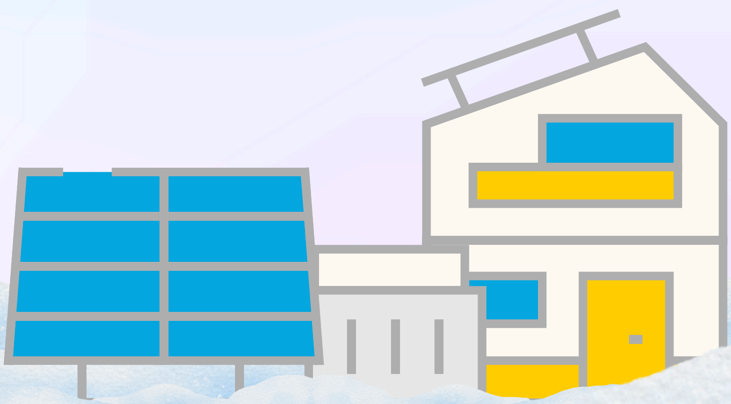
Cabin Solar in Nunavut

Your guide to installing solar energy for off-grid buildings in Nunavut



Relay Education

Arctic Renewables Society
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Purpose of the Guide

This is a guide to help you install an off-grid solar energy system for a cabin in Nunavut. It covers everything from how to plan the right type of system to information on equipment, terminology and installation. You'll find two installation methods, for wall or roof mounted systems, and guidance on how to choose the right one for your set-up.

Special considerations for freezing temperatures, geography and sizing for cabins are included. This guide walks you through the process step by step, whether you're starting to think about solar for your cabin or you're ready to begin installation.

This resource was written for participants of a Cabin Solar Installation Course by Relay Education, a charity, focused on building skills and understanding of renewable energy. It was developed in partnership with Arctic Renewables Society to provide clear, accessible information for Nunavummiut.

We hope this guide is a helpful starting point for your solar journey and supports your goal of powering your cabin with renewable energy.

This guide is intended for general informational purposes only. It does not constitute professional engineering, electrical, or legal advice. While efforts have been made to ensure accuracy, off-grid solar systems can vary widely depending on location, design, and local regulations. Always consult with a certified electrician, solar installer, or local authority before starting any off-grid or electrical project. The authors and publishers are not responsible for any damages, injuries, or losses resulting from the use of the information in this guide.

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Electricity and Solar Basics

Benefits of Solar Energy

There are many benefits to installing a solar energy system on your cabin or home. Solar energy helps reduce air pollution because it does not release harmful greenhouse gases, which contributes to health problems and climate change. It also lowers electricity costs since sunlight is free after solar panels are installed. Solar panels are useful in remote areas where power lines do not reach. They provide electricity without needing large infrastructure.

In terms of social and economic benefits, the solar industry creates jobs in manufacturing, installation, and maintenance, which helps local economies. Solar energy reduces reliance on fossil fuels, lowering fuel costs and increasing energy independence for communities and countries.

Solar power is a clean, reliable, and cost effective energy source. It helps protect the environment, while supporting communities and growing the economy

Financial Support Programs

The Government of Nunavut has two rebate programs for residents, the Renewable Energy Homeowner Grant Program and the Renewable Energy Cabin Grant Program. The Renewable Energy Homeowner Grant Program provides a rebate to cover 50% of the project costs, up to a maximum of $30,000, for installing a renewable energy system on a home. These are grid connected energy systems, and the homeowner must first be granted permission by Qulliq Energy Corporation (QEC) to connect to the electrical network.

The program began in 2022. At the time of writing this publication, there is no end date for the program, but there is a maximum annual amount of funding that is available across the territory. https://www.nunavuthousing.ca/programs/homeownership

The Renewable Energy Cabin Grant Program is a rebate of up to $5,000 to individuals who install an off-grid solar or off-grid wind energy system on a cabin. The rebate can be used to cover the costs of buying CSA certified equipment, along with shipping costs. Labour from the cabin owner cannot be covered by the rebate. The program began in 2022. At the time of writing this publication, there is no end date for the program, but there is a maximum annual amount of funding that is available across the territory. https://climatechangenunavut.ca/en/renewable-energy-cabin-grant-program-guide

Electricity Basics

Voltage and Current

Voltage is the difference in electrical charge between two points. It's measured in volts (V).

Current is a flow of charged particles moving through an electrical conductor. It's measured in amperes (I), which is commonly called amps. Current is often referred to as amperage and the terms are interchangeable.

Voltage and current are two terms that describe electricity. They have a direct relationship together. Voltage and current can be challenging concepts to understand since electricity cannot be seen. The movement of water is a helpful comparison.

Voltage is like water pressure, and current is like the movement of water through pipes. Imagine a sink tap. Water pressure builds up behind the tap because of water stored in a tank or reservoir. When the tap is closed, no water flows, but the pressure is still there. When the tap is opened, water moves through the pipes and out of the tap because of the pressure. In the same way, an electrical outlet works like a tap, providing electricity when something is plugged in.

There is voltage in the wires connected to the outlet, but if there is nothing plugged into it, there is no current. When an electrical load is plugged into the outlet and turned on, electrons begin to “flow” through the wires, creating current that is pushed by the voltage.

Electrical Power and Energy

Electrons are tiny, negatively charged particles found in atoms. They move through wires to create electricity.

Electrical Load is anything that uses electricity to run, like a lightbulb, motor, heater, electronic, or appliance. It converts electrical energy into light, heat, sound, or motion. When "a load" is referred to in electricity, it means any device or system that draws power from a source. This can be a single appliance or the total electrical demand of a building.

Electrical power is how fast electrical energy moves in a circuit. It's measured in watts (W). Electrical power is calculated by multiplying the voltage by the current.

The formula is: Power (P) = Voltage (V) × Current (I)

Electrical energy is the energy created by the movement of charged particles in a circuit. It's the total amount of power used or transferred over time while electricity flows through a circuit. Electrical energy is measured in watt hours (Wh). A common unit is kilowatt hours (kWh), which equals 1000 Wh.

The formula is: Energy (E) = Power (P) × Time (t)

Electrical power and energy are related, but they are not the same. Power tells us how fast energy is used or produced in a system. For example, a 100 W lightbulb uses more power than a 60 W lightbulb because it generates more light and is brighter. Energy is the total amount of power used over time. If a 100 W lightbulb stays on for 1 hour, it uses 100 Wh of energy. If it stays on for 10 hours, it uses 1000 Wh, or 1 kWh, of energy.

It's easy to misunderstand the difference between power and energy, and it's a common mistake to use the two words interchangeably. An analogy can be useful to explain the difference between power and energy. When considering combustion engines, power is the horsepower of the engine. The energy is the amount of fuel consumed when running the engine.

Alternating and Direct Current

Alternating Current (AC) is the flow of electric charge that reverses direction repeatedly. In an AC circuit, electrons move back and forth instead of flowing in just one direction. AC is used in most buildings and electrical grids because it's easier to send over long distances. Most electrical outlets in North American homes and businesses provide alternating current.

Direct Current (DC) is the flow of electric charge in one direction. In a DC circuit, electrons move steadily from the negative side to the positive side of the power source. Common uses of DC power include solar panels and batteries.

AC is used in most devices with a motor, such as fans and pumps, and in electric heating, such as toasters and space heaters. It's also easier to send AC over long distances, which is why it powers homes, buildings, and electrical grids. Diesel and gas generators produce AC electricity. Wind Turbines also produce AC electricity.

DC is used in devices that need a steady flow of energy, like phones and computers. A sign of DC is a positive (+) and negative (-) symbol found on a power source or diagram. This is because DC flows in one direction, from negative to positive, and must continue throughout the circuit. This one-way flow of current is referred to as polarity.

Polarity

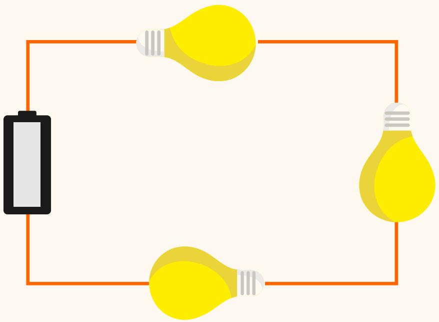
Polarity is a term used to refer to the direction of the electrical current flow in a DC circuit. A DC circuit has a constant positive and negative side, for example the positive (+) and negative (-) terminals on a battery. Direct current flows in one constant direction, from + to -. For DC circuits or DC devices (which includes solar panels and batteries) to work properly, it is important to follow polarity throughout the circuit by always connecting positive to negative.

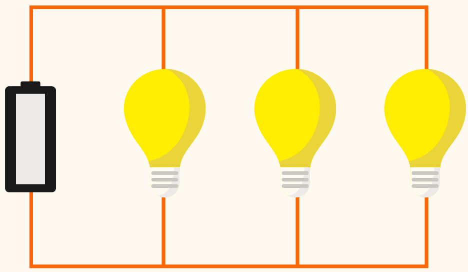
If the polarity in a DC circuit is reversed, then the device or circuit will not work properly. For example, when replacing batteries in a remote controller, you must put the batteries in the correct orientation so that the positive battery terminal of one battery is touching the negative terminal of the next one. If a battery is replaced backwards, and either two positive or two negative terminals are touching, then the polarity of the circuit is reversed and the current will not be able to flow in the correct direction.

Series and Parallel Circuits

Series circuits are an electrical circuit where the loads (components) are connected in a single path, one after another. The current flows through each load (component) in order. If one part breaks or is disconnected, the whole circuit stops working.

Parallel circuits are an electrical circuit where the loads (components) are connected in multiple paths. The current flows through more than one path at the same time. If one part fails, the other loads (components) still work, because there are other paths for the current to flow through.





Parallel circuits are commonly used because they are more reliable and practical, allowing for individual control of devices. If a house was wired in series, every device would have to be on at the same time, and unplugging one device would open the circuit and turn everything off. Using parallel circuits in buildings allows for more control over which devices are on and off. Buildings have an electrical panel which has breakers connected to each circuit, and all these circuits are wired in parallel.

<u>Voltage and current behave differently depending on the circuit.</u>

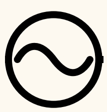
In a series circuit, the total voltage is the sum of the voltage of each component, while the current stays the same throughout the circuit.

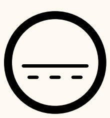
Voltage equation in series: $V_{total} = V_1 + V_2 + V_3 + \ldots$
Current equation in series: $I_{total} = I_1 = I_2 = I_3 = \ldots$

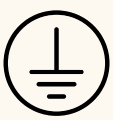
In a parallel circuit, the voltage is the same across all components, while the total current is the sum of the currents in each path.

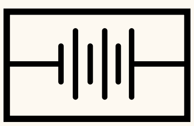
Voltage equation in parallel: $V_{total} = V_1 = V_2 = V_3 = \ldots$
Current equation in parallel: $I_{total} = I_1 + I_2 + I_3 + \ldots$

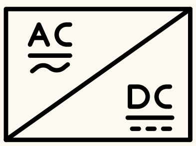
Common Electrical Symbols


AC sine wave

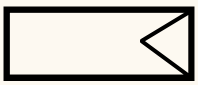

DC dotted line

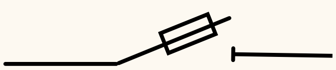

Grounding


Battery



Inverter


Solar panel


DC rated fuse

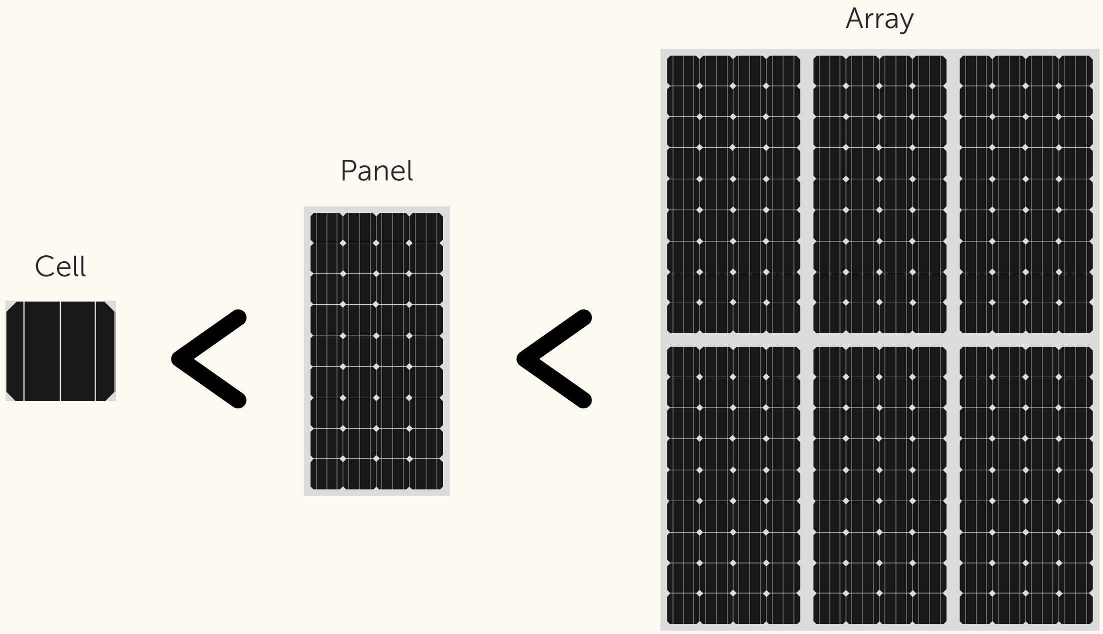

DC rated isolator


Circuit breaker

Solar Basics

Solar Photovoltaic (PV) Terminology

A solar panel is made of multiple individual solar cells.
A solar panel is also known as a module.
A solar array is when multiple panels are connected.



A grid-tied solar array is a solar energy system that generates power for the electricity grid. Grid-tied solar arrays do not require energy storage systems. When solar panels are generating electricity in a grid-tied system, the building they are connected to will use the power and any extra power is sent to the electricity grid. Electricity is drawn from the grid to meet energy demands of the building when there is not enough sunlight to power it.

A stand-alone system, also known as an off-grid system or a cabin solar system, is a solar energy system that generates electrical power to charge a battery. Electrical loads in the building are connected to the battery and use stored energy from the battery as needed. Stand-alone systems are independent of electricity grids. They are a self-contained power generation, storage, and distribution system.

Solar Array Sizes

Sizes of solar arrays are measured by the amount of electrical power that they can generate. They are not measured by the surface area that panels cover, because not all solar panels are the same. Modern and efficient panels generate more power than older, less efficient panels, yet they are about the same physical size and cover similar surface areas.

Solar array sizes are measured in watts (W). Power demand for homes and buildings is measured in kilowatts (kW) and megawatts (MW) are used for large scale solar projects.

To figure out the size of a solar array, add the wattage of each panel together. For example, if there are six panels in an array, and each panel generates 350 watts of power, then the array is 6x350 W=2,100 W or 2.1 kW.

Deciding Location for Solar Array

Solar panels generate the most power when sunlight is directed at a 90-degree angle to the panel. This provides the largest transfer of energy between the sunlight and the electrons in the panel because it limits the amount of sunlight being reflected off the glass surface of the panel.

Solar panels should always be pointed towards the sun's position in the sky. In the northern hemisphere, that means panels should be facing south, or as southerly as possible. In the southern hemisphere, panels should be facing north.

02

Cabin Solar Equipment

Solar Panels

Solar panels are the main part of a solar array. They convert sunlight into electricity by using photovoltaic (PV) cells. There are three types of solar panels: monocrystalline, polycrystalline, and thin-film. Solar module is the technical term for a solar panel.

Monocrystalline solar panels are made from single crystals of silicon. They are typically black, and each cell is uniform in colour, with no variance in shade or tone.

- Pros: Long lifespan at 25 years; high efficiency, converting more than 20% of the sunlight into electricity; space efficient due to the higher efficiency; non-toxic materials are the basis of the solar cells (silicon and aluminum).
- Cons: The manufacturing process is complex which makes them (relatively) more expensive; generates the most waste from manufacturing, when compared to other types of panels.

Polycrystalline solar panels are made from multiple silicon crystals that are melted together, which gives them a grainy texture and are not a uniform colour. They are typically blue in colour, with multiple hues of blue in each cell.

- Pros: Long lifespan at 25 years; slightly less expensive than polycrystalline; decent efficiency, converting around 15-18% of sunlight into electricity; production generates less waste than monocrystalline panels; non-toxic materials are the basis of the solar cells (silicon and aluminum).
- Cons: Lower efficiency due to being made from multiple small silicon crystals; requires more space to generate the same amount of electricity as monocrystalline, due to the lower efficiency.

Thin-film solar panels are made by placing a very thin layer of a PV material onto a flexible surface. They are lightweight and flexible, and generally black in colour.

- Pros: lightweight and flexible, allowing for easier installation on irregular surfaces; least expensive to manufacture; perform better in low-light conditions compared to crystalline panels.
- Cons: shortest lifespan, generally lasting 15-20 years; lowest efficiency, converting only 10-12% of sunlight into electricity; require most amount of space when compared to crystalline arrays that generate the same amount of electricity; often have toxic materials like cadmium.

Nameplates

All solar panels will have a nameplate. This is a label or tag for the panel that provides valuable information about the panel’s performance and characteristics. This is important to consider when designing a system. You would need to consider the panel’s information when making decisions about the system design: like how many panels are needed, what kind of charge controller to use, and how to combine the panels into strings. These terms are explained later in this section.

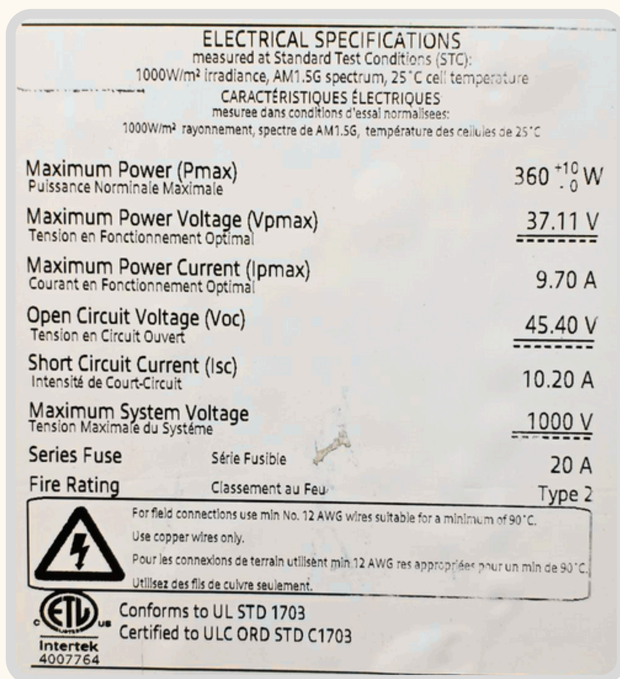
Common information and values found on solar panel nameplates:

- Maximum power (Pmax): the power that the panel will generate under ideal sunlight conditions
- Voltage at maximum power (Vmp): the operating voltage when the panel is under ideal sunlight conditions
- Current at maximum power (Imp): the operating current when the panel is under ideal sunlight conditions
- Open circuit voltage (Voc): the voltage of the panel when it's not connected to a circuit
- Short circuit current (Isc): the current that is produced in the extreme condition of a short circuit
- Temperature co-efficient: the percentage that the panel’s power output drops, with every degree Celsius increase in temperature.

Nameplate example

This nameplate tells us:

- The panel can produce 360 watts of power under ideal sunlight conditions.
- It will run at 37.11 volts and 9.70 amps of current when at peak power.
- If the panel is not connected to anything, it can have up to 45.40 volts.
- In extreme conditions, when the panel is short-circuited, it could produce up to 10.20 amps.



Batteries

A battery is a device that stores chemical energy and converts it to electricity. Batteries are needed for a solar energy system because they allow the use of electricity at any time of day, even when the solar panels are not generating electricity. A solar energy system with no batteries will only generate usable electricity when the solar array is exposed to sunlight.

Batteries are defined by voltage and amp-hours (Ah). Common battery voltages are 12 V, 24 V and 48 V. There are a wide range of amp-hours when considering different batteries. The larger the amp-hour, the more energy the battery can store. To figure out the total energy a battery can store, multiply the voltage by the amp-hour of that battery. For example, a 12 V 100 Ah battery can store 1200 Wh, or 1.2 kWh of energy.

A battery bank is the term used when multiple batteries are used together in a solar energy system. The number and size of batteries is determined by the design of the solar energy system, and the voltage and current of each individual battery. Battery banks should only use batteries that are the same make and model and of a similar age (not different batteries from different years).

There are several types of batteries which are defined by the different chemicals and elements that they are made from. It's important to choose a deep cycle battery for an off-grid system. A deep cycle battery can be repeatedly discharged and recharged, while providing a steady amount of power over a lengthy period.

Deep cycle batteries are different than car batteries. Car batteries are SLI (Starting, Lighting, Ignition) batteries, meaning they are designed to provide a high burst of power for a short amount of time, like when starting an engine. The number of cold-cranking amps (CCA) is a way of defining car batteries, and a deep cycle battery will not have any mention of CCAs.

The most common deep cycle batteries are flooded lead acid, sealed lead acid, and lithium iron phosphate.

Flooded Lead Acid (FLA) batteries are lead acid batteries. They are a proven technology, having been used in stand-alone systems for decades. FLA batteries are the least expensive type of off-grid battery but need the most maintenance. These batteries have a liquid electrolyte which must be kept at a regular volume and needs to have distilled water added into the battery periodically. The battery can lose efficiency and may also experience irreparable damage if not maintained properly. There is also a hazard of spilling the acid inside FLA batteries if the battery is mishandled. FLA batteries can be used in freezing temperatures, but they may not perform at their best levels and could become permanently damaged if not at a full charge.

Absorbent Glass Mat (AGM), also known as sealed lead acid batteries, are a different type of lead acid battery. They use a fiberglass mat to hold the electrolyte in place instead of using a liquid electrolyte. They are sealed, which makes them easier to use and maintain, because there is no liquid that needs to be topped up. They are also safer because there is no acid that can spill from the battery. AGM batteries are more expensive than FLA batteries, but they are also safer and more efficient. AGM batteries can be used in freezing temperatures, but they may not perform at their best levels and could become permanently damaged if not at a full charge. AGM batteries do perform better than FLA in freezing temperatures and are the recommended battery type for the arctic.

Lithium Iron Phosphate (LFP and sometimes called by the chemical name, $LiFePO_4$) batteries are a newer technology compared to lead acid batteries. They are a type of lithium battery, known for high efficiency, long life and safety. LFP batteries require no maintenance. They are more energy dense than lead acid batteries and can store more energy in the same physical space. LFP batteries can last twice as long as lead acid batteries.

They are the most expensive battery type for a stand-alone solar energy system and may require specific charging equipment which could make them not compatible with older systems. LFP batteries perform poorly at freezing temperatures and are not recommended for arctic temperatures. Some premium LFP batteries have an added capability of self-heating to keep them at a constant temperature.

Depth of Discharge and Charge Cycles

Depth of discharge (DoD) refers to how much of a battery's energy has been used or discharged compared to its total capacity and is measured as a percentage of total battery charge. For example, if a battery starts at 100% charge and you use a quarter of the energy in the battery, the DoD is 25%. A battery that is at half charge has a DoD of 50%. Battery manufacturers will list the recommended DoD for their products. Going past the recommended DoD will degrade the battery and lower its lifespan, and doing this on a regular basis will greatly degrade the battery. Always read and follow manufacturer directions and stay within the acceptable DoD range of your battery.

Lead acid batteries (FLA and AGM) often have a recommended DoD of 50%, which means that you should only use half of the battery's total capacity before recharging. Going above 50% DoD, meaning using more than half of the battery's capacity, can result in permanent damage to the battery. AGM batteries will have a higher DoD than FLA, some able to reach 70% DoD.

LFP batteries have a higher depth of discharge, meaning they can handle deeper discharges. The recommended DoD for LFP batteries is often 80% or more, meaning you can use most of the stored energy without fear of damaging the battery.

Charge cycles is the number of times that a battery can be fully charged and discharged before it starts to lose its ability to hold a full charge. Battery manufacturers will provide a number value of charge cycles for their products. For example, a battery that has 500 charge cycles means that this battery can be discharged completely and recharged again 500 times before it will begin losing its ability to hold a charge.

One cycle is equal to recharging a fully discharged battery one time. For example, if this battery with 500 charge cycles is fully discharged every day during its use, it should last 500 days before it will need to be replaced. If this same battery is discharged by 50% and fully recharged each day, it should last 1000 days before it will need replacing (500/0.5=1000). If it is discharged only 20% and fully recharged each day, it should last 2500 days (500/0.2=2500).

Lead acid batteries (FLA and AGM) typically have 500-1000 charge cycles. LFP batteries have a much higher charge cycle, generally between 3000-5000 cycles. LFP batteries are more expensive than lead acid batteries, however they will last much longer and will not need replacing as often as lead acid batteries. When selecting a battery, be sure to compare charge cycles as this can play a key role in battery price and longevity.

How Temperature Affects Batteries

All batteries experience a reduction in performance at subzero temperatures, below 0 °C/32 °F. Some batteries perform better in freezing temperatures than others. It's recommended to read and follow the manufacturer’s instructions for your specific battery. Batteries should be installed in a heat controlled environment for best performance and lifespan.

Lead acid batteries (FLA and AGM) can perform below zero temperatures and perform best when at or close to full charge. AGM batteries perform better than FLA batteries. When fully charged, lead acid batteries can run from temperatures between -40 °C to -70 °C. When at half charge, they may freeze at temperatures between -20 °C to 0 °C. The best operating temperature is at 25 °C/77 °F.

LFP batteries do not perform well in freezing temperatures. It's not recommended to use in temperatures colder than -10 °C/14 °F. Some premium LFP batteries can heat themselves and remain at a constant temperature to improve performance.

Lead Acid Batteries: Charge and Freezing Points

Charge	Freezing Point in Celsius °C	Freezing Point in Fahrenheit °F
100%	-67.8 °C	-90 °F
75%	-40 °C	-40 °F
66%	-31.7 °C	-25 °F
50%	-26.1 °C	-15 °F
25%	-15 °C	5 °F
Discharged	-9.4 °C	15 °F

Comparison of Batteries for Off-Grid Solar

Battery	Flooded lead acid	Absorbent glass mat	Lithium iron phosphate
Cost	Low	Medium	High
Lifespan	5 to 7 years	5 to 10 years	10 to 15 years
Charges	500-1000	1000-2000	3000-5000
Depth of discharge	50%	50-70%	80-90%
Required maintenance	High	None	None
Safety	Risk of spills	Safe	Safe
Optimal operating temperature	25°C/77°F	25°C/77°F	20°C to 25°C / 68°F to 77°F
Acceptable temperature operating range	0°C to 49°C / 32°F to 120°F	0°C to 40°C / 32°F to 104°F	0°C to 49°C / 32°F to 120°F°
Use in freezing temperatures	Can be used	Optimal	Not recommended

Flooded Lead Acid (FLA)

Absorbent Glass Mat (AGM)

Lithium Iron Phosphate (LFP)

Charge Controller

A charge controller controls the flow of electricity from the panels to the batteries. It ensures the proper amount of energy goes to the batteries and prevents overcharging and over discharging of the batteries, which have the potential to damage the battery permanently.

Example of an affordable charge controller. Images are not to scale to one another.

Example of a higher end charge controller with more functions.

Choosing the proper sized charge controller depends on a few factors. The first is the voltage of the battery or battery bank. Common voltages are 12 V, 24 V and 48 V. Some charge controllers can work with any voltage, while others are designed for one DC input voltage.

The charge controller must also be able to handle the amount of power coming from the solar array. Each controller will have a maximum power rating, and if the array generates above this rating the charge controller will not allow all the power through to the battery. If this were to happen it means the array is oversized for the charge controller.

Charge controllers are also sized depending on the solar array's current. The input current of the controller should not be exceeded by the array. This current rating should be higher than the maximum current coming from the array. If current from the array is too high, then either a larger charge controller should be connected, or the wiring configuration of the panels in the array should be changed.

For example, if using a charge controller with a 30 A rating and the solar array is two panels, each with an Isc rating of 20 A, then the panels cannot be connected in parallel because the combined current would reach up to 40 A. These two panels must be connected in series which would keep the current of the circuit at 20 A, allowing for the 30 A charge controller to be used.

Inverter

The inverter converts the direct current (DC) electricity from the panels and batteries into alternating current (AC). This allows the DC electricity from the solar energy system to be used to power everyday devices.

Inverters will have a DC voltage rating, which should match the voltage of the battery. Common DC voltage ratings are 12 V, 24 V or 48 V. Some inverters can be set to accept a range of voltages and others are designed for one DC input voltage.

Inverters are also defined by how much power they can deliver. Common inverter sizes for cabin solar systems would be 1000 W, 2000 W, 3000 W and 5000 W inverters. The larger the inverter, the more power it can draw from the battery.

Example of an inverter.

To decide which inverter is best for your system, you need to know what loads will be powered by the inverter. Every device and appliance running will pull an amount of power, and these power ratings must be added together to decide what size of inverter is needed. If the power that the loads require is larger than the inverter can handle, then the inverter could be damaged. Most inverters have overload protection and will shut off or give a warning error if trying to draw too much power.

If the inverter is being overloaded often, then the inverter should be upgraded to one with a higher power rating, or fewer devices should be plugged in at the same time. Appliances that generate heat, such as toasters, kettles, and blow dryers, use large amounts of power when compared to lighting or electronics. If using a load that requires a lot of power, you may need to disconnect other loads for this one to work. The rest of the devices can be reconnected to the inverter when the power intensive load is finished. For example, if running a microwave, you may need to disconnect other electrical loads while the microwave is running.

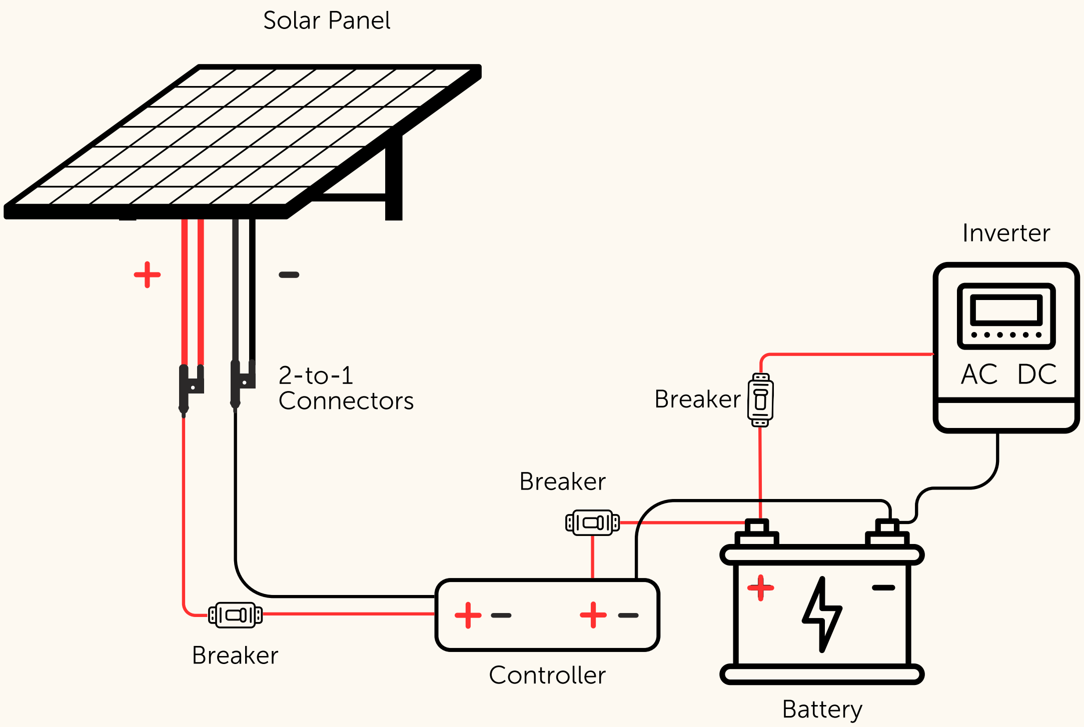
Some appliances also have motors that work as a "surge" or "start-up" power. These appliances require more power to start compared to the power needed to keep them running. Surge power should also be considered when sizing inverters, as this can add a large amount of power, even if only needed for a short amount of time. An example of an appliance that uses surge power is a refrigerator.

There are two main types of inverters: modified sine wave inverters and pure sine wave inverters.

<u>Modified sine wave inverters</u> produce a simpler form of AC electricity that works with basic appliances like lighting and fans. They are less expensive and work well with many household loads, however they are not good for powering sensitive electronics. There is a possibility that these electronics could become damaged if using a modified sine wave inverter.

<u>Pure sine wave inverters</u> produce clean and smooth AC electricity which is identical to the electricity that is found in the power grid. It works well with all appliances and loads, including sensitive electronics such as microwaves, computers, and televisions. They are more expensive than a modified sine wave inverter with the same power rating, but they are also the more versatile inverter.

Sample Equipment Set-up for Off-Grid Solar Diagram



03

Sizing a Cabin Solar System

Chapter three is about system sizing. The first size to decide is the storage capacity of the system's battery or battery bank based on electrical loads and desired days of autonomy. The second size to figure out is the solar array, based on expected sunlight hours and desired charge rate of the batteries. Finally, figuring out the proper wire gauge and size of breakers and fuses will be discussed.

Electrical Loads

A load is anything that draws power from the solar energy system. Some devices and appliances require a steady and constant flow of electricity, while others have a fluctuating electrical demand. The power that an appliance needs can be found by inspecting the device for its nameplate label. This label is usually found on the bottom or the back of a device, and will list the electrical specifications, such as the operating current or the power the device requires.

Below is a list of common electrical loads and the estimated energy use. This table is for estimates only. When performing your own load analysis, be sure to find power consumption ratings for your specific loads and estimate the number of hours you plan to use the devices.

Load	Load	Load	Load
LED Lightbulb	10	5	0.05
Incandescent Lightbulb	60	5	0.3
Phone Charger	5	3	0.015
Television	100	5	0.5
Satellite Internet Router	45	24	1.08
Microwave	1000	0.5	0.5
Electric Kettle	1500	0.5	0.75
Electric Space Heater	1500	5	7.5
Hair Dryer	1500	0.1	0.15
Desktop Computer	300	6	1.8
Floor Fan	75	8	0.6

Performing a Load Analysis

A load analysis is the process of figuring out how much energy is needed to power all the loads that will be used in an off-grid energy system.

To perform a load analysis, you need to:

- Make a list of everything that uses electricity
- Figure out how much power each load needs
- Total them to figure out the power and energy needed for your off-grid system

Once it's decided how much energy the system needs then you can design an off-grid energy system that will meet these power needs.

Figuring out load requirements: You need to figure out how much power it takes the load to run. This value is sometimes listed on the nameplate of the device. If the operating current/amperage is written instead, multiply that by 120 V to figure out the power. If there is no information on the device about the power demands, you can find this information in the user manual or online.

If calculating power by multiplying the voltage by the current, be sure that the current value is in amps (A) and not milliamps (mA). If the value is in mA, divide this by 1000 to make it A, and then multiply this by 120 V to figure out the power.

Once the load’s power is known, multiply by the number of hours each day that this load will be running to figure out daily energy consumption. For example, if an LED lightbulb requires 15 W of power and is turned on for 6 hours a day, the daily energy use is 90 Wh. If there are four of these lightbulbs being used for the same length of time, the daily energy use is 90 Wh x 4 = 360 Wh, or 0.36 kWh (360 Wh x 0.001 = 0.36 kWh).

If an electric kettle requires 1200 W to work and is used for 15 minutes each day, the daily energy use is 300 Wh or 0.3 kWh (1200W x 0.25 hr = 300 Wh).

Some appliances and electrical loads have a range of power demand while they are running, such as fridges and freezers. Fridges and freezers are plugged in for 24 hours a day, but they cycle on and off and they do not have a steady, regular power demand.

The easiest way to figure out the daily power demand of an appliance such as a fridge or freezer is to look up the annual energy use of that specific model. This can be found in the user manual or through an internet search. Once the annual energy use is found divide the value by 365 to find the average daily energy use of that appliance. For example, a mini fridge has an annual energy consumption of 420 kWh/yr. This means that the mini fridge uses an average of 1.15 kWh/day (420/365=1.15).

It's important to understand how to calculate the daily energy use for appliances that cycle on and off during regular use, such as fridges and freezers, however most electrical loads will require a consistent power supply while they are in use.

After calculating the daily energy use for each load, add them together to find the total energy the off-grid system needs to supply each day. Completing a table such as the one below is a straightforward way to perform a load analysis:

	Determine Power			Determine Energy	
	Determine Power			Hrs/Day	Energy (Power x Hours)
Electric Kettle	120 V	10 A	1200 W	0.25	0.3 kWh
LED Lightbulb	120 V	0.117 A	15 W	6	0.09 kWh
Cell Phone Charger	120 V	0.21 A	25 W	2	0.05 kWh
Circular Saw	120 V	12.5 A	1500 W	0.25	0.38 kWh
				Total daily energy use:	1.97 kWh

Days of Autonomy

Days of autonomy are how many days the off-grid system can run without needing to recharge from the solar array. The purpose of having days of autonomy is to make sure power does not run out when there is an extended period of low daily sunlight hitting the solar array.

When deciding your desired number of days of autonomy, you will need to know your average daily power needs and any seasonal differences in energy usage and sunlight hours too. It’s recommended to have a solar energy system that can store energy for at least two days. It only takes one day of poor weather to disrupt power coming from the solar array, which will reduce the amount of energy available.

The number of days of autonomy depends on the use of the off-grid system. If a cabin is being used on weekends for a maximum of two days, then having one and a half to two days of autonomy may be enough for this system. If a cabin is being used for a week or longer, it would be ideal to have a minimum of four days of autonomy.

Determining Required Battery Storage Capacity

To figure out the correct battery size for your off-grid solar system you must multiply the daily energy needs by the days of autonomy. You must also keep the battery’s DoD in mind when determining storage capacity.

Equation is: Daily energy needs x Days of Autonomy = Battery energy storage needed

For example, if daily energy use is 5.2 kWh and you want two days of autonomy, this will require a roughly 10 kWh battery energy storage system (5.2 kWh x 2 = 10.4 kWh). If four days of autonomy is wanted for the same energy use, this will require a roughly 20 kWh battery storage system (5.2 kWh x 4 = 20.8 kWh).

If a battery can only be discharged to 50%, this will also affect the size of the battery storage system. Lead Acid batteries should not be discharged below 50%, so a 20 kWh battery system will only have 10 kWh of energy available. LFP batteries can be discharged to 0%, so it's not necessary to consider depth of discharge when sizing a battery energy storage system with LFP.

Charge Rate of System

To figure out the time needed for a system to fully charge, you must know:

- the total power of the solar array
- the total energy storage capacity of the battery
- the approximate daily amount of sunlight hours

Multiplying the number of sunlight hours by the nameplate power of the array will decide how much energy that solar array will generate. This can then be compared to the energy storage capacity to decide how long it would take to become fully charged.

For example, a 2 kW solar array that is exposed to six hours of direct sunlight will generate 12 kWh of electrical energy in one day. If the battery bank is 10 kWh, it will take this solar array about five hours to fully charge this battery.

If the solar array is 500 W, or 0.5 kW, and has 6 hours/day of direct sunlight, it will generate 3 kWh. If the battery was 10 kWh, it would take more than three days of full sunlight for the array to charge the battery.

Peak Sun Hours

Peak sun hours are the hours when sunlight is at its most effective for solar energy generation. It's used to estimate how much solar energy a system can produce in a specific location based on that location’s average daily sunlight intensity. It will be dependent on geographic location and local climate conditions and weather patterns. Peak sun hours will vary greatly depending on the season.

The exact measurement of peak sun hours is the amount of time during the day that the sun’s intensity is strong enough to produce 1000 W of solar energy per square meter (1 kW/m^2).

This is a quick reference table which shows the peak sun hours for three locations across Nunavut.

Refer to the table in the Reference section for a month-by-month breakdown of peak sun hours for these locations.

	Summer	Spring/Fall	Winter
Iqaluit	5.5	3	0.5
Rankin Inlet	5.5	3	0.5
Cambridge Bay	6	3.5	0.5

Sizing Electrical Disconnects: Breakers and Fuses

A disconnect switch is a device that allows you to turn off or "disconnect" power from a circuit. It's often used as a safety measure to make sure no electricity is flowing before you do any work on the electrical system. It acts like a switch that cuts off the power from the source to prevent accidents or electrical hazards when someone needs to fix or maintain the system.

Disconnects come in two common forms: breakers and fuses.

A breaker is a safety device that acts like a switch and can be turned off and on. Breakers are designed to automatically stop the flow of electricity if the circuit becomes overloaded or if there is a surge in current caused by a short circuit. It protects wiring, cabin solar components, and electrical loads from becoming damaged due to a surge in current. To safely perform maintenance on a circuit, it's important to switch the breaker off to ensure the circuit is open and there is no accidental shock or injury when working on the equipment.

DC breakers are different than AC breakers. Only use a DC breaker when installing a cabin solar system. Using an AC breaker in a cabin solar system can be dangerous as it will not behave correctly with the direct current. DC breakers will have a positive and a negative side, and it’s important to install it properly to maintain polarity across the circuit.

A fuse will also open a circuit if there is a surge of current, but it cannot be used as a switch. The fuse will “blow” or break when there is a surge of current, due to a small wire or piece of metal inside the fuse which melts when it becomes too hot due to extra current. When a fuse blows it will need to be replaced with a new one since it can only be used once, and fuses do not have “on/off” switches.

Differences Between a Circuit Breaker and a Fuse

- Resetting vs. replacing: A circuit breaker can be reset after it trips, but a fuse needs to be replaced once it blows.
- Speed and operation: A fuse reacts faster to a surge in current and will blow quickly, while a circuit breaker may take a bit longer.
- Cost and maintenance: Fuses are generally cheaper, but since they need to be replaced, you may have to spend more over time. Circuit breakers are more expensive but last longer and can be reset after tripping.

When figuring out current limitations, it’s best practice to make sure fuses, breakers, and equipment current ratings are at least 25% higher than the maximum expected continuous current in the system.

For example, if an array of panels produces a current of 20 A, the current rating on the charge controller should be no less than 25 A (20 A x 1.25 = 25 A) and the breaker installed in between the solar array and the charge controller should also be no smaller than 25 A.

There should always be more space for current when sizing the system components because without this added space, it would take a small surge of current to trip the breaker. Small surges of current can be common, especially on days with strong sunlight hitting the array, so a small breaker would trip often and become an annoyance.

There are standard amp ratings for breakers. Using the example above, the ideal breaker to use would be a 25 A breaker, however this size of breaker might not be manufactured, or you may not be able to find it. You would then go up to the next breaker size. 30A would be a suitable breaker size and is readily available. You should not go any higher than this since it's possible to oversize the breaker. An oversized breaker could cause damage to equipment or personal injury because it’s too large to detect a surge from your equipment.

Wire Gauge

Wire gauge refers to the thickness of an electrical wire. The gauge decides how much electrical current the wire can carry safely without overheating or getting damaged. A thick wire can carry more current than a thin wire, much like how a river carries more water than a stream.

Wire thickness is measured using the American Wire Gauge (AWG) system. In this system, a lower number means a thicker wire, and a higher number means a thinner wire.

It’s important to use the proper size of wire gauge in an electrical circuit for safety. If a wire gauge is too thin, it might not handle the electricity properly. In extreme cases the wire could melt from the current and cause an electrical fire. Below is a table showing common wire gauges and the maximum electrical current that each gauge can carry.

Common Wire Gauges for Off-Grid Solar

When wiring an AC system in a house or building, the common gauges used are 14 AWG, 12 AWG and 10 AWG. In a cabin solar system, the smallest gauge that will be used is 10 AWG.

10 AWG wire is used when connecting the solar panels to the charge controller. The positive and negative leads that are attached to the back of the solar panel are made with wire that is 10 AWG. When connecting to these wires, it's important and necessary to use the same gauge of wire.

To connect the charge controller to the batteries, it's recommended to use 4 AWG wire. This can change depending on the size and capability of the charge controller, and size of the battery bank. For robust charge controllers that can move large currents to the battery, it may be necessary to use 2/0 AWG wires between the controller and the battery. For small charge controllers, it may not be physically possible to connect a 4 AWG wire to the small connection points. Use the largest gauge possible, depending on your charge controller, and do not use a wire smaller than 10 AWG.

The connections between batteries within a battery bank should use a minimum of 2/0 AWG wires. A bus bar could also be used, which is a solid metal bar that is connected between batteries. When connecting batteries together to create a battery bank, the goal is to transfer large amounts of current with minimal resistance, which is why it's important to use a thick wire such as 2/0 AWG.

It's recommended to use 4 AWG wire when connecting the battery bank to the inverter. Some inverters will come with pre-manufactured wires that can be used for this stage of the installation. Always follow product manuals and manufacturer instructions when deciding which wire gauge to use when connecting an inverter to a battery bank.

It's common practice to use 6 AWG wire when grounding and bonding equipment. This follows the rules within the Canadian Electric Code. This 6 AWG wire can be bare copper (i.e. has no insulation material around the outside of the wire), or it may have a green insulation material around it. If using insulated wire for grounding and bonding, it's important to ensure metal to metal contact is made. This may require some of the insulation to be cut away or peeled back to ensure the copper wire is in direct contact with the metal component that is being grounded or bonded.

Always follow product manuals and manufacturer instructions when deciding which wire gauge to use when connecting a solar array or battery bank to a charge controller.

If you have access to the Canadian Electrical Codebook, refer to Table 2, to figure out the maximum amperage that specific wire gauges can carry.

A simple wire gauge chart for converting AWG wire sizes. Maximum allowed ampacity for copper wires. For ambient temperature of 30 °C.

Wire Size, AWG	Ampacity (A)
14	15
12	20
10	30
8	40
6	55
4	70
3	85
2	95
1	110
1/0 or 0	125
2/0 or 00	145
3/0 or 000	165
4/0 or 0000	195

04

Off-Grid System Installation Methods

Site Selection and Preparation

The most cost effective and straight forward way to install solar panels is on the roof or wall of an existing building. Solar panels can be installed on a ground mounted racking system, but this option has higher material costs and requires more work for installation, including running wires either underground or overhead to the building. This guide will focus on installation methods for mounting on the roof or wall of a structure.

The primary considerations for deciding where to install the array on site are shading and the sun's path in the sky. Solar panels work best when sunlight strikes them at a 90-degree angle. In the northern hemisphere, they should face directly south, or as close to south as possible, for maximum efficiency. Shading can reduce a solar panel's energy output. Install panels in areas that are never in the shade for best performance. Common sources of shading include chimneys, trees, nearby buildings, and snow.

Solar panels can be installed in either horizontal or vertical orientation, also known as portrait or landscape. The orientation of the panel does not affect the power they will produce.

Another consideration is where to put the interior components: the charge controller, battery, and inverter. Wires need to be connected from the solar array to the charge controller. Keep the distance between them as short as possible. A shorter distance means less work during installation, fewer materials, and less voltage loss between the array and the battery.

Securing the Solar Array to a Building

It's important to make sure the array is attached to the structural components of the building, so the system will not be damaged or cause harm when there are storms or heavy winds. For rooftop mounting, the array must be secured to the rafters or trusses. For wall mounting, the array must be secured to the studs.

How to Prevent Water Damage

Improperly installed solar arrays can cause water damage, so it's important to properly waterproof all hardware during installation. Use a sealant when installing mounting components to prevent water from penetrating exterior barriers such as roofing materials and wall siding. There are specialty roofing sealants which you can use, but any silicon based sealant designed for exterior applications will protect against water. You may not see signs of water damage at first, but a tiny leak can lead to building issues within months or years, like mold or structural damage.

You should drill a pilot hole before you secure a bolt into a rafter or stud. This will make sure the bolt hits the rafter or stud and helps take pressure off the wood when the bolt is secured. After drilling the pilot hole, use a caulking gun to apply sealant into the hole and around its edges. The sealant will be drawn into the hole for a watertight seal when the bolt is secured. Add a bead of sealant around each bolt where it meets the roof or wall once everything is secured.

You should also seal all entry points where wires go inside the building. A bead of caulking should be applied around any wires where it enters the exterior and can also be applied inside the building as needed. This prevents water damage and helps stop heat loss from air leaks.

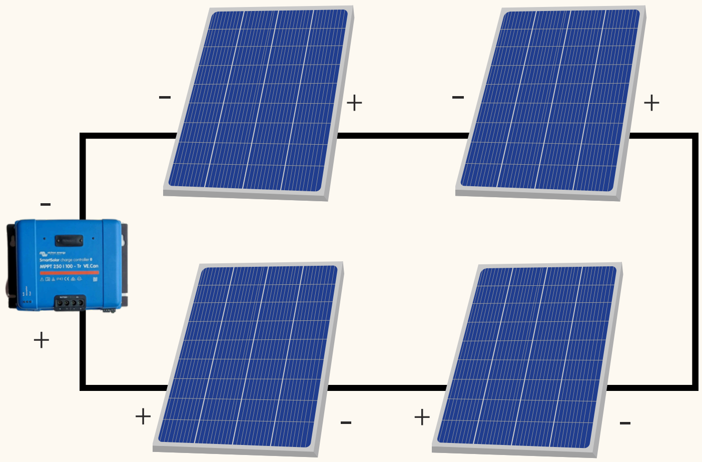
Wiring

Strings of Panels

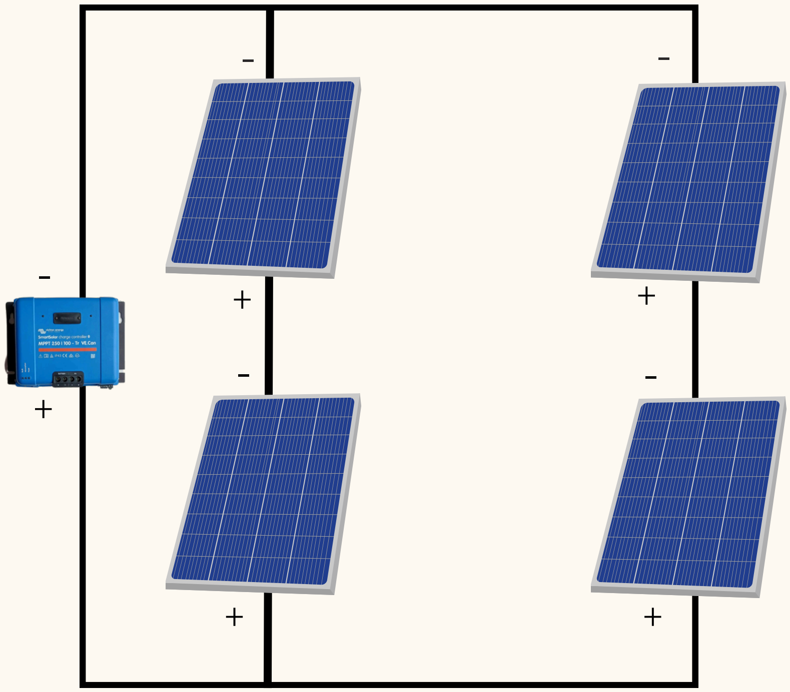
A string of panels is when two or more solar panels are connected in a circuit. It's important to always connect the positive lead of one panel to the negative lead of the other panel when connecting multiple panels. When using multiple solar panels, you need to choose how to connect them: series, parallel, or a combination of both.

- In a series connection, the voltages of each panel add up, while the current stays the same as a single panel.
- In a parallel connection, the currents of each panel add up, while the voltage stays the same as a single panel.

Consider four solar panels connected into one array. The panels have a Voc of 30 V, and an Isc of 10 A. If the four panels are connected in series together, the total voltage of the string of panels will be 30 Vx4=120 V and the amperage will be 10 A.



An alternative method for combining these four panels could be to make two strings of two panels each in series with each other and then connecting the two strings together in parallel. With two panels in a series circuit, the voltage of the string would be 60 V and the amperage would be 10 A. When those two identical strings are connected in parallel, the voltage for the entire circuit will remain at 60 V and the amperage will double to 20 A.



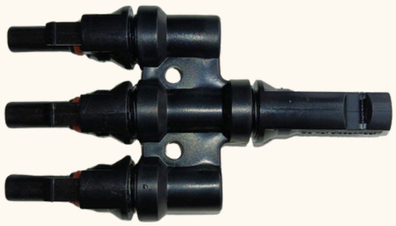
The power being generated by each circuit is the same. Power is voltage multiplied by current. For the first string orientation, voltage is 120 V and current is 10 A, which comes to 1200 W of power, or 1.2 kW. For the second string orientation, voltage is 60 V and the current is 20 A, which also comes to 1200 W (1.2 kW). The difference between the two circuits is that the second arrangement will charge the batteries quicker, due to the higher current.

There are products that allow the easy connection of two or three strings of solar panels into a parallel circuit. They are referred to as branch connectors. They have similar connectors to the connectors on the leads of the solar panels.

The two-to-one branch connector will allow two strings to be connected in parallel. Plug the positive leads of each string into the corresponding branch connector and plug the negative leads of each string into the other branch connector.

For three-to-one branch connectors, the positive and negative lead of the third string can be connected to the corresponding branch connector.

2-to-1 branch connector



3-to-1 branch connector

How String Layout Impacts Charge Controller Compatibility

The arrangement of solar panels and strings of panels depends on the electrical limits of the charge controller. Each charge controller has a maximum current capacity it can handle. Exceeding this limit could trip a breaker or damage the charge controller.

When figuring out current limitations, it's standard practice to ensure fuses, breakers, and equipment current ratings are no more than 25% higher than the maximum expected current in the system.

For example, if an array of panels produces a current of 20 A, the current rating on the charge controller should be no less than 25 A (20 A x 1.25 = 25 A). If there are two charge controllers, one with a 20 A limit and the other with a 30 A limit, then the 30 A should be selected.

There should always be more space for current when sizing the system components because without this added space, it would take a small surge of current to trip the breaker.

Mounting and Racking Hardware

Mounting and racking hardware are used to attach solar panels and other equipment to buildings. Solar panels are typically installed on the roof or an exterior wall.

Many companies make mounting and racking hardware. Designs will vary, but they function in similar ways. This guide covers two common installation methods but it's always best to follow the manufacturer's instructions for proper set-up.

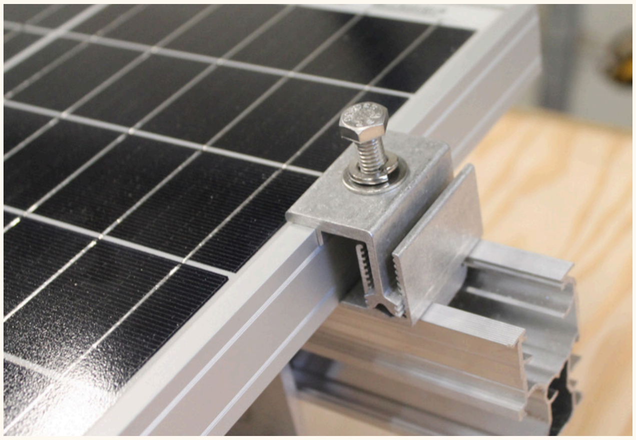
Mounting with Rails

Racking systems with rails will involve installing aluminum rails onto mounts, which are secured to rafters or studs with bolts. Two rails will be installed for each row of solar panels.

It's common to install rails horizontally, but they can also be installed vertically. Rails are the best method for mounting long rows of panels but can also be used for installing a single panel.

The solar panels are clamped at four points to the rails once the rails have been mounted to the rafters or studs. Two clamps on the upper rail and two on the lower rail.

Rails mounted horizontally on a roof.

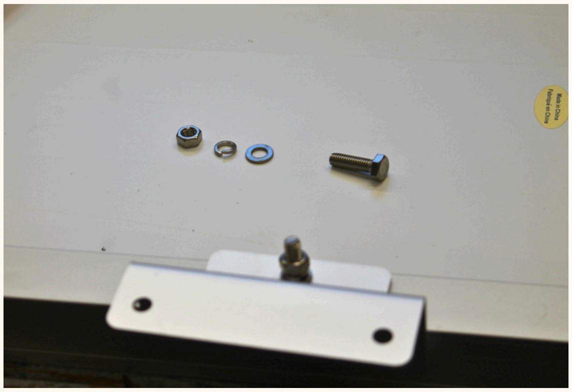


Close-up of an end clip.

The rail manufacturer will have designed mounting and clamping hardware that fits securely to their rail design. Always follow the manufacturer’s instructions to make sure your hardware is installed and secured properly.

Mounting with Z-Brackets

Another mounting product for small solar arrays (one to a few panels) is the Z-Bracket. This is a small metal mount that is connected to the back side of the panel frame with a nut and bolt. Each panel has four mounts and is then secured to the roof or wall with at least two screws on each mount.



If using Z-Brackets to secure a panel to the wall, it may be necessary to attach two pieces of wood (two-by-fours or two-by-sixes) horizontally or vertically to the wall first. See image top left for example. The pieces of wood would be secured to the wall stud using lag bolts. 4 inch to 6 inch lag bolts are best, especially for areas with high wind speeds. The Z-Brackets can then be secured anywhere on the wood.

Step-by-step Guide to Install Racking with Rails

1. Inspect the surface where the solar panels will be installed and make sure there is no shading. Mark the four corners of the panel on the surface using a measuring tape and a pencil.

2. Mark the top rail position: Measure one quarter of the way down from the top of the panel placement and make a mark. Mark the bottom rail position: Measure one quarter of the way up from the bottom of the panel placement and make a mark.

3. Find the studs or rafters.
For rafters:

- If the interior of the cabin is unfinished, it will be easy to see the rafters.
- Tap the surface of the roof lightly with a hammer. Solid sounding areas show a stud, while hollow sounding areas show an empty space.
- Alternately, go into the attic and measure from a wall to the first stud, then use standard spacing of 16 or 24 inches to find others.

For wall studs:

- If the interior of the cabin is unfinished, it will be easy to see the studs.
- For a cabin with a finished interior, use a tape measure and one reference point, such as a door or window frame, to approximately locate the stud. Most common spacing for studs is 16 inches or 24 inches apart.
- Using a stud finder is also a way to find studs in walls but will only work on the interior side of the wall.

4. Drill pilot holes for lag bolts. Use a 1/8″ inch drill bit or a comparable size to drill holes where the lag bolts will be installed.

This step is important to ensure the bolt will be secured into a rafter or stud. It prevents the wood from splitting when inserting the bolt.

5. Apply a bead of outdoor silicone caulking in the holes to help prevent leaks.

6. Use an impact driver to install the hanger bolts into the pilot holes.

7. Install the mounting hardware. Attach the remaining mounting hardware in the order specified by the manufacturer. Example: Washer → L-bracket → Washer → Lock Washer → ½-inch Nut.

8. Measure and cut the rails if needed.

- If the rails are not pre-cut, measure the required length.
- Leave two to four inches of extra space on each end for end clamps.
- For example, if a panel is 30 inches wide, the rail should be at least 34 to 38 inches long.
- If necessary, trim the rails later once the solar panel is installed.

9. Attach rails to the mounting hardware.
· Loosely secure the rails ensuring they are aligned and square with each other.
· Tighten the mounting hardware once positioned correctly.

10. Drill a hole through the roof or wall to bring the wires inside. Drilling a hole directly through the middle of a rafter or stud that is the same size as the wires is the easiest way to run wires from the outside to the inside of a cabin. This creates a secure tunnel for the wire, while also making it easy to fish the wire through the wall or roof. Drill one properly sized hole for each wire. Add some caulking around the entry and exit point of each wire to prevent air and heat loss through the openings. For a less permanent system, wires could enter the cabin through a slightly open door or window.

Electrical Wiring Set-up

Important: Do not connect the solar panel to the DC wires yet. Connecting them at this stage would make the wires live, which would create the risk of sparks, fire, or personal injury.

1. Run the wiring.
DC Wires (positive and negative):

- Run the positive and negative DC wires from inside the cabin to the outside.
- Secure the wires to the top rail using zip ties.
- Inside the cabin, route the wires toward the charge controller.
- Cover the ends of the wires with electrical tape to prevent accidental contact. Do not connect these wires to the panels yet, as this will make the wires live.

Grounding wire:

- Run a grounding wire from inside the cabin to the outside.
- Install a grounding lug to each of the rails.
- Secure the grounding wire to the rail grounding lugs.
- Leave extra wire to ground the panel frames later.

2. Complete the electrical set-up inside. Follow the steps in section "Electrical Connections of Off-grid Components" before continuing to the final steps of installing solar panels to rail mounting.

Final Steps: Installing the Solar Panel to Rail Mounting

1. Attach a grounding lug to the back of the panel frame according to the manufacturer's instructions.

2. Lift the panel into place.

3. Connect the panel wires:

- Positive lead from the panel to the negative DC wire from the cabin.
- Negative lead from the panel to the positive DC wire from the cabin.
- Secure the grounding wire to the panel frame using the grounding lug.
- Trim any excess grounding wire if needed.

4. Secure the panel to the rails.

5. Tidy the wiring by securing any loose wires to the rails with zip ties. Most panels have small holes in the back of the frame that can also be used to secure wires with zip ties.

6. Hold the panel in place and secure it to the rails using the end clamps. Always follow the manufacturer's instructions.

7. Double-check all connections and ensure the panel is securely fastened.

8. The solar panel is now installed.

Step-by-step Guide to Install Z-Brackets

1. Inspect the surface where the solar panels will be installed and make sure there is no shading. Mark the four corners of the panel on the surface using a measuring tape and a pencil.

2. Secure the Z-Brackets to the backside of the panel frame. Always follow the installation instructions for your specific product. There should be four Z-Brackets for each panel. Most panel frames will have manufactured holes in the underside of the frame, which can be used to secure the Z-Bracket to the frame with nuts and bolts. If there are no holes, secure the Z-Bracket with a self-tapping screw or carefully drill the necessary holes into the frame.

3. Find the studs or rafters.
For rafters:

- If the interior of the cabin is unfinished, it will be easy to see the rafters.
- Tap the roof surface lightly with a hammer. Solid sounding areas show a stud, while hollow sounding areas show an empty space.
- Alternately, go into the attic and measure from a wall to the first stud, then use standard spacing of 16 or 24 inches to find others.

For wall studs:

- If the interior of the cabin is unfinished, it will be easy to see the studs.
- For a cabin with a finished interior, use a tape measure and one reference point, such as a door or window frame, to approximately locate the stud. Most common spacing for studs is 16 inches or 24 inches apart.
- Using a stud finder is also a way to find studs in interior walls.

4. Once the rafters or studs are found, place two pieces of wood into position. It's recommended to use wood that is at least two-by-six, but two-by-four can be used. The pieces of wood should be cut to an equal length. It's good practice to make the wood longer than the panel by at least 2 to 4 inches on either side to ensure there is enough space for the Z-Bracket to be secured. The wood should be spaced so that the Z-Brackets can rest evenly on it when positioned on the roof or wall.

5. Drill pilot holes for lag bolts. Use a 1/8" inch drill bit or a comparable size to drill holes where the lag bolts will be installed. Drill pilot holes into the rafters or studs. Also drill pilot holes through the pieces of wood that will be secured to the wall or roof, ensuring that the pilot holes in the wood line up evenly with the pilot holes in the studs or rafter.

This step is important to ensure the bolt will be secured into a rafter or stud. It prevents the wood from splitting when inserting the bolt.

6. Apply a bead of outdoor silicone caulking in the holes to help prevent leaks.

7. Use an impact driver to secure the pieces of wood to the roof or wall using 3.5 inch or 4 inch lag bolts.

8. Drill a hole through the roof or wall to bring the wires inside. Drilling a hole directly through the middle of a rafter or stud that is the same size as the wires is the easiest way to run wires from the outside to the inside of a cabin. This creates a secure tunnel for the wire, while also making it easy to fish the wire through the wall or roof. Drill one properly sized hole for each wire. Add some caulking around the entry and exit point of each wire to prevent air and heat loss through the openings. For a less permanent system, wires could enter the cabin through an open door or window.

Electrical Wiring Set-up

Important: Do not connect the solar panel to the DC wires yet. Connecting them at this stage would make the wires live, which would create the risk of sparks, fire, or personal injury.

1. Run the wiring.
DC Wires (positive and negative):

- Run the positive and negative DC wires from inside the cabin to the outside.
- Ensure there is enough wire outside the cabin to reach the leads of the solar panels. Do not connect these wires to the panels yet, as this will make the wires live.
- Inside the cabin, route the wires toward the charge controller.
- Cover the ends of the wires with electrical tape to prevent accidental contact. Do not connect these wires to the panels yet, as this will make the wires live.

Grounding wire:

- Run a grounding wire from inside the cabin to the outside.
- Leave enough grounding wire accessible outside the cabin to ground the panel frame later. For arrays with more than one solar panel, every frame must have a grounding lug secured to it so the grounding wire can be attached to each panel.

2. Complete the electrical set-up inside. Follow the steps in section “Electrical Connections of Off-grid Components” before continuing to the final steps of installing solar panels to rail mounting.

Final Steps: Installing the Solar Panel with Z-Brackets

1. Mount the panel(s) by securing each Z-Bracket to the wood. Mounting on a wall is best done with two people, where one can hold the panel in place and flush against the wall while the other person secures the Z-Brackets.

2. Complete the installation of the electrical components inside the cabin before connecting the solar array to the positive and negative wires that run into the cabin and connect to the charge controller.

3. When installation is complete inside the cabin and all breakers are in the OFF position it's safe to connect the leads from the solar array to the charge controller.

Electrical Connections of Off-grid Components

1. Decide where the electrical equipment will be placed inside the cabin. This includes the charge controller, battery, inverter, and all wiring and breakers.

2. It's best practice to secure some or all the electrical equipment to a piece of plywood and then secure it to a wall or interior of a cabinet. Some or all the wiring connections can be secured before hanging, and the wires can be secured to the plywood in a clean and organized way.

3. Attach the positive and negative DC wires from the solar array to the proper connection points on the charge controller. Always follow manufacturer's instructions for proper connection method.

4. Install an appropriately sized fuse or DC breaker on the positive DC wire that runs from the panel to the charge controller. To decide the proper size for breakers and fuses, refer to the section on Sizing Electrical Disconnects. The breaker will act as a disconnect switch. Keep the breaker in the "off" position, which will prevent electricity moving from the solar panels to the charge controller. Remember, with DC breakers there is a positive and negative side. Ensure polarity is followed for safe and functional installation.

5. If using more than one battery, connect the batteries in the preferred circuit to produce the desired voltage and current. Keep the wires between batteries as short as possible, and make sure the wires between each battery are the same length.

6. Connect a length of DC wire to the negative terminal on the charge controller. Connect the other end of this wire to the negative terminal on the battery.

7. Connect a length of DC wire to the positive terminal on the charge controller. Connect the other end of this wire to a DC breaker or fuse. To decide the proper size for breakers and fuses, refer to the section on Sizing Electrical Disconnects. The breaker will act as a disconnect switch. Keep the breaker in the “off” position, which will prevent electricity moving from the batteries to the charge controller. Secure a wire with the same gauge to the other end of the breaker or fuse.

<u>It’s possible the next step will cause an electrical spark.</u>

It’s recommended to wear proper safety protection, including safety glasses and safety gloves before completing these steps.

If a positive DC wire is connected to the battery's positive terminal without a breaker, or if the breaker is installed incorrectly, it can create a small spark. To prevent a spark, ensure that the breaker is turned off. This will keep the circuit open between the battery and charge controller.

IMPORTANT SAFETY WARNING: Never connect the positive and negative battery terminals of the same battery using wire or any metal object.

- This can cause a short circuit and lead to a large spark, which may damage equipment or injure someone nearby.
- If wires are connected to these terminals they are now "live" and have an electrical current.
- Make sure the ends of any wires connected to the battery are kept apart.
- If wires need to be left unattended, wrap the ends of each wire with electrical tape for safety.
- When using metal hand tools, such as wrenches and screwdrivers, be careful not to accidentally touch both terminals on a battery with the tool, as this will also cause a short circuit.

1. Secure the positive wire from the fuse or breaker to the positive battery terminal.

2. Keep all breakers in the off position during installation.

3. Some charge controllers can have loads attached to them. Some will also have a USB port. If you're only using the charge controller for DC power and no inverter is being used, then the installation is complete. Go back outside and complete the steps of mounting the solar panel. Return inside, turn on any breakers, and the charge controller display should activate.

4. If using an inverter, connect the negative terminal of the inverter to the negative terminal of the battery.

5. Connect a wire from the positive terminal of the inverter to an appropriately sized fuse or DC breaker and then connect a wire from the other end of the fuse or DC breaker to the positive terminal of the battery.

6. When all equipment is grounded properly, it's time to return outside and plug the panel leads into the positive and negative wires that lead to the charge controller. Return to the earlier section and complete the steps for mounting the panel.

7. If there is a breaker between the battery and charge controller, turn this on first. The display or lighting of the charge controller should become active since it's now being powered by the battery. Wait for 10 seconds after the charge controller is powered before moving to the next step.

8. Switch on the breaker between the solar array and charge controller. A sign on the charge controller display may change, showing that the solar panels are sending electricity to the battery. This will only happen if the panels have sunlight on them. Refer to the user manual for your charge controller to ensure its energized correctly and working properly.

9. If battery voltage is at a suitable charge, flip the switch on the inverter. This will now allow the use of AC electricity, powered by the DC battery. The off-grid system is ready for use.

Note: It's recommended to leave the battery connected to the solar array for at least one sunny day before drawing power through the inverter. This will ensure that the battery is at a full charge before first use of the system.

Grounding Electrical Equipment

Disclaimer: This guide provides general information on grounding electrical equipment in a solar energy system. Electrical codes and regulations vary by location. Always consult a qualified electrician and check local electrical codes before installing or changing any electrical system. Improper grounding can result in electric shock, equipment damage, or fire hazards.

Why Grounding is Important

Grounding provides a safe path for electricity to flow to the earth in case of a fault or short circuit. This helps to:

- Protect people from electric shock.
- Prevent damage to equipment.
- Reduce the risk of electrical fires from faulty wiring.

How to Ground a Solar Energy System

1. Grounding solar panels

- Attach a grounding lug to the panel frame using the pre-drilled grounding hole with a nut and bolt. If there's no hole, use a self-tapping screw. Connect the grounding wire to the lug.

2. Grounding the inverter and charge controller

- If the charge controller or inverter has a built-in grounding screw, attach a grounding lug using a nut and connect a grounding wire to the lug. Always follow the manufacturer’s instructions for grounding.
- If the charge controller or inverter does not have a clear and obvious place for a grounding lug, the equipment may not be CSA compatible. Check the manufacturer’s instructions on how to properly ground this equipment.

3. Connecting the grounding wire

- Use a 6 AWG gauge copper wire to safely handle electrical surges. Connect all grounded components to one grounding point.

5. Setting up a grounding point

- If the cabin is already grounded, attach the grounding wire to any part of the grounded structure.
- If the cabin is not grounded, install a grounding rod or plate:
    - For a grounding rod, drive the rod into the ground and attach the grounding wire.
    - For a grounding plate, bury it below the frost line. Ensure the hole allows the plate to sit horizontally in a flat position. Never install it on its side or end.

Always check local electrical codes and building codes to make sure you're using the correct grounding method for your region.

Proper grounding ensures safety, protects equipment, and meets electrical regulations. Always verify installation requirements before completing the grounding process.

Safety Certifications for Equipment

When buying electrical equipment, it's important to figure out what safety standards it's designed to. Always check for certification marks before buying products. Below are common safety certificate marks in North America.

The primary certification mark in Canada is by CSA Group. It indicates that the product was tested and has met the certification requirements for electrical, plumbing and/or mechanical products.

The other two common safety certification marks are UL and ETL.

Important note: The CE mark is a well-known certification for equipment. It shows that the product meets European standards, but these standards are different from those in Canada. Products with only the CE mark may not meet the same safety standards for use in Canada.

Energizing the System

When all connections are made, and with all breakers switched to the off position, you are ready to energize the system. Always follow the correct procedure when energizing a system.

1. Switch the breaker between the battery and the charge controller to the ON position. Wait a few moments until the charge controller is turned on. This could be shown by an LED light, activation of a display screen, or through a product app. If the charge controller does not activate, double check all connections between the controller and battery. Another troubleshooting practise is to use a multimeter to check the voltage of the battery, and ensure this voltage is enough to activate the charge controller, as per the charge controller manufacturer instructions.

2. Switch the breaker between the solar array and the charge controller to the ON position. Wait a few moments until the charge controller monitor shows that current is flowing between the array and the controller. Current will only flow if the solar panels are exposed to sunlight. If there is no sign that the array is sending a current to the controller, double check all connections. Make sure polarity is consistent through the system with the positive and negative ends of wires connected in the proper orientation.

3. Turn ON the inverter by flipping a switch on the unit and/or turning on the breaker between the battery and inverter. Only do this when the battery is close to fully charged. Once the inverter shows that it's on, loads can be connected to it and electricity can be drawn from the system.

De-Energizing the System

If maintenance is needed or the system must be turned off for any reason, reverse the energizing procedure.

1. Turn OFF the inverter by flipping a switch on the unit and/or turning off the breaker between the battery and inverter. Best practice would be to turn off or disconnect all loads from the inverter to ensure no loads are damaged when the inverter is switched off.

2. Switch the breaker between the solar PV array and the charge controller to the OFF position.

3. Switch the breaker between the battery and the charge controller to the OFF position.

05

Operation, Maintenance, Troubleshooting

Safety and Testing

Personal Protection Equipment

It's recommended to wear safety gloves and glasses when working on cabin solar systems. This ensures no contact with harmful chemicals or sharp components and protects against electrical sparks. Hard toed work boots should be worn when installing the system and performing maintenance duties, especially when lifting and carrying heavy batteries.

If installing the solar array on a roof or any surface that is more than six feet off the ground, proper safety procedures should always be followed, including wearing fall restraint and fall arrest equipment when needed.

Non-Contact Voltage Tester

A non-contact voltage tester is a tool used to check if electricity is present in a circuit or electrical device. It helps find if a wire, a piece of metal, or any other conductive material is live, meaning that it has electrical power flowing through it.

Voltage testers should be used before working on electrical systems of any kind, including cabin solar systems. It helps ensure safety while working on electrical systems and can prevent accidents such as electrical shocks or sparks.

Always read and follow all the manufacturer's instructions before using a non-contact voltage tester.

There are no on/off switches on a solar panel. The leads coming from the back of the panel are always live when the panel is under sunlight and should be handled with caution if the ends of the
wires are exposed.

A non-contact voltage tester

Multimeter

A multimeter is a versatile tool used to measure different electrical values across a circuit, such as voltage, current, and resistance. It's an important diagnostic tool when checking a cabin solar system and troubleshooting problems that arise.

The common use of a multimeter when running a cabin solar system is to check voltage across the system. For example, checking the voltage of a battery to figure out its charge or ensuring there is a voltage from a positive and negative PV wire to show the array wiring is correct.

All multimeters will have a maximum voltage they can handle. Multimeters have analog or digital displays. Some digital models adjust the voltage level they are testing automatically, while some require the voltage range to be selected manually. Always consult the user manual of your multimeter to ensure correct usage.

Proper Maintenance

Daily Maintenance

Monitoring power production

- Check the display: If the charge controller or inverter comes with a display or monitoring capabilities, check daily to see how much power is being generated by the solar panels and how much is being stored in the batteries.
- Observe battery charge level: Make sure the batteries are not too low or over charged. The ideal charge range is between 50% and 80% of the battery's full capacity.
- Look for error messages: Some systems provide error codes or warnings. If you see any unusual signs, take note and consult the system's manual.

How to check a battery's state of charge

- Battery monitor system: Some charge controllers or batteries with monitoring systems will have a display which provides a real-time reading of the battery bank's state of charge (SOC). Some equipment may have Bluetooth capability and can be controlled through an application on a cell phone or tablet.
- Measure the battery voltage: Using a multimeter, measure the voltage across the positive and negative terminals of the battery or battery bank. The voltage reading will give an estimate of the battery's charge level. Batteries have different voltage ranges: consult with the user manual to find precise voltage levels for your battery.

General guide for 12 V lead acid batteries

- Fully charged: 12.6 V – 12.8 V
- 50% charge: 12.0 V
- 20% charge: 11.8 V
- Discharged: 11.5 V or below (dangerously low)
- For a 24 V battery bank, double the above voltages. For example, 100% will be minimum 25.2 V and 50% will be 24.0 V. For a 48 V battery bank, quadruple the above voltages.

Inspect components for overheating

If a charge controller or inverter feels hot to the touch, the system may require better ventilation. Ensure there is adequate airflow around the unit. Use a soft brush or vacuum to clean any fans, filters, and air vents.

If a battery or battery bank feels hot or if there is visible bulging of the plastic around the battery, turn off the system by following the de-energizing process in De-energizing the System section in the earlier chapter. Use a multimeter to confirm the battery voltage is at a normal operating level. Verify the charge controller settings are correct, as overcharging can cause batteries to overheat. Check all connections to the battery, ensuring no wires are loose and no corrosion is present at the battery terminals. Ensure all wires connected to the battery are the proper gauge. Ensure there is proper ventilation around the battery.

After fixing any of the above issues, energize the system and check the batteries over a suitable length of time to ensure the overheating is not persistent. If nothing looks out of order or if the batteries continue to overheat, contacting the product manufacturer or consulting a professional is recommended.

Monthly Maintenance

Inspect the solar panels: Check for debris sitting on the panels, removing anything that could block sunlight. If panels are dirty, gently clean the surface with dish soap and hot water. Inspect the panel(s) for cracks, chips, discolouring, or any form of physical damage.

Check controller settings: Make sure the charge controller is set to the correct voltage for your system’s batteries. Incorrect settings can lead to overcharging or undercharging, which can shorten the life of your batteries.

If using FLA batteries check the water levels in each cell. Top up with distilled water as needed. Do not over fill, as this can cause battery over charging.

Annual Maintenance

Inspect all wiring and connections: Look for any frayed wires, loose connections, or signs of corrosion in all wiring. Replace any damaged wiring at once. Ensure all components are still properly grounded. Hand-tighten all screws and bolts throughout the system that hold wires in place, as loose connections can cause power losses and equipment damage.

Test the system's back-up power: If a battery storage system is connected to a generator for back-up power, test by disconnecting the solar array from the batteries and turning on the generator. Ensure back-up power is running as expected.

Common Issues and System Management

Before performing any maintenance that requires disconnecting wires from system components, ensure that the system is de-energized. A system is de-energized when all the breakers have been turned off. This prevents electricity from moving through the system. First, turn off the inverter and/or the breaker that is between the inverter and batteries. Next, turn off the breaker between the solar panels and the charge controller. Finally, turn off the breaker between the batteries and the charge controller.

Once the system is de-energized you should check for loose connections. Tighten any screws or bolts that are holding wires in place. Give a small tug to any wire that has a lug crimped on the end or a screw holding it in place. It's possible for a wire or lug to appear secure, but sometimes a tug on the wire can cause it to become disconnected and must be correctly tightened or crimped.

Ensure polarity across the system: Incorrectly wiring a DC circuit can result in low or no current. Be sure that all connections between system components follow the correct polarity.

When you are ready to energize the system, turn on the breaker between the battery and charge controller and wait 10 seconds. Next, turn on the breaker between the solar array and the charge controller. Finally, turn on the breaker between the battery and the inverter.

Storing Your System When Not in Use

If you are leaving a stand-alone system for a long time, especially during the winter months, then it's important to ensure there are no loads connected to the battery. Unplug any loads connected to the inverter and switch the inverter off, along with the associated breakers if installed. You can also disconnect the inverter completely from the battery. Batteries should be at a full charge prior to storing. It's recommended to leave the batteries connected to the charge controller and the panels during storage, as this will allow the battery charge to stay high thanks to the “trickle charge” it receives from the panels when the sun is out.

Always read and follow manufacturer directions about storing your specific batteries and other electrical components.

Battery Storage and Temperature

It's important to keep all batteries fully charged when storing them for an extended length of time. A fully charged battery will be able to withstand much colder temperatures than a partially charged battery. A partially charged battery may become damaged if exposed to freezing temperatures. Lead acid batteries can withstand temperatures below -40 degrees Celsius when fully charged, but if less than 50% charged they may freeze at temperatures between -20 to 0 degrees Celsius.

LFP batteries perform poorly at freezing temperatures and are not recommended for arctic temperatures. Some premium LFP batteries have an added capability of self-heating to keep them at a constant temperature.

Batteries should not be stored in temperatures above 40°C or 104°F. High heat can damage the inside of the battery and make it wear out faster.

When to Replace Batteries

All batteries have a lifespan and will require replacing over time. The length of time between replacing depends on the type of battery (FLA, AGM or LFP), the rated charge cycles, the frequency of use, and the depth of discharge. Keep track of the battery's age and plan for replacement if it's no longer holding a full charge.

Flooded lead acid (FLA) batteries have a typical lifespan of four to seven years. They also need regular maintenance, ensuring that all fluid levels in the battery cells are correct.

AGM batteries have a typical lifespan of five to 10 years. They are maintenance free but should be checked for proper charging and temperature management. AGM batteries are the best for extreme cold temperatures, able to run when fully charged to temperatures as low as -40 degrees Celsius.

Lithium Iron Phosphate (LFP or LiFePO4) batteries have an average lifespan of 10 to 15 years. They are maintenance free; however, most are equipped with a battery management system (BMS) that protects against overcharging, overdischarging, and extreme temperatures. They should not be used in freezing temperatures for an extended period; however, some manufacturers have self-heating LFP batteries.

Battery life can vary depending on use. The more deeply you discharge a battery, the shorter its lifespan. Shallow discharges (e.g., staying within 30%–50% DoD) can help extend the life of any battery.

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About Arctic Renewables Society

The Arctic Renewables Society was formed in 2019 to promote the advancement of renewable energy through education and training, project development, and other activities that can help the green energy sector. Our goal is to reduce greenhouse gas emissions and diesel consumption in Nunavut. https://www.arcticrenewables.ca/

About Relay Education

Relay delivers renewable energy and environmental education and training programs in classrooms and communities. Relay is creating change for a better future and fostering the next generation of green leaders. Our mission is to educate, inspire and help individuals and communities in building a 100% renewable energy future. https://relayeducation.com/

Resources

Government of Nunavut Renewable Energy Homeowner Grant Program:
https://www.nunavuthousing.ca/programs/homeownership

Government of Nunavut Renewable Energy Cabin Grant Program:
https://climatechangenunavut.ca/en/renewable-energy-cabin-grant-program-guide

Load Analysis Worksheet

Blank Worksheet
Sample Worksheet

This worksheet can be completed to decide the average daily energy consumption of each electrical load that will be powered by your off-grid system. Adding up the daily energy consumptions will give you the total daily energy usage for your cabin. Multiply the total by the number of days of autonomy to decide what the storage capacity must be for your battery or battery bank.

Peak Sunlight Hours

Peak sunlight hours in Nunavut by month

Relay Education

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