MINISTRY OF PUBLIC UTILITIES, ENERGY, LOGISTICS & E-GOVERNANCE

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ENERGY ACCESS HANDBOOK NO. 2

LAIT UP BELIZE!

Stand-alone Solar Systems

Everything you need to know...

How to use this Handbook

This handbook is intended to help you – as user of a stand-alone solar system – to get the best use and the most benefits from your solar system. Like all equipment and systems, you can get more benefits from the system if you understand how it works, how to use it wisely and how to maintain it when there are any problems.

The scope of this handbook is to cover stand-alone solar systems. This means solar systems with modular components that operate on their own for a particular building or buildings – and not connected in any way to an electricity network.

There are thousands of stand-alone solar systems in Belize. Most of these have been purchased and installed by homeowners to the best of their abilities. However, a large number of these existing stand-alone solar systems are either not working at all or working sub-optimally. This is a wasteful situation when many of these non-functional stand-alone solar systems can be repaired or operated in a systematic manner based on good design and installation practice and good use of the systems.

This handbook seeks to assist new and current owners of stand-alone solar systems to ensure that their system is working as best possible and in the most reliable (and cost-effective) manner.

Stand-alone Solar System in San Carlos Community, Orange Walk District, Belize.

Photo Credit: Luis Larregola

Stand-alone Solar System
at Mabil Ha Primary School
Toledo District, Belize

Photo Credit: Luis Larregola

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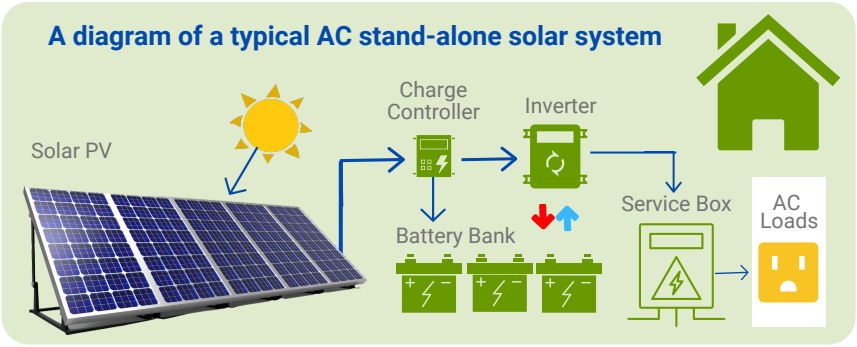
Introduction to stand-alone solar systems

What is a stand-alone solar system?

A stand-alone solar system is a system for generating electrical power directly from the sun and supplying this electrical power to a dedicated customer independently of an electricity grid. The electrical power is stored in banks of rechargeable batteries to provide power at night or during periods of overcast weather. A stand-alone solar system is also referred to as a photovoltaic (PV) system or a solar home system (SHS).

There are two basic types of stand-alone solar systems, namely:

1. smaller systems that operate on low-voltage (usually 12 V) on direct current (DC) only for small DC appliances
2. larger systems that supply the typical 110 V and 60 Hz alternating current (AC) for typical electricity appliances that may be used on the national grid



What are the benefits of a stand-alone system?

Stand-alone PV systems are ideal for providing electricity for energy services to customers / owners in remote rural areas for lighting, appliances and other uses, where other power sources are either impractical or are unavailable to provide power. In these cases, purchasing a stand alone system may be more cost effective than paying premium prices for the electricity company to run distribution lines to your location.

With a stand-alone system, rural residents with no access to the national grid can enjoy electricity for everyday energy services such as lighting, phone charging, TV/media, refrigeration, ventilation and cooling, laundry and kitchen appliances, as well as productive uses of energy for income generation, education and health.

How does it operate?

The solar generation in a stand-alone system is made up of a number of individual photovoltaic (PV) panels usually of 12 or 24 volts (DC) with power outputs of between 50 and 300+ watts each. These PV modules are then combined into a single array to give the desired power output which then charges banks of batteries via a charge controller during the day for use at night (or when the sun is unavailable) directly from the batteries through the charge controller (for DC systems) or via an inverter (for AC systems).

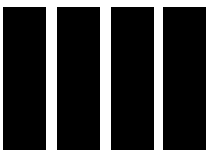
The solar panels for small-scale solar systems must be placed in a location facing South or Southeast that is undisturbed and with no shading (at all) on the solar panels between 09:30am and 4:30pm. The solar panels should have good airflow above and below to keep them as cool as possible (not laying directly on a roof or the ground).

The solar panel should be mounted at an angle of tilt (typically 10 – 15° to the horizontal) to ensure good orientation to the sun and to allow dust and debris to wash off in the rain.

What are the main parts of the solar system and how long do they last?

Solar PV Panels
converts sunlight to electricity

15 - 20 Years



Charge Controller
manages the flow of electricity between the solar panel, battery and appliances

5 – 10 Years

Lead Acid Battery
stores electricity for appliance use at night or on overcast days

2 – 3 Years

Lithium-Ion Battery
stores electricity for appliance use at night or on overcast days

8 – 10 Years

Inverter
converts DC power from the solar panel and battery to AC power

Wires & Switchgear
connects the system components to allow electricity to flow safely and with minimum losses

10 – 20 Years

Appliances
The appliances convert the electricity into energy services such as light, cooling, etc.

Typical Stand Alone Solar System set up with its various indoor components.

Photo Credit: Luis Larregola

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How to use your stand-alone system to get the maximum benefits

There is a limit on amount of electricity produced and stored with small stand-alone systems. To enjoy the usage of electricity during hours of no sunlight, these are the appliances that you should and shouldn't use.

- Know your system – to understand how much electricity it can generate and store on a typical day so that you can adjust your use of appliances to correspond with this generation and storage capacity.
- Use energy efficient appliances that are suited to stand-alone solar systems
- Use these appliances wisely within the generation and storage capacity of the stand-alone solar system

How much electricity can my solar system provide?

A well-designed solar system in Belize should have solar panel and battery sizes that are in the optimal ratio correspond to within the range of 50 – 75 Watts of generation capacity per 100 ampere-hours of storage with lead acid batteries (for 12 V systems) or per 50 ampere-hours for Li-Ion batteries.

Solar Generation Capacity	Lead Acid Batteries (12V)	Lithium Ion Batteries (12V)
50 - 75 W	75 - 100 Ah	40 - 50 Ah
100 - 200 W	150 - 300 Ah	75 - 150 Ah

Systems with this ratio of generation to storage can be expected to provide the following average daily electricity for appliances.

Generation Capacity	Ave. Daily Electricity for Appliances	Typical Appliance Use
40 W	75 - 100 Wh/day	• 4 LED lights for 10 hours per day
100 W	350 Wh/day	• 4 LED lights for 10 hours per day • 1 fan for 3 hours per day • 1 notebook computer for 4 hours per day
300 W	1,000 Wh/day	• 8 LED lights for 10 hours per day • 1 fan for 3 hours per day • 1 notebook computer for 4 hours per day • 1 small refrigerator

What devices can I use on my solar system?

Stand-alone solar systems work best when supplying electrical appliances that are very energy efficient or used for short periods of time (such as a blender/food processor). Of course, only 12 DC appliances can be used on smaller DC stand-alone solar systems whereas 'normal' energy efficient appliances can be used on larger AC standalone systems. The following are the appliances that you should and shouldn't use.

Smaller DC system	Larger AC system
	

What is the best time to use appliances?

Generally, the best time to use your appliances on a stand-alone solar system is between 10 am and 3 pm when the sun is highest. This also ensures that the electricity that is generated from the solar panels is not cycled through the battery before supplying the appliances – which is more efficient overall. Once your battery storage is full, you will have enough electricity for lighting and other necessities at night, especially before bedtime and early morning hours, and also on overcast days.

How do I maintain my system?

Stand-alone solar systems work best when the battery is fully charged from time to time (perhaps on a weekly basis, if possible). The battery is the 'heart' of the stand-alone solar system. For the battery to operate in the best way possible, it must receive electricity from the solar panels, wiring and charge controller and it must supply electricity to the appliances via the charge controller (for DC systems) or the inverter (for AC systems), the house wiring and switchgear.

Overall

- Check that the system is safe – with a fuse on the positive battery terminal, circuit breakers or fuses for appliances in place
- Monitor the state of charge of the battery on a daily basis by looking at the indicator lights on the charge controller and/or inverter and understanding how to interpret the state of charge from these indicator lights
- Check that all the wiring connections are in a good condition – not loose in any way and with a good connection
- Check that the correct appliances are being used (DC or AC – as appropriate – and energy efficient) and not used for too long

The Appliances

- Do not connect appliances other than those authorized
- Check connections and power sockets to ensure safe and effective connections
- Switch off and disconnect appliances when not in use (to avoid any 'ghost' or standby consumption)
- Clean the light bulbs once per month to increase effectiveness

The House Wiring

- Check that all switchgear is working for safe operation of appliances
- Check all connections to ensure safe and effective operation
- Check that all wiring is in conduit or secured with saddles to ensure no movement or damage to the wiring

The Battery

- Check that the battery is safely installed and out of reach of unauthorized persons
- Check that the battery has good ventilation all around for safety, cooling and efficient operation
- Check that the battery fuse (on the positive terminal) or circuit breaker is in place and working correctly
- For wet cells Lead-acid batteries, check battery water and acid levels weekly and use only distilled water to refill the battery water.
- Inspect the wire connections and clean away any corrosion you find
- Clean the terminals and make sure all connections at the battery are snug. This unpleasant task is unnecessary if you are using maintenance-free AGM/gel batteries or lithium-ion batteries.
- Do not connect devices other than those authorized

The Charge Controller

- Check that the charge controller is safely installed and out of reach of unauthorized persons
- Check the wire connections regularly to ensure that they are clean and secure. A loose connection causes resistance and heat, both of which are detrimental to system performance.
- Do not allow dripping water near the equipment
- Check the operating indicators on the charge controller to ensure that it is operating in the normal operational mode for charging and discharging (not in load-shedding due to low battery voltage in the case of DC systems)

The Solar Wiring

- Check that the wiring between the solar panels is thick enough for the peak charging currents and to avoid losses
- Check all connections to ensure safe, waterproof and effective operation
- Check that all wiring is in conduit or secured with saddles to ensure no movement or damage to the wiring due to wind (or other) interference

The Solar Panel

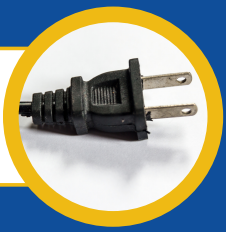
- Check that the solar panels are mounted to:
  - face south or south-east with an angle of tilt of approx. 10 – 15° to the horizontal and
  - with no shading (at all) between 9:30 am and 4:30 pm
  - with at least 3" of clearance all around (especially underneath) for effective cooling and maximum performance
- Check that there is no dust on the solar panels.If so, gently clean the panels with clean water and a non-abrasive sponge. Do this at least every three months to reduce build-up of dust or debris that can hinder the effectiveness of the solar energy generation from the sun rays.

- Trim hanging branches or remove any objects (like poles or wires) that may be blocking the sun rays from the surface area of the panels.
- Do not throw stones or objects where the solar panel is located to avoid damage to the solar panels

What are some of the best practices in saving energy for maximum benefits?

Use a power supply cord with off/on switches to plug in your equipment. This makes it easy to switch off electricity when appliances are not in use.

Another way to be sure to reduce electricity is to unplug the equipment. This also eliminates standby power usage.



Use natural sunlight and switch off lights during daylight hours. Perform your energy-required tasks during 10am to 3pm when the sun is most effective.

Perform regular maintenance on your solar system components.

Useful tips for installation of stand-alone solar systems

It is advisable to employ a skilled technician to install your stand-alone solar system so that safely and reliability are ensured. However, if you must do so independently, it is important to keep the components of the PV system within rated parameters. Extremely high voltages on a small charge controller can result in overloading of the system. Also the polarity (negative and positive) of the connections between panels, charge controller, batteries and/or inverter has to be strictly observed. Reversing polarities can result in damaging any of the components.

The order in which the components are to be installed is also very important. When installing the system, the charge controller has to be connected to the batteries first, then to the panels. When de-installing, the solar panels have to be disconnected first and subsequently the batteries.

Safety Measures - Breaker

If you have a solar PV system in your home or small business, it is important to make sure that the electrical protections are correct. This guide specifically focuses on the protections for the part of the system that involves the solar panels, which generate direct current (DC). Here is a simple guide to help you review your system:

Identify the breaker:
The breaker is a small box that is generally located near your solar panels, before the connection to the charge controller or the inverter. It may have a switch that moves between the "ON" (on) and "OFF" (off) positions.

Check the label: On the front of the breaker, there should be a label that indicates whether it is for alternating current (AC) or direct current (DC). If you see the letters "AC" or the symbol ~ on the label, it means that it is an AC breaker.

Look for the amperage value: Also on the label, you should see a number followed by the letter "A". This number indicates the amount of current that the breaker can handle. For example, if you see "32A", it means that the breaker can handle up to 32 amps.

If after reviewing your system you find that you are using an AC breaker on the part of your system that involves the solar panels, it is important to contact a specialist. Solar panels generate direct current (DC), and using an AC breaker can cause problems and potentially damage your system.

Remember, it is always better to be safe than sorry. If you have any doubts about your solar PV system, do not hesitate to seek help from a professional.

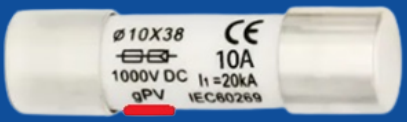
Safety Measures - Battery

Batteries are an essential part of your solar system, especially if you have an off-grid system or if you use battery storage for when the sun is not shining. Just like solar panels, batteries also need proper protections to operate safely and efficiently.

Here is a simple guide to help you review your system:

Identify the battery breaker or fuse:
This is generally located between the battery and the charge controller or inverter. It may be a switch that moves between the "ON" (on) and "OFF" (off) positions, or it may be a fuse that needs to be replaced if it burns out.

Check the label:
On the front of the battery breaker or fuse, there should be a label that indicates its current capacity. This capacity should be adequate for the maximum current that your inverter (and/or DC loads) require(s) for its rated surge capacity (maximum power output). It is very important to be able to see the gPV sign.



Fuses vs Breakers: Fuses are single-use devices that burn out when the current exceeds their rated capacity. They are inexpensive and reliable, but they need to be replaced if they burn out. Breakers, on the other hand, are reusable devices that trip when the current exceeds their rated capacity. They are more convenient than fuses, as they can be reset by simply moving the switch back to the "ON" position, but they are typically more expensive.

If after reviewing your system you find that you do not have the proper protections for your battery system, it is important that you contact a specialist. A battery system without the proper protections can be dangerous and can damage other components of your solar system.

Remember, it is always better to be safe than sorry. If you have any doubts about your solar battery system, do not hesitate to seek help from a professional.

3 How to troubleshoot your system

Like all systems, stand-alone solar systems can have breakdowns or problems. Fortunately, these can often be easily fixed. Here are some basic measures that can be taken to resolve any issues with your stand-alone system. A qualified technician will be required for more serious matters.

Lighting / Appliances

Issue	Causes	Solution
The light goes dim or does not work; or appliance does not work	1. Light/appliance not switched on properly 2. Bad connection or incorrect wiring 3. Faulty light bulb/appliance 4. Old or Faulty Battery 5. Solar panel is not charging correctly	1. Check the light or appliance on another stand-alone solar system or electricity supply 2. Check all wiring connections 3. Replace if the bulb/appliances still don't work 4. Check that the inverter or charge controller is not in load-shed mode to protect over-discharged batteries 5. Test and replace batteries 6. Clean the solar panel(s). Check that the solar panel is not shaded. Check solar panel wiring.

Inverter / Charge Controller System

Issue	Causes	Solution
The inverter or charge controller indicator lights (or alarm sound) is constantly going off	1. The battery electricity storage is too low or depleted 2. The wire connection is loose 3. The battery is old or faulty	1. Turn off all appliances until the battery is recharged (which may be after some days) 2. Secure/tighten the poles/wire on the battery. Clean any corrosion on the poles 3. Test and replace batteries 4. Clean the solar panel(s). Check that the solar panel is not shaded. Check solar panel wiring.

Battery System

Issue	Causes	Solution
The electricity from the system only lasts a few hours	1. The battery is not being charged properly. The solar panel could be dirty or in the shade 2. Successive cloudy days (in rainy season) 3. Bad electrical connection(s) in the wiring (on solar panels, charge controller, battery and inverter) 4. Old batteries or battery misuse	1. Clean the solar panel(s). Check that the solar panel is not shaded. Check solar panel wiring 2. Check all wiring connections 3. Recharge the battery on sunny days 4. Test and replace battery

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Information Resources

- **Energypedia** - https://energypedia.info/wiki/Basic_Energy_Services_-Stand_Alone_/_Off_grid_Energy_Systems
- **Caribbean Centre for Renewable Energy & Energy Efficiency** - www.ccreee.org
- **EU Energy Community** - www.energy-community.org
- **United Nations SDG 7** - https://sdgs.un.org/goals/goal7
- **Solar Energy Industry Association** - www.seia.org/initiatives/about-solar-energy

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