for a project that could displace a meaningful amount of diesel in the community would range between $7-9 million for a solar project or $10-12 million for a wind project. However, a solar energy project will produce less energy overall compared to a wind energy project.

Who will build the project, and how long will it take?

A project of this size requires many engineers, material suppliers, and trade contractors from all disciplines to come together. The project will be led by Kivalliq Alternative Energy, a partnership between Sakku Investments Corporation and Northern Energy Capital, with a variety of contracting opportunities available to complete the design and construction. A wind project in the community may take 3-4 years to develop and build, while a solar project may take 2-3 years.

Who would own and operate the clean energy project, and who will the revenue go to?

Under Qulliq Energy Corporation's (QEC) Independent Power Producer policy, this type of project would be owned by Kivalliq Alternative Energy (KAE), a non-utility entity that produces and sells electricity to QEC. KAE is a partnership between Sakku Investments Corporation and Northern Energy Capital, and revenue will be used to maintain the facility and provide a return on initial capital investment.

Will a clean energy project lower the price of energy in the community?

It is unlikely that this project would have any impact on the local price of energy, as these rates are set by the utility.

FREQUENTLY ASKED QUESTIONS

What environmental impacts could the project have?

Both wind and solar energy typically have very low environmental impacts. Wind turbines may interfere with birds and bats during flight, so sites are carefully screened and placed away from such flight paths and habitats. As with similar infrastructure projects, land disturbance cannot be avoided and remediation will be completed where possible to return lands to their pre-disturbed state. Wind and solar energy also displace fossil fuel use, resulting in less environmental impacts from fuel spills.

Will the project impact traditional land use activities like hunting?

Candidate sites are carefully screened in collaboration with local knowledge holders to minimize impact on traditional use of the land as much as possible.

How long do solar and wind energy projects last?

Wind energy projects have an average lifespan of 25 years, while solar projects can operate for 30 years or more.

What kind of maintenance work is required to keep a project like this operating?

Wind facilities require regular maintenance to ensure all parts are working properly. Maintenance personnel must inspect the structure and ascend to the top of the turbine to inspect electrical components in the nacelle (hub). Rarely, if ever, a crane may be required to replace components at heights. Solar facilities have no moving parts and need less maintenance, but still require regular inspections by maintenance personnel with electrical knowledge, and may need to be cleared of snow.

Are wind and solar energy proven and reliable technologies, even in cold climates?

Yes. In fact, solar energy performs better in cold temperatures, as long as the panels are free of snow. Colder, higher density air also provides more energy to move turbine blades, and wind energy technology has improved vastly in cold climates over the last decade. Blade heating technology now exists which allows wind turbines to perform well even in cold, rime-ice prone climates.

Appendix 3 - Technology Comparison Study

CORAL HARBOUR

TECHNOLOGY COMPARISON ANALYSIS

September 2020

Prepared By:

Green Cat Renewables Canada Corporation

Prepared For:

Kivalliq Alternative Energy

Revision	Date	Author	Checked By	Approved By
0.1 Draft for Client Review	August 28th, 2020	NE	BS	SW
1.0 Final Issue	September 4th, 2020	NE	BS	SW

CONTENTS

1. INTRODUCTION

Green Cat Renewables (herein GCR) have been retained by Kivalliq Alternative Energy (herein the 'developer') to conduct a technology comparison analysis for proposed variations of different solar array layouts near the town of Coral Harbour, Nunavut. It is understood that the developer is looking at potential options for renewable power generation to offset diesel generation in the community of Coral Harbour. GCR are modelling different solar array layout scenarios for the purposes of realizing the most practical and efficient solution to produce the highest yield in that region.

The layout options considered are:

- A South facing fixed tilt,
- An East/West split fixed tilt array, and
- An East/West tracker system.

Additional analyses were made using bi-facial modules to understand the additional energy yield associated with the energy captured from the backside of the panels for the south facing fixed tilt array and tracker system.

Calculations have been undertaken using PVsyst v7.0 software package and are based on standard in-built data for irradiation and climatic variability.

The assessment did not consider costs and manufacturer availability for the suggested designs, this will be considered at a later stage in the feasibility process.

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2. SITE LOCATION AND MODEL PARAMETERS

Coral Harbour is a small Inuit community located in the Canadian territory of Nunavut. The geographical coordinates used for this assessment are 64.1394° latitude and -83.1835° longitude. **Figure 1** shows the town off the coast of Hudson Bay.

Figure 1 – Town of Coral Harbour in Nunavut Canada (extract from Google Earth)

Global Horizontal Irradiance (GHI) and temperature data were obtained from Meteronorm 7.2. Horizontal irradiance was converted into inclined irradiance using the Perez model within PVsyst 7.0.

Monthly albedo values were derived from snow cover on the ground data provided by the Government of Canada [1] as well as typical values used from the PVsyst software. **Table 2-1** below highlights the albedo for each month used in all scenarios of the design layout.

Table 2-1 Monthly albedo values

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.82	0.75	0.75	0.65	0.55	0.3	0.2	0.2	0.3	0.55	0.75	0.82

[1] Historical Data from the Government of Canada

Each system used within the comparison has been specified as 130kWp with an AC output of 100 kW (nominal power ratio of 1.3) to allow for a fair comparison and have been configured using the same components where possible. This includes orientating all modules in landscape. **Table 2-2** details the components used within the assessment.

Table 2-2 Project Components

Component	Name	# of Units
PV Panel	Longi Solar 540 Wp 35V	240
Inverter	Power Electronics FreeSun FS0050 LVT 50 kW	2

Table 2-3 illustrates losses associated with soiling factors. This considers the accumulation of dirt/snow and its effect on system performance. Detailed losses attributed to the system design will be outlined in **Section 4**.

Table 2-3 Monthly soiling values (%)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5.0	5.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	5.0	5.0	5.0

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3. MODELLING ASSUMPTIONS

The energy yield assessment considered three separate solar array layouts: south-facing fixed layout, E-W fixed layout and an E-W tracker system.

A comparison between different inter-row spacing was conducted to understand the impact shading has on the overall output of the system. Models considered 10m – 50m in increments of 10m to understand the difference in yield. Differences in spacing up to 20m resulted in losses greater than 7% associated to shading. Spacing greater than 20m was found to result in less than 2% of the total energy production, meaning the benefit of increased spacing was diminishing beyond this distance. Therefore, 20m was used as the maximum spacing parameter for the assessment.

Snow cover can reach over half a meter during the winter months. [2] As a result, models were assessed at a higher height than typical setups of similar systems in other parts of the world. For this assessment 3 meters was used for height above ground of the panels.

The following sections looks at more specific design parameters used in each system.

[2] Snow cover during January 2020 reached a height of 53cm.

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3.1. SOUTH FACING FIXED LAYOUT

This layout operates a fixed array with a racking system mounted at a fixed tilt that props the panels at one height for the duration of the lifetime of the project. Fixed structures are robust, reliable and are utilized in most solar arrays around the world. This setup tends to be the most cost efficient as it has fewer moving parts, leading to lower maintenance costs over the life of the project. In the analysis, GCR considered varying panel tilts to optimize the south facing fixed layout and find the maximum energy yield. The analysis modelled of a range of angles from 35° to 65°. Angles ranging between 45-55° were found to be the most optimal tilt for energy production in this location.

Figure 3-1, overleaf, shows an illustration of the system.

Figure 3-1 – South facing fixed tilt system

Table 3-1 lists the assumptions used for the south facing fixed layout.

Table 3-1 Model Parameters

Required Inputs	Specified Parameters
Panel Tilt	45°
Azimuth	0° (facing south)
Spacing	20m
Height above ground	3.0m

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3.2. E-W FIXED LAYOUT

The East/West fixed system consists of panels evenly distributed between an east facing and west facing configuration. **Figure 3-2**, illustrates the layout of this system. A tilt angle of 45° was found to be the optimum tilt angle for this configuration.

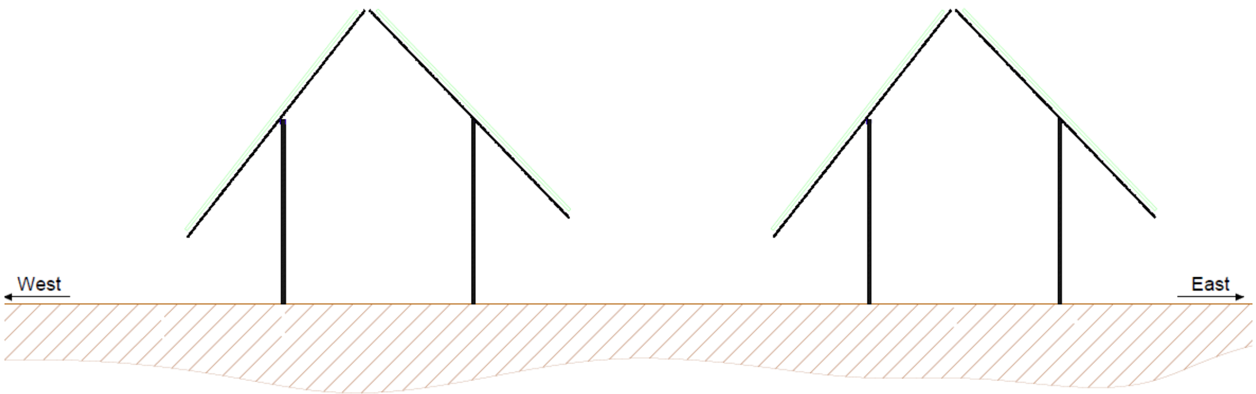

Figure 3-2 – EW fixed layout system

Table 3-2 below lists the assumptions used for the E-W fixed layout.

Table 3-2 Model Parameters

Required Inputs	Specified Parameters
Panel Tilt	45°
Azimuth	90°/-90°
Spacing	20m
Height above ground	3.0m

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3.3. E-W TRACKER SYSTEM

This layout operates a single axis tracker system that follows the sun's path throughout the day in an east to west direction. It typically maximizes energy production from the panels over the course of the year. The analysis considered different panel minimum/maximum tilts that can produce the highest overall energy yield. This ranged from 45° to 85° at the panels highest point. As a rule of thumb, the greater the minimum/maximum tracking angle the better the system performed.

Figure 3-3 demonstrates the movement the panels follow through as the sun moves throughout the day.

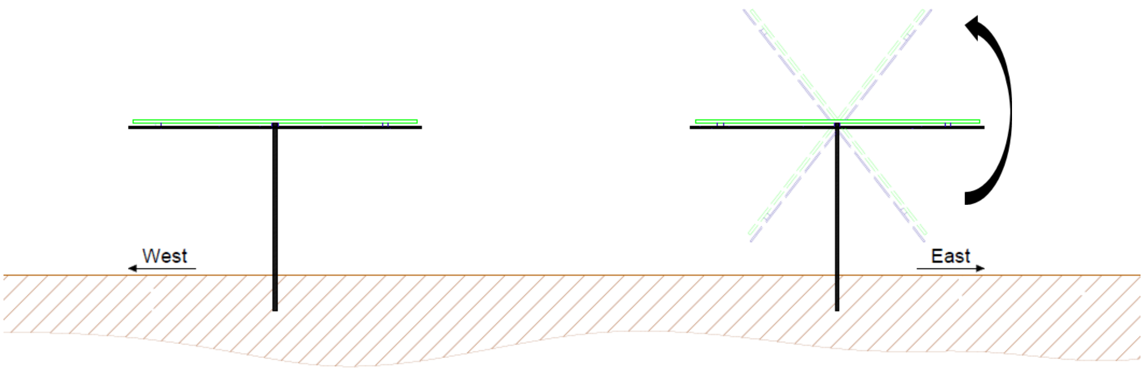

Figure 3-3 – Single axis tracking system

Table 3-3 below lists the assumptions used for the single axis tracking system.

Table 3-3 Model Parameters

Required Inputs	Specified Parameters
Min/Max Angle of Panel	±85°
Tracking axis orientation	0°
Spacing	20m
Height above ground	3.0m

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4. RESULTS

The following table presents the PVSyst modelling results comparing the solar array layout options.

Table 4-1 Comparison of PV systems

System	South facing fixed tilt array	South facing fixed tilt array with bi-facial modules	E/W split fixed tilt array	E/W tracker system with mono-facial modules	E/W tracker system with bi-facial modules
Panel manufacturer	Longi Solar	Longi Solar	Longi Solar	Longi Solar	Longi Solar
Panel Model	LR5-72 HIH 540M	LR5-72 HIH 540M	LR5-72 HIH 540M	LR5-72 HIH 540M	LR5-72 HIH 540M
Panel Rated capacity	540 Wp	540 Wp	540 Wp	540 Wp	540 Wp
Efficiency at STC	21.17%	21.17%	21.17%	21.17%	21.17%
Number of panels	240	240	240	240	240
Total installed capacity (kWp)	130 kWp	130 kWp	130 kWp	130 kWp	130 kWp
Array height above ground	3.0m	3.0m	3.0m	3.0m	3.0m
Resultant shading limit angle (degrees)	8.0%	8.0%	11.1°	N/A	±79.8° (Phi limit)
Near Shadings: Irradiance Loss	-3.05%	-3.05%	-2.91%	-1.84%	-3.21%
Incidence Angle Modifier (IAM) loss	-1.87%	-1.87%	-2.86%	-1.41%	-1.28%
Soiling Loss	-2.77%	-2.77%	-2.48%	-2.49%	-2.50%
PV Loss Due to Irradiance	-0.85%	-0.79%	-1.54%	-0.58%	-0.50%
PV Loss Due to Temperature	+4.48%	+4.49%	+4.59%	+3.83%	+3.87%
Module Quality Loss	+0.37%	+0.37%	+0.37%	+0.37%	+0.37%
Light Induced Degradation	-2.00%	-2.00%	-2.00%	-2.00%	-2.00%
Module Array Mismatch Loss	-3.65%	-3.87%	-3.69%	-3.72%	-3.78%
DC Ohmic Wiring Loss	-1.00%	-1.05%	-0.84%	-1.01%	-1.05%
Inverter Loss During Operation (Efficiency)	-4.42%	-4.27%	-4.88%	-4.32%	-4.26%
Inverter Loss Over Nominal Inv. Power	-2.11%	-3.47%	-0.12%	-0.27%	-0.81%
Inverter Loss due to Voltage threshold	0.00%	0.00%	0.00%	0.00%	0.00%
Inverter Loss due to Power threshold	-0.05%	-0.03%	-0.06%	-0.05%	-0.01%
Effective Irradiance on backside	N/A	+12.49%	N/A	N/A	+7.66%

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System	South facing fixed tilt array	South facing fixed tilt array with bi-facial modules	E/W split fixed tilt array	E/W tracker system with mono-facial modules	E/W tracker system with bi-facial modules
Theoretical Performance Ratio	80.06%	87.30%	81.11%	83.50%	87.50%
Provisional Year 0 Energy Output (MWh)	163.8	177.4	113.9	195.1	209.3
Theoretical Specific Power (kWh/kWp/year)	1264	1369	879	1505	1615
Relative Yield	-	+7.67%	-30.46%	+16.04%	+21.74%

Assumed losses were kept consistent for each system assessed to allow for a fairer comparison between system types.

Results show a 45° tilt angle to be optimal for energy yield for a south facing fixed tilt system near Coral Harbour. Table 4-2 highlights the comparisons between different tilt angles utilizing the same parameters. The performance ratio of this system was 80.06%.

Table 4-2 Comparison of tilt angles for the south facing fixed tilt array

Tilt Angle	Energy Output (MWh/yr)
35°	160.0
45°	163.8
55°	163.7
65°	160.9

The E-W fixed orientation produced the lowest energy output between the three different systems, 113.9MWh/yr. This is attributed to the system not capitalizing the peak of daylight during the middle of the day when the sun's path is at its highest in the horizon. As such, the generation profile for this system is 'flatter' and utilizes more useful energy during the morning and evening periods. The performance ratio was 81.11%.

The tracker system outperformed the south facing fixed layout by more than 30MWh/yr. It produced 195.1MWh/yr annually. The performance ratio for the tracker system was 83.5%. Though the tracker system has the highest yield it is typically the most expensive due to more moving parts and maintenance costs.

The use of bi-facial PV modules was investigated. Bi-facial modules produce power from both sides of a PV module increasing energy generation. Incorporating this modification increased the total energy yield by 7% on the overall performance of the system.

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Provisional year 0 energy output of each design system based on the assumptions in Section 3 is highlighted in **Figure 4-1**.

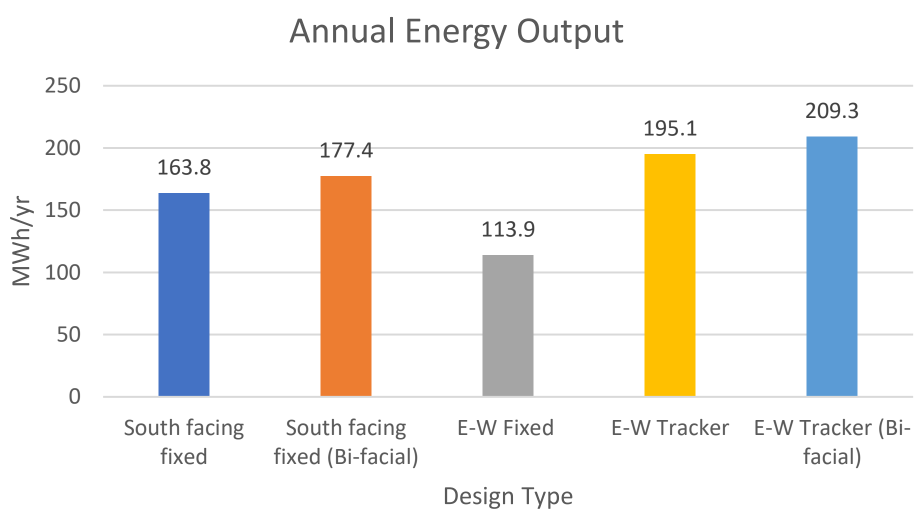

Figure 4-1 – Energy yield for the PV designs modelled as annual output

The PVsyst output reports are available upon request.

5. CONCLUSION

Three PV systems have been evaluated for assessing what produces the highest annual energy yield. The assessment was carried out using PVsyst with various assumptions highlighted in the report.

Results show:

- A tilt angle between 45° and 55° for the fixed systems and 20m spacing were found to be the most optimal design parameters. Increases to either feature results in negligible increase to energy yield.
- 20m was found to be the most optimal spacing distance between panels as smaller distances resulted in losses of 5% or greater to the total energy production due to shading.
- E-W fixed produced the least amount of energy, although, a flatter daily generation profile was observed.
- Using bi-facial modules can add an extra 6 to 8% to the overall performance of a PV system.
- The E-W tracker system had the highest yield at 195.1MWh/year for a 100 kW design. This resulted in a 21.7% yield increase relative to a south facing fixed tilt array with mono-facial modules. The tracker system typically costs more, and a cost benefit analysis will need to be made at a later stage to understand the economics of this design layout.

The Coral Harbour project has good potential of solar energy utilization that can offset current diesel supply during the summer months. A more refined case can be made once potential sites have been identified for the potential of PV panels.

Appendix 4 - Salliq Solar Project EYA Report and PVsyst Modelling

Coral Harbour Solar Project

Energy Yield Assessment

Client: Northern Energy Capital
Reference: 20-029
Version 1.1

December 2021

N O R T H E R N
E N E R G Y
C A P I T A L

Report Prepared for:
Northern Energy Capital

Author:
Jeremy Chan

Cameron Sutherland

Checked by	Cameron Sutherland	Date	11/18/2021
Approved by	Steph Wood	Date	11/18/2021

Issue History	Date	Details
V1.0	11/23/2021	Issued for Initial Draft
V1.1	12/07/2021	Issued for Approval

Table of Contents

1 Introduction

1.1 Project Overview

Northern Energy Capital retained Green Cat Renewables Corporation (GCR) to conduct an Energy Yield Assessment (EYA) for the Coral Harbour Solar Project (the Project). The proposed solar photovoltaic (PV) project requires approximately 6.5 acres of land and is located approximately 11km from the town of Coral Harbour and 1.5km from the Coral Harbour airport in Nunavut, Canada. The Project will consist of approximately 2,000 fixed-tilt solar modules with a total generation capacity of 0.96 MW_{AC}.

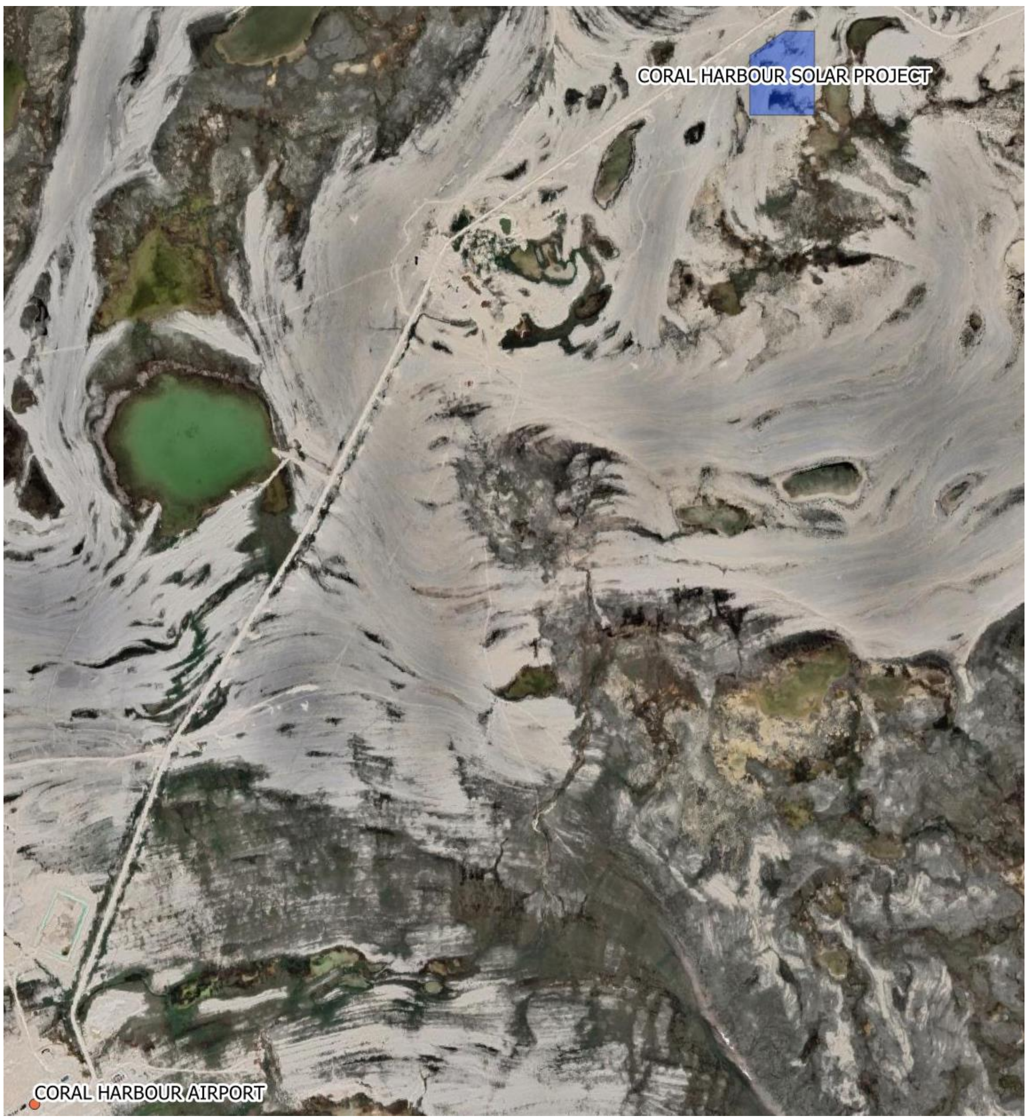

Figure 1-1: Coral Harbour Solar Project Site and Location

2 Assessment Methodology

2.1 Modelling Software

The energy generation was modelled in PVsyst 7.2 simulation software. PVsyst is considered the solar industry's preferred software simulation tool for bankable energy yield analyses.

2.2 Irradiance

Irradiance levels used within this assessment have been obtained from the Meteonorm 8.0 database. Meteonorm is a solar irradiance database developed by Meteotest. It was first released in 1985 and is widely used throughout the solar energy industry for assessing irradiance to inform energy yield production from solar farms throughout the world.

The Meteonorm irradiance figures are based on a combination of measured and modelled irradiance. The horizontal irradiance is converted to the in-plane irradiance within PVsyst using the Perez Model.

2.3 Assumptions

In September 2020, GCR prepared a technology comparison review for Northern Energy Capital that assessed various solar layout options to determine which option had the highest annual energy yield. It was determined that the fixed tilt system with 20m spacing and 45° tilt angle was the most optimal design.[1] Using the parameters defined in this report and typical design assumptions of similar solar projects, an energy yield assessment was conducted.

The array configuration modelled within the Energy Yield Assessment is shown in Table 2-1.

Table 2-1: Array Configuration

Parameter	Value	Description
Axis Tracking	None (Fixed Tilt)	Modules are mounted on fixed tilt racking
PV Module	Longi LR5-72HBD-540M Bifacial	Manufacturer and Model
PV Module Capacity	540W	Module Capacity at Standard Test Conditions
Inverter	Sungrow SG350HX	Manufacturer and Model
Inverter Rating (Max)	352kVA	Inverter Rating at Standard Test conditions
Inverter Rating (Nominal)	320 kVA	Inverter Rating at 40°C
Panel Azimuth	180° (Due South)	Azimuthal position measured from true north
Panel Tilt	45°	Tilt angle of the module measured from vertical
Panels on Vertical	2	Number of panels per table on the vertical axis
Panels on Horizontal	12	Number of panels per table on the horizontal axis
Panels per Table	24	Number of panels per table

[1] Coral Harbour - Technology Comparison Analysis (Sept. 2020)

Parameter	Value	Description
Inter Row Spacing	20m	Center to center distance between table rows
Inter Table Spacing	0.25m	Distance between tables
Minimum Module Height Above Ground	0.6m[2]	Approximate height at the bottom of the array
Maximum Module Height Above Ground	3.79m	Approximate height at the top of the array
Albedo	Varies Monthly[3]	Fraction of global incident radiation reflected by the ground

2.4 Site Layout

A site layout was created using the assumptions above as a basis of design. The layout can be seen in Figure 2-1 below. This layout was used to create a shading profile in PVsyst that calculated the energy losses due to shading.

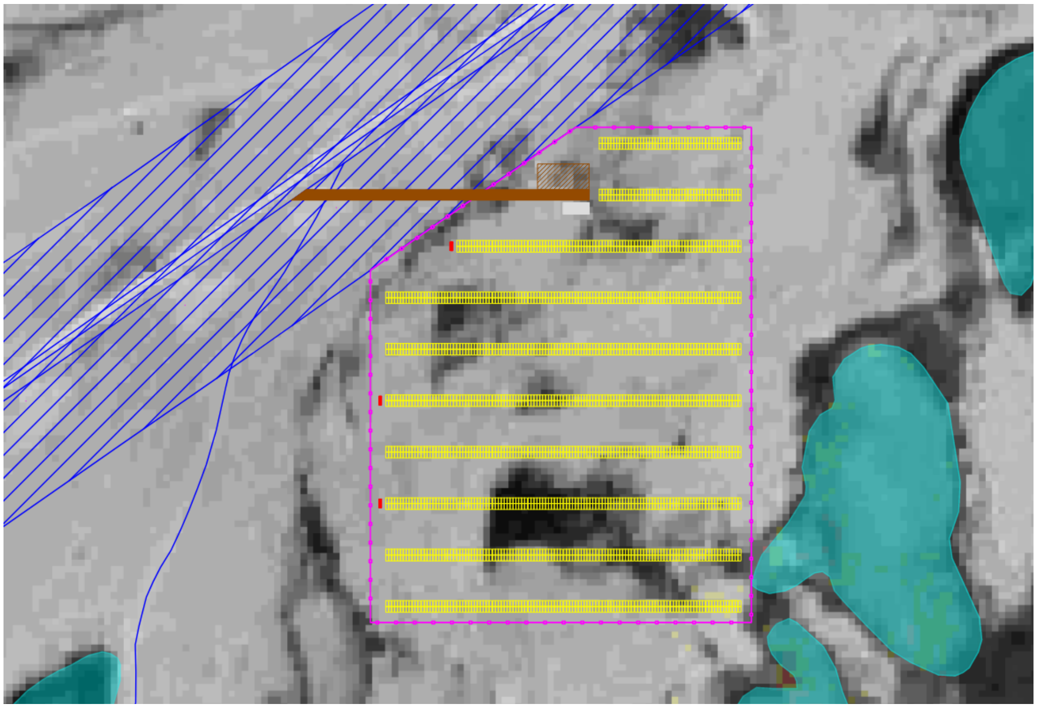

Figure 2-1: Coral Harbour Solar Project Site Layout

[2] Average snow depth in 2020 was approximately 0.5m. An additional 0.1m has been added to minimize the effects of accumulated snow on energy yield
[3] Monthly albedo values derived from snow on ground data provided by the Government of Canada and typical PVsyst albedo values

3 Results

The results of the energy yield assessment are given in Table 3-1. The full PVsyst report can be found in Appendix A.

Table 3-1: PVsyst Energy Yield Assessment Results

Parameter	Value	Comment
Average Annual Global Horizontal Irradiance	1030 kWh/m^2	Meteonorm 8.0 database figure.
Near Shadings: Irradiance Loss	-4.95%	Includes for inter-row shading.,
IAM Factor	-1.90%	Includes for irradiance reaching PV cell's surface.
Soiling Loss Factor	-2.71%	Includes for soiling losses.
Ground Reflection Gain	2.45%	Includes for gains from ground reflection losses.
Bifacial Annual Global Incident Radiation on Ground	708 kWh/m^2	Determined in PVsyst based on the ground cover ratio.
Global Irradiance on Rear Side	15.68% (216 kWh/m^2)	Overall irradiance exposure on the rear side of the modules. Includes for rear shading losses of ground reflection losses (albedo specified), total diffuse irradiance and the rear side view factor.
Annual Array Nominal Energy at STC	1,709 MWh	Energy theoretically available at the module surface
Annual Array Virtual Energy at MPP	1,667 MWh	PVsyst calculation. Accounts for losses on the DC side prior to the inverter.
Annual AC energy at Inverter Output	1,626 MWh	PVsyst calculation. Energy available at the inverter output (accounting for inverter losses)., prior to accounting for the distance between the inverter, transformer, and connection point.
Annual Energy to Grid	**1,596 MWh**	Energy available for grid export. This figure is representative of a raw energy yield and does not account for scheduled downtime and grid availability or degradation.

4 Conclusion

The proposed site has been assessed to determine the theoretical energy yield of the Project. It was determined that the site could feasibly accommodate a PV array of approximately 1.115 MWp. The potential energy yield of the Project is 1,596 MWh per year.

Appendix A – PVsyst Report

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Version 7.2.8

PVsyst - Simulation report

Grid-Connected System

Project: Naujaat Solar Project_Meteonorm

Variant: Naujaat 1MW, 45deg, 20m_ground

Ground system (tables) on a hill

System power: 1322 kWp

Naujaat - Canada

Author

Green Cat Renewables (United Kingdom)

Project: Naujaat Solar Project_Meteonorm

Variant: Naujaat 1MW, 45deg, 20m_ground

Green Cat Renewables (United Kingdom)

Project summary

Geographical Site
Naujaat
Canada

Situation

Latitude	66.53 °N
Longitude	-86.25 °W
Altitude	18 m
Time zone	UTC-6

Meteo data
Repulse Bay (Naujaat)
Meteonorm 8.0 (1981-2000) - Synthetic

Monthly albedo values

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Albedo	0.82	0.75	0.75	0.65	0.55	0.30	0.20	0.20	0.30	0.55	0.75	0.82

System summary

Grid-Connected System

Ground system (tables) on a hill

PV Field Orientation
Fixed plane
Tilt/Azimuth 45 / 3 °

Near Shadings
Linear shadings

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	2448 units
Pnom total	1322 kWp

Inverters

Nb. of units	4 units
Pnom total	1280 kWac
Pnom ratio	1.033

Results summary

Produced Energy	1866 MWh/year	Specific production	1412 kWh/kWp/year	Perf. Ratio PR	98.87 %

Table of contents

General parameters

Grid-Connected System — **Ground system (tables) on a hill**

PV Field Orientation

Orientation
Fixed plane
Tilt/Azimuth 45 / 3 °

Sheds configuration
Nb. of sheds 102 units

Sizes
Sheds spacing 20.0 m
Collector width 4.52 m
Ground Cov. Ratio (GCR) 22.6 %

Shading limit angle
Limit profile angle 10.8 °

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
Linear shadings

User's needs
Unlimited load (grid)

Bifacial system
Model 2D Calculation
unlimited sheds

Bifacial model geometry

Sheds Spacing	20.00 m
Sheds width	4.52 m
Limit profile angle	10.8 °
GCR	22.6 %
Height above ground	1.50 m

Bifacial model definitions

Ground albedo average	0.55
Bifaciality factor	70 %
Rear shading factor	5.0 %
Rear mismatch loss	10.0 %
Shed transparent fraction	0.0 %

Monthly ground albedo values

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
0.82	0.75	0.75	0.65	0.55	0.30	0.20	0.20	0.30	0.55	0.75	0.82	0.55

PV Array Characteristics

PV module

Manufacturer	Longi Solar
Model	LR5-72 HBD 540 M Bifacial
(Original PVsyst database)	
Unit Nom. Power	540 Wp
Number of PV modules	2448 units
Nominal (STC)	1322 kWp
Modules	102 Strings x 24 In series
At operating cond. (50°C)	
Pmpp	1208 kWp
U mpp	895 V
I mpp	1349 A

Inverter

Manufacturer	Sungrow
Model	SG350HX-15A-Preliminary
(Custom parameters definition)	
Unit Nom. Power	320 kWac
Number of inverters	4 units
Total power	1280 kWac
Operating voltage	500-1500 V
Max. power (=>30°C)	352 kWac
Pnom ratio (DC:AC)	1.03

Total PV power

Nominal (STC)	1322 kWp
Total	2448 modules
Module area	6257 m²
Cell area	5675 m²

Total inverter power

Total power	1280 kWac
Nb. of inverters	4 units
Pnom ratio	1.03

Array losses

Array Soiling Losses
Average loss Fraction 3.4 %

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
5.0%	5.0%	3.0%	3.0%	2.0%	2.0%	2.0%	2.0%	2.0%	5.0%	5.0%	5.0%

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 11 mΩ
Loss Fraction 1.5 % at STC

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.1 % at STC

LID - Light Induced Degradation
Loss Fraction 2.0 %

Module Quality Loss
Loss Fraction -0.4 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

AC wiring losses

Inv. output line up to MV transfo
Inverter voltage 800 Vac tri
Loss Fraction 0.50 % at STC
Inverter: SG350HX-15A-Preliminary
Wire section (4 Inv.) Copper 4 x 3 x 185 mm²
Average wires length 97 m

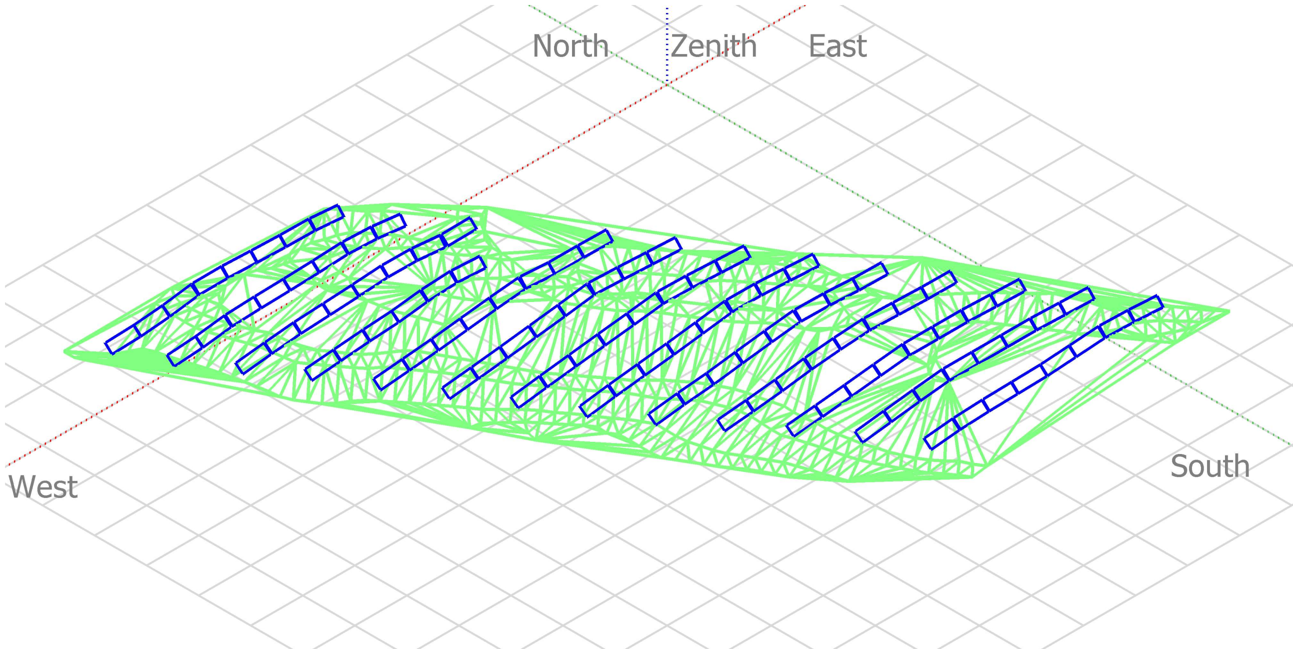
MV line up to Injection
MV Voltage 20 kV
Wires Copper 3 x 6 mm²
Length 490 m
Loss Fraction 0.50 % at STC

AC losses in transformers

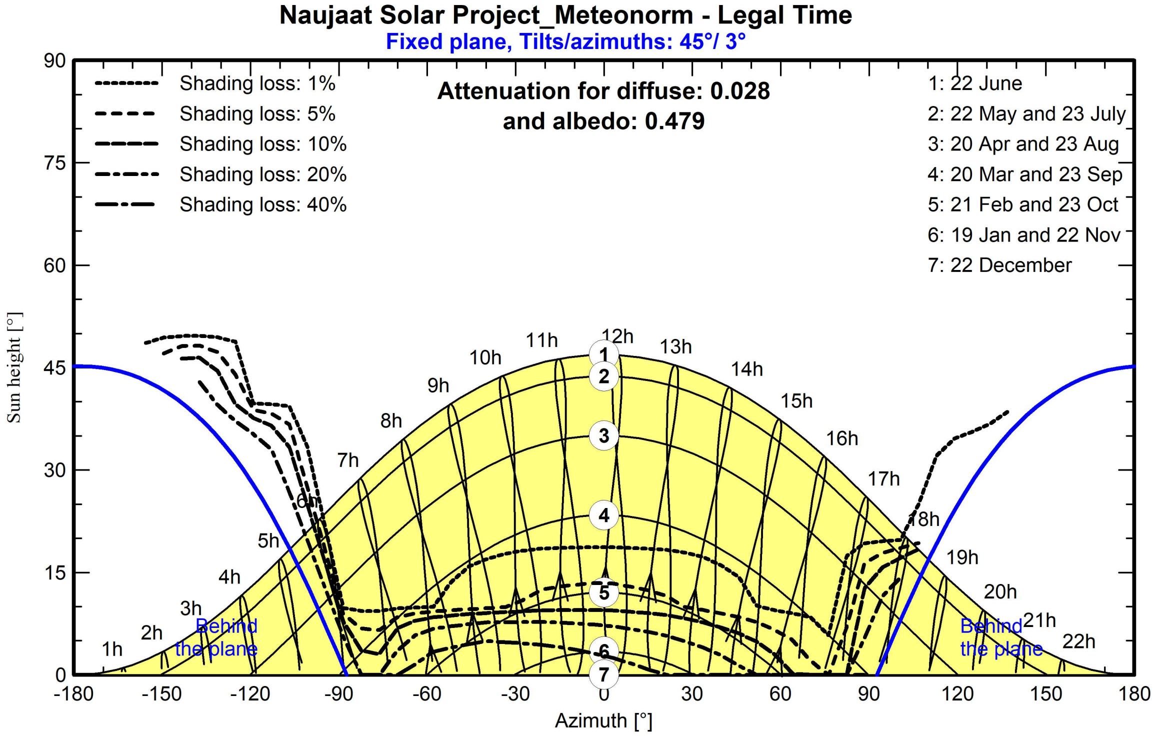
MV transfo
Grid voltage 20 kV
Operating losses at STC
Nominal power at STC 1303 kVA
Iron loss (24/24 Connexion) 1.30 kW
Loss Fraction 0.10 % at STC
Coils equivalent resistance 3 x 4.91 mΩ
Loss Fraction 1.00 % at STC

Near shadings parameter

Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram



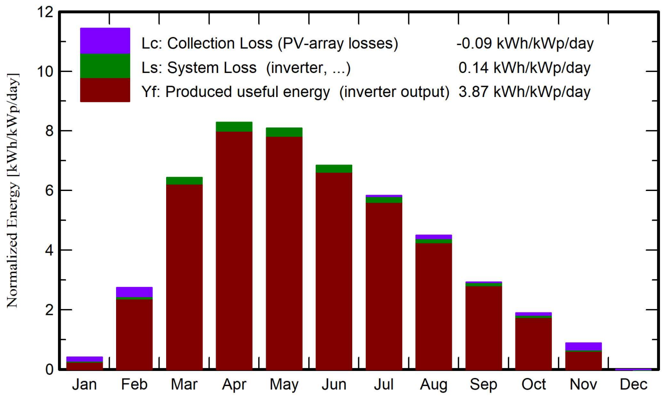
Main results

System Production

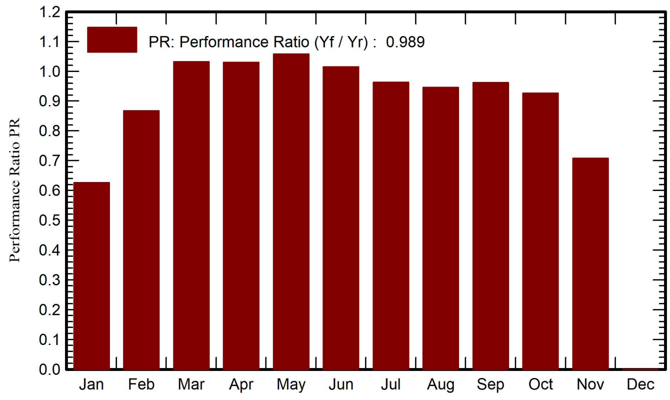
Produced Energy 1866 MWh/year

Specific production 1412 kWh/kWp/year
Performance Ratio PR 98.87 %

Normalized productions (per installed kWp)



Performance Ratio PR



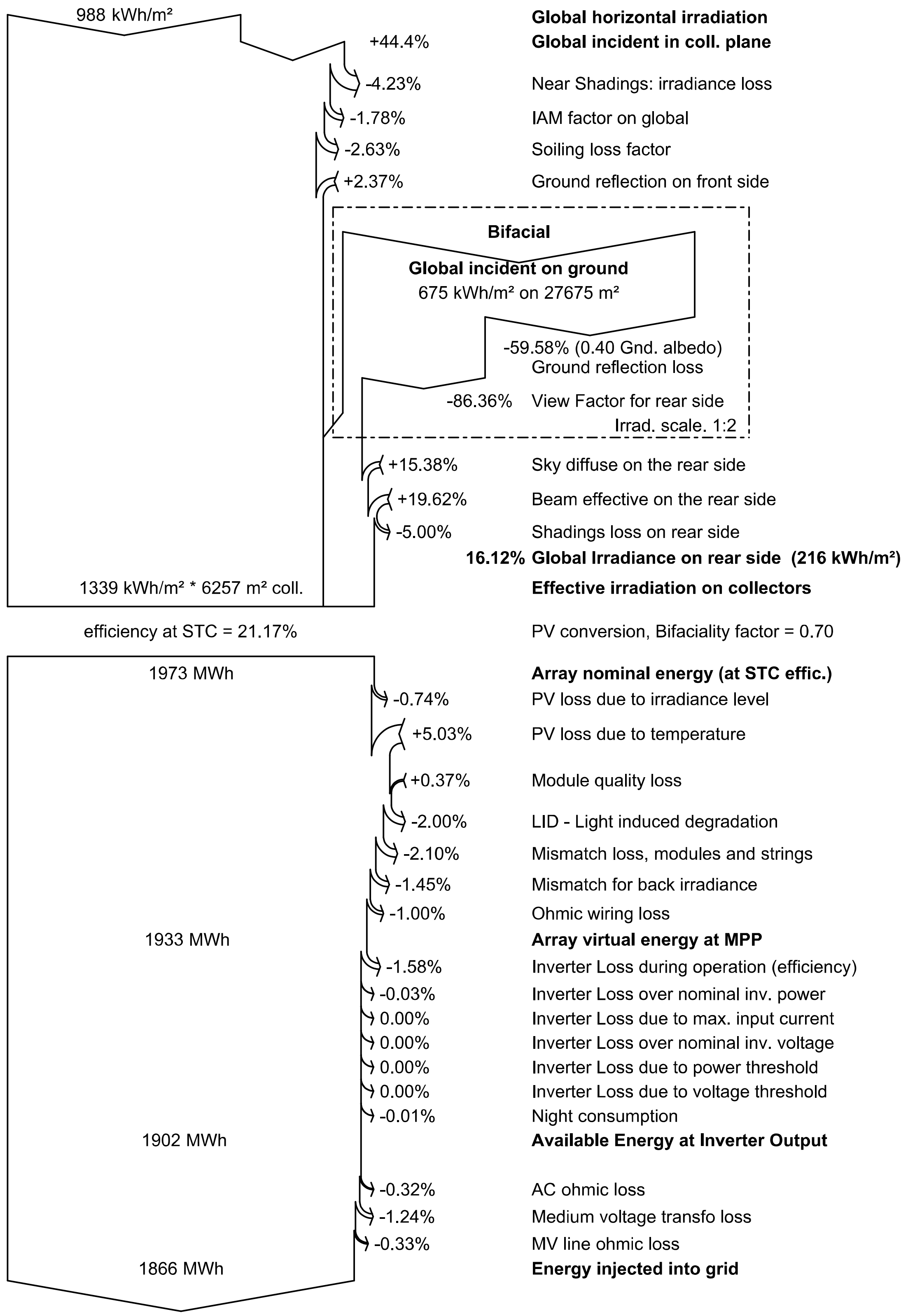
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	2.4	1.53	-29.47	12.6	8.3	11.7	10.4	0.626
February	19.9	7.42	-29.91	76.7	63.6	90.8	87.9	0.868
March	77.8	15.31	-25.44	187.0	175.4	263.5	255.0	1.031
April	142.8	23.89	-16.30	233.3	222.3	328.4	317.6	1.030
May	189.5	51.68	-6.17	229.3	220.9	331.5	320.8	1.058
June	184.6	69.57	2.94	195.9	187.7	271.5	262.7	1.015
July	169.9	73.06	9.76	180.8	172.8	237.9	230.2	0.963
August	113.8	56.11	7.71	139.4	133.4	180.4	174.4	0.946
September	56.5	31.23	1.61	87.8	83.6	115.8	111.6	0.962
October	25.2	13.91	-5.77	58.7	52.3	74.8	71.9	0.926
November	6.0	3.81	-15.83	26.3	18.3	26.2	24.6	0.707
December	0.0	0.00	-23.83	0.0	0.0	0.0	-1.0	1.000
Year	988.4	347.52	-10.78	1427.7	1338.7	1932.5	1866.0	0.989

Legends

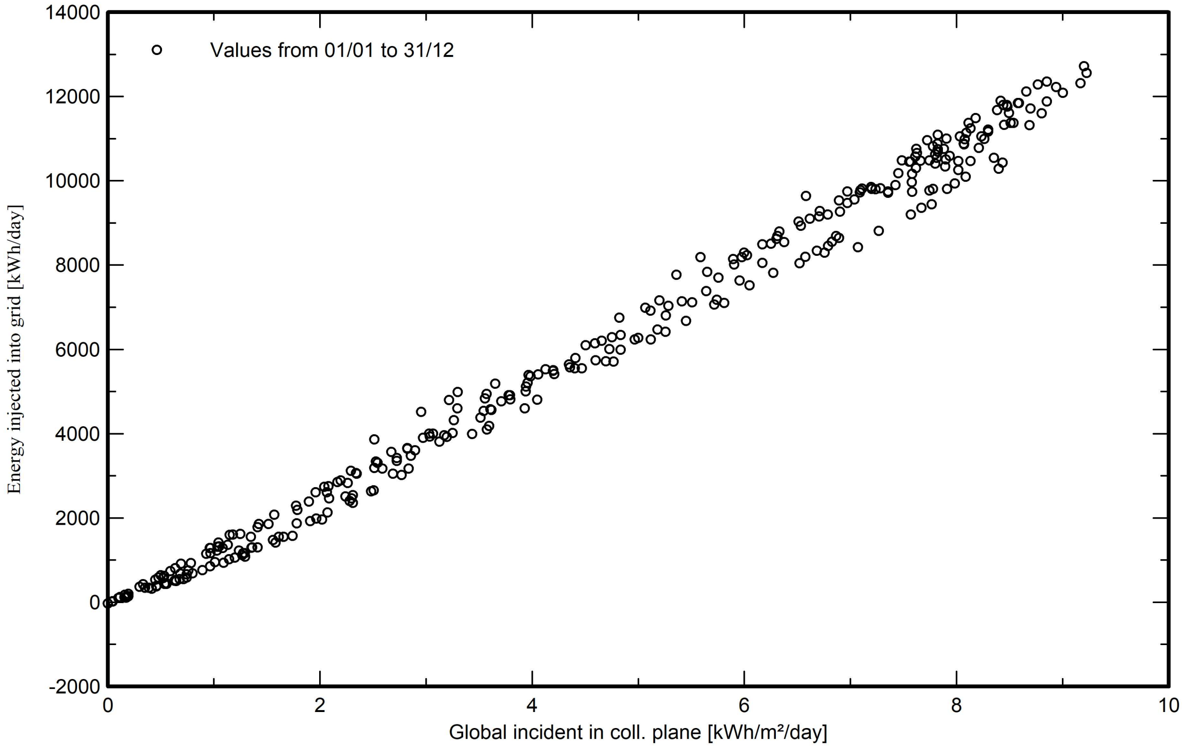
GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

Loss diagram



Special graphs

Daily Input/Output diagram



System Output Power Distribution