



HALIFAX REGIONAL MUNICIPALITY

Ragged Lake Composting Facility Solar Feasibility Study



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Acronyms, Abbreviations, Definitions

– A –

A, abbreviation for Ampere. Ampere is the base unit of electric current as defined in the International System of Units (SI). Ampere is defined as one coulomb of charge per second

– K –

kVA, abbreviation for KiloVolt-Ampere. Volt-Ampere is the unit used for the apparent power in an electrical circuit. Volt-Amperes are usually used for analyzing alternating current circuits and is dimensionally equivalent to the watt. Volt-Ampere ratings are most useful in rating equipment in which there is an inductive load.

kVA_r, abbreviation for KiloVolt-Ampere Reactive. Volt-Ampere reactive is the unit of measurement of reactive power. Reactive power exists in an alternating current circuit when the current and voltage are not in phase.

kW, abbreviation for KiloWatt. A Watt is a unit of power or radiant flux as defined in the International System of Units (SI). This unit is defined as 1 joule per second and is used to quantify the rate of energy transfer. It is commonly used as a billing metric for power delivered to larger consumers by the electrical utilities' providers.

kWh, abbreviation for KiloWatt-Hour. A Watt-hour is a unit of energy equal to one kilowatt of power sustained for one hour, or 3600 kilojoules. It is commonly used as a billing metric for energy delivered to consumers by the electrical utilities' providers.

– P –

psf, abbreviation for pounds per square foot. Pounds per square foot is a unit of pressure resulting from a force of one pound-force applied to an area of one square inch.

1.0 Introduction

This report assesses the feasibility of ground mounted solar photovoltaics installation at the new Ragged Lake Composting Facility in Halifax, Nova Scotia (NS). Solar Feasibility evaluations are based on two distinct methods for cost savings, firstly by reduction in monthly energy utilization at kWh rates, and second by potentially reducing the peak demand load for the facility. Dillon assessed the existing facilities information to predict the new facilities load profile to determine the ability to reduce peak monthly demand.

The results of this solar feasibility study have been developed with two ownership options for Halifax Regional Municipality (HRM) to consider, the owner, and lessor.

2.0 Facilities Data

The first stage in determining the feasibility of installing a ground photovoltaic solar collector is to develop a suitable understanding of the underlying conditions and implications present at the desired location of installation. Throughout this section, the existing Electrical infrastructure design of the Ragged Lake Composting Facility will be analyzed. This analysis, coupled with existing metering data from the utility as well as local geographical and meteorological information will form the basis of our constraints for system payback.

This study has been informed by HRM supplied facility drawings, Nova Scotia Power Incorporated (NSPI) billing data, and meteorological data retrieved from local monitoring stations.

2.1 Planned Electrical Infrastructure Design

The planned electrical infrastructure for the new composting facility includes two separate service entrances. The first service entrance is to a 3200A, 347/600V, 3 phase, 4 wire switchboard (SWG-100), with a 3200A main breaker frame set at 2800A. The second service entrance is a 2000A, 347/600V, 3 phase, 4 wire switchboard (SWG-200), with a 2000A main breaker frame set to 1600A.

2.2 Energy Consumption

HRM has provided Dillon with access to the existing facilities billing data from NSPI for August 2022 to July 2023, including the 15-minute meter readings for October 2023. Each standard hydro bill is made up of a variety of factors, including demand billing, energy consumption, and applicable service charges”

- Demand billing is a measurement of power within the year and is typically expressed in kilowatts (kW) or kilovolt-amperes (kVA). It represents the peak power usage during a given period, such as a month or a year; and

- Energy consumption is a measurement of the actual energy used and is typically expressed in kilowatt-hours (kWh). It represents the total amount of electricity consumed over a specific time frame.

Analysis of the 15-minute interval meter readings show that the existing facilities peak operating hours occurred between the hours of 8:30 and 16:30 daily with an average electrical demand peak of 80kW per month. This consistent, daily peak load is a favorable condition for the application of photovoltaics as the facility will be able to realize savings in both energy consumption and demand reduction on a regular basis as can be seen in Table 1 of Section 2.3.

Using the data provided by the utility, the demand over a 24-hour period within each month has been trended, Figure 1. This was done using the peak data point recorded within the month at each 5-minute interval. The decision to use peak instead of average was made to align with how the utility calculates the facility bill, as noted above. By using the monthly peak facility loading over a 24-hour period, Figure 1, along with the potential solar radiation (Section 2.4.1), the anticipated reduction in demand can then be developed. This will assist in developing the feasibility of the energy storage systems, size, pricing, and utilization strategy.

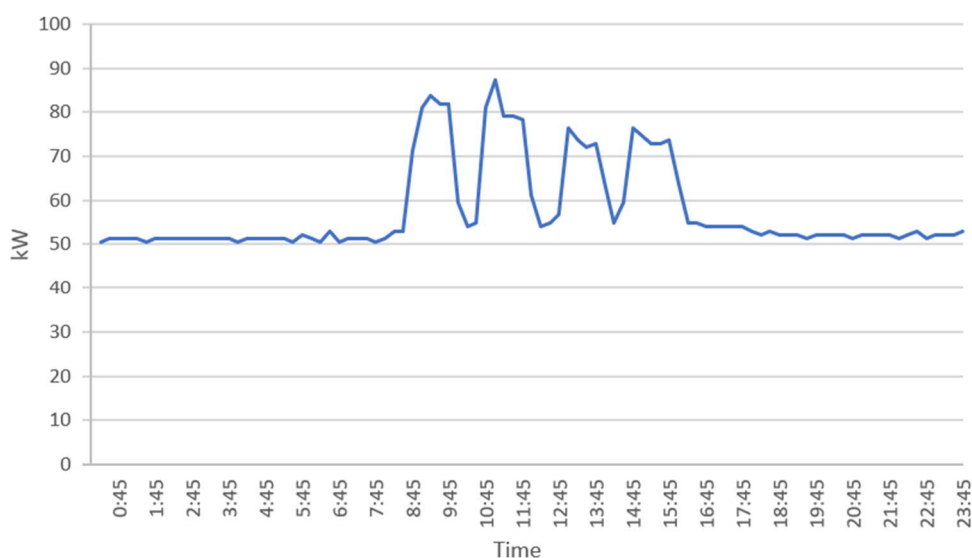


Figure 1: Peak Existing Facility Loading Over 24-hour Period

2.3

Nova Scotia Power Tariff

In addition to the energy consumption information provided, the client also provided information from NSPI in the form of monthly bills for existing facility. This data allows us to realize the full scope of the tariffs paid by the facility and which charges could be mitigated through the installation of a renewable power generator and which may not be. The existing facility is considered a Medium Industrial service

by Nova Scotia Power. A breakdown of the current billing metrics can be seen below in Table 1. Demand billing and Energy billing typically play the largest role in determining the overall feasibility of the system.

Table 1: Nova Scotia Power Electricity Rate Schedule

Billing Metric	Charge	Unit Metric
Demand Billing	\$12.601	Per kW/90%kVA
Energy Billing	\$0.09639	Per kWh
Service Charge	\$20.74	Per Month

2.4 New Facility Baseline Energy Costs

The energy payment to the new facility follows a formula based on the Project Agreement between HRM and HCR (project company for the new organics facility). This equation shown here has been calculated using the information provided in Section 2.3 to provide a baseline for comparisons in savings moving forward.

$$\text{MEP} = \text{MESC} + (\text{MED} \times \text{DC}) + (\text{FEC} + (\text{VEC} \times \text{ACT})) \times \text{EC} + \text{Credit}$$

$$\text{MEP} = \$20.74 + (750\text{kVA} \times \$12.601/\text{kVA}) + (500,000\text{kWh} + (13\text{kWh}/\text{t} \times 5000\text{t})) \times \$0.09639$$

$$\text{MEP (Monthly Energy Payment)} = \$63,931.84$$

As defined in the Project Agreement:

MEP: monthly energy payment

MESP: Monthly Energy Service Charge

MED: Maximum Energy Demand (kVA)

DC: Demand Charge (\$/kVa)

FEC: Fixed Energy Consumption (kWh)

VEC: Variable Energy Consumption (kWh)

ACT: actual total tonnage processed

EC: Energy Charge (\$/kWh)

Credit: The Utility Credit from the electricity bill

Utilizing this Monthly Energy Payment, the new facility is expected to cost HRM \$767,182.08 per year prior to adjustments for inflation or energy escalation rates put forward by NSPI.

2.5 Location Data

Location is a key consideration when determining the optimal facing, angle, and mounting structure for photovoltaic systems. This is due to several environmental considerations that impact the generation of solar energy. The first being orientation with respect to North/South. There are four different types of North and South orientations: Geographic, Magnetic, Geomagnetic, and Orbital Plane. Magnetic and

geomagnetic are not as commonly used when determining the orientation of the sun due to modern advances in satellite imagery. Geographic North is typically used on architectural plans and maps, it refers to the geographic north-pole and aligns with the planetary rotational axis. Orbital Plane “North” refers to the planetary orientation on our solar systems plane and doesn’t have a single north-pole, but a northern and southern latitude at +/-66.5 degrees. Due to this phenomenon, if a photovoltaic system is installed geographically North of the Tropic of Cancer (23.5°N), the panels will face True South all year. And if the system is geographically installed between the Tropic of Cancer (23.5°N) and the Tropic of Capricorn (23.5°S), the sun will shift between North Facing and South Facing throughout the year.

The new Ragged Lake Facility is located at 44.61°N and -63.68°W, and therefore, the solar panels would be configured in a southward direction year-round as a non-tracking system. This identified configuration will inform the limits of the model used to calculate spacing and peak power production. The typical optimal angles for a non-tracking system based on seasonal quarters of the year is shown in Table 2.

Table 2: Non-Tracking Optimal Angles

Season	Calculation	Typical Optimal Angle
Spring	Lat-2.5°	42.11°
Summer	(Lat*0.9)-23.5°	16.65°
Fall	Lat-2.5°	42.11°
Winter	(Lat*0.9)+29°	63.65°
Annual	(Lat*0.76)+4.5°	38.40°

Note that this information is based on optimal power production per one module. For instance, while the winter season has optimal angles that are much steeper, due to the relative elevation of the sun in the sky, they cast longer shadows and consume much more space than that of a shallower angle in summer. Therefore, when evaluating an entire system of modules, it is often that the angle is adjusted to a non-optimal position to allow for the installation of a larger number of panels. This strategy may ultimately increase the overall power production of the system, especially in scenarios where space is limited.

Furthermore, these angles may vary slightly from true optimization through modeling due to historic periods of meteorological activity in the region being studied.

2.5.1 Local Meteorological Data

Currently the Province of Nova Scotia utilizes many ground mounted weather monitoring stations that collect irradiance data. The area is serviced by the Shearwater Jetty monitoring station which is 14 km away from the Ragged Lake site in an easterly direction. To determine the payback period with a higher degree of accuracy in this feasibility study, the climate data from this monitoring station is provided in addition to a “synthetic” file that takes into consideration changes in longitude and latitude to provide a

viable range for solar irradiance in the Halifax Region. Table 3 shows the typical daily solar radiation on a horizontal plane measured in kWh/m²/day from the monitoring station.

Table 3: Typical Daily Solar Radiation on a Horizontal Plan (kWh/m²/D)

Month	Shearwater Jetty	"Synthetic" Halifax
January	1.55	1.25
February	2.44	2.37
March	3.51	3.68
April	4.31	4.44
May	5.02	5.51
June	5.55	5.83
July	5.48	5.47
August	4.88	5.03
September	3.98	4.10
October	2.68	2.54
November	1.58	1.42
December	1.26	1.03
Annual Average	3.53	3.57

3.0

Photovoltaic Installation Components

3.1

Photovoltaic Modules

Photovoltaic modules, also known as solar PV modules, are a piece of electrical infrastructure that produces electricity when exposed to photons (a particle of light) in a process called the photovoltaic effect. In this section, we'll describe how this works, specifically with respect to silicon based photovoltaic modules which make up much of the available market.

The photovoltaic effect occurs when a photon of light strikes an atom of a semiconductor such as silicon and knocks loose an electron. If positive and negative wire leads are connected to this semiconductor a circuit is formed and the loose electron will flow through the system producing a Direct Current (DC). This electricity can then be used to power equipment before flowing back into the positive side of the semiconductor. This positive and negative side of the semiconductor is produced through creating a PN junction within the cell. The P-type side of the junction is silicon positively charged due to the introduction of a layer of boron, while the N-type side are constructed on a phosphorous layer resulting in a negative charge. This change in electrical charge creates the electric field through which the loose electrons will flow.

Using this principle, industry has been able to construct multiple types of photovoltaic modules for use in converting solar energy into usable electricity to power homes, schools, and businesses. In this study,

we'll be looking at Passivated Emitter and Rear Contact (PERC) type panels and will look at their power production characteristics through using both monofacial panels and bifacial panels. These panels are the typical commercial panels with previous generations being Monocrystalline and Polycrystalline panels with lower efficiencies.

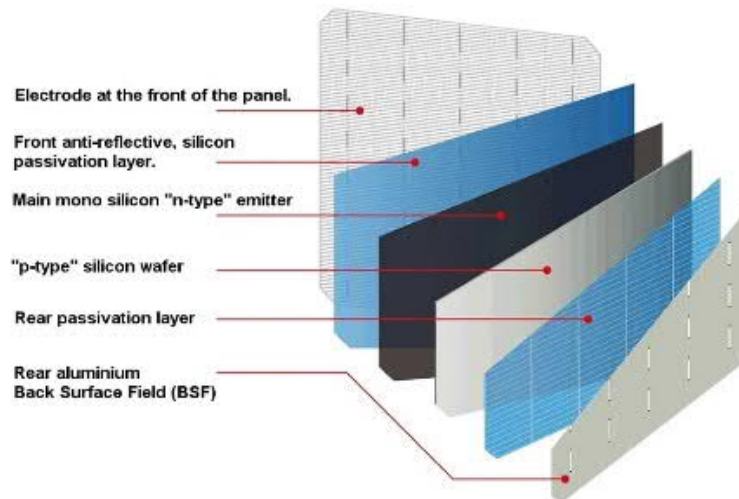
3.1.1 Passivated Emitter and Rear Contact (PERC) Modules

PERC modules have additional layers to the P-Type and N-Type described earlier. These layers are as follows:

Front Contact	The electrical contact in which electrons flow back into the N-Type Silicon layer.
Anti-Reflection Passivation	This layer stops reverse power flow and mitigates some reflection of light back into the environment.
N-Type Silicon	Negative side of the semiconductor.
P-Type Silicon Bulk	Positive side of the semiconductor.
Back Surface Field	Prevents additional inefficiencies in which electrons flow past the rear contacts and do not generate electricity.
Passivation Layer	Protect the internal semiconductor devices after the completion of metallization and is formed with deposition of an oxide layer and a nitride layer. This layer extends the lifespan of the photovoltaic module.
Capping Layer	Suppresses nitrogen diffusion to prevent the formation of oxynitride on the oxide layer within underlying silicon.
Rear Contact	The electrical contacts in which electrons flow to from their origination point in the N-Type Silicon layer.

The addition of these layers being the Front Contact, N-Type, P-Type and Rear Contact allow PERC modules to have an efficiency 1% higher than that of standard mono-crystalline panels. Given that the standard module efficiencies hover around 15-23%, a system using PERC modules can result in the generation of more than 5% additional energy than a system using other modules if all other conditions are equivalent. However due to the increased complexity in manufacturing, they are more expensive than either poly or mono-crystalline modules. PERC is not a standalone technology; it is applied with poly or mono-crystalline technology to produce a panel that has a higher power production capability.

The components of a typical PERC panel are presented in Figure 2.



Source: <https://www.solarpowerpanels.net.au/perc-solar-cells/>

Figure 2: PERC Panel Diagram

3.1.2 Monofacial vs. Bifacial

Monofacial and bifacial, as the name suggests, relates to the number of sides of the photovoltaic panel that have been populated with solar cells. One advantage of including a second side of solar cells is that power production can be increased in the same amount of available space. While only one of the two faces in a bifacial system generates power through direct sunlight, the other side uses reflectance to harvest “missed” solar energy.

Bifacial modules operate more effectively at steeper mounting angles which allows them to capture more reflected energy from their surroundings. Furthermore, the type of structure the panels are mounted on will impact the amount of light reflected. For instance, a white or light-coloured roof membrane is better at reflecting energy than that of a black or dark coloured membrane.

3.1.3 Modules Forecast

Polycrystalline panels were the staple of the industry prior to 2017 but now are becoming increasingly difficult to source and therefore, were not considered as an option whereas the PERC panel type market share is continuing to increase. Considering commercial tendering and engineering design timelines, the options evaluated in the feasibility study are based on technology that is currently at the top of the photovoltaics market. This allows for the report to have a longer applicable lifecycle as opposed to using the current market panels.

Based on current market trends, the majority of newer, more efficient panels are being developed as bi-facial only. Due to this, the bifacial panels selected for this report are available at 600W/module while the monofacial panels are limited to a maximum of 550W/module.

The following panels have been selected as the basis of the feasibility study, and can be found in Appendix C:

- Option 1: Longi Solar No.: LR5-72HPH-550M G2 – Monocrystalline PERC Photovoltaic panel; and
- Option 2: Longi Solar No.: LR7-72HGD-600M – Monocrystalline PERC Bifacial Photovoltaic panel.

The Longi panels have a 25-year warranty for monofacial panels and 30-year warranty for bifacial panels with regards to power degradation.

Expanding on Section 3.1.1., both Mono and Bifacial Monocrystalline solar panels are known for their high efficiency, their monocrystalline silicon construction, allows for the conversion of more sunlight into electricity, maximizing energy output and optimizing performance of the system. Additionally, these panels can withstand various weather conditions, including high wind loads and heavy snow, ensuring long-term operation and reduced maintenance requirements especially important for remote communities. Moreover, the advanced PERC technology incorporated in these panels enhances their efficiency and power output, making them an excellent choice for residential, commercial, and utility-scale solar installations.

3.2 Inverters

The vast majority of building and grid electrical systems operate on either Single-Phase or Three-Phase Alternating Current (AC) power. This form of electricity flows in both directions in the circuit as the voltage changes from positive to negative. As noted in Section 3.1, photovoltaic modules produce Direct Current (DC), which in turn generates DC power. This differs from AC power in that electricity flows constantly in one direction and maintains a constant voltage. To use the DC power generated by a photovoltaic solar collector, it must be transformed from DC to AC through a power electronics device known as an inverter.

The fundamental principles of an inverter require the positive input and negative input of a DC system to be varied at a frequency that matches the grid frequency (60 Hz in North America) to produce the positive and negative voltages associated with AC power. However, this will lead to a square voltage waveform instead of the sinusoidal waveform pattern AC generators produce. This new square waveform is put through a variety of electrical filters and electronic modules to “smooth” the waveform to match the sinusoidal pattern produced by electrical utilities and emergency power generators.

The following inverters (a typical example is presented in Figure 3) have been selected as the basis of the feasibility study, and can be found in Appendix D:

- SMA Solar Technology No.: Sunny Highpower SHP150-20-PEAK3; and

- SMA Solar Technology No.: Sunny Highpower SHP100-20-PEAK3.



Source: <https://www.sma-america.com/products/solarinverters/sunny-highpower-peak3>

Figure 3: Sunny High Power Inverter

4.0 Project Delivery Methods

Currently there are several project delivery and integration methods to consider for implementation that will be discussed herein. Each project delivery method is unique in the way that it utilizes the produced energy, which impacts the potential payback of the system as a whole.

4.1 Stand-Alone & Grid Tied

The first system of note is a Stand-Alone & Grid tied photovoltaic plant. In a Stand-Alone & Grid tied system, all energy generated from the system is directly injected to the utility power grid. A high-level block diagram of the energy flow in a Stand-Alone & Grid tied is shown below in Figure 4. This system has several key advantages and disadvantages to the overall configuration, size, and payback to be discussed.

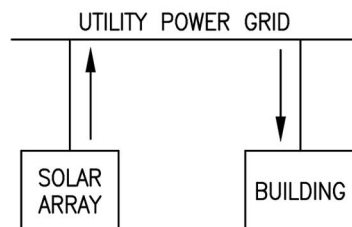


Figure 4: Stand-Alone & Grid Tied Energy Flow

Advantages include the ability to procure a system with a nameplate capacity to suit the overall site conditions in terms of space and configuration. However due to it being interconnected to the NSPI grid and not an HRM facility, there are several disadvantages to note.

1. Carbon emissions reductions through energy production cannot be realized at another facility as the power is blended with the NSPI emissions profile.
 - a. However, the carbon could be verified, and carbon credits could be sold for additional revenue on the voluntary market.
2. A power purchase agreement would need to be negotiated between HRM & NSPI to sell the electricity, where this includes a fixed price for energy on a \$/MWh basis over a 25-year term it cannot take advantage of rate escalations on the NSPI Grid.
 - a. This also means that project payback and feasibility would be developed as part of a negotiation to determine the levelized cost of electricity to the project to sell to the grid and cannot be evaluated as part of this study.

4.2 Facility Integrated

The second system investigated is facility integrated, with two different delivery methods being investigated, Distributed Generation (Section 4.2.1) and Net Metered (Section 4.2.2).

A Facility Integrated system utilizes the solar energy produced by the photovoltaic generation system either instead of or before sending it to the Grid.

This has some distinct advantages over a Stand-Alone system in that carbon emissions reductions can be quantified, which reduces overall carbon emissions tax burdens on the facility which can be much higher than the price of selling offset credits. Additionally, the power is consumed or sold at the same rate paid by the facility to the utility, which can be significantly higher than the price of a power purchase agreement and will increase over time as the utility increases rates to replace existing infrastructure, or adjust to pressures of inflation.

Each system has their own unique advantages and disadvantages with respect to this facility – as outlined below;

4.2.1 Distributed Generation

A Distributed Generator does not have a maximum nameplate capacity, this means that similar to a Stand-Alone system it could be sized to suit the overall site conditions in terms of space and configuration. However, due to Bill 145 (The Electricity Act) in Nova Scotia, and the NSPI regulations, any system sized above 1MW cannot sell power to the grid if it's not governed by a power purchase agreement. A high-level block diagram of the energy flow in a distributed generation configuration is shown below in Figure 5.

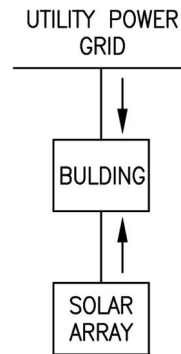


Figure 5: Facility Integrated Distributed Generation Energy Flow

At the Ragged Lake site for example, it is estimated that the maximum power production of the facility is 750 kVA which should be approximately 600kW. This means that should the facility run at a constant 600/750 kW/kVA, at any point which the solar produces more power than the building consumes, it must shut down a portion of the system to ensure no power is seen by the grid. This results in a potential loss of revenue of 40%.

This can be mitigated through the use of Battery Energy Storage Systems; however, these systems are prohibitively expensive if the reliance is just on kWh savings as would be the case here. Dillon does not recommend this system for implementation at the Ragged Lake facility.

4.2.2 Net Metered

A Net Metered system does have a maximum nameplate capacity of 1MW per Bill 145 (The Electricity Act) in Nova Scotia, and the NSPI regulations. As can be seen in Appendix E, a 1MW system leaves space on the site and doesn't take the full advantage of the site layout. However, all energy produced can be sold to the utility after consumption by the facility it is connected to. A high-level block diagram of the energy flow in a net metered configuration is shown below in Figure 6.

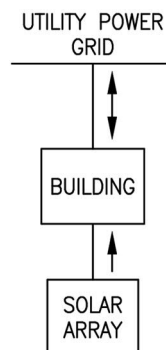


Figure 6: Facility Integrated Net Metered Energy Flow

This Net Metered system is Dillon's recommendation and Section 6.0 has used this approach.

4.3 Community Solar Program

The final system of note falls under the Community Solar for Buildings program. This system can be a modification of either of the systems described in Section 4.1, or 4.2.2. This means it can have the advantages of either system, with additional benefits noted herein.

If this program is used with a Stand-Alone & Grid tied system, the power purchase agreement is set by the Government of Nova Scotia and is historically between \$0.25 - 0.35/kWh which is substantially more than either a net metered benefit or a NSPI Power Purchase Agreement.

If this program is used with a Facility Integrated & Net Metered system, the power purchase agreement is still set by the Government of Nova Scotia and is historically between \$0.25 - 0.35/kWh, however in order to ensure this is not generating false meter readings on the NSPI system, it is separately metered within the building, and power is essentially “Sold” to the grid then “purchased” by the building. This results in an overall benefit to the facility of the cost of the Power purchase agreement minus the electricity cost to NSPI.

In both cases as a Power Purchase agreement includes a fixed price for energy on a \$/MWh basis over a 25-year term it cannot take advantage of rate escalations on the NSPI grid, this provides an additional disadvantage to a Facility Integrated & Net Metered system where the overall benefit to the facility will shrink over time.

4.4 Ownership Options

4.4.1 Owner

As the owner of the solar array, HRM would be responsible for all construction, operations, and maintenance associated with the solar array. HRM would generate all revenue from energy production with this ownership option, and this scenario is used in the analysis of this report as these are quantifiable values.

4.4.2 Lessor

HRM leased the land to a solar developer, there would not be any capital costs for HRM, however, they would not directly realize any revenue generated from the energy production. Instead, they may earn a rent from the solar developer for the land use depending on the structure of the agreement between the parties. This option was not evaluated in this study as the feasibility would depend on the agreements between the parties. This should be revisited in the future with all three parties involved: HRM and the solar developer.

5.0

Infrastructure Modifications

5.1

Electrical Infrastructure

Based on our preliminary electrical analysis, the design for the new composting facility's electrical infrastructure lacks sufficient electrical capacity to support the addition of a photovoltaic collector system. Additional infrastructure would need to be installed to collect the power from the inverters and solar panels and distribute it through the facility.

Section 64 of the Canadian Electrical Code (CEC) allows the sum of all source circuits supplying power to a busbar to be a maximum of 120% of the rating of the busbar. The existing 3200A bus of switchgear SWG-100 has the potential to have up to 3840A of source circuits. The main breaker within the switchgear is 3200A, leaving a maximum of 640A available for solar installation. Switchgear SWG-100 needs to be upgraded to a 4000A bus to accommodate the proposed new 1MW PV system. From SWG-100, a new 1000A, 3 phase, 4 wire, 480V distribution panel would be installed downstream from a transformer with breaker capacity for the new inverters. Furthermore, this new panel would have owners metering to support the development of internal promotional pieces in the future.

Beyond the requirements of the internal electrical infrastructure NSPI would need to replace their existing meter with a new bi-directional meter. The design team would also be required to coordinate with NSPI for the implementation of a solar project.

5.2

Structural Infrastructure

There are several options for supports for the solar arrangement, as detailed below. The best option for the solar array will depend on the type of racking system used and the ground characteristics of the proposed location. A geotechnical report should be developed to confirm requirements with each support structure option.

Option 1 - Helical Pile Supports

Helical piles are a type of steel pipe pile with a permanent helix shaped auger flyte that can be easily screwed into the ground. They are a type of pile support that requires zero excavation and can be installed quite rapidly. In addition, the installation on helical piles is not impacted by high groundwater tables, which has been noted as a concern based on the site conditions. Helical pile supports are used for the purposes for this report and the cost estimate within Section 7.1.1.

Option 2 – Micro Piles

Typical micro piles require socketing the piles into the bedrock to resist the design loads. This could potentially lead to longer pile lengths than helical piles. In continuing to compare this option to helical piles, additional costs would be required for the supply and installation of the rock sockets which would

not be needed if helical piles were used. Therefore, it is anticipated that the micro pile option would have much higher costs compared to that of Helical Piles.

Option 3 - Precast Concrete Foundations

Precast concrete foundations are less labor intensive than cast-in place concrete foundations due to the concrete fabrication being completed off-site. There is also greater control over the quality as it is cured within a controlled environment. The cost difference of precast concrete foundations to that of the helical and micro piles would depend on the results of a geotechnical investigation.

Option 4 – Cast-In Place Concrete Foundations:

With the installation of typical cast-in place concrete foundations, the footings are to be installed to a minimum of 1.2 m below frost depth which would likely lead to a higher volume of concrete in comparison to that of the pre-cast spread footings. Therefore, it is anticipated that this option would cost considerably more than other options.

5.3 Project Schedule

Development of the proposed solar array is expected to take place over a three-year period as follows:

- Year 1 (2026) – The geotechnical investigation for the site will take place. Engineering design for the new solar array and integration to the new facility, as well as transmission coordination with Nova Scotia Power will take place;
- Year 2 (2027) – Construction activities in relation to the development of the new solar array will take place; and
- Year 3 (2028) – Construction activities in the relation to the development of the new solar array to be completed. Following the completion of constructing the solar array, testing and commissioning will take place.

This proposed schedule is based on the schedule of closure provided within the *Ragged Lake Composting Facility Closure Plan* report provided to HRM in February 2024.

6.0 Solar Analysis

6.1 Model Constraints

In this section, a review and application of constraints to our daily solar radiation will be conducted to assist in determining energy (kWh) production.

6.1.1 Tilt Angle

The proposed location for the ground mounted solar array has enough space to accommodate larger row spacing, which allows for a larger tilt angle of 40 degrees to be used for the analysis to maximize the solar energy produced, based on the value found in Section 2.5. With the tilt angle set to 40 degrees,

the resulting impact on the overall system needs to be determined. By applying the difference in angles to the amount of radiation noted in Table 3 of Section 2.5.1, the resulting radiation absorbed by the panels is determined and shown in Table 4.

Table 4: Typical Daily Solar Radiation at “Synthetic” Halifax on Inclined Planes (kWh/m²/D)

Month	South 0 degrees from Horizontal	South 40 degrees from Horizontal
January	1.25	2.09
February	2.37	3.60
March	3.68	4.83
April	4.44	5.10
May	5.51	5.42
June	5.83	5.51
July	5.47	5.29
August	5.03	5.35
September	4.10	5.00
October	2.54	3.60
November	1.42	2.17
December	1.03	1.89
Annual Average	3.57	4.16

6.1.2 System Losses

Many factors influence the overall power received by the AC infrastructure, such as wire resistance, electronic switching, dirt and soiling, system downtime, operating temperature, transformer and inverter losses, shading, and weather. Over the years, a combination of historical operating data, codes and requirement info, manufacturing data, and industry best practices have been analyzed to develop an acceptable range of values to apply to these categories and are shown in Table 5. Also included in Table 5 is Dillon’s standard Derate Value, which was determined based on the acceptable range, market data and subject matter expertise.

Table 5: DC to AC Derating Factors*

Derate Factors	Derate Value	Acceptable Ranges
Module power tolerance	0.95	0.88-1.0 5
Inverter and transformer	0.98	0.88-0.98
Module mismatch	0.99	0.97-0.995
Diodes and connections	0.995	0.99-0.997
DC wiring	0.98	0.97-0.99
AC wiring	0.99	0.98-0.993
Soiling	0.95	0.30-0.995
System Downtime	0.98	0.00-0.995
Shading	0.99	0.00-1.00
Inverter Efficiencies	0.96	By Product

Derate Factors	Derate Value	Acceptable Ranges
Temperature Losses	0.92	Depending on Climate
Overall DC-to-AC Derate	0.724	-

*: The derating factor is defined as the scaling of the output power of the solar panel to consider the wire losses, losses due to dust particles, increased temperature, or any other thing that deviates the output power of the solar panel from the expected value.

Additionally, as photovoltaic panels generate energy through knocking electrons in the silicon atoms loose there is power degradation to consider, not all electrons make it back into the system or end up recombining with the silicon layers. Each panel has a different warranted power efficiency over warranty period (25 years for monofacial panels and 30 years for bifacial panels) that must be considered as we evaluate energy production throughout the life cycle. This power degradation can be found in Appendix C and has been applied in the payback calculations and determination in Section 7.2.

6.1.3 Bifacial Gain

As noted in Section 3.1.2, bifacial solar modules can collect sunlight not only on the front face of the panel but also from the rear face. The amount of additional energy yield from a bifacial module depends on two main factors: the light reflectance of the surface beneath the module, and the installation height of the module. These two factors are important as the rear face of the panel is only collecting scattered, reflected, and diffuse radiation. The higher the reflectance of the roof or ground and the height it is mounted at above the structure or ground, the higher the additional yield. Reflectance of the surface is described as its Albedo. Albedo describes the ratio between the light reflected from the surface and the natural incident radiation and is a dimensionless quantity expressed as a percentage. The higher the reflectance, the higher the Albedo. The surface of the Ragged Lake Composting Facility array location is a green grassy area with a medium hue, matte green surface which corresponds to an approximate Albedo of 30%.

Using this Albedo in bifacial calculations will result in an increased energy production that will amount to 8%.

6.1.4 DC-to-AC Ratio

The DC to AC ratio refers to the number of installed photovoltaic modules over the size of the DC to AC inverter. This ratio is important as the inverter will not produce its nameplate capacity at all points of the day due to limited amounts of sunlight. The higher this ratio, the sooner the inverter will reach peak power production capabilities. Too high however, will cause the inverter to overshoot the nameplate resulting in a loss of energy when the solar intensity is stronger. The below table shows the DC:AC ratios for the various systems outlined and analyzed in this report.

Table 6: DC & AC System Nameplate

Nameplate	DC Size	AC Size	DC:AC Ratio
Option 1: PERC (Solar Array Size)	1,056,000	1,000,000	1.056:1
Option 2: Bifacial PERC (Solar Array Size)	1,058,000	1,000,000	1.058:1

6.1.5 Power Generation Degradation

Over the lifecycle of the system, the efficiency of the panels and other system components will be reduced. The energy the system sized and described in 6.1.4 can produce has had the effects of the power generation degradation applied to in and shown in Table 7 below. This is based on the specific panels chosen in this analysis and will vary based on panel technologies chosen and shows the annual energy production of the system as a whole decreasing over time. Over a 25-year life cycle for Option 1 the power output is estimated to decrease at a rate of 0.72% per annum per PVsyst's aging tool for this specific panel, while Option 2 has a 30-year warrantied life cycle and decreases at a slower rate of 0.60% per annum. This power degradation is considered for the analysis presented in Section 7.2.

Table 7: Yearly Energy Production for Solar Options (kWh)

Year	Option 1	Option 2
1	1383100	1505910
2	1373142	1496875
3	1363255	1486097
4	1353440	1475397
5	1343695	1464774
6	1334020	1454228
7	1324415	1443757
8	1314880	1433362
9	1305412	1423042
10	1296013	1412796
11	1286682	1402624
12	1277418	1392525
13	1268220	1382499
14	1259089	1372545
15	1250024	1362663
16	1241024	1352852
17	1232088	1343111
18	1223217	1333441
19	1214410	1323840

Year	Option 1	Option 2
20	1205666	1314308
21	1196986	1304845
22	1188367	1295450
23	1179811	1286123
24	1171316	1276863
25	1162883	1267670
26	1154510*	1258542
27	1146198*	1249481
28	1137945*	1240485
29	1129752*	1231553
30	1121618*	1222686

*Power Warranty to 80% of rated power has ended at this point.

7.0

Feasibility – Net Metered Solution

The following cost estimate and payback analysis is based on a solar array solution producing 1MW of energy which allows the system to adhere to Bill 145 (The Electricity Act) in Nova Scotia and NSPI regulations. This 1MW solar farm is composed of 1920 monofacial solar modules covering 20,087 m² or 1764 bifacial solar modules covering 18,580 m².

Based on the overall site area of the existing composting facility, there is the space to house a solar farm estimated to consist of 5890 solar modules, capable of producing 3.34 MW of energy when using the bifacial modules used for Option 2 based on the total area of the site and the percentage used for this reports 1MW array size. As indicated in Section 4.2.1, a system of this size was not considered for this report.

The following assumptions were included within the following analysis:

- Efficiency per Module – 21.5% (monofacial), 23% (bifacial);
- Discount Rate – 5%;
- Inflation – 3.25%;
- NSPI CO2 Intensity Degradation – 15%/year (This does not impact energy production);
- Modul Power Degradation – 0.55%/year (monofacial), 0.4% (bifacial); and
- Utility Rate Escalation Rate – 5%/year.

7.1 Cost Estimate

7.1.1 Photovoltaic Panel Systems

There are many components to a grid tied photovoltaic solar collector system that must be accounted for as part of the feasibility study and capital cost estimate, including additional electrical infrastructure noted in Section 5.1. Components of the photovoltaic solar collector system included in the estimate are as follows: photovoltaic modules, racking system, string inverters, rapid shutdown, 480V transformers, and ancillary equipment such as cabling, conduit and disconnect switches.

In addition to the component costs received from local suppliers and manufacturers, labour and installation rates were retrieved from local installers and cross referenced against previous experience to further develop the cost estimate. From this, an additional 5% contingency was applied along with a 15% allowance for contractor and distributor overhead and profit. Taxes however are not included in this report. The assumptions for the estimate are included in Table 8 and total capital costs for both options can be found in Table 9.

Table 8: Facility Integrated, Net Metered Capital Cost Estimate Assumptions per Option

	Option 1	Option 2
Photovoltaic Panels	550W mono-silicon PERC photovoltaic panel Longi LR5-72HPH-550M G2	600W mono-silicon PERC bifacial photovoltaic panel Longi LR5-72HTH-600M Bifacial
Mounted Racking System	40-degree tilted	
Inverters	3-phase DC to AC string inverters Sunny Highpower SHP150-20-PEAK3 Sunny Highpower SHP100-20-PEAK3	
Rapid Shutdown	DC rapid shutdown combiner boxes	
Electrical Panels	1000A 480V 3 phase 4 wire electrical panel	
Transformers	347/600:480V 1000kVA transformer	
Electrical Misc.	Disconnect switches, cables, conduit, transformer pad, replacement parts, etc.	

Table 9: Facility Integrated, Net Metered Capital Cost

	Option 1	Option 2
Photovoltaic Panels	\$408,000	\$507,150
Supports for Modules	\$432,000	\$396,900
Inverters*	\$106,000	\$106,000
Accessories/ Fasteners	\$38,400	\$38,400
Wiring	\$96,000	\$96,000
Display Screen	\$600	\$600
Pyranometer	\$12,000	\$12,000
Transformer	\$75,000	\$75,000
Electrical Panels	\$40,000	\$40,000
Engineering	\$75,000	\$75,000
Module Installation	\$288,000	\$264,600
Inverter Installation	\$42,000	\$42,000
Transport	\$9,600	\$9,600
Subtotal	\$1,622,600	\$1,663,250
5% Contingency	\$81,130	\$83,162.5
15% OH & Profit	\$243,390	\$249,487.5
Total	\$1,947,120	\$1,995,900

*Assume one replacement required during payback period.

7.1.2 Operation and Maintenance Costs

Maintenance and operation of photovoltaic collectors includes the two primary aspects of maintaining a solar PV system are to regularly monitor your system's performance through the data logger and to clean the panels about 6-10 times in a year. Beyond this, it is advisable to have your installer conduct at least two visits in a year just to check the general health of your system. These costs can be seen here below in Table 10 associated with each of the photovoltaic options. A detailed breakdown of the operation and maintenance costs can be found in Appendix A. Additionally, due to the standard inverter life span of 9-10 years, the annual O&M costs factor in costs for the replacement of the inverter system at years 10, and 20.

Table 10: Annual Operation and Maintenance Costs

	Option 1	Option 2
Provision for Inverter Replacements	\$10,600	\$10,600
Cleaning	\$6,000	\$6,000
Total	\$16,600	\$16,600
Including Inflation	\$27,418	\$27,418

7.2

Payback

As shown throughout this report and from the data derived from the existing facilities NSPI electric utility bills provided, there are two distinct methods that cost savings can be realized; 1) reduction in monthly energy utilization at kWh rates, and 2) reduction in monthly peak power demand. However, where reduction in monthly peak power cannot be analyzed at this time without more detailed load profiles for the new building, annual energy utilization cost reductions are shown below in Table 11. Note that the values provided within the table are the annual savings realized, incorporating the electricity sale profits and operations costs for the totals. A breakdown of the estimated yearly savings is shown in Appendix A.

Table 11: Yearly Energy Savings for Solar Options (\$)

Year	Option 1	Option 2
1	\$131,530	\$144,683
2	\$139,020	\$152,784
3	\$146,926	\$161,330
4	\$155,274	\$170,345
5	\$164,086	\$179,855
6	\$173,389	\$189,888
7	\$183,209	\$200,470
8	\$193,576	\$211,633
9	\$204,518	\$223,408
10	\$216,068	\$235,828
11	\$228,260	\$248,927
12	\$241,127	\$262,744
13	\$254,708	\$277,316
14	\$269,042	\$292,686
15	\$284,170	\$308,895
16	\$300,136	\$325,990
17	\$316,985	\$344,018
18	\$334,767	\$363,031
19	\$353,532	\$383,081
20	\$373,334	\$404,224
21	\$394,230	\$426,521
22	\$416,280	\$450,032
23	\$439,548	\$474,825
24	\$464,099	\$500,969
25	\$490,005	\$528,535

Year	Option 1	Option 2
26	\$517,339	\$557,603
27	\$546,180	\$588,252
28	\$576,611	\$620,568
29	\$608,717	\$654,641
30	\$642,592	\$690,566
Total	\$9,759,259	\$10,573,646

*Refer to Table 7 for annual energy production, and section 2.2, & 7.0 for financial constraints

With this information, determining the payback period is then possible, however, it is prudent to consider the current market trends in terms of inflation and demand to get a true sense of the payback period. HRM has requested an inflation rate of 3.25% to be used in this analysis, which has been included within our calculations. However, the cost growth of electrical power over the same period has been on an upward trend and is not in line with standard inflation. Considering growth over the past decade, emerging climate policies and the aging assets, we've allowed for a 5% electrical escalation cost modifier throughout the lifecycle of the payback period.

These factors coupled with the annual average data from Table 11, and the cost estimate baseline in Table 9, results in the following simple payback period for the grid tied options shown in Table 12.

Table 12: Facility Integrated, Net Metered Options Simple Payback (kWh rates)

	Option 1	Option 2
Payback Period	13 Years, 11 Months	13 Years, 0 Months
Net Present Value	\$2,302,714.51	\$2,621,700.14

*Net Present Value is per 2024-dollar value

As shown in Table 12, the implementation of a solar PV array is revenue positive and capable of paying itself off within the warranted lifespan listed in Section 3.1.3.

Due to the power production estimated being lower than the contract value of 500,000kWh per month, the savings listed in Table 11 is a direct reduction on the price being paid by HRM to the facility operators on an annual basis. This results in a reduction of 16.15% against the baseline energy consumption costs of the building.

7.2.1 Capital Cost & Payback Modifier Programs

The results of this feasibility study have been based on the standard billing rate currently applied to the facility that would remain in place under a Net Metering agreement. Another potential payback model could consist of selling all generated energy directly to NSPI under a power purchase agreement; however, this could be at a lower \$/kWh than purchasing energy and put the owner in an undesirable

position. There may be additional power purchase agreements and programs to assist with capital cost of the installation. One potentially applicable program has been outlined below.

Applicable programs should be investigated in detail by HRM and the consulting engineering firm responsible for the design of any photovoltaic solar collector system at such time in which the system design moves forward to construction. One program of note is led by Efficiency Nova Scotia (ENS). This program allows a rebate of \$0.10/kWh of solar energy produced for within the first year if the payback period is less than 15 years. Eligibility of this program will need to be confirmed with ENS.

7.3

Conclusions and Recommendations

From the information outlined in this report, it is clear that the potential generation of solar power is a viable option for the Ragged Lake Composting Facility within the first life cycle of the photovoltaic collectors given the warranty period of the respective panels with a return on investment between 13 years to 13 years, 11 months. Prior to the implementation of a PV system, the following recommendations are provided to further evaluate the additional potential benefits of the system:

1. Complete a geotechnical investigation

A geotechnical report for the site should be completed to confirm the requirements with each support structure option and determine the optimal for the site.

2. Engage Nova Scotia Power to complete System Impact Study Agreement

This is to ensure that the proposed system is in compliance with NSPI standards.

3. Re-evaluate system when building load profile is developed for the new facility

Re-evaluating the proposed system when the building load profile is developed will open the facility to more payback options. With the building load profile, the impact of implementing a battery energy storage system on the system could be evaluated.

4. Perform Lightning Risk Assessment

Appendix A

PVsyst Report – Option 1

PVsyst - Simulation report

Grid-Connected System

Project: HRM Solid Waste Facility

Variant: Field Array

Sheds on ground

System power: 1056 kWp

Goodwood - Canada

Author

Dillon Consulting Limited (Canada)

7071 Bayers Road

Suite 2001

Halifax / B3L 2C2

Canada



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

VC0, Simulation date:
03/20/24 11:22
with v7.4.2

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Project summary

Geographical Site

Goodwood

Canada

Situation

Latitude 44.61 °N
Longitude -63.68 °W
Altitude 107 m
Time zone UTC-4

Project settings

Albedo 0.20

Meteo data

Goodwood - Solid Waste

Meteonorm 8.1 (1991-2005), Sat=100% - Synthetic

System summary

Grid-Connected System

Simulation for year no 1

PV Field Orientation

Fixed plane

Tilt/Azimuth 40 / 0 °

Sheds on ground

Near Shadings

Linear shadings : Fast (table)

User's needs

Unlimited load (grid)

System information

PV Array

Nb. of modules 1920 units
Pnom total 1056 kWp

Inverters

Nb. of units 7 units
Pnom total 1000 kWac
Pnom ratio 1.056

Results summary

Produced Energy 1382947 kWh/year Specific production 1310 kWh/kWp/year Perf. Ratio PR 86.51 %

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General parameters, PV Array Characteristics, System losses	3
Near shading definition - Iso-shadings diagram	6
Main results	7
Loss diagram	8
Predef. graphs	9
Single-line diagram	10
Cost of the system	11
Financial analysis	12
CO ₂ Emission Balance	15



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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General parameters

Grid-Connected System

PV Field Orientation

Orientation

Fixed plane
Tilt/Azimuth 40 / 0 °

Horizon

Free Horizon

Sheds on ground

Sheds configuration

Nb. of sheds 24 units

Sizes

Sheds spacing 10.00 m
Collector width 2.29 m
Ground Cov. Ratio (GCR) 22.9 %
Top inactive band 0.02 m
Bottom inactive band 0.02 m

Shading limit angle

Limit profile angle 10.2 °

Near Shadings

Linear shadings : Fast (table)

Models used

Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

User's needs

Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer Longi Solar
Model LR5-72HPH-550M G2
(Original PVsyst database)

Unit Nom. Power 550 Wp
Number of PV modules 1728 units
Nominal (STC) 950 kWp

Array #1 - PV Array

Number of PV modules 288 units
Nominal (STC) 158 kWp
Modules 12 Strings x 24 In series

At operating cond. (50°C)

Pmpp 145 kWp
U mpp 907 V
I mpp 160 A

Array #2 - Sub-array #2

Number of PV modules 288 units
Nominal (STC) 158 kWp
Modules 12 Strings x 24 In series

At operating cond. (50°C)

Pmpp 145 kWp
U mpp 907 V
I mpp 160 A

Array #3 - Sub-array #3

Number of PV modules 288 units
Nominal (STC) 158 kWp
Modules 12 Strings x 24 In series

At operating cond. (50°C)

Pmpp 145 kWp
U mpp 907 V
I mpp 160 A

Inverter

Manufacturer SMA
Model Sunny Highpower SHP150-20-PEAK3
(Original PVsyst database)

Unit Nom. Power 150 kWac
Number of inverters 6 units
Total power 900 kWac

Number of inverters 1 unit
Total power 150 kWac

Operating voltage 855-1450 V
Pnom ratio (DC:AC) 1.06

Number of inverters 1 unit
Total power 150 kWac

Operating voltage 855-1450 V
Pnom ratio (DC:AC) 1.06

Number of inverters 1 unit
Total power 150 kWac

Operating voltage 855-1450 V
Pnom ratio (DC:AC) 1.06



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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PV Array Characteristics

Array #4 - Sub-array #4

Number of PV modules	288 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 24 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
P _{mpp}	145 kWp	P _{nom} ratio (DC:AC)	1.06
U _{mpp}	907 V		
I _{mpp}	160 A		

Array #5 - Sub-array #5

Number of PV modules	288 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 24 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
P _{mpp}	145 kWp	P _{nom} ratio (DC:AC)	1.06
U _{mpp}	907 V		
I _{mpp}	160 A		

Array #6 - Sub-array #6

Number of PV modules	288 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 24 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
P _{mpp}	145 kWp	P _{nom} ratio (DC:AC)	1.06
U _{mpp}	907 V		
I _{mpp}	160 A		

Array #7 - Sub-array #7

PV module		Inverter	
Manufacturer	Longi Solar	Manufacturer	SMA
Model	LR5-72HPH-550M G2	Model	Sunny Highpower SHP100-20-PEAK3
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	550 Wp	Unit Nom. Power	100 kWac
Number of PV modules	192 units	Number of inverters	1 unit
Nominal (STC)	106 kWp	Total power	100 kWac
Modules	12 Strings x 16 In series	Operating voltage	570-1000 V
At operating cond. (50°C)		P _{nom} ratio (DC:AC)	1.06
P _{mpp}	96.7 kWp		
U _{mpp}	605 V		
I _{mpp}	160 A		

Total PV power

Nominal (STC)	1056 kWp	Total inverter power	
Total	1920 modules	Total power	1000 kWac
Module area	4960 m²	Number of inverters	7 units
Cell area	4604 m²	P _{nom} ratio	1.06

Array losses

Array Soiling Losses

Loss Fraction 3.0 %

Thermal Loss factor

Module temperature according to irradiance
U_c (const) 29.0 W/m²K
U_v (wind) 0.0 W/m²K/m/s

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 -0.8 %

Module mismatch losses

Loss Fraction 2.0 % at MPP



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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Array losses

Strings Mismatch loss

Loss Fraction 0.2 %

Module average degradation

Year no 1
Loss factor 0.8 %/year

Mismatch due to degradation

Imp RMS dispersion 0.4 %/year
Vmp RMS dispersion 0.4 %/year

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

DC wiring losses

Global wiring resistance 10 mΩ
Loss Fraction 1.5 % at STC

Array #1 - PV Array

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

Array #3 - Sub-array #3

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

Array #5 - Sub-array #5

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

Array #7 - Sub-array #7

Global array res. 63 mΩ
Loss Fraction 1.5 % at STC

Array #2 - Sub-array #2

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

Array #4 - Sub-array #4

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

Array #6 - Sub-array #6

Global array res. 94 mΩ
Loss Fraction 1.5 % at STC

AC wiring losses

Inv. output line up to injection point

Inverter voltage 600 Vac tri
Loss Fraction 0.24 % at STC

Inverters: Sunny Highpower SHP150-20-PEAK3, Sunny Highpower SHP100-20-PEAK3

Wire section (7 Inv.) Copper 7 x 3 x 50 mm²
Average wires length 14 m



Project: HRM Solid Waste Facility

Variant: Field Array

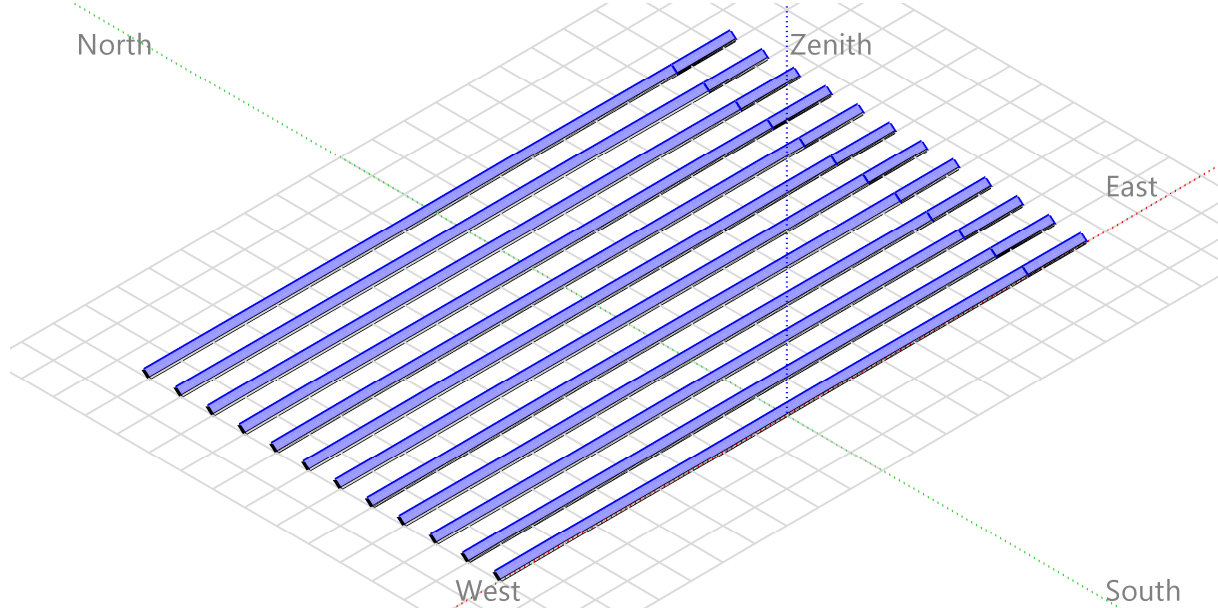
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Near shadings parameter

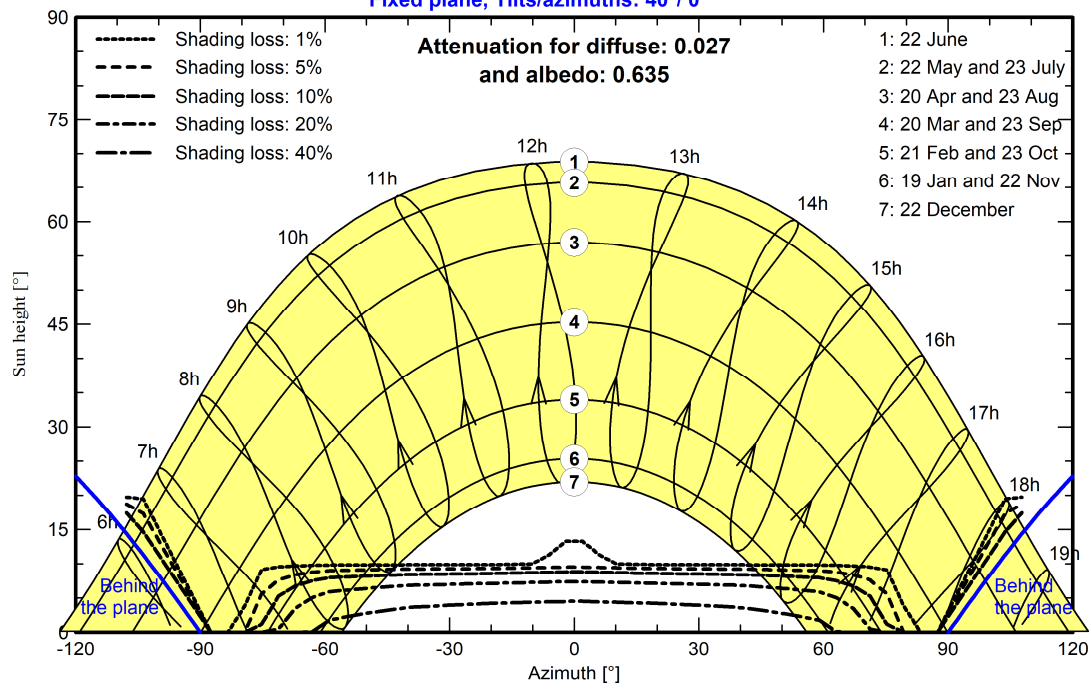
Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1

Fixed plane, Tilts/azimuths: 40°/ 0°





Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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Main results

System Production

Produced Energy 1382947 kWh/year

Specific production

1310 kWh/kWp/year

Perf. Ratio PR

86.51 %

Economic evaluation

Investment

Global 1,947,120.00 CAD

Specific 1.84 CAD/Wp

Yearly cost

Annuities

0.00 CAD/yr

Run. costs

27,417.55 CAD/yr

Payback period

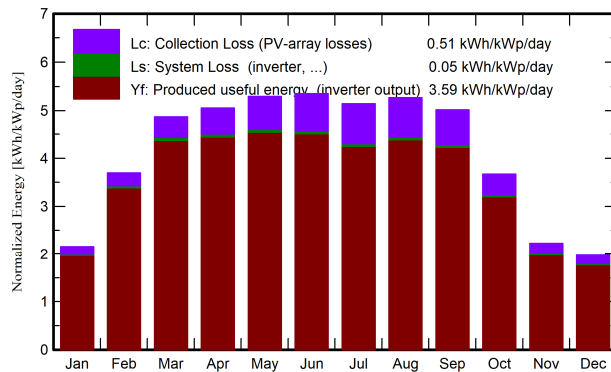
13.9 years

LCOE

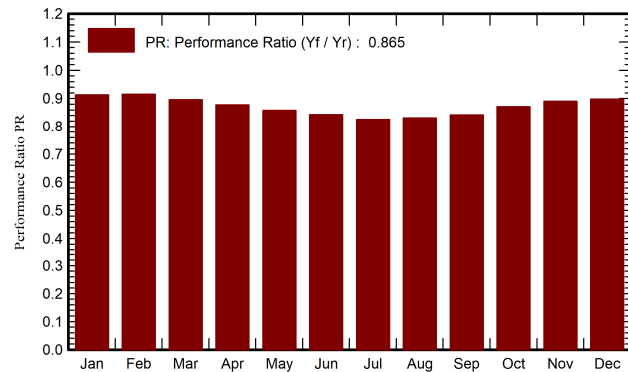
Energy cost

0.10 CAD/kWh

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray kWh	E_Grid kWh	PR ratio
January	38.7	22.38	-5.36	67.1	62.7	65559	64659	0.913
February	66.4	29.83	-5.05	103.5	97.8	101495	100101	0.916
March	114.0	45.13	-1.41	151.2	142.0	145194	143137	0.896
April	137.5	63.49	3.85	151.8	141.5	142713	140751	0.878
May	170.9	83.40	9.49	164.2	152.1	150806	148813	0.858
June	175.0	95.41	14.45	160.5	148.2	144739	142932	0.843
July	169.5	83.86	19.18	159.5	147.6	140937	139156	0.826
August	156.0	76.37	19.14	163.4	151.9	145359	143524	0.832
September	123.1	51.55	15.95	150.6	140.8	135748	133963	0.842
October	78.8	38.43	10.11	113.9	106.9	106242	104854	0.872
November	42.5	26.54	3.75	67.0	62.9	63823	63001	0.891
December	32.0	17.07	-1.78	61.2	57.1	58854	58056	0.898
Year	1304.3	633.46	6.93	1513.9	1411.3	1401470	1382947	0.865

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



Project: HRM Solid Waste Facility

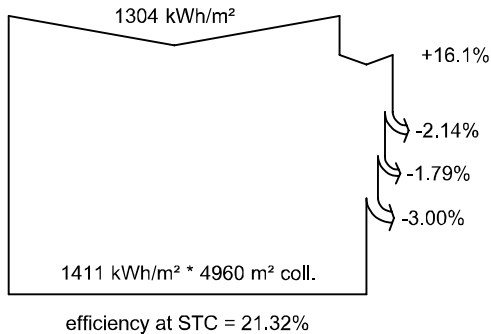
Variant: Field Array

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Loss diagram



Global horizontal irradiation
Global incident in coll. plane

Near Shadings: irradiance loss
IAM factor on global
Soiling loss factor

Effective irradiation on collectors

PV conversion

Array nominal energy (at STC effic.)

Module Degradation Loss (for year #1)
PV loss due to irradiance level
PV loss due to temperature
Module quality loss

LID - Light induced degradation

Mismatch loss, modules and strings

Ohmic wiring loss

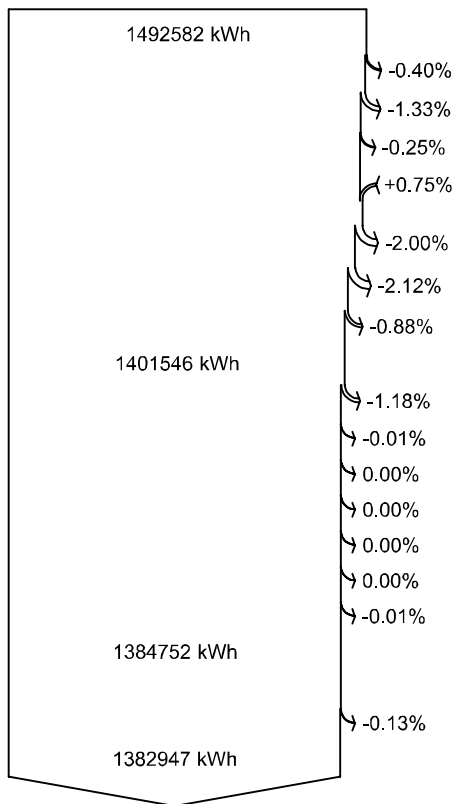
Array virtual energy at MPP

Inverter Loss during operation (efficiency)
Inverter Loss over nominal inv. power
Inverter Loss due to max. input current
Inverter Loss over nominal inv. voltage
Inverter Loss due to power threshold
Inverter Loss due to voltage threshold
Night consumption

Available Energy at Inverter Output

AC ohmic loss

Energy injected into grid





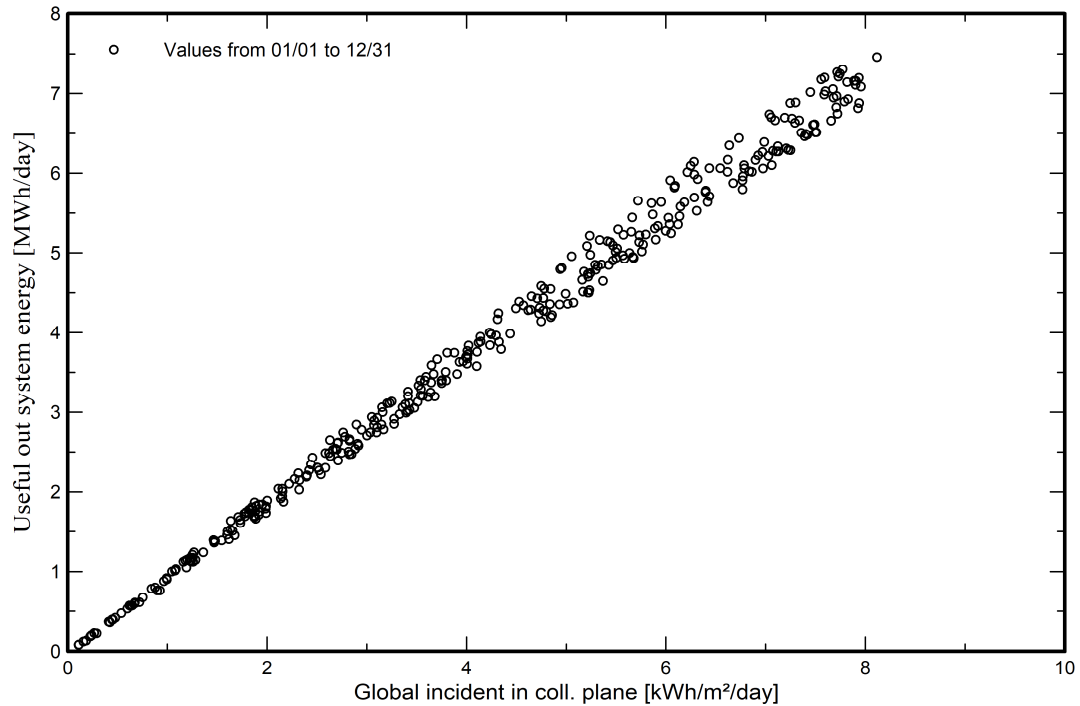
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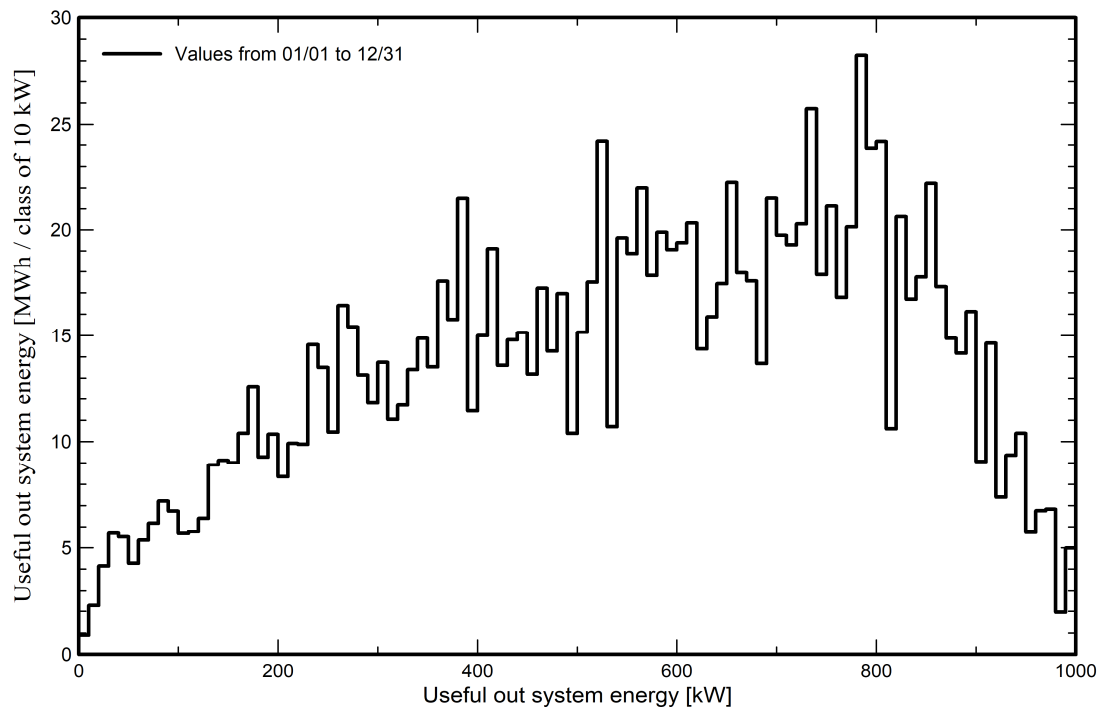
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Predef. graphs

Daily Input/Output diagram



System Output Power Distribution

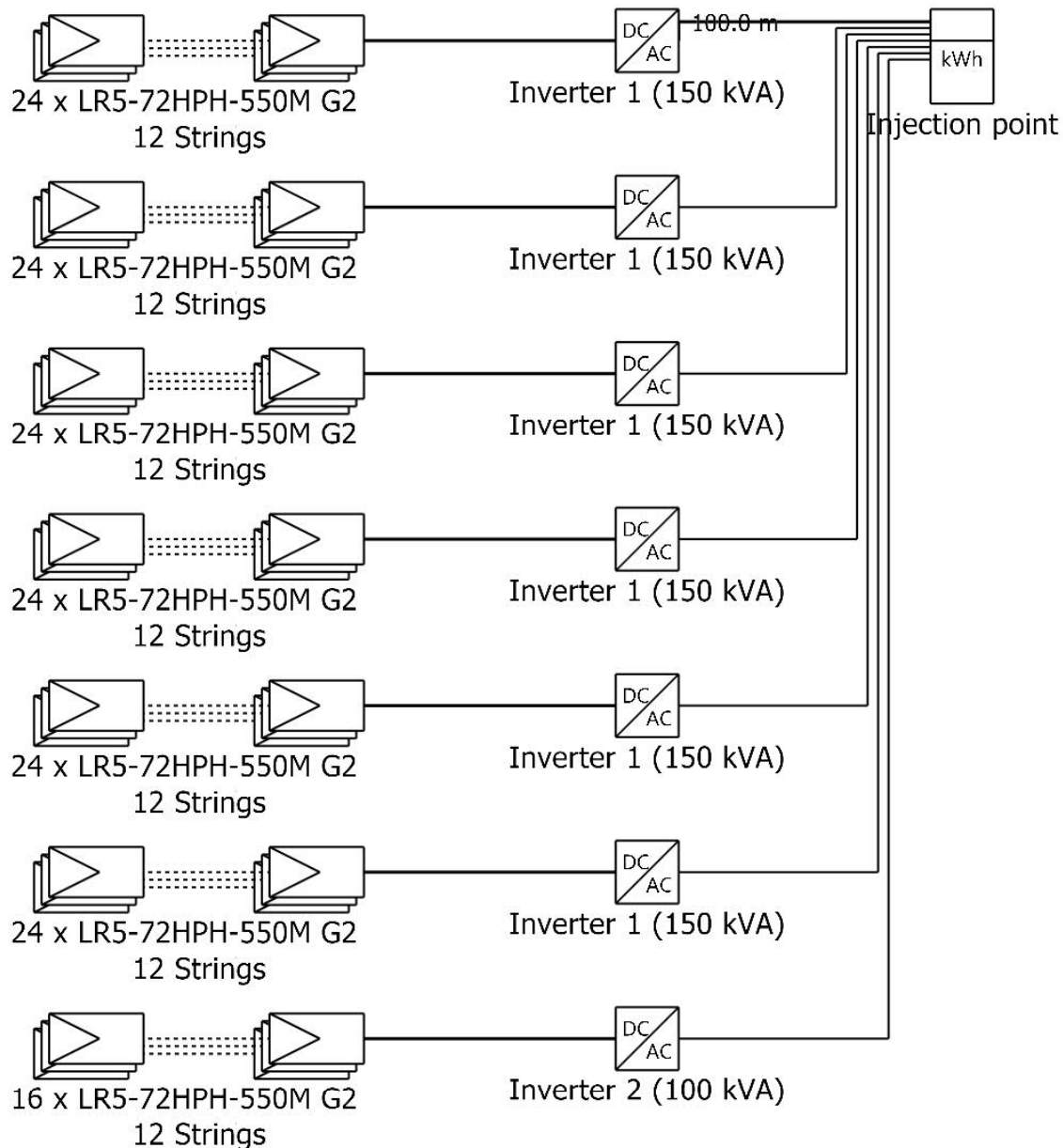




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Single-line diagram



PV module	LR5-72HPH-550M G2
Inverter 1	Sunny Highpower SHP150-20-PEAK3
Inverter 2	Sunny Highpower SHP100-20-PEAK3
String 1	24 x LR5-72HPH-550M G2
String 2	16 x LR5-72HPH-550M G2

HRM Solid Waste Facility Dillon Consulting Limited (Canada)

VC0 : Field Array

03/21/24



Project: HRM Solid Waste Facility

Variant: Field Array

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Cost of the system

Installation costs

Item	Quantity units	Cost CAD	Total CAD
PV modules			
LR5-72HPH-550M G2	1920	212.50	408,000.00
Supports for modules	1920	225.00	432,000.00
Inverters			
Sunny Highpower SHP150-20-PEAK3	6	16,000.00	96,000.00
Sunny Highpower SHP100-20-PEAK3	1	10,000.00	10,000.00
Other components			
Accessories, fasteners	7680	5.00	38,400.00
Wiring	1920	50.00	96,000.00
Monitoring system, display screen	1	600.00	600.00
Measurement system, pyranometer	1	12,000.00	12,000.00
Transformer	1	75,000.00	75,000.00
Electrical Panel	1	40,000.00	40,000.00
Studies and analysis			
Engineering	1	75,000.00	75,000.00
Installation			
Global installation cost per module	1920	150.00	288,000.00
Global installation cost per inverter	7	6,000.00	42,000.00
Transport	1920	5.00	9,600.00
Contingency			81,130.00
Overhead & Profit			243,390.00
		Total	1,947,120.00
		Depreciable asset	1,099,400.00

Operating costs

Item	Total CAD/year
Maintenance	
Provision for inverter replacement	10,600.00
Cleaning	6,000.00
Total (OPEX)	16,600.00
Including inflation (3.25%)	27,417.55

System summary

Total installation cost	1,947,120.00 CAD
Operating costs (incl. inflation 3.25%/year)	27,417.55 CAD/year
Produced Energy	1383 MWh/year
Cost of produced energy (LCOE)	0.098 CAD/kWh



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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Financial analysis

Simulation period

Project lifetime 30 years Start year 2024

Income variation over time

Inflation 3.25 %/year
Production variation (aging) 0.40 %/year
Discount rate 5.00 %/year

Income dependent expenses

Income tax rate 0.00 %/year
Other income tax 0.00 %/year
Dividends 0.00 %/year

Depreciable assets

Asset	Depreciation method	Depreciation period (years)	Salvage value (CAD)	Depreciable (CAD)
PV modules				
LR5-72HPH-550M G2	Straight-line	30	0.00	408,000.00
Supports for modules	Straight-line	20	0.00	432,000.00
Inverters				
Sunny Highpower SHP150-20-PEAK3	Straight-line	20	0.00	96,000.00
Sunny Highpower SHP100-20-PEAK3	Straight-line	30	0.00	10,000.00
Accessories, fasteners	Straight-line	20	0.00	38,400.00
Transformer	Straight-line	30	0.00	75,000.00
Electrical Panel	Straight-line	30	0.00	40,000.00
		Total	0.00	1,099,400.00

Financing

Own funds 1,808,820.00 CAD
Subsidies 138,300.00 CAD

Electricity sale

Feed-in tariff 0.1071 CAD/kWh
Duration of tariff warranty 30 years
Annual connection tax 0.00 CAD/kWh
Annual tariff variation +5.0 %/year
Feed-in tariff decrease after warranty 0.00 %

Return on investment

Payback period 13.9 years
Net present value (NPV) 2,302,714.51 CAD
Internal rate of return (IRR) 11.47 %
Return on investment (ROI) 127.3 %



Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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Dillon Consulting Limited (Canada)

Financial analysis

Detailed economic results (CAD)

Year	Electricity sale	Own funds	Run. costs	Deprec. allow.	Taxable income	Taxes	After-tax profit	Cumul. profit	% amorti.
0	0	1,808,820	0	0	0	0	0	-1,808,820	0.0%
1	148,130	0	16,600	46,087	85,444	0	131,530	-1,683,553	6.9%
2	156,159	0	17,140	46,087	92,933	0	139,020	-1,557,458	13.9%
3	164,623	0	17,697	46,087	100,840	0	146,926	-1,430,538	20.9%
4	173,545	0	18,272	46,087	109,187	0	155,274	-1,302,793	28.0%
5	182,952	0	18,866	46,087	117,999	0	164,086	-1,174,228	35.1%
6	192,868	0	19,479	46,087	127,302	0	173,389	-1,044,842	42.2%
7	203,321	0	20,112	46,087	137,123	0	183,209	-914,639	49.4%
8	214,341	0	20,765	46,087	147,489	0	193,576	-783,619	56.7%
9	225,958	0	21,440	46,087	158,431	0	204,518	-651,785	64.0%
10	238,205	0	22,137	46,087	169,982	0	216,068	-519,138	71.3%
11	251,116	0	22,856	46,087	182,173	0	228,260	-385,679	78.7%
12	264,726	0	23,599	46,087	195,040	0	241,127	-251,410	86.1%
13	279,075	0	24,366	46,087	208,622	0	254,708	-116,333	93.6%
14	294,200	0	25,158	46,087	222,956	0	269,042	19,551	101.1%
15	310,146	0	25,976	46,087	238,084	0	284,170	156,242	108.6%
16	326,956	0	26,820	46,087	254,049	0	300,136	293,738	116.2%
17	344,677	0	27,692	46,087	270,899	0	316,985	432,038	123.9%
18	363,359	0	28,592	46,087	288,680	0	334,767	571,140	131.6%
19	383,053	0	29,521	46,087	307,445	0	353,532	711,045	139.3%
20	403,814	0	30,480	46,087	327,247	0	373,334	851,750	147.1%
21	425,701	0	31,471	17,767	376,463	0	394,230	993,256	154.9%
22	448,774	0	32,494	17,767	398,513	0	416,280	1,135,561	162.8%
23	473,097	0	33,550	17,767	421,781	0	439,548	1,278,665	170.7%
24	498,739	0	34,640	17,767	446,332	0	464,099	1,422,568	178.6%
25	525,771	0	35,766	17,767	472,238	0	490,005	1,567,267	186.6%
26	554,268	0	36,928	17,767	499,573	0	517,339	1,712,764	194.7%
27	584,309	0	38,128	17,767	528,414	0	546,180	1,859,058	202.8%
28	615,978	0	39,368	17,767	558,844	0	576,611	2,006,148	210.9%
29	649,364	0	40,647	17,767	590,951	0	608,717	2,154,033	219.1%
30	684,560	0	41,968	17,767	624,825	0	642,592	2,302,715	227.3%
Total	10,581,786	1,808,820	822,527	1,099,400	8,659,859	0	9,759,259	2,302,715	227.3%



Project: HRM Solid Waste Facility

Variant: Field Array

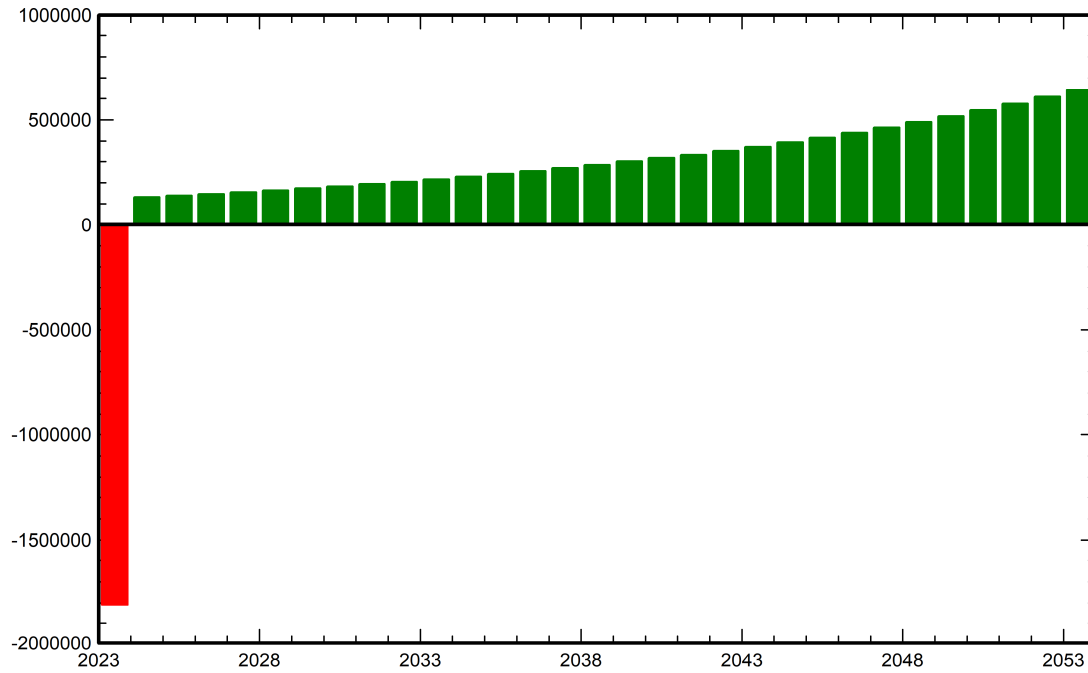
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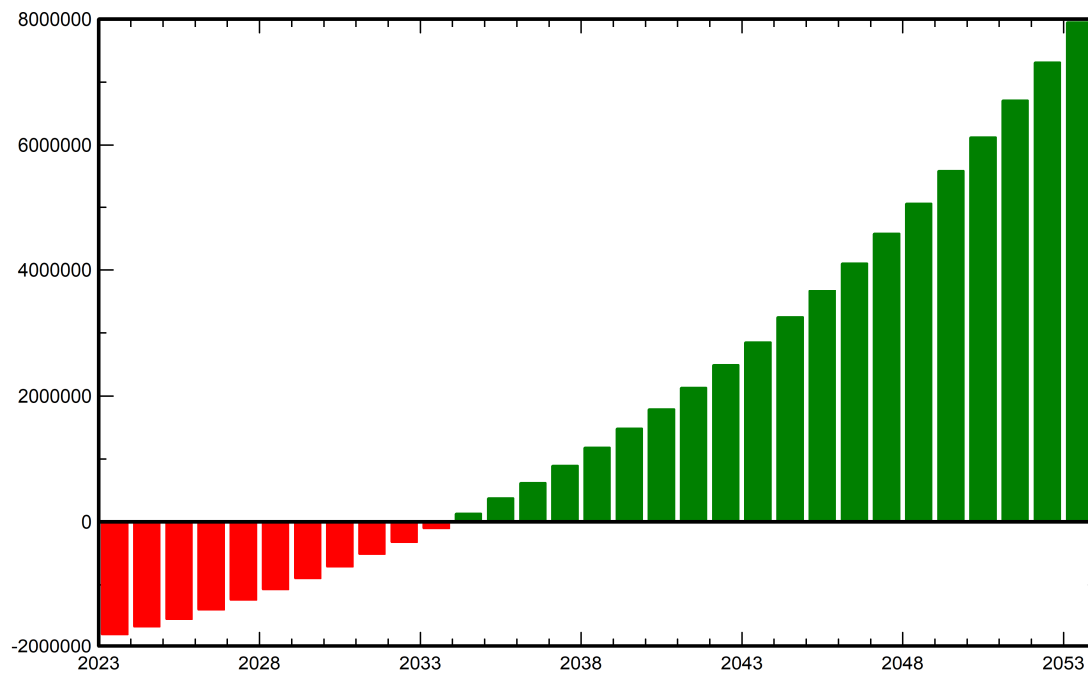
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Financial analysis

Yearly net profit (CAD)



Cumulative cashflow (CAD)





Project: HRM Solid Waste Facility

Variant: Field Array

PVsyst V7.4.2

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CO₂ Emission Balance

Total: 4757.2 tCO₂

Generated emissions

Total: 274.93 tCO₂

Source: Detailed calculation from table below

Replaced Emissions

Total: 22818.6 tCO₂

System production: 1382.95 MWh/yr

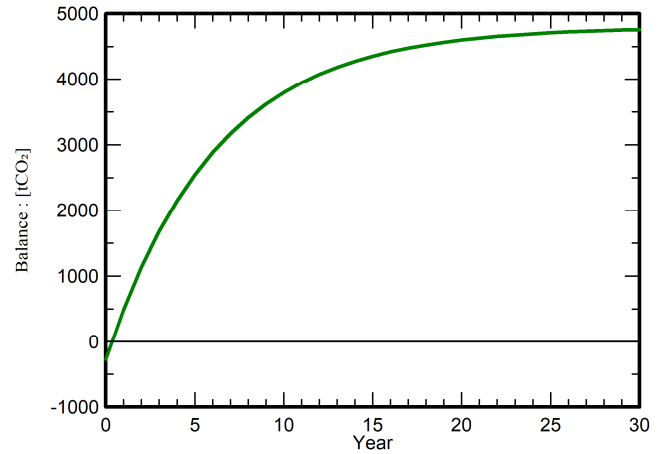
Grid Lifecycle Emissions: 550 gCO₂/kWh

Source: Custom value supplied by user

Lifetime: 30 years

Annual degradation: 15.0 %

Saved CO₂ Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[kgCO ₂]
Modules	1713 kgCO ₂ /kWp	158 kWp	271295
Supports	1.22 kgCO ₂ /kg	2880 kg	3515
Inverters	121 kgCO ₂ /units	1.00 units	121

Appendix B

PVsyst Report – Option 2

PVsyst - Simulation report

Grid-Connected System

Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

Sheds on ground

System power: 1058 kWp

Goodwood - Canada

Author

Dillon Consulting Limited (Canada)

7071 Bayers Road

Suite 2001

Halifax / B3L 2C2

Canada



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

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Project summary

Geographical Site

Goodwood

Canada

Situation

Latitude 44.61 °N
Longitude -63.68 °W
Altitude 107 m
Time zone UTC-4

Project settings

Albedo 0.20

Meteo data

Goodwood - Solid Waste

Meteonorm 8.1 (1991-2005), Sat=100% - Synthetic

System summary

Grid-Connected System

Simulation for year no 1

PV Field Orientation

Fixed plane

Tilt/Azimuth 40 / 0 °

Sheds on ground

Near Shadings

Linear shadings : Fast (table)

User's needs

Unlimited load (grid)

System information

PV Array

Nb. of modules 1764 units
Pnom total 1058 kWp

Inverters

Nb. of units 7 units
Pnom total 1000 kWac
Pnom ratio 1.058

Results summary

Produced Energy 1505612 kWh/year Specific production 1423 kWh/kWp/year Perf. Ratio PR 93.97 %

Table of contents

Project and results summary	2
General parameters, PV Array Characteristics, System losses	3
Near shading definition - Iso-shadings diagram	7
Main results	8
Loss diagram	9
Predef. graphs	10
Single-line diagram	11
Cost of the system	12
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CO ₂ Emission Balance	16



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
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General parameters

Grid-Connected System

PV Field Orientation

Orientation

Fixed plane
Tilt/Azimuth 40 / 0 °

Sheds on ground

Sheds configuration

Nb. of sheds 24 units
Sizes
Sheds spacing 10.00 m
Collector width 2.29 m
Ground Cov. Ratio (GCR) 22.9 %
Top inactive band 0.02 m
Bottom inactive band 0.02 m

Shading limit angle

Limit profile angle 10.2 °

Models used

Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon

Free Horizon

Near Shadings

Linear shadings : Fast (table)

User's needs

Unlimited load (grid)

Bifacial system

Model 2D Calculation
unlimited sheds

Bifacial model geometry

Sheds spacing 10.00 m
Sheds width 2.33 m
Limit profile angle 10.2 °
GCR 23.3 %
Height above ground 1.50 m

Bifacial model definitions

Ground albedo average 0.35
Bifaciality factor 80 %
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
0.50	0.50	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.50	0.35

PV Array Characteristics

PV module

Manufacturer Longi
Model LR7-72HGD-600M

(Custom parameters definition)

Unit Nom. Power 600 Wp
Number of PV modules 1584 units
Nominal (STC) 950 kWp

Array #1 - PV Array

Number of PV modules 264 units
Nominal (STC) 158 kWp
Modules 12 Strings x 22 In series

At operating cond. (50°C)

Pmpp 147 kWp
U mpp 886 V
I mpp 166 A

Inverter

Manufacturer SMA
Model Sunny Highpower SHP150-20-PEAK3

(Original PVsyst database)

Unit Nom. Power 150 kWac
Number of inverters 6 units
Total power 900 kWac

Number of inverters 1 unit
Total power 150 kWac

Operating voltage 855-1450 V
Pnom ratio (DC:AC) 1.06



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

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PV Array Characteristics

Array #2 - Sub-array #2

Number of PV modules	264 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 22 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
Pmpp	147 kWp	Pnom ratio (DC:AC)	1.06
U mpp	886 V		
I mpp	166 A		

Array #3 - Sub-array #3

Number of PV modules	264 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 22 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
Pmpp	147 kWp	Pnom ratio (DC:AC)	1.06
U mpp	886 V		
I mpp	166 A		

Array #4 - Sub-array #4

Number of PV modules	264 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 22 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
Pmpp	147 kWp	Pnom ratio (DC:AC)	1.06
U mpp	886 V		
I mpp	166 A		

Array #5 - Sub-array #5

Number of PV modules	264 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 22 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
Pmpp	147 kWp	Pnom ratio (DC:AC)	1.06
U mpp	886 V		
I mpp	166 A		

Array #6 - Sub-array #6

Number of PV modules	264 units	Number of inverters	1 unit
Nominal (STC)	158 kWp	Total power	150 kWac
Modules	12 Strings x 22 In series		
At operating cond. (50°C)		Operating voltage	855-1450 V
Pmpp	147 kWp	Pnom ratio (DC:AC)	1.06
U mpp	886 V		
I mpp	166 A		



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

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PV Array Characteristics

Array #7 - Sub-array #7

PV module

Manufacturer Longi
Model LR7-72HGD-600M
(Custom parameters definition)
Unit Nom. Power 600 Wp
Number of PV modules 180 units
Nominal (STC) 108 kWp
Modules 12 Strings x 15 In series

At operating cond. (50°C)

Pmpp 100 kWp
U mpp 604 V
I mpp 166 A

Total PV power

Nominal (STC) 1058 kWp
Total 1764 modules
Module area 4765 m²

Inverter

Manufacturer SMA
Model Sunny Highpower SHP100-20-PEAK3
(Original PVsyst database)

Unit Nom. Power 100 kWac
Number of inverters 1 unit
Total power 100 kWac
Operating voltage 570-1000 V
Pnom ratio (DC:AC) 1.08

Total inverter power

Total power 1000 kWac
Number of inverters 7 units
Pnom ratio 1.06

Array losses

Array Soiling Losses

Loss Fraction 3.0 %

Thermal Loss factor

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

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 3.0 %

Module mismatch losses

Loss Fraction 2.0 % at MPP

Strings Mismatch loss

Loss Fraction 0.2 %

Module average degradation

Year no 1
Loss factor 0.68 %/year

Mismatch due to degradation

Imp RMS dispersion 0.4 %/year
Vmp RMS dispersion 0.4 %/year

IAM loss factor

Incidence effect (IAM): Fresnel smooth glass, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

DC wiring losses

Global wiring resistance 10 mΩ
Loss Fraction 1.5 % at STC

Array #1 - PV Array

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC

Array #3 - Sub-array #3

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC

Array #5 - Sub-array #5

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC

Array #2 - Sub-array #2

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC

Array #4 - Sub-array #4

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC

Array #6 - Sub-array #6

Global array res. 87 mΩ
Loss Fraction 1.5 % at STC



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

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DC wiring losses

Array #7 - Sub-array #7

Global array res.	59 mΩ
Loss Fraction	1.5 % at STC

System losses

Unavailability of the system

Time fraction	0.5 %
	1.8 days,
	3 periods

AC wiring losses

Inv. output line up to injection point

Inverter voltage	600 Vac tri
Loss Fraction	0.24 % at STC

Inverters: Sunny Highpower SHP150-20-PEAK3, Sunny Highpower SHP100-20-PEAK3

Wire section (7 Inv.)	Copper 7 x 3 x 50 mm ²
Average wires length	14 m



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

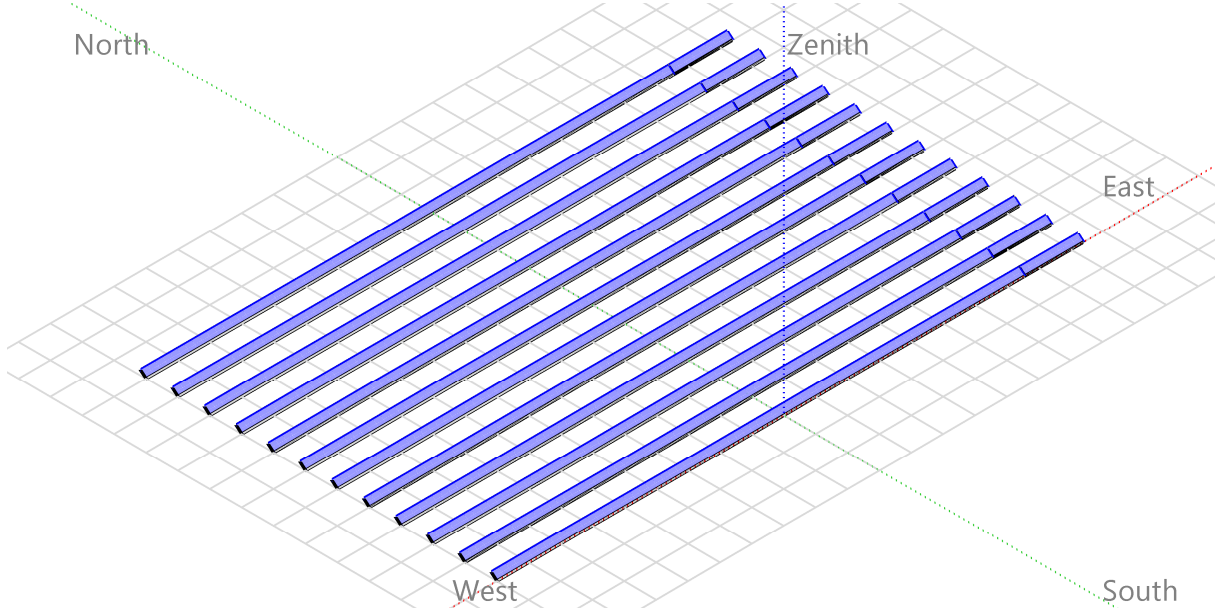
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VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Near shadings parameter

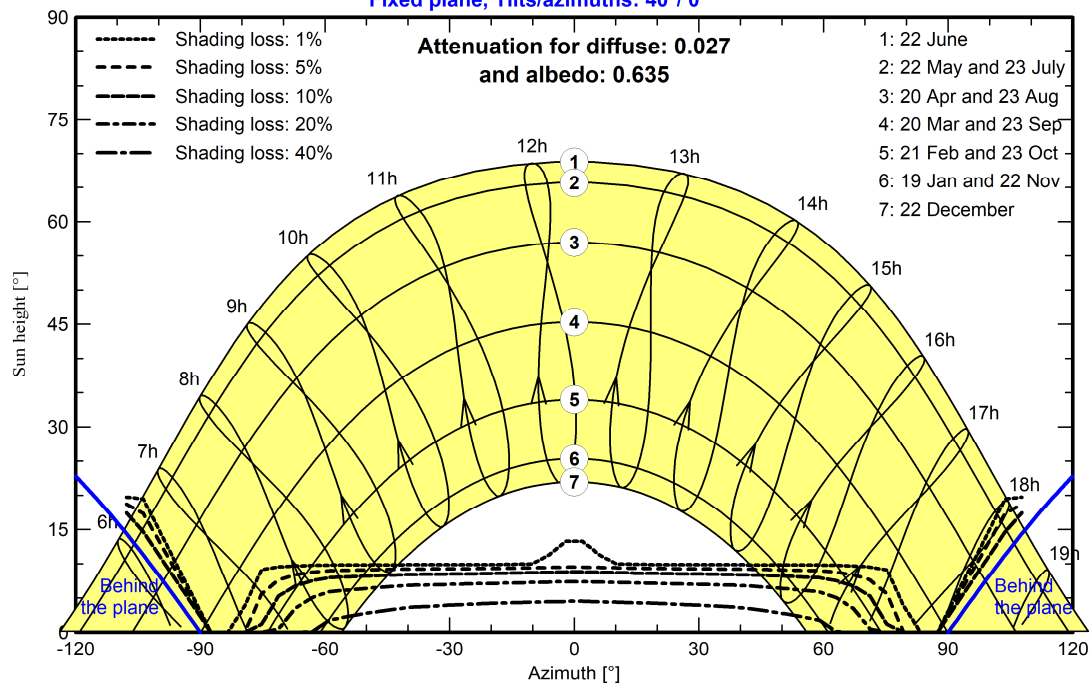
Perspective of the PV-field and surrounding shading scene



Iso-shadings diagram

Orientation #1

Fixed plane, Tilts/azimuths: 40°/ 0°





Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Dillon Consulting Limited (Canada)

Main results

System Production

Produced Energy 1505612 kWh/year

Specific production

1423 kWh/kWp/year

Perf. Ratio PR

93.97 %

Economic evaluation

Investment

Global 1,995,900.00 CAD

Specific 1.89 CAD/Wp

Yearly cost

Annuities

0.00 CAD/yr

Run. costs

27,417.55 CAD/yr

Payback period

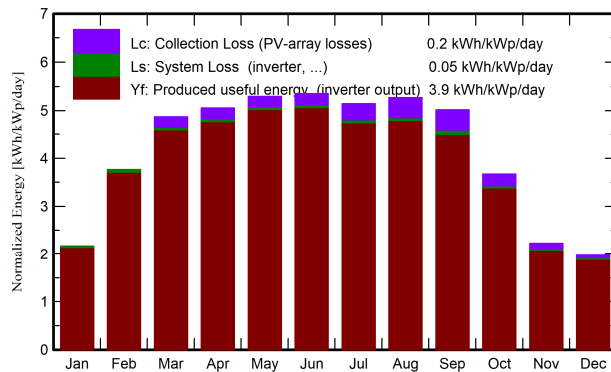
13.0 years

LCOE

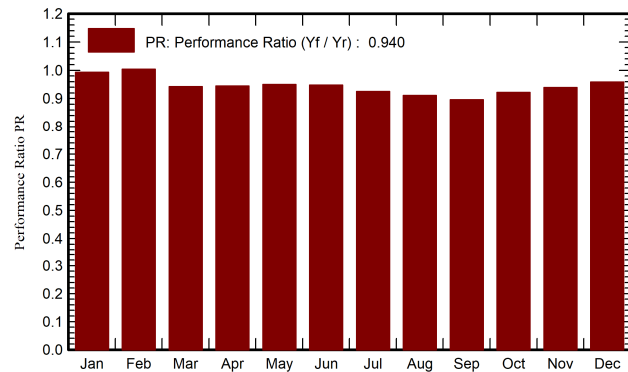
Energy cost

0.09 CAD/kWh

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray kWh	E_Grid kWh	PR ratio
January	38.7	22.38	-5.36	67.1	63.1	71445	70501	0.993
February	66.4	29.83	-5.05	103.5	98.7	111527	110011	1.004
March	114.0	45.13	-1.41	151.2	142.6	152881	150762	0.942
April	137.5	63.49	3.85	151.8	142.6	153831	151753	0.944
May	170.9	83.40	9.49	164.2	153.7	167233	165054	0.950
June	175.0	95.41	14.45	160.5	149.9	163032	161006	0.948
July	169.5	83.86	19.18	159.5	149.2	158160	156162	0.925
August	156.0	76.37	19.14	163.4	153.2	159645	157629	0.912
September	123.1	51.55	15.95	150.6	141.6	145699	142902	0.896
October	78.8	38.43	10.11	113.9	107.3	112592	111156	0.922
November	42.5	26.54	3.75	67.0	63.0	67396	66558	0.939
December	32.0	17.07	-1.78	61.2	57.4	63224	62118	0.959
Year	1304.3	633.45	6.93	1513.9	1422.3	1526664	1505612	0.940

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



Project: HRM Solid Waste Facility

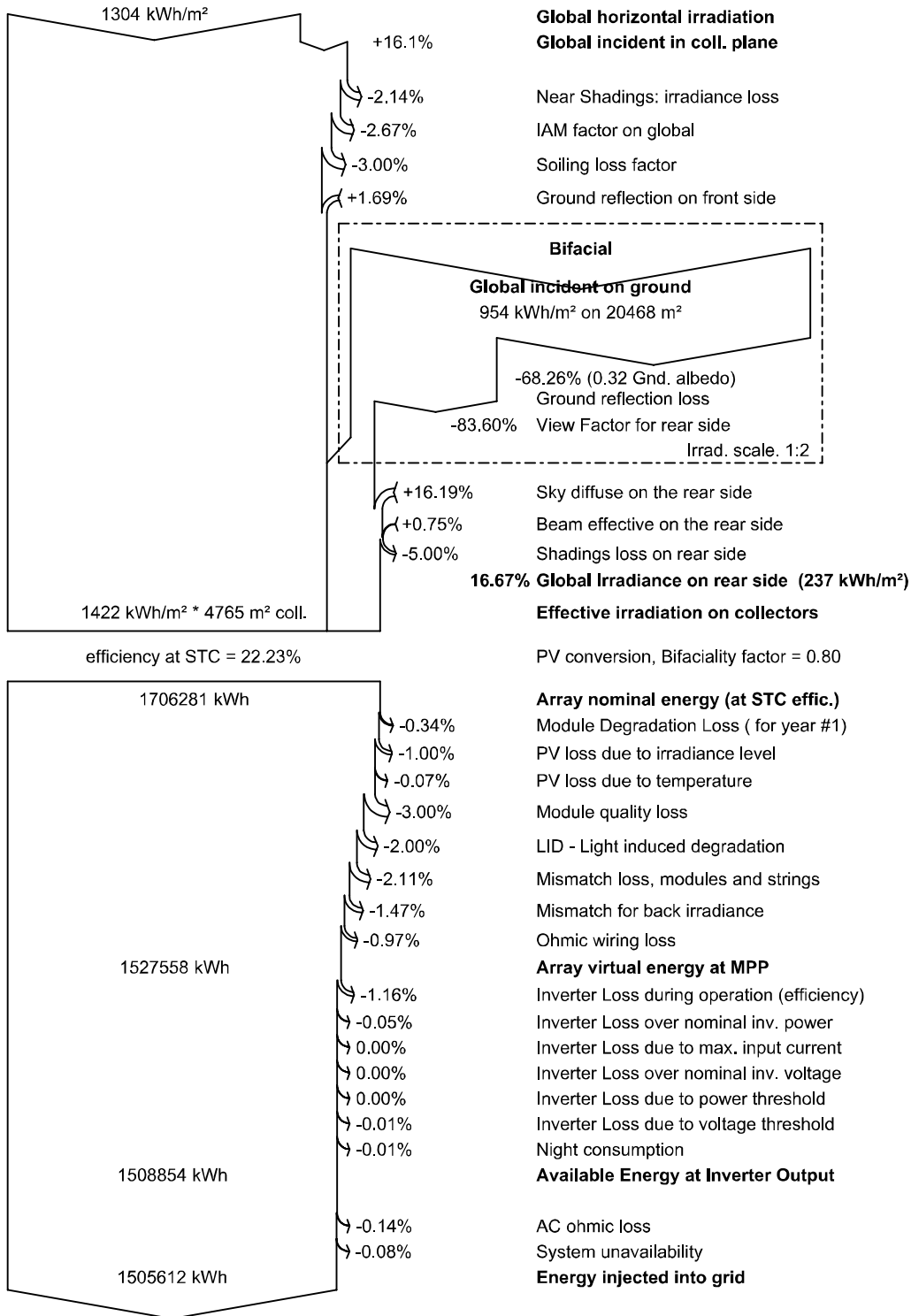
Variant: Field Array - Bifacial

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PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

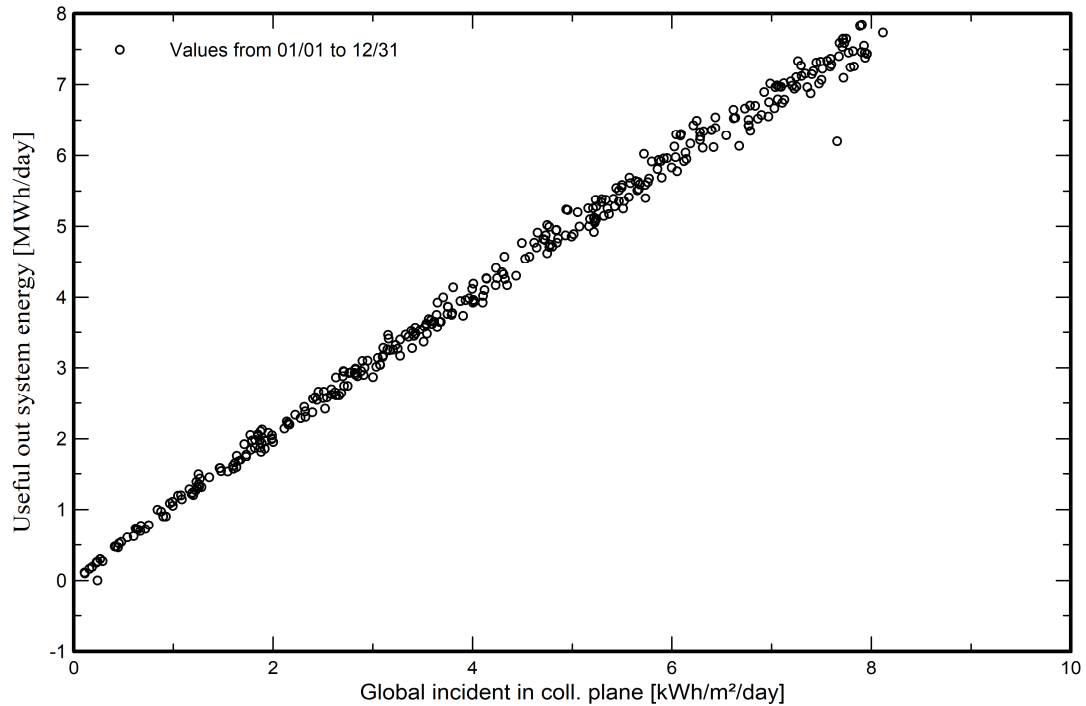
Loss diagram



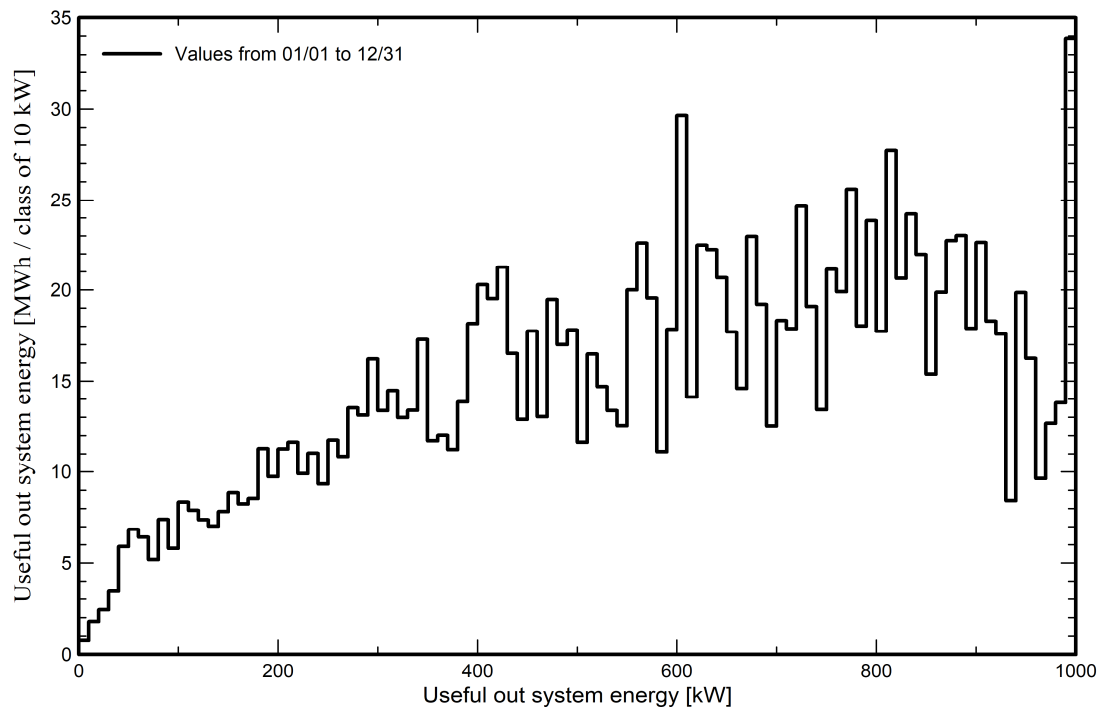


Predef. graphs

Daily Input/Output diagram



System Output Power Distribution

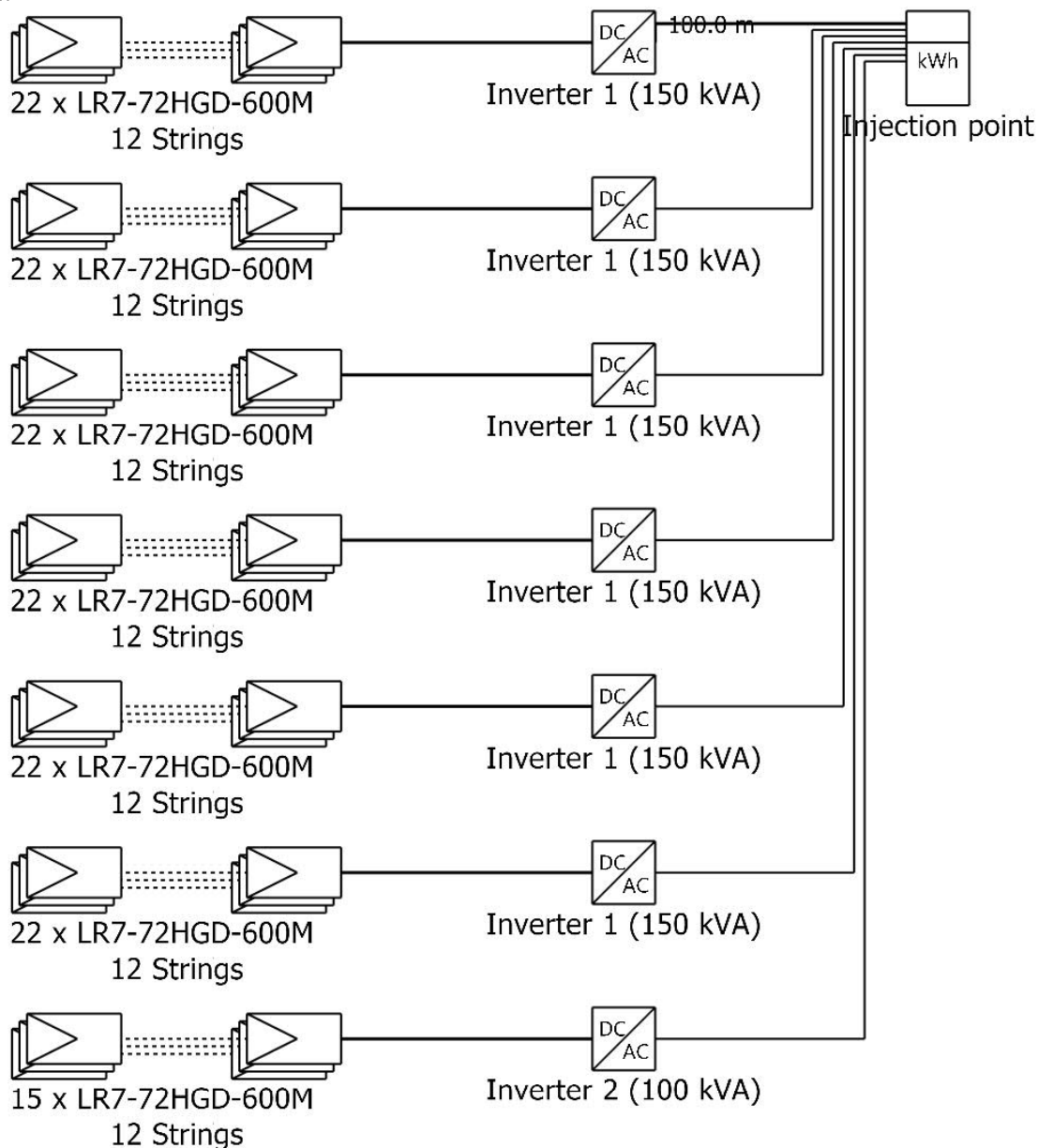




PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Single-line diagram



PV module	LR7-72HGD-600M
Inverter 1	Sunny Highpower SHP150-20-PEAK3
Inverter 2	Sunny Highpower SHP100-20-PEAK3
String 1	22 x LR7-72HGD-600M
String 2	15 x LR7-72HGD-600M

HRM Solid Waste Facility

Dillon Consulting Li
mited (Canada)

VC1 : Field Array - Bifacial

03/20/24



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

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Cost of the system

Installation costs

Item	Quantity units	Cost CAD	Total CAD
PV modules			
LR7-72HGD-600M	1764	287.50	507,150.00
Supports for modules	1764	225.00	396,900.00
Inverters			
Sunny Highpower SHP150-20-PEAK3	6	16,000.00	96,000.00
Sunny Highpower SHP100-20-PEAK3	1	10,000.00	10,000.00
Other components			
Accessories, fasteners	7680	5.00	38,400.00
Wiring	1920	50.00	96,000.00
Monitoring system, display screen	1	600.00	600.00
Measurement system, pyranometer	1	12,000.00	12,000.00
Transformer	1	75,000.00	75,000.00
Electrical Panel	1	40,000.00	40,000.00
Studies and analysis			
Engineering	1	75,000.00	75,000.00
Installation			
Global installation cost per module	1764	150.00	264,600.00
Global installation cost per inverter	7	6,000.00	42,000.00
Transport	1920	5.00	9,600.00
Contingency			83,162.50
Overhead & Profit			249,487.50
		Total	1,995,900.00
		Depreciable asset	1,163,450.00

Operating costs

Item	Total CAD/year
Maintenance	
Provision for inverter replacement	10,600.00
Cleaning	6,000.00
Total (OPEX)	16,600.00
Including inflation (3.25%)	27,417.55

System summary

Total installation cost	1,995,900.00 CAD
Operating costs (incl. inflation 3.25%/year)	27,417.55 CAD/year
Produced Energy	1506 MWh/year
Cost of produced energy (LCOE)	0.092 CAD/kWh



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Dillon Consulting Limited (Canada)

Financial analysis

Simulation period

Project lifetime 30 years Start year 2024

Income variation over time

Inflation 3.25 %/year
Production variation (aging) 0.34 %/year
Discount rate 5.00 %/year

Income dependent expenses

Income tax rate 0.00 %/year
Other income tax 0.00 %/year
Dividends 0.00 %/year

Depreciable assets

Asset	Depreciation method	Depreciation period (years)	Salvage value (CAD)	Depreciable (CAD)
PV modules				
LR7-72HGD-600M	Straight-line	30	0.00	507,150.00
Supports for modules	Straight-line	20	0.00	396,900.00
Inverters				
Sunny Highpower SHP150-20-PEAK3	Straight-line	20	0.00	96,000.00
Sunny Highpower SHP100-20-PEAK3	Straight-line	30	0.00	10,000.00
Accessories, fasteners	Straight-line	20	0.00	38,400.00
Transformer	Straight-line	30	0.00	75,000.00
Electrical Panel	Straight-line	30	0.00	40,000.00
		Total	0.00	1,163,450.00

Financing

Own funds 1,845,300.00 CAD
Subsidies 150,600.00 CAD

Electricity sale

Feed-in tariff 0.1071 CAD/kWh
Duration of tariff warranty 30 years
Annual connection tax 0.00 CAD/kWh
Annual tariff variation +5.0 %/year
Feed-in tariff decrease after warranty 0.00 %

Return on investment

Payback period 13.0 years
Net present value (NPV) 2,621,700.14 CAD
Internal rate of return (IRR) 12.12 %
Return on investment (ROI) 142.1 %



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Dillon Consulting Limited (Canada)

Financial analysis

Detailed economic results (CAD)

Year	Electricity sale	Own funds	Run. costs	Deprec. allow.	Taxable income	Taxes	After-tax profit	Cumul. profit	% amorti.
0	0	1,845,300	0	0	0	0	0	-1,845,300	0.0%
1	161,283	0	16,600	47,637	97,047	0	144,683	-1,707,506	7.5%
2	169,923	0	17,140	47,637	105,147	0	152,784	-1,568,927	15.0%
3	179,026	0	17,697	47,637	113,693	0	161,330	-1,429,564	22.5%
4	188,617	0	18,272	47,637	122,708	0	170,345	-1,289,421	30.1%
5	198,721	0	18,866	47,637	132,219	0	179,855	-1,148,500	37.8%
6	209,366	0	19,479	47,637	142,251	0	189,888	-1,006,803	45.4%
7	220,582	0	20,112	47,637	152,834	0	200,470	-864,332	53.2%
8	232,399	0	20,765	47,637	163,997	0	211,633	-721,091	60.9%
9	244,848	0	21,440	47,637	175,771	0	223,408	-577,080	68.7%
10	257,965	0	22,137	47,637	188,191	0	235,828	-432,302	76.6%
11	271,784	0	22,856	47,637	201,291	0	248,927	-286,760	84.5%
12	286,343	0	23,599	47,637	215,107	0	262,744	-140,454	92.4%
13	301,683	0	24,366	47,637	229,680	0	277,316	6,613	100.4%
14	317,844	0	25,158	47,637	245,049	0	292,686	154,439	108.4%
15	334,871	0	25,976	47,637	261,258	0	308,895	303,023	116.4%
16	352,810	0	26,820	47,637	278,353	0	325,990	452,362	124.5%
17	371,710	0	27,692	47,637	296,381	0	344,018	602,456	132.6%
18	391,622	0	28,592	47,637	315,394	0	363,031	753,303	140.8%
19	412,601	0	29,521	47,637	335,444	0	383,081	904,901	149.0%
20	434,704	0	30,480	47,637	356,588	0	404,224	1,057,249	157.3%
21	457,992	0	31,471	21,072	405,449	0	426,521	1,210,345	165.6%
22	482,526	0	32,494	21,072	428,961	0	450,032	1,364,189	173.9%
23	508,375	0	33,550	21,072	453,754	0	474,825	1,518,778	182.3%
24	535,609	0	34,640	21,072	479,897	0	500,969	1,674,113	190.7%
25	564,301	0	35,766	21,072	507,464	0	528,535	1,830,191	199.2%
26	594,531	0	36,928	21,072	536,531	0	557,603	1,987,011	207.7%
27	626,380	0	38,128	21,072	567,180	0	588,252	2,144,573	216.2%
28	659,935	0	39,368	21,072	599,496	0	620,568	2,302,876	224.8%
29	695,288	0	40,647	21,072	633,569	0	654,641	2,461,919	233.4%
30	732,534	0	41,968	21,072	669,495	0	690,566	2,621,700	242.1%
Total	11,396,173	1,845,300	822,527	1,163,450	9,410,196	0	10,573,646	2,621,700	242.1%



Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

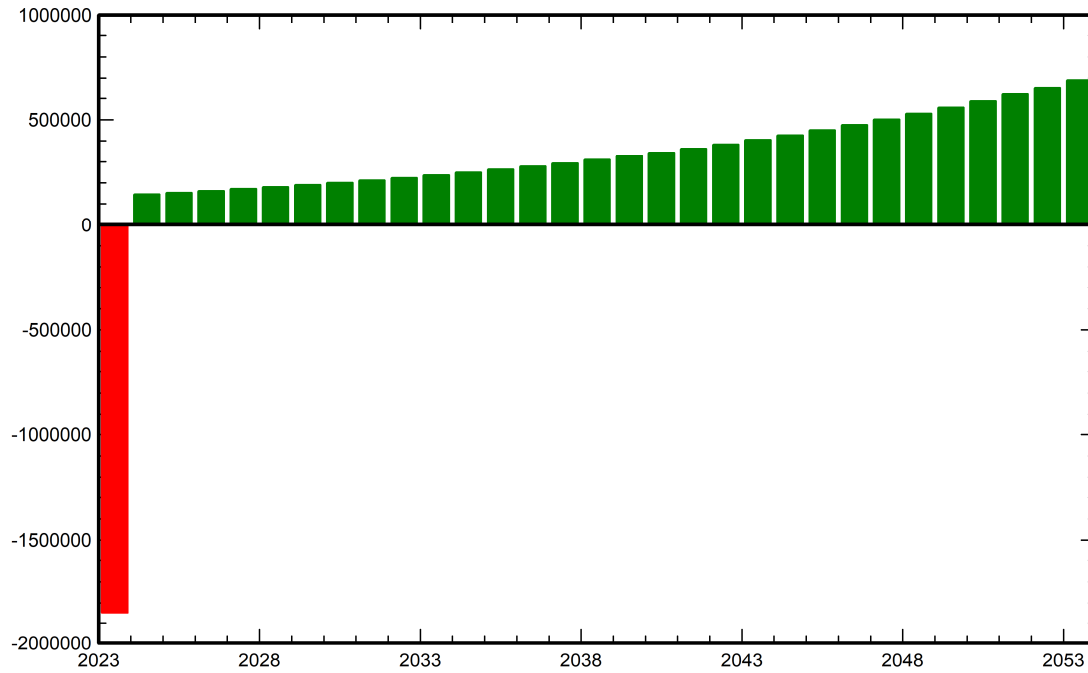
PVsyst V7.4.2

VC1, Simulation date:
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with v7.4.2

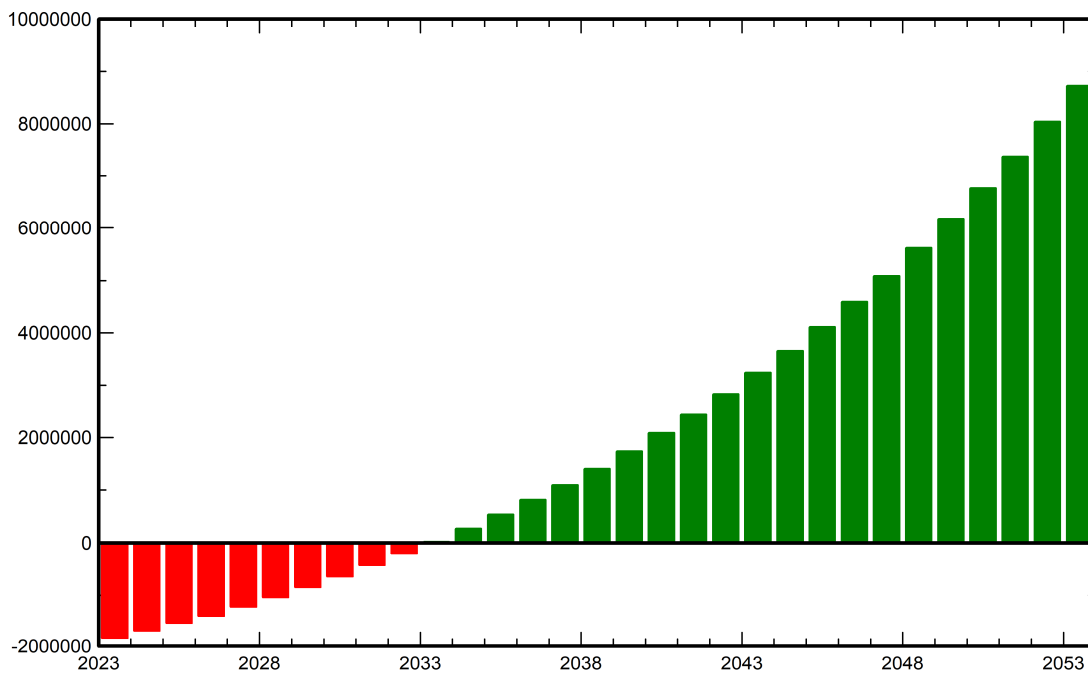
Dillon Consulting Limited (Canada)

Financial analysis

Yearly net profit (CAD)



Cumulative cashflow (CAD)





Project: HRM Solid Waste Facility

Variant: Field Array - Bifacial

PVsyst V7.4.2

VC1, Simulation date:
03/20/24 11:47
with v7.4.2

Dillon Consulting Limited (Canada)

CO₂ Emission Balance

Total: 5203.5 tCO₂

Generated emissions

Total: 274.93 tCO₂

Source: Detailed calculation from table below

Replaced Emissions

Total: 24842.6 tCO₂

System production: 1505.61 MWh/yr

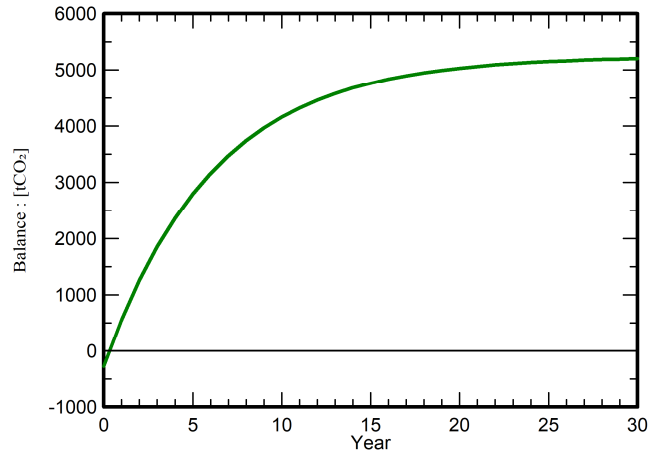
Grid Lifecycle Emissions: 550 gCO₂/kWh

Source: Custom value supplied by user

Lifetime: 30 years

Annual degradation: 15.0 %

Saved CO₂ Emission vs. Time



System Lifecycle Emissions Details

Item	LCE	Quantity	Subtotal
			[kgCO ₂]
Modules	1570 kgCO ₂ /kWp	173 kWp	271295
Supports	1.22 kgCO ₂ /kg	2880 kg	3515
Inverters	121 kgCO ₂ /units	1.00 units	121

Appendix C

Solar Modules

Hi-MO 5m

LR5-72HPH 530~550M

- Based on M10-182mm wafer, best choice for ultra-large power plants
- Advanced module technology delivers superior module efficiency
 - M10 Gallium-doped Wafer • Smart Soldering • 9-busbar Half-cut Cell
- Excellent outdoor power generation performance
- High module quality ensures long-term reliability



12-year Warranty for
Materials and Processing



25-year Warranty for Extra
Linear Power Output

Complete System and Product Certifications

IEC 61215, IEC 61730, UL 61730

ISO 9001:2015: ISO Quality Management System

ISO 14001: 2015: ISO Environment Management System

TS62941: Guideline for module design qualification and type approval

ISO 45001: 2018: Occupational Health and Safety

LONGi



21.5%
MAX MODULE
EFFICIENCY

0~+5W
POWER
TOLERANCE

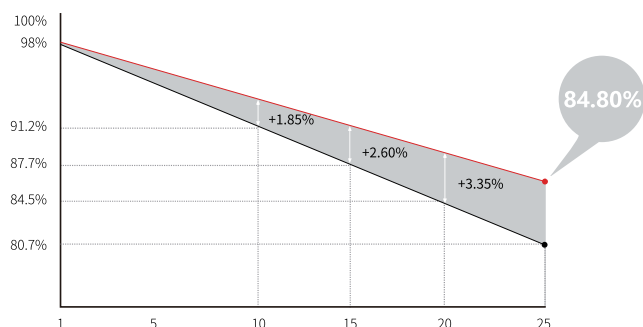
<2%
FIRST YEAR
POWER DEGRADATION

0.55%
YEAR 2-25
POWER DEGRADATION

HALF-CELL
Lower operating temperature

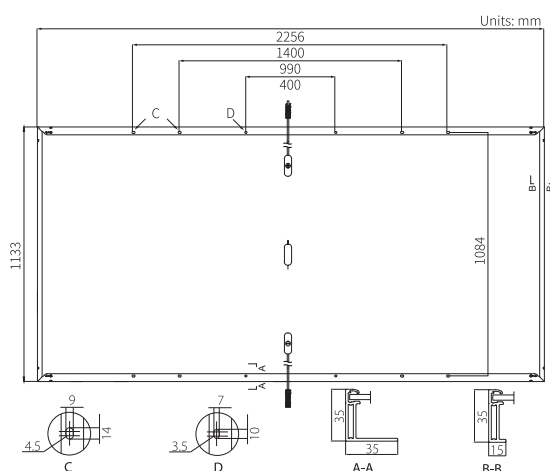
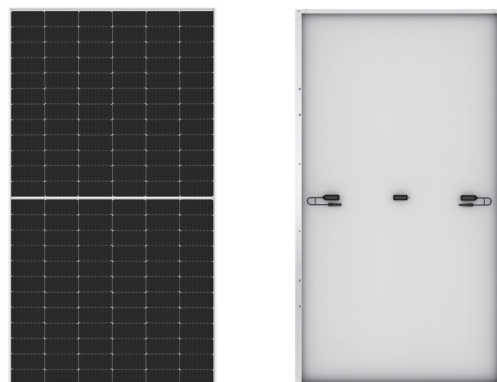
Additional Value

25-Year Power Warranty



Mechanical Parameters

Cell Orientation	144 (6×24)
Junction Box	IP68, three diodes
Output Cable	4mm ² , +400, -200mm/±1400mm length can be customized
Glass	Single glass, 3.2mm coated tempered glass
Frame	Anodized aluminum alloy frame
Weight	27.2kg
Dimension	2256×1133×35mm
Packaging	31pcs per pallet / 155pcs per 20' GP / 620pcs per 40' HC



Electrical Characteristics

STC : AM1.5 1000W/m² 25°C NOCT : AM1.5 800W/m² 20°C 1m/s Test uncertainty for Pmax: ±3%

Module Type	LR5-72HPH-530M		LR5-72HPH-535M		LR5-72HPH-540M		LR5-72HPH-545M		LR5-72HPH-550M	
Testing Condition	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax/W)	530	395.8	535	399.5	540	403.3	545	407.0	550	410.7
Open Circuit Voltage (Voc/V)	49.20	46.12	49.35	46.26	49.50	46.41	49.65	46.55	49.80	46.69
Short Circuit Current (Isc/A)	13.71	11.09	13.78	11.15	13.85	11.20	13.92	11.25	13.98	11.31
Voltage at Maximum Power (Vmp/V)	41.35	38.50	41.50	38.64	41.65	38.78	41.80	38.92	41.95	39.06
Current at Maximum Power (Imp/A)	12.82	10.28	12.90	10.34	12.97	10.40	13.04	10.46	13.12	10.52
Module Efficiency(%)	20.7		20.9		21.1		21.3		21.5	

Operating Parameters

Operational Temperature	-40°C ~ +85°C
Power Output Tolerance	0 ~ +5 W
Voc and Isc Tolerance	±3%
Maximum System Voltage	DC1500V (IEC/UL)
Maximum Series Fuse Rating	25A
Nominal Operating Cell Temperature	45±2°C
Protection Class	Class II
Fire Rating	UL type 1 or 2

Mechanical Loading

Front Side Maximum Static Loading	5400Pa
Rear Side Maximum Static Loading	2400Pa
Hailstone Test	25mm Hailstone at the speed of 23m/s

Temperature Ratings (STC)

Temperature Coefficient of Isc	+0.048%/°C
Temperature Coefficient of Voc	-0.270%/°C
Temperature Coefficient of Pmax	-0.350%/°C

Hi-MO 7

LR7-72HGD 585~620M

- High-performance PV modules for utility power plants
- Advanced HPDC cell technology delivers superior module efficiency and power
- High bifaciality and excellent power temperature coefficient achieves high energy yield
- LONGi lifecycle quality ensures long-term performance

12

12-year Warranty for
Materials and Processing

30

30-year Warranty for Extra
Linear Power Output

Complete System and Product Certifications

IEC 61215, IEC 61730, UL 61730

ISO9001:2015: ISO Quality Management System

ISO14001: 2015: ISO Environment Management System

ISO45001: 2018: Occupational Health and Safety

IEC62941: Guideline for module design qualification and type approval

LONGi



23.0%
MAX MODULE
EFFICIENCY

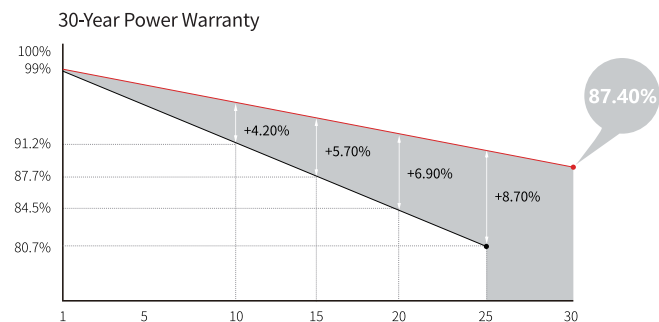
0~3%
POWER
TOLERANCE

<1%
FIRST YEAR
POWER DEGRADATION

0.4%
YEAR 2-30
POWER DEGRADATION

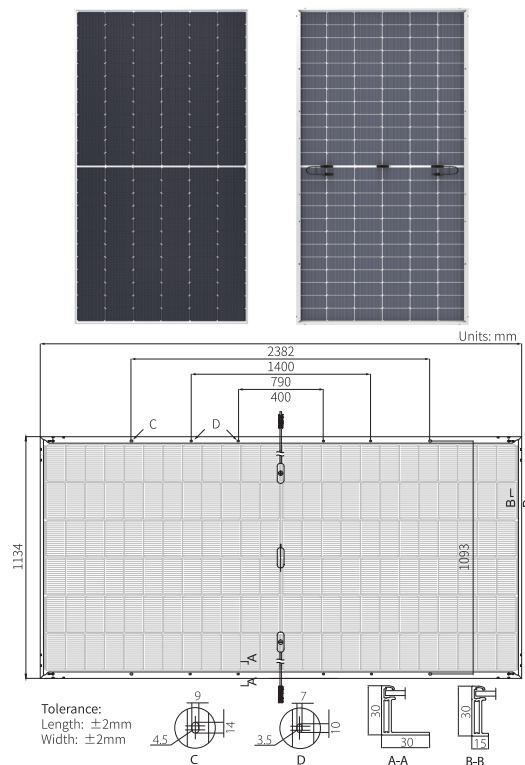
HALF-CELL
Lower operating temperature

Additional Value



Mechanical Parameters

Cell Orientation	144 (6×24)
Junction Box	IP68, three diodes
Output Cable	4mm ² , +400, -200mm/±1400mm length can be customized
Glass	Dual glass, 2.0+2.0mm semi-tempered glass
Frame	Anodized aluminum alloy frame
Weight	33.5kg
Dimension	2382×1134×30mm
Packaging	36pcs per pallet / 144pcs per 20' GP / 720pcs per 40' HC



Electrical Characteristics

STC : AM1.5 1000W/m² 25°C

NOCT : AM1.5 800W/m² 20°C 1m/s

Test uncertainty for Pmax: ±3%

Module Type	LR7-72HGD-585M		LR7-72HGD-590M		LR7-72HGD-595M		LR7-72HGD-600M		LR7-72HGD-605M		LR7-72HGD-610M		LR7-72HGD-615M		LR7-72HGD-620M	
Testing Condition	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax/W)	585	445.3	590	449.1	595	452.9	600	456.7	605	460.6	610	464.4	615	468.2	620	472.0
Open Circuit Voltage (Voc/V)	52.01	49.43	52.12	49.53	52.23	49.64	52.34	49.74	52.44	49.84	52.55	49.94	52.66	50.04	52.77	50.15
Short Circuit Current (Isc/A)	14.29	11.48	14.37	11.54	14.45	11.61	14.53	11.67	14.61	11.74	14.69	11.80	14.77	11.86	14.85	11.92
Voltage at Maximum Power (Vmp/V)	43.57	41.41	43.68	41.51	43.79	41.63	43.90	41.72	44.00	41.82	44.11	41.92	44.22	42.03	44.33	42.13
Current at Maximum Power (Imp/A)	13.43	10.76	13.51	10.82	13.59	10.88	13.67	10.95	13.75	11.02	13.83	11.08	13.91	11.14	13.99	11.21
Module Efficiency(%)	21.7		21.8		22.0		22.2		22.4		22.6		22.8		23.0	

Electrical characteristics with different rear side power gain (reference to 605W front)

Pmax /W	Voc/V	Isc /A	Vmp/V	Imp /A	Pmax gain
635	52.44	15.35	44.00	14.44	5%
666	52.44	16.08	44.00	15.13	10%
696	52.54	16.81	44.10	15.81	15%
726	52.54	17.54	44.10	16.50	20%
756	52.54	18.27	44.10	17.19	25%

Operating Parameters

Operational Temperature	-40°C ~ +85°C
Power Output Tolerance	0 ~ 3%
Maximum System Voltage	DC1500V (IEC/UL)
Maximum Series Fuse Rating	30A
Nominal Operating Cell Temperature	45±2°C
Protection Class	Class II
Bifaciality	80±5%
Fire Rating	UL type 29 IEC Class C

Mechanical Loading

Front Side Maximum Static Loading	5400Pa
Rear Side Maximum Static Loading	2400Pa
Hailstone Test	25mm Hailstone at the speed of 23m/s

Temperature Ratings (STC)

Temperature Coefficient of Isc	+0.045%/°C
Temperature Coefficient of Voc	-0.230%/°C
Temperature Coefficient of Pmax	-0.280%/°C

Appendix D

Inverters



/ SHP 125-US-21 / SHP 150-US-21 / SHP 165-US-21 / SHP 172-US-21



Sunny Highpower PEAK3-US

125 / 150 / 165 / 172

A superior distributed generation
solution for large-scale power plants

25 YEAR
DESIGN LIFE



SMA
Smart Connected



Cost effective

- Modular architecture reduces BOS and maximizes system uptime
- Compact design and high power density maximize transportation and logistical efficiency

Maximum flexibility

- Scalable 1,500 VDC building block with best-in-class performance
- Flexible architecture creates scalability while maximizing land usage

Simple install, commissioning

- Ergonomic handling and simple connections enable quick installation
- Centralized commissioning and control with SMA Data Manager

Highly innovative

- SMA Smart Connected reduces O&M costs and simplifies field-service
- Powered by award winning ennexOS cross sector energy management platform

The Sunny Highpower PEAK3 1,500 VDC inverter offers high power density in a modular architecture that achieves a cost-optimized solution for large-scale PV integrators.

With fast, simple installation and commissioning, the PEAK3 is accelerating the path to energization. SMA has also brought its field-proven Smart Connected technology to the PEAK3, which simplifies O&M and contributes to lower lifetime service costs. The PEAK3 power plant solution is powered by the ennexOS cross sector energy management platform, 2018 winner of the Intersolar smarter E AWARD.

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Appendix E

Site Plan

