OutBack POWER™

an EnerSys® company

SkyBox

True Hybrid Energy System

Handbook

About OutBack Power

OutBack Power Technologies is a leader in advanced energy conversion technology. OutBack Power products include true sine wave inverter/chargers, maximum power point tracking charge controllers, and system communication components, as well as circuit breakers, batteries, accessories, and assembled systems.

Applicability

These instructions apply to OutBack Power model SBX5048-120/240 only.

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Warranty

The warranty for this product can be downloaded from https://www.outbackpower.com/resources/warranty/procedures or you may request a copy by sending a self addressed envelope to the above address.

Notice of Copyright

Trademarks

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Preface

The SkyBox True Hybrid Energy System is a machine that connects the solar panels on your roof to the toaster in your kitchen so you can use solar or battery energy to power that toaster. This guide will walk you through the basic decisions you need to make to successfully set up a SkyBox. We will also dive into the details for each component of the SkyBox for ambitious installers and tinkerers out there.

This Handbook does not have linear instructions. You can pick which chapter is most relevant to your situation and go straight there without wading through pages of unnecessary information. However, this Handbook IS NOT a replacement for the *SkyBox Quick Start Guide* (link 1)[1] provided in the box with the product. We won't be reviewing any wiring steps, just operation and behaviors.

If you're a SkyBox newbie, the best place to start is at the beginning with **Making it Run** on page 5. Go through this section, try it out on your SkyBox, then come back and read about all the details and special features that make SkyBox unique. The details and special features of this inverter are covered in **The Nitty Gritty** on page 17.

The following sections will sometimes make references to SkyBox settings. These are shown in ***bold italic*** text. Detailed explanations can be found in the *SkyBox Programming Guide*.

The Screen

The SkyBox display is a resistive, touch-sensitive interface. Unlike your cell phone, this screen supports single touch and relies on pressure from your finger or a stylus — it does not make use of the human body's natural conductivity. It monitors all aspects of SkyBox performance. Items such as **buttons**, **tiles** , or icons respond or open when tapped with a finger or stylus.

For a description of all controls, see the *SkyBox Overview Guide* (link 2). For an in-depth description of all functions, see the *SkyBox Programming Guide* (link 3).

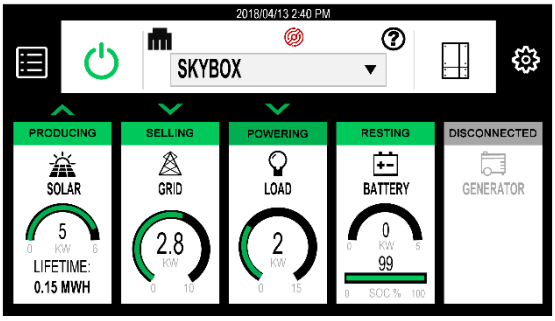

Figure 1 SkyBox Screen

The Set-Up Wizard

The set-up wizard walks you through each section of settings in order to get your SkyBox up and running. The first time your SkyBox is turned on, the Wizard will appear. The Wizard does not cover rapid shutdown or the use of the auxiliary terminals.

One setting in the Wizard is the selection of AC Profile. The AC Profile tells the SkyBox how to interact with the utility grid. You must select an AC Profile during setup, regardless of whether grid power will be used. To decide which AC Profile to use, see page 5.

After the initial setup, you can access the wizard by logging in as ***Installer*** and navigating to the ***Configure*** menu on the **System** tab.

[1] Each numbered link is an active hyperlink, but it also refers to the corresponding QR code at the top of the page.

Making it Run

Materials

You will need the following:

- Properly installed SkyBox inverter
- SkyBox BOS
- *SkyBox Overview Guide*
- *SkyBox Quick Start Guide*

Optional:

- A small stylus to tap on the SkyBox touchscreen
- *SkyBox Programming Guide*

Choosing the Right AC Profile

Use the flow chart to the right to determine which grid use profile is the most appropriate for your system. Each profile is discussed in more detail in **The Power Grid and You** on page 6.

Programming

To make the initial program settings, use the Setup Wizard that appears during power-up. These settings include the AC Profile, battery charging, screen brightness, passwords, and so on.

To make additional settings after closing the Wizard, see the *SkyBox Programming Guide*.

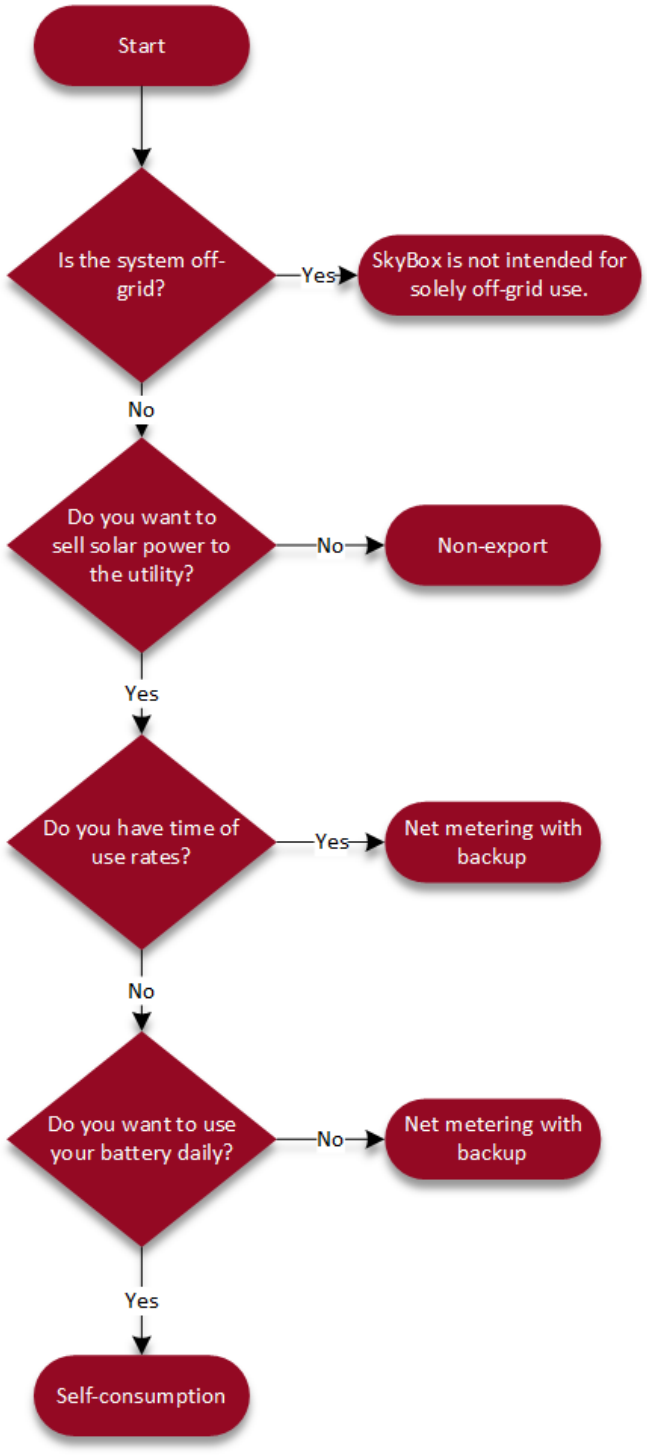

Figure 3 AC Profiles

The Basics

The Power Grid and You

SkyBox is designed with four AC profiles. Each profile interacts with the utility grid in a different manner. In all of the AC profiles, no battery power will be supplied to the site when the battery reaches ***Minimum SOC*** (state-of-charge). This means if there is a power outage and you drain your battery to this low setting, your refrigerator, freezer, wifi, etc. will be off until the utility power returns or the battery is charged.

Sell for All You're Worth (Net Metering With Backup)

When the ***Net metering with backup*** profile is selected, the SkyBox harvests as much solar power as it can. After sending power to your protected loads, all extra power will be sent to the utility.

Protected loads are those household items needing electricity to run that you'd rather not lose during a power outage. This usually includes things like your freezer, refrigerator, internet router, etc. If the load demand (the amount of electricity needed to run all those things) exceeds the available solar power, the SkyBox will buy power from the utility to cover the difference.

IMPORTANT:

This is the ONLY profile which functions correctly WITHOUT a battery installed.

When running in a standalone fashion (without a battery), the SkyBox operates like any other grid-dependent inverter. Solar power is produced, harvested, and sent to the utility while the utility is active (no power outage). During an outage, the SkyBox shuts down and no solar power is harvested.

When paired with batteries, the SkyBox keeps the batteries full. This ensures that when power goes out, your lights stay on for the maximum time. Ideally, your installer (or you, the installer) sizes the system so this maximum time is an entire night of protected loads. This assumes the sun is available the next morning and solar power takes over, allowing the battery to take a break.

This profile is best used when the utility is normally stable and only short interruptions are expected.

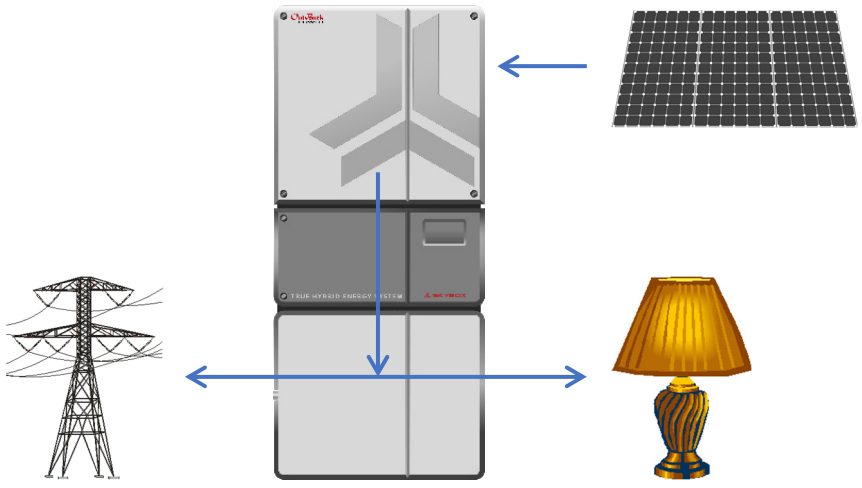

Figure 4 **Net Metering with Backup Power Flow**

Cycle That Battery (Self-Consumption)

Self-consumption is the best profile for those who have high energy rates and low return when selling power, but are still able to send power back to the utility. When this profile is selected, the SkyBox will harvest as much solar power as it can. After sending power to your protected loads, all extra power will be sent to the utility grid.

When the protected loads (freezer, refrigerator, etc.) need more power than the available solar power, the SkyBox uses the battery to make up the difference. The SkyBox drains the battery as long as solar power is less than the load demand until the battery reaches the ***Minimum SOC*** setting. At this point, the SkyBox stops draining the battery and makes up any power needed by buying from the utility.

Because you've told the SkyBox to 'zero' its utility use, the only allowed charging source for the battery is solar power. There are a few exceptions to this rule, but in this section we are only covering the main ideas. The exceptions are found in **Charging Source** on page 11.

Here's the ideal scenario for this profile. The battery reaches ***Minimum SOC*** sometime during the night and the loads are powered from the grid for a minimal amount of time. Once the sun rises and the array starts producing power, the SkyBox begins charging the battery. The battery only charges if the power needed by the loads is less than the available solar power.

The SkyBox will continue charging the battery until it reaches the ***Maximum SOC*** setting. The battery is not drained again until it reaches the ***Maximum SOC*** setting.

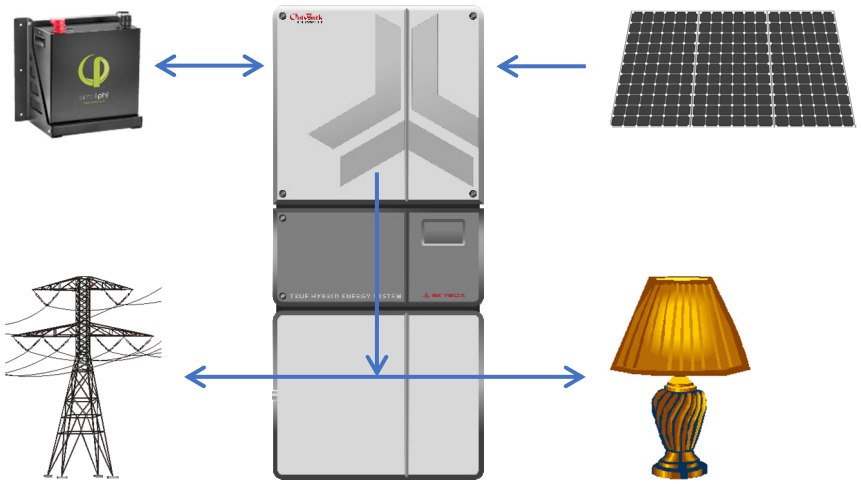

Figure 5 Self-consumption Power Flow

Don’t Sell (Non-Export)

The ***Non-export*** profile is best for systems in utility districts that do not allow power to be sold back to the utility. As the name implies, the SkyBox will not export any power when programmed in this profile. Unlike ***Net metering with backup*** and ***Self-consumption***, a SkyBox in ***Non-export*** only harvests enough solar power to meet the power needed by the loads. This means some power could be lost when loads are low and the sun is shining. Typically, this occurs during midday.

When the protected loads (freezer, refrigerator, etc.) need more power than the available solar power, the SkyBox uses the battery to make up the difference. The SkyBox drains the battery as long as solar power is less than the load demand until the battery reaches the ***Minimum SOC*** setting. At this point, the SkyBox stops draining the battery and makes up any power needed by buying from the utility.

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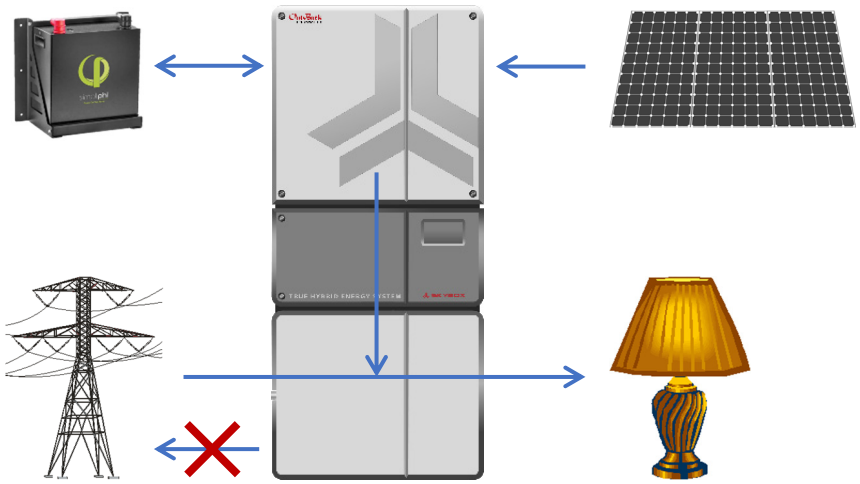


Figure 6 Non-export Power Flow

I Want To Be Off-Grid, But Not Really (Maximum Independence)

This profile should not be chosen without a lot of forethought. It is intentionally not included in the flow chart on page 5. The solar array must be sized appropriately to support both the average loads and battery charging simultaneously. The battery bank must be sized to support the loads overnight at the very least.

In this profile, the SkyBox physically disconnects from the grid and runs off solar power and battery alone until the battery reaches the ***Minimum SOC*** setting. At this point, the SkyBox re-connects to the grid and any loads are carried by the grid. Until the batteries reach 85% of the ***Maximum SOC*** setting, solar power will not contribute to the loads. The SkyBox disconnects from the grid once the battery reaches the ***Maximum SOC*** setting.

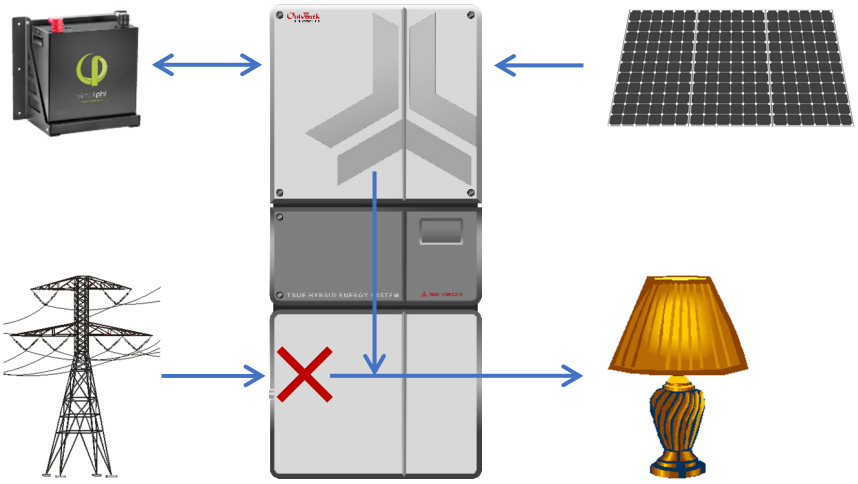


Figure 7 Maximum Independence Power Flow

Keeping Your Battery Alive and Well

IMPORTANT:

The minimum allowed battery voltage is 42 Vdc. The SkyBox will not connect to a battery below 42 Vdc. A battery discharged below this level must be charged from an external source.

Battery Types

Many batteries have been tested and are compatible with the SkyBox. Each choice in the drop-down menu loads the SkyBox with the correct charging voltages for each battery. All that is needed is to tell the SkyBox the number of paralleled items (strings) in the energy storage system.

Given the increasing popularity and variety of lithium-ion batteries now available, it is important to clarify the interoperability and safety considerations for pairing these batteries with OutBack Power inverters and charge controllers. Lithium-ion batteries present different safety risks and performance impacts than the lead-acid batteries many of our products were originally designed around. For this reason, OutBack Power has adopted a white-list approach to battery interoperability. The Compatible Batteries list (link 4) includes batteries that have been reviewed and tested by OutBack Power personnel and whose manufacturers have provided specific guidance on equipment settings and limitations. Use of batteries not on this list — including unlisted battery models from the same manufacturers — is at the risk of the installer and host site and may result in your warranty being void. This remains the case regardless of any technical advice or assistance that may be provided by OutBack Power, its personnel, or representatives.

Please refer to the application notes (link 5) and any manufacturer recommendations for recommended settings. Note that inclusion on this list does not constitute an endorsement of these battery products and that not all combinations carry the safety listings required by some permitting authorities.

PLEASE NOTE THAT OUTBACK POWER DOES NOT CLAIM RESPONSIBILITY FOR ANY DAMAGE DONE BY OR TO BATTERIES THAT ARE DEPLOYED USING THE INFORMATION FOUND IN THIS NOTICE.

What if you've chosen to add energy storage later? In this case, your system should be operating in ***Net metering with backup*** and your battery choice should be ***None***. This tells the SkyBox that no interaction is necessary with the battery and that no loads can be powered when there is a utility outage.

If you've chosen to use a battery that is not included in the pre-configured list, you'll need to read **Using My Own Custom Batteries** on page 18.

Charge Cycle

The SkyBox uses a three-stage charging method. The *SkyBox Programming Guide* provides a basic explanation of this process.

What you'll see on the SkyBox screen for ***Charge status***:

- ***Charger Off*** – No charge cycle triggered
- ***Bulk*** – Battery has reached re-bulk voltage or ***Minimum SOC*** or is currently charging up to absorb voltage
- ***Absorb*** – Battery has finished the bulk stage and is charging at the absorb voltage
- ***Float*** – Battery has reached re-float voltage or is currently charging at the float voltage

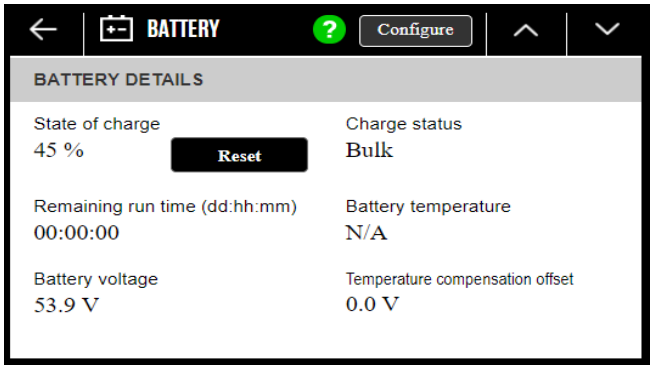


Figure 8 Battery Details Screen

Battery Temperature Compensation

Battery performance changes when the temperature varies above or below room temperature (77°F or 25°C). Temperature compensation is a process that adjusts battery charging to correct for these changes.

CAUTION: Hazard to Equipment

Temperature compensation should never be used with lithium batteries. Set the ***Temperature Compensation*** setting to 0 mV/˚C*cell.

The SkyBox, when equipped with the Remote Temperature Sensor (RTS), compensates for changes in temperature. To achieve a representative temperature, the RTS is attached to a single battery near the center of the bank. The SkyBox has a designated port for RTS installation. See the *SkyBox Quick Start Guide* for more information.

If you do not have the RTS installed, you will get a notification on startup. This is even true if you are using a lithium battery, which should not have the RTS anyway. This notification is there to remind the user that temperature compensation is specifically important for lead-acid batteries.

For an explanation of how temperature compensation works, see the *SkyBox Programming Guide.*

Charging Source

Let's walk through a charge scenario. Normally, you simply make solar power on your roof and send it to the utility. However, yesterday you had a power outage that lasted through the night. The SkyBox was great and you hardly noticed there was an outage. Now your backup battery (attached to the SkyBox) is sitting at 30% state of charge. It's a sunny morning and the power has been restored. The SkyBox begins charging your battery. If both solar power and utility power are available, the SkyBox uses solar power before trying to charge from another source (like the utility). This function is independent of the chosen grid use profile.

While the SkyBox normally prioritizes using solar power over the utility, there are certain conditions which prevent the SkyBox from using utility power at all to charge the battery.

- AC Profile is set to ***Self-consumption***, OR
- AC Profile is set to ***Non-export***, OR
- AC Profile is set to ***Maximum independence***, OR
- Charge limit is set to zero kilowatts

There are also certain times when the SkyBox uses power from *any available source* to charge the battery. This is usually to protect the battery.

- A manual charge cycle has been initiated, OR
- A low battery cutout event has occurred

Charge Cycle Initiation

Condition: Grid connected, battery at minimum state-of-charge (SOC)

If the SkyBox reaches the ***Minimum SOC*** setting while connected to the grid, the SkyBox initiates a recovery cycle. A recovery cycle stops the battery from discharging and begins to draw power from the grid for all loads. The cycle continues as normal (bulk, absorb, float), drawing power from the allowed source, until the ***Maximum SOC*** is reached. At this point, if the system is programmed to use the battery to support loads, it will begin discharging the battery. A user cannot manually stop a recovery cycle. See **Energy Arbitrage** on page 23 for more details on charging when using time-of-use.

Condition: Battery voltage goes below the re-float or re-bulk setting

Similar to the legacy products, battery voltage decreasing below re-float or re-bulk will not prevent the battery from discharging to support the loads. When the re-bulk or re-float set point is reached, ***Charge status*** will change from ***Charger Off*** to either ***Bulk*** or ***Float***. Once the battery is no longer required to support the loads, solar and grid power (if applicable) are used to charge the battery. A user can manually stop this cycle.

Condition: Battery state-of-charge reaches Minimum SOC, off-grid

If solar power is available, the SkyBox initiates a bulk stage and begins charging the battery from solar power and/or the grid. The SkyBox will not discharge the battery again to support the loads until it has reached 85% of ***Maximum SOC***.

Battery Charging Precautions

- A system fault causing the system to stop producing power will force the SkyBox to take its idle power (~200 W) from the battery.
- During a low battery cutout event, the ***Grid Charge Limit*** provides a protective feature allowing the battery to charge from any available source. Setting this limit to zero eliminates this battery protection. If an LBCO event occurs while the ***Grid Charge Limit*** is set to zero and no solar power is available, the battery will not charge, and will remain at ow voltage.
- Master inverter battery settings do not auto-populate to any other inverters. They must be set independently. See the *SkyBox Stacking Application Note* (link 6) for more information.
- Batteries will only charge from solar power when the available solar power exceeds load demand.

Harnessing the Sun

SkyBox can harvest up to 5 kW of power from a solar array and send this power to the battery, your home, the utility, or any combination of these three places.

Usually, you will see the SkyBox ***Producing*** on the solar tile. At night, or when the sun is exceptionally weak, the SkyBox home screen will display ***Sleeping*** on the solar tile. The SkyBox "wakes up" once the array voltage reaches 250 Vdc. At this point, it runs three self-tests to ensure it is safe to connect to the array. If you stand next to the SkyBox during these tests, you'll hear the PV relay click closed and open again. The descriptions of these tests can be found in **PV Self-Tests** on page 26.

Once the self-tests have passed, SkyBox closes the PV relay. On the SkyBox home screen, the **SOLAR** tile changes to a yellow bar with the title ***Sweeping***. To "sweep" the array means the SkyBox searches for the voltage point where the most power is produced. While it would seem like this would be the highest voltage, it's usually not. The "maximum power point voltage" is closer to the middle of the voltage range for the array. Since the SkyBox is looking for the most power throughout the whole range of voltage, you'll see the power displayed on the home screen go up and down. This operation occurs when one of the following conditions is met:

- Solar startup (morning)
- Forced (button push)
- Every hour off-grid if a 200 W or more deficit exists between PV and load
- If significant change to the maximum power point occurs while on-grid

In most applications, SkyBox continually harvests as much solar power as it can to provide power to the loads and to charge the battery. However, when operating in ***Non-export*** or off-grid (grid relay is open), the SkyBox only harvests as much power as necessary. In either of these cases, if you have a 5 kW array and the day is sunny, but you only have 500 W of load with a full battery, SkyBox will only produce 500 W of solar power. This means the array is not under producing, it is just being under-utilized.

Solar Gotchas

Many installers who have used OutBack Power products in the past are very familiar with how to set up an array for a charge controller and inverter system. However, since the SkyBox is a completely different platform these rules no longer apply. The SkyBox needs to be treated as a brand new system.

Two commonplace items CANNOT be used on a SkyBox array: optimizers and lightning arrestors or other surge protection. Both of these hardware items can cause interference with the IRD and AFCI self-tests (see **PV Self-Tests** on page 26). This completely prevents the SkyBox from connecting to the solar array.

Maximum Power Point Tracking

Maximum power point tracking (MPPT) is the technology used by the SkyBox to optimize the harvest of power from PV arrays. At this time, SkyBox only supports one MPPT array. This just means you can't have two different arrays facing in completely opposite directions connected to the SkyBox and expect to get full power out of either.

Computer Stuff

You're on vacation, relaxing by an alpine lake and your buddy (who somehow has internet access on his phone way out there) tells you there was a big storm back home and no one has power. What now?! Is your SkyBox running? What about that refrigerator and freezer full of food in the garage? Enter OPTICS RE, the OutBack Power remote monitoring system.

OPTICS RE allows system installers and owners to monitor and control system settings from any internet connected device. This means you could use your buddy's phone at that alpine lake to make sure your SkyBox is keeping that freezer supplied with power.

Setting Up Your OPTICS RE Account

The first step in setting up your OPTICS account is actually connecting the SkyBox to your home network. The wiring steps are outlined in the *SkyBox Quick Start Guide*. In a nutshell, connect a CAT5 cable to the **WALL** port in the SkyBox and plug the other end into your router. You'll know if this was successful or not by the color of the ethernet icon **A** as shown in Figure 9. Black indicates a good connection, yellow a partial connection, and red is no connection.

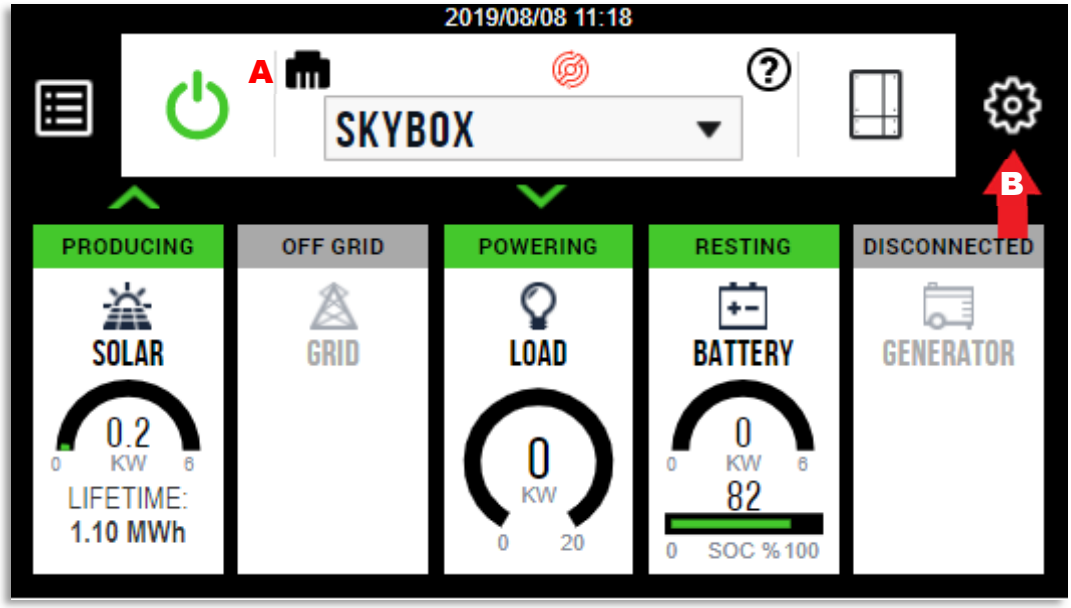


Figure 9 Home Screen

Step 1: Once your SkyBox is connected to the internet, locate its MAC address.

A. Press the settings button, which is the gear wheel **B** shown in Figure 9.

B. Navigate to the **Network** tab.

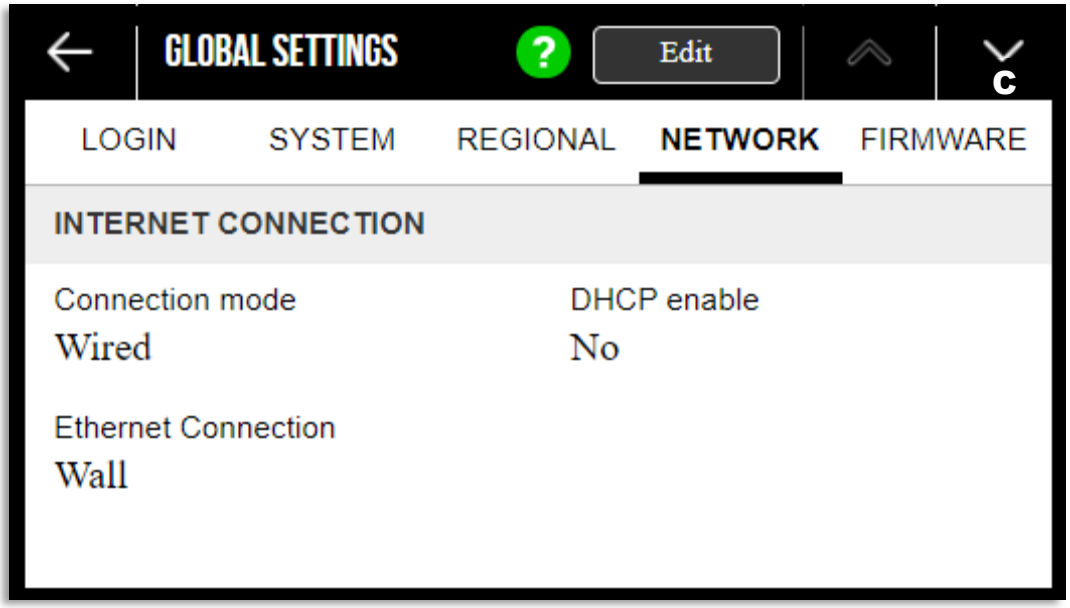


Figure 10 Network Tab

C. Using the down chevron **C** in Figure 10, page down three times. You should arrive at the screen below. OPTICS RE is enabled by default. Write down the ***Mac Address*** (**D** in Figure 11).

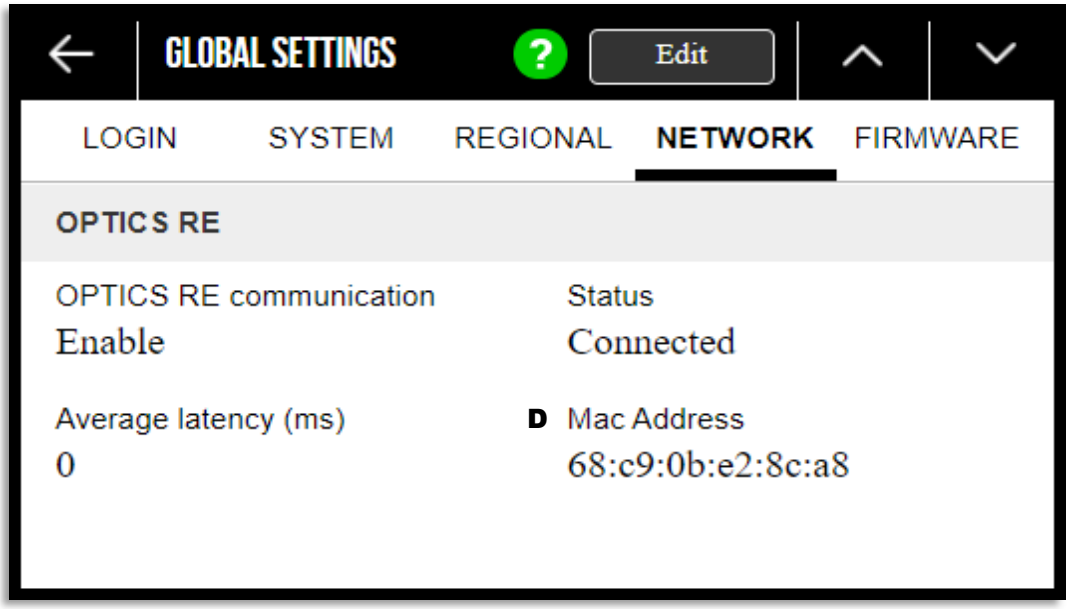


Figure 11 MAC Address

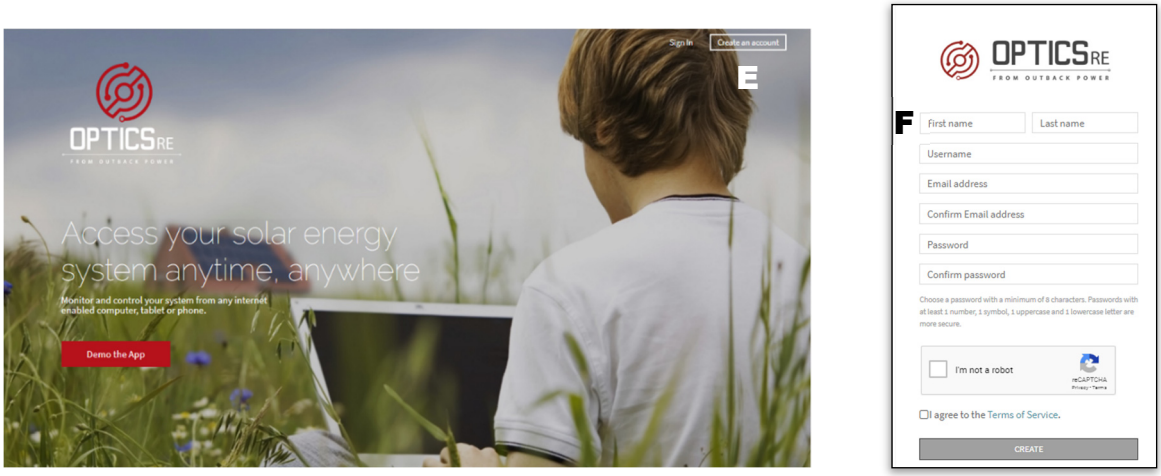


Figure 12 OPTICS RE Account

Step 2: Creating an Account

Create an account to be able to log in. From www.opticsre.com, click **Create an Account**. See **E** in Figure 12.

Step 3: Creating a Profile

Create a profile to monitor a specific site or system. (See **F** in Figure 12.) Once signed into the account, click **Add a System**. Follow the on-screen wizard. Completing this section requires the MAC address from Step 1.

After entering the MAC address, you will be asked to name a profile, site, and system.

A profile is the highest level container which is managed by a profile administrator. Each profile can have any number of sites underneath it. A site is a physical location that can have any number of systems underneath it. A system is the lowest level classification and is a specific group of OutBack devices working together.

Step 4: Monitor Your SkyBox

Now that your system is all set up, you can monitor your SkyBox from anywhere. Figure 13 shows an example of an OPTICS RE SkyBox system. More information is available through the OPTICS RE Knowledge Base.

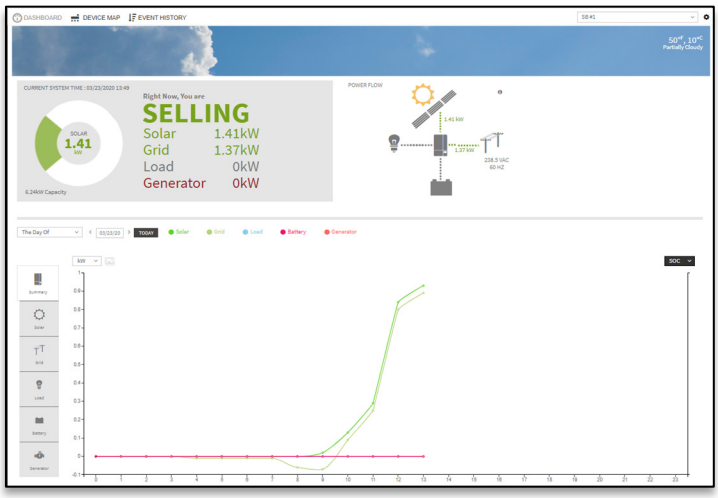


Figure 13 SkyBox on OPTICS RE

The Nitty Gritty

This section is geared toward those installers and homeowners who are thoroughly familiar with the previous section. In this section, we'll use a few acronyms and technical terms the reader is assumed to know and understand. If you're still learning about solar plus storage and/or the SkyBox, make sure you've read the previous section. If you're an installer, it wouldn't hurt for you to have installed a few basic SkyBox systems before continuing through this Handbook.

More Power Please

What if 5 kW just doesn't cut it for your site? With proper planning, two SkyBoxes can be linked to work together to provide up to 10 kW of power. We call this stacking. Two SkyBoxes can be stacked. If you find you need more power than this, contact OutBack Sales (link 7) before proceeding.

In this configuration, one SkyBox acts as the 'leader' and one as the 'follower'. The master is in charge of the system's overall behavior when operating off-grid (power outage, the ***Maximum independence*** profile, etc.). Each SkyBox acts independently when operating on-grid. The *SkyBox Stacking Application Note* describes more details.

What About This Inverter I Already Have? (AC Coupling)

While AC coupling is not the most preferred use for the SkyBox, or any battery-based inverter, it is possible to link your old grid-dependent inverter with the SkyBox.

So, what happens when these two devices work together? In normal day-to-day operations, not much changes. Your old inverter continues to produce solar power from the existing array and send it to the grid, albeit now the power is routed through the SkyBox. The SkyBox also produces power from its own solar array (if installed).

The biggest change comes when the utility goes down. Previously with just a grid-dependent inverter, if the power went out, so did the grid-dependent inverter. Even though the sun could still be shining, no power was being produced because there was no safe place to send it. Now, when the utility goes down, the SkyBox fakes the grid-dependent inverter into thinking the utility is still operational. The grid-dependent inverter continues on its way, making power from the solar panels and sending it through to "the grid", which is really the SkyBox. The SkyBox takes this power and sends it either to the protected loads, uses it to charge the battery connected to the SkyBox, or both.

The ability to AC couple with grid-dependent inverters is inherent in the SkyBox firmware (with version 1.4.15 and later). More details along with a wiring diagram can be found in the *SkyBox AC Coupling Planning Guide* (link 8).

It’s Cloudy, My Batteries Are Dead, and the Power is Out – What Now? (Using a Generator)

The SkyBox accepts generator input when needed; however, it doesn’t accept every generator at every time. The SkyBox is picky and wants a generator that produces a (mostly) smooth waveform.

The best way to describe the operation is with an example. Let’s say that it’s night, your batteries have been taxed by a cloudy day, the power has been cut off by the utility, and you have several heavy loads running. The generator-start function recognizes the need to start the generator in order to conserve the batteries. The SkyBox sends a signal to a starting circuit on the generator. The generator starts and spins up to the rated voltage and frequency. The SkyBox closes the generator relay as long three conditions are met: 1) the grid relay is open, 2) the generator voltage and frequency are within tolerances, and 3) PV is not running all the loads. Once all conditions are verified, it closes the generator relay. Generator power is directly connected to the loads.

Next, the SkyBox wants to charge the batteries. You have configured it so that it can use generator power to charge if needed. There are more conditions here. In order to charge the batteries using generator power, the SkyBox must sense at least 4 Aac (~500 to 600 W) on its load port. PV cannot be present.

- The load ensures the generator waveform has been dampened enough for the SkyBox to connect without risking any damage.
- If PV is present, the SkyBox will use the generator to power the loads and use PV to charge the batteries.
- These items mean that no mixing of generator power and solar power is allowed.

The example shows the conditions that need to be met for the SkyBox to connect to a generator, but how do you start the generator in the first place? The SkyBox uses a function called ***Advanced Generator Start*** (AGS) to control the starting and stopping of the generator. To read up on AGS, see the applicable section in the *SkyBox Programming Guide*.

If you’ve chosen to manually start the generator, but have AGS configured, know that AGS will never stop a manually started generator. Just remember that if you start it, you also have to stop it.

Using My Own Custom Batteries

Okay – great! The SkyBox is compatible with many batteries, but you’ll need to track down all the information about your battery before connecting it to the SkyBox.

Given the increasing popularity and variety of lithium-ion batteries now available, it is important to clarify the interoperability and safety considerations for pairing these batteries with OutBack Power inverters and charge controllers. Lithium-ion batteries present different safety risks and performance impacts than the lead-acid batteries many of our products were originally designed around. For this reason, OutBack Power has adopted a white-list approach to battery interoperability. The Compatible Batteries list (see link on page 18) includes batteries that have been reviewed and tested by OutBack Power personnel and whose manufacturers have provided specific guidance on equipment settings and limitations. Use of batteries not on this list — including unlisted battery models from the same manufacturers — is at the risk of the installer and host site and may result in your warranty being void. This remains the case regardless of any technical advice or assistance that may be provided by OutBack Power, its personnel, or representatives.

Please refer to the application notes and any manufacturer recommendations for recommended settings. Note that inclusion on this list does not constitute an endorsement of these battery products and that not all combinations carry the safety listings required by some permitting authorities.

PLEASE NOTE THAT OUTBACK POWER DOES NOT CLAIM RESPONSIBILITY FOR ANY DAMAGE DONE BY OR TO BATTERIES THAT ARE DEPLOYED USING THE INFORMATION FOUND IN THIS NOTICE.

Some ground rules before we start talking about the custom settings:

- The voltage range on SkyBox is 42 to 60 Vdc. That's it. Nothing more, nothing less.
- If your battery needs to speak with the inverter in order to operate, too bad — SkyBox only talks with compatible batteries from the list on the website. (See the link on page 10.)
- All lithium batteries require careful programming to avoid over- or undercharging.
- OutBack Technical Support cannot assist you with programming values that are not available in the list. We will point you back to the battery manufacturer, so you might as well just start with them.

Now that the ground rules are out of the way, let's talk specifics. First is the low battery cutout (LBCO) set point. This setting should be the voltage equivalent of a completely empty battery. Why? Because the SkyBox uses the LBCO value to define 0% state-of-charge (SOC).

If LBCO is set too high, the battery will reach LBCO well before it actually reaches 0% SOC. The SkyBox will assume the capacity has decreased and recalculate the SOC accordingly. Over a few cycles, this can result in the SkyBox only using a fraction of the energy available to it and cutting off power to the loads prematurely. A similar result is seen when the ***Battery amp-hours per string*** or the ***Number of strings*** are set incorrectly.

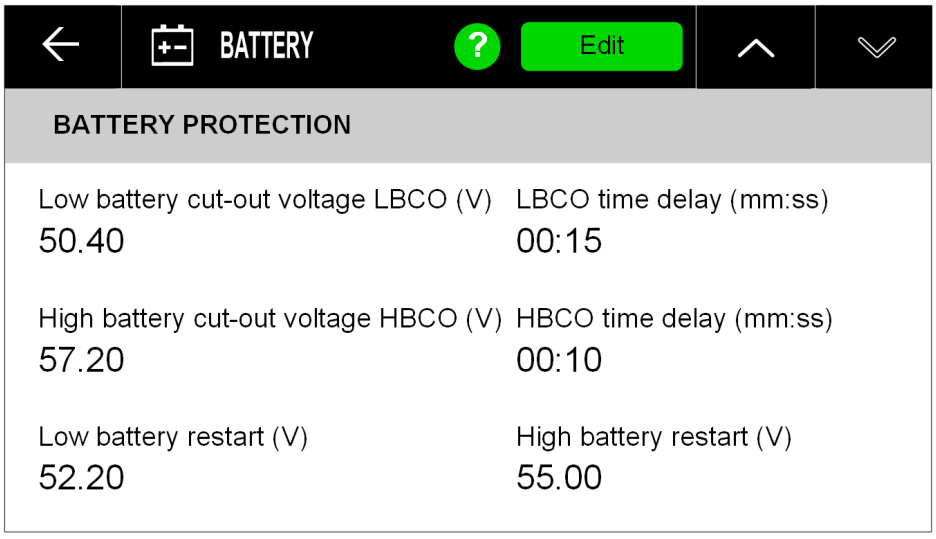


Figure 14 Battery Protection Settings

Next, pay special attention to the charging parameters. If one of these is set incorrectly, it throws off the whole system and you'll see red lines and error messages.

The equalize voltage should be the highest in value or at the very least, equal to absorb. If your batteries are not supposed to be equalized, then set the EQ voltage equal to the absorb voltage for safety. The absorb voltage should be followed by float, re-float, then re-bulk voltages. If one of these voltages is out of order (say re-bulk higher than re-float), you will either not be allowed to save your changes, or the system will auto-correct the voltages to a different value than you had set.

Protection level voltages should be set so that LBCO is the lowest voltage and HBCO (high battery cut out) is the highest voltage by at least 1 volt from any charging value. This will ensure there are no conflicts in the system.

Aux Terminals and Rapid Shutdown

The SkyBox has a 12-volt output and a normally open (NO) auxiliary relay. Either can be configured for AGS or rapid shutdown. The 12-volt output and relay operate independently of each other.

Configuring the auxiliary terminal for AGS does not mean that rapid shutdown is no longer enabled. The rapid shutdown function in the SkyBox is dependent on the connection between the auxiliary terminals 4 and 12. (See the link to the *Quick Start Guide* on page 4 and refer to item 12 in the **Wiring** section.) When rapid shutdown is selected as an auxiliary function, the SkyBox activates either the output or the relay when it senses a rapid shutdown command.

Rapid Shutdown Options

You have two basic options when setting up a SkyBox to comply with the rapid shutdown requirements of the NEC 2017: The IMO FireRaptor and the Tigo TS4-S. OutBack Power has tested both the FireRaptor and the TS4-S successfully.

Both options work with the OutBack Rapid Shutdown Initiator (RSI) and individual modules attached to each panel in the array. If the main power goes out, the FireRaptors or TS4-S modules lose power and shutdown the power of the array. The SkyBox senses this loss of continuity at its rapid shutdown terminals (pins 4 and 12) and discontinues operations until the condition is cleared. Wiring diagrams and a more in-depth explanation can be found in the *SkyBox Rapid Shutdown Application Note*.

Modbus Controls

If you would like to connect to the SkyBox using the SunSpec protocol, please contact OutBack Power Sales.

External CTs

External current transducers (CTs or XCTs) are used with the SkyBox to monitor a combined input from the utility. When installed and programmed into SkyBox, this moves where the SkyBox senses the utility. Good news for you! This means you can support your normal, unprotected loads and still not export power to the utility. Also, if the main panel is not right next to the SkyBox, you can extend the total length of the CT leads up to 10 meters.

An installation document, the SkyBox XCT Install Guide (link 9), is available with more details.

How does the SkyBox know what loads are protected and what loads are not? Let's look at an example.

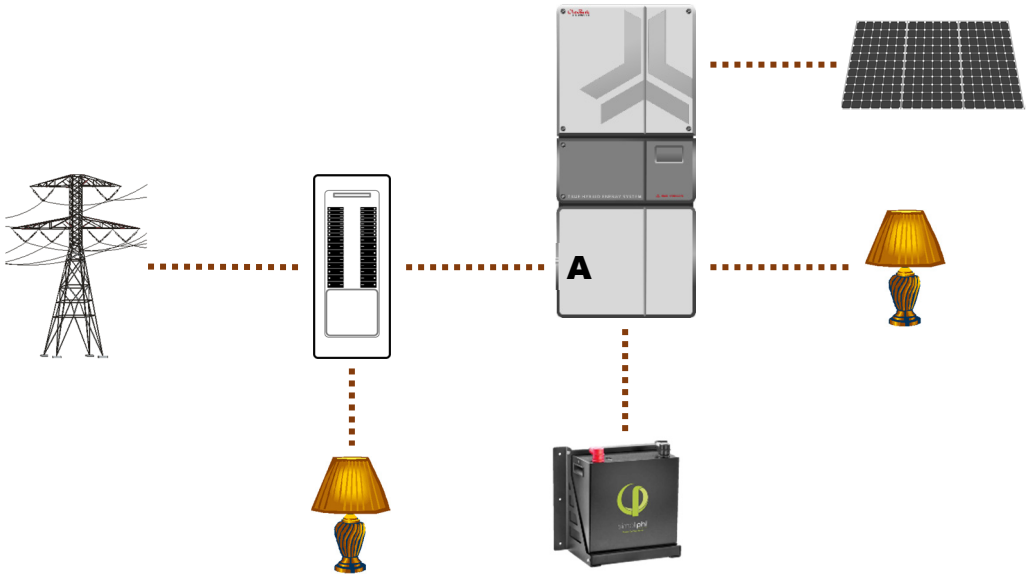


Figure 15 Standard SkyBox Block Diagram

In Figure 15, the SkyBox senses power coming from and going to the grid at location **A**. In this figure, it is the physical connection which we'll call the grid port. This is the connection to the main service panel, located inside the wiring compartment of the SkyBox. When configured for the ***Non-export*** profile, the SkyBox changes its power usage so that no power goes out from the inverter to the utility through the grid port. When in the ***Self-consumption*** profile, the SkyBox minimizes power coming *in* through **A** but *does not* limit any power going *out*.

With external CTs installed, the sensing location **A** moves. Now the grid port is irrelevant and the SkyBox manipulates power at the CT location. See Figure 16.

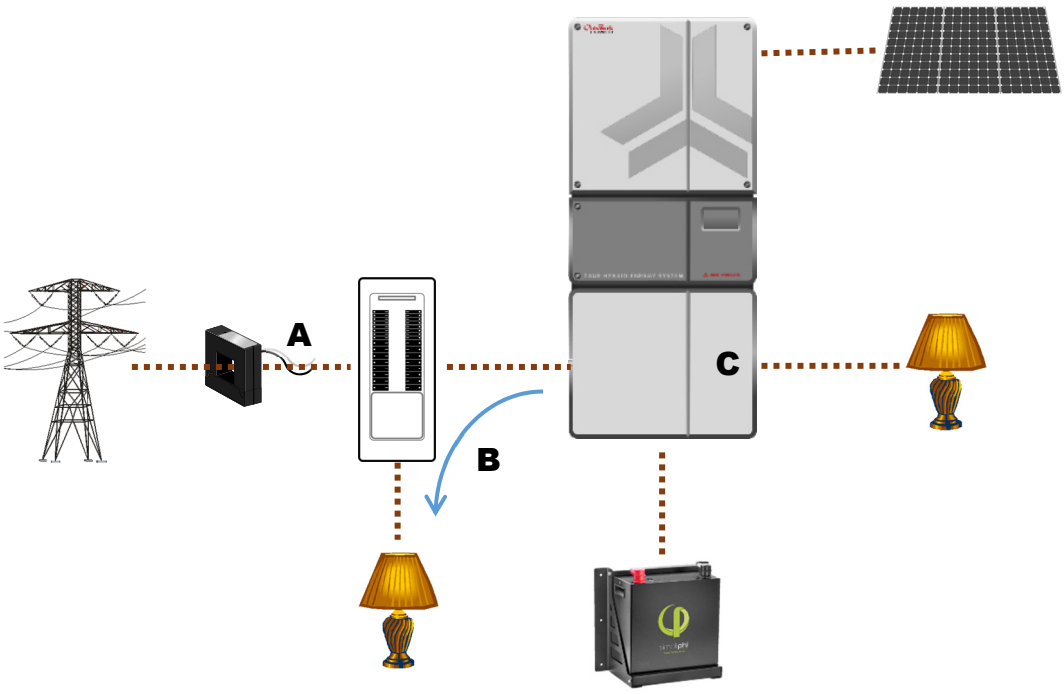


Figure 16 Skybox Block Diagram with External CTs

In Figure 16, when the SkyBox minimizes utility power coming into the system, it minimizes the power coming into the house, rather than just the SkyBox itself. Because **A** is now located at the main grid input, the SkyBox knows how much power is coming into the whole home. It can supply battery power through the grid port to the unprotected loads (**B**) without sending that power to the utility. Some installers may call this 'selling the battery', but no power is actually being sold or going to the utility in any way.

Using the CT location measurement, the grid port measurement, and the load port measurement (located at **C**), the SkyBox determines a ***Total Combined Load*** value. This value is displayed on the **LOAD** tile. If you tap on this tile, the SkyBox shows you the values broken into unprotected and protected loads. Protected loads are measured at **C**. In general, whatever is not measured going out of the load port is considered an unprotected load.

10

Energy Arbitrage

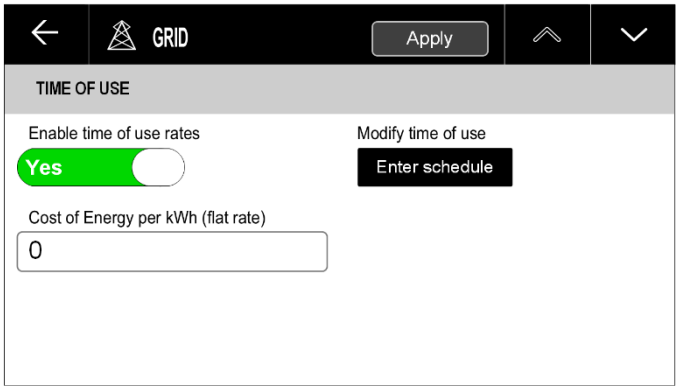
(aka: I just want my utility bill to shrink already!)

Time of Use

The time of use (TOU) function in the SkyBox is meant for those in areas with energy rates that go up and down depending on the time of day. Mostly, these expensive times are when you're most likely to be home — a few hours in the morning and several in the evening. This function allows you to use the utility power when it's cheap and use your battery when utility power is expensive.

How does the SkyBox know what your utility rates are? How about the cost of your battery? Unfortunately, the SkyBox isn't quite so advanced that it can read your mind so … you have to tell it these things.

When configuring the SkyBox for time of use operation, the best AC profile is ***Net metering with backup***. Then, you'll want to make sure the ***Enable time of use rates*** toggle is set to ***Yes***. Once this is done, you'll have access to the schedule. At first, this is presented as 32 blank schedule blocks, the first of which is shown in Figure 17. Don't worry! You only need to fill as many as you need. The rest are ignored.



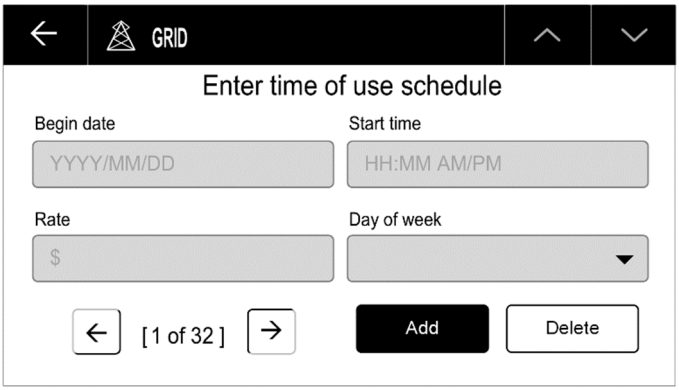


Figure 17 Time of Use Settings

NOTE:

You could read the following paragraph and look through all the equations to understand this function. Or you could watch a four minute video (link 10) on the WattSchool YouTube channel.

Start your schedule with midnight as the start time, then build the rest of your schedule from there to midnight again. Apply all changes. Navigate back to the grid configuration menu by using the back arrow. This will bring up a message asking if you want to discard any (unsaved) changes. Select yes. In this case, you don't have any unsaved changes once you hit save on the individual schedule block.

The last piece of information the SkyBox needs from you is the cost of your battery, or more accurately, the cost of using your battery. This is the ***Levelized Cost of Energy*** (LCOE) value. Here's the formula:

$$\frac{LCOE}{kWh} = \left(\frac{Total\ Cost\ of\ Batteries}{Number\ of\ Batteries \times Battery\ Capacity \times Lifetime\ Cycles \times Efficiency}\right)$$

Equation 1 LCOE

If you're not familiar with this style of equation, an example should help. The best way to ensure you have the right values plugged in is to make sure your units come out correctly. The academic term here is unit analysis. If you can, you should always do this type of analysis. It will save you from doing all of your work in kilowatts (power) just to realize you should have been in kilowatt-hours (energy) the whole time!

Example

Consider the system below:

- (3) 48V lithium batteries in parallel
- Each battery has a capacity of 8 kWh per cycle
- Each battery has a cycle life of 7500 cycles
- From the datasheet for the batteries, the efficiency is 98%.
- This setup cost me $30,000 which included the batteries themselves, the electrical materials, and the cost of the installation.

$$\frac{\$30000}{\text{bank}} \cdot \frac{\text{bank}}{7500\ \text{cycles}} \cdot \frac{}{3\ \text{batteries}} \cdot \frac{\text{battery*cycle}}{8\ \text{kWh}} \cdot \frac{}{98\%} = \$0.17/\text{kWh}$$

Calculation 1

And now make sure that all the units cancel so the equation ends with dollars per kilowatt-hour.

$$\frac{\$30000}{\text{bank}} \cdot \frac{\text{bank}}{7500\ \text{cycles}} \cdot \frac{}{3\ \text{batteries}} \cdot \frac{\text{battery*cycle}}{8\ \text{kWh}} \cdot \frac{}{98\%} = \$0.17/\text{kWh}$$

Calculation 2

Now that you have told the SkyBox how expensive things are, and at what time, the SkyBox compares the value for each grid rate to the LCOE value. When the grid rate is cheaper, the SkyBox operates in the ***Net metering with backup*** profile, meaning power for the loads is taken from the grid when solar power isn't enough and the battery is not used. When the grid rate is more expensive than the battery, the SkyBox operates in the ***Self-consumption*** profile. This change in profile is only done internally. The display will continue to say ***Net metering with backup*** for the profile. Here's a visual representation of this concept:

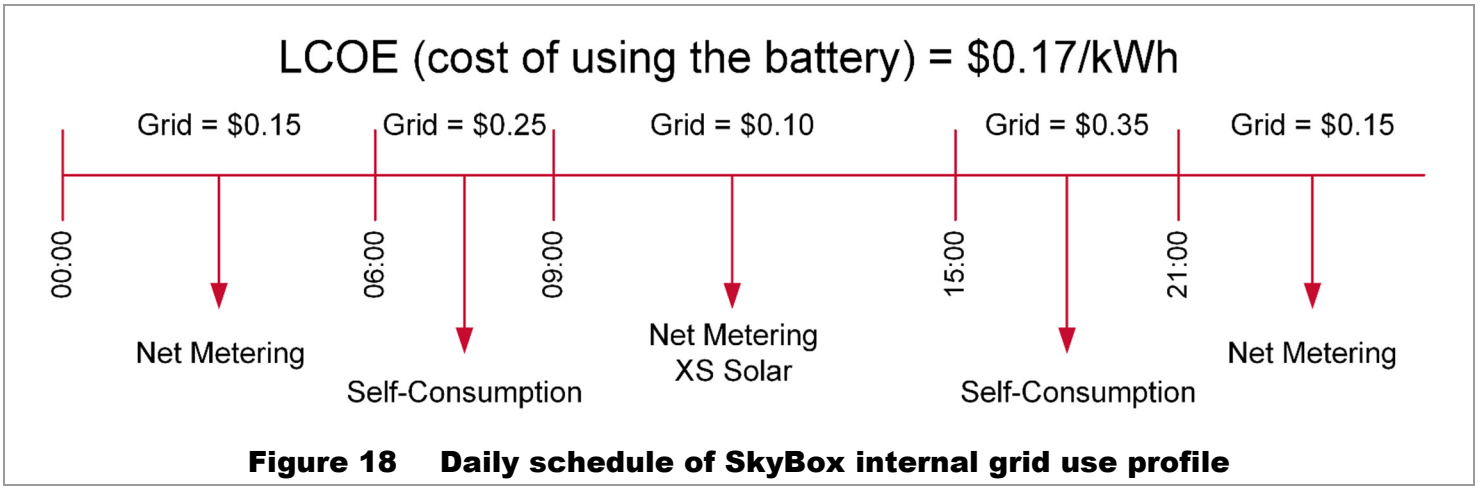


Figure 18 Daily schedule of SkyBox internal grid use profile

If you've read **The Power Grid and You** on page 6, you would know that normally, when SkyBox is set to the ***Self-consumption*** profile, the battery will reach ***Minimum SOC*** and stop providing power to the loads until it is fully charged at ***Maximum SOC***. This is not the case with the profile ***Net metering with backup*** and the TOU function. Figure 19 shows an illustration of this concept. ***Self-consumption*** is represented by the red time blocks.

In the scenario below, the battery is discharged during the 06:00 – 09:00 timeframe and reaches ***Minimum SOC*** before the rate change. All loads in excess of the solar power produced are carried by the grid. The battery remains at rest until the rate changes, then it begins charging using grid power at the ***Grid Charge Limit***. The battery remains below the ***Maximum SOC*** during the 09:00 – 15:00 timeframe. When the grid rate changes again at 15:00, based on the way ***Self-consumption*** works, you would think the battery would remain at rest until it is charged. Not so. The internal command telling the SkyBox not to discharge cleared at 09:00 when the internal profile changed to ***Net metering with backup***. This is visible at the end of the first red time block in Figure 19.

If programmed correctly, the SkyBox discharges the battery during the times when utility power is more expensive than the battery. The battery charges from solar or utility power when allowed and when the utility power is less expensive than the battery. Once the utility power is expensive again, the battery discharges to support the loads regardless of the state of charge and if the previous charge cycle was completed.

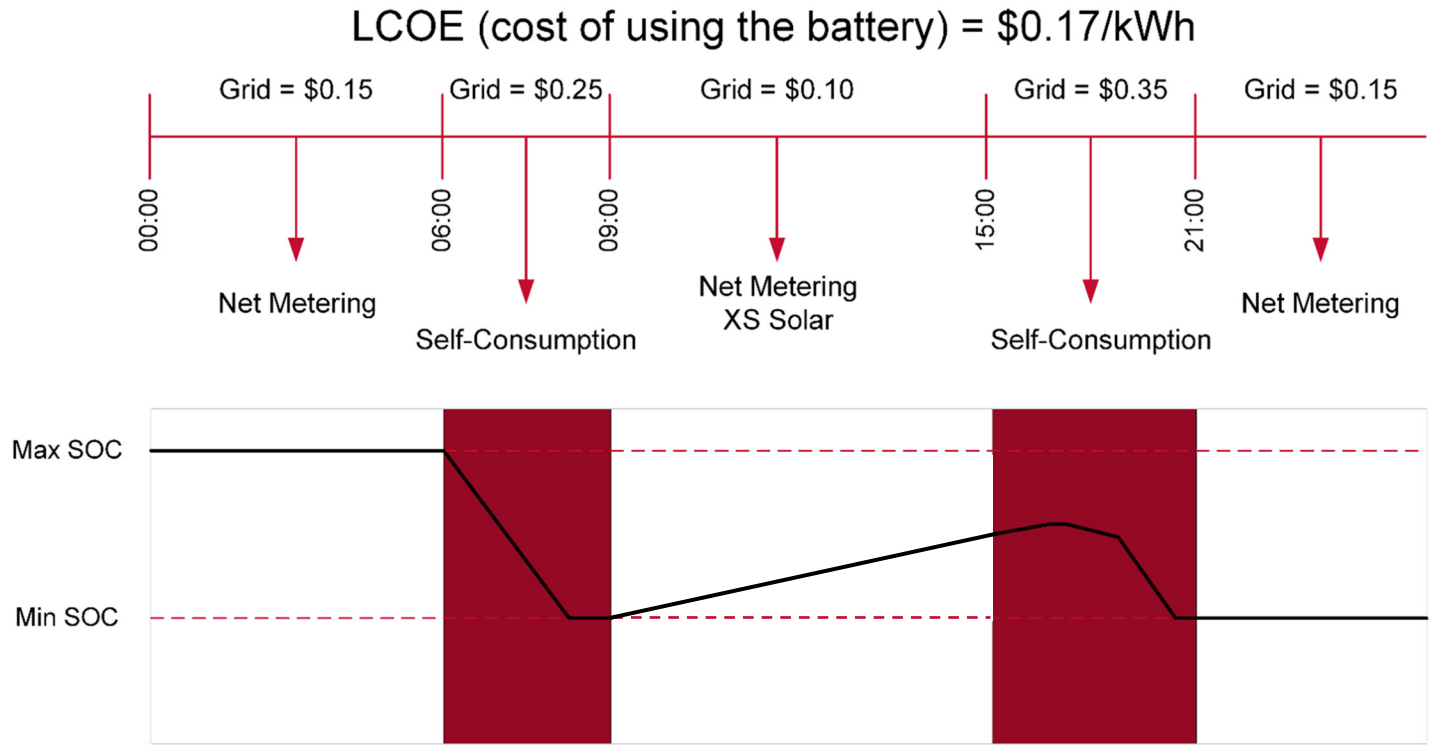


Figure 19 Daily schedule and visual of battery SOC

NOTE:

The SkyBox does not check your actual grid rates, your actual TOU schedule, or your LCOE. Feel free to adjust any of these three parameters to tailor the SkyBox's energy arbitrage to your situation and make the best use of the components you have installed.

The Catch-All Section

This section contains miscellaneous information.

PV Self-Tests

NOTE:

A failed self-test DOES NOT mean that a ground fault or arc fault has occurred. A failed self-test indicates the circuit is not functioning properly.

There are three separate self-tests SkyBox runs before beginning PV production.

1. Ground Fault Self-Test. This tests the ground fault detection/interruption (GFDI) circuit for proper function. A failed test alert would show as ***SC - PV GFDI Self-Test Failed***.
2. Arc Fault Self-Test. This tests the arc fault circuit interruption (AFCI) circuit for proper function. A failed test alert would show as ***SC - PV AFCI Self-Test Failed***.
3. IRD Test. This tests for PV input line impedance imbalance. If the array is grounded, intentionally or not, this test will fail. A failed test alert would show as ***SC – PV Impedance OOR***.

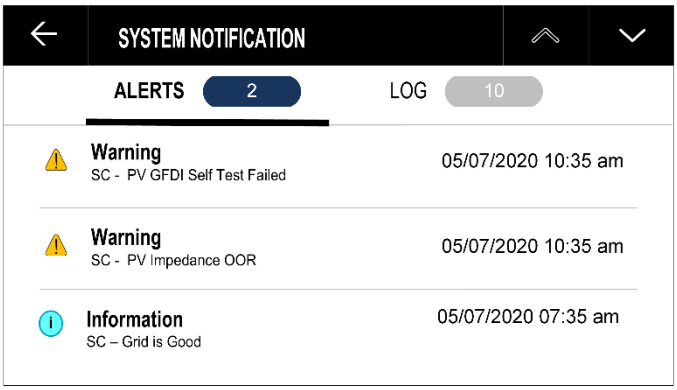


Figure 20 PV Self-Test Failure Alert

The GFDI and AFCI self-tests DO NOT test the array for a ground fault or an arc fault. These self-tests verify the operability of the detection circuits. If a self-test fails, there may be an issue with the detection circuit.

If any of these tests fail and you wish to re-run the tests, cycle the PV disconnect switch open then shut. The tests should re-run automatically. If not, under the **P V** tile, three pages down, a manual button can be found for each individual test.

Sometimes, other equipment may interfere with the self-tests and cause them to fail. The IRD test, for example, may fail due to an excessive marine layer or rain. This specific test is very sensitive and will automatically re-test after the array voltage increases by 15 Vdc.

All PV faults are persistent through power cycles. This means power cycling the unit will not clear the fault. For instance, if you find the fault in the evening, the fault can't be cleared until the following morning when PV voltage is present and greater than 250 Vdc.

NOTES:

Troubleshooting

The table below shows the most common errors installers and homeowners run into when working with the SkyBox.

Table 1

Symptom	Fault Code	System Type	Possible Cause	Possible Remedy
Impedance self-test failed	PV – 1024	Any	Array is grounded.	PV array must be floating for SkyBox to harvest power. Check voltages from PV+ to ground and PV- to ground with array disconnected from the SkyBox to start the isolation process.
Arc fault active on startup	PV – 64	Any	Arc fault cable from BOS has not been connected to inverter.	Connect the arc fault cable to inverter. See *Quick Start Guide* **Wiring** section, item 9.
			Optimizers or other electronics are connected to the array.	Disconnect any extra equipment from the array.
Rapid shutdown active	PV – 4	Any	Rapid shutdown device or jumper (between pins 4 and 12) have not been installed.	Check connection between pins 4 and 12. Install device or jumper as needed. See *Quick Start Guide* **Wiring** section, item 12.
On/Off button red, no AC output, will not accept AC input		AC source (grid or generator)	Rapid shutdown device or jumper (between pins 4 and 12) have not been installed.	Check connection between pins 4 and 12. Install device or jumper as needed. See *Quick Start Guide* **Wiring** section, item 12.
On/Off button green, but unit is not inverting		Any	***Units installed*** vs. ***Units detected*** do not match.	Verify ***Units installed*** number. Change as necessary to match ***Units detected***.
Blank screen, unit unresponsive, battery voltage present		Off-grid	Insufficient 'bootstrap' voltage.	SkyBox requires 44 Vdc or more before it can function. Check voltage.
			Battery related internal fault.	Cycle all power and restart.
			Surge load related internal fault.	Remove likely loads, cycle all power, and restart.
PV tile displays ***Waiting***		Any	Grid timer has not expired.	Wait until timer expires.
			In non-export with <200W of load.	Increase loading or change AC profiles.
			Unit is faulted or off.	Ensure the **On/Off** button is green. If it is black, turn the unit on. If it is red or yellow, troubleshoot the fault listed in the event logs.
Alert message: ***SC CAN Communication Failure***		Any	Disruption in internal communications.	If the unit does not automatically recover, contact Technical Support (link 11).
Alert message: ***Non-recoverable fault***		Any	Hardware fault or fault during battery to load only.	Cycle power to the unit. Numbers generated during error message will correspond to messages in event logs.
Slow display speed		Any	Display processing error.	Cycle power to the unit by opening all breakers. Allow the screen to go blank before restarting.
Screen freezes		Any	Display processing error.	To recover, press and hold anywhere on the screen and hold for 30 seconds.
Network failed to initialize		Any	Ethernet was disabled during initial Setup Wizard	Contact Technical Support (link 11).

Low charge rate	Any charging source	Charge complete or nearly complete	Check DC voltage and charging stage.
		High temperature	Performance is derated in higher temperatures. Allow SkyBox to cool, or apply external cooling.
		High loads	If total loads and charging exceed the AC input and PV sources, the charge rate decreases to give priority to the loads. Turn off some loads and test the charging rate again.
Will not charge	Generator source	Requires minimum 4 Aac load before charging can occur	Apply load to SkyBox.
		Will not use generator to charge if PV power is already charging	No action required.
No AC output, will not accept AC input	AC source (grid or generator)	Unit turned off	Make certain the **On/Off** button is set to ON.
		Rapid shutdown has occurred	Check **ALERT** messages and Rapid Shutdown Initiator.
	No batteries	AC source does not meet requirements	Check the AC source (voltage, frequency, and other factors).
Will not connect to AC source	AC source (grid or generator)	AC source does not meet requirements	Check the AC source (voltage, frequency, and other factors).
	Generator source	Grid source is present	SkyBox will not connect to the generator if grid is present.
	Grid source	Connection timer is still running	Wait for timer to expire (**GRID** tile reads ***Waiting***).
		Use Grid set to ***DROP***	Set to ***USE***
		Programmed disconnection (due to time of day, operating mode, or other priority)	Adjust programming as needed (requires login).
Will not sell	Grid source	Batteries still charging	SkyBox will not sell while the charger is active and all available solar power is used to cover the loads and charging. Wait until the charge cycle is complete, then try again.
Reduced selling	Grid source	***Sell limit*** set too low	Adjust setting as needed (requires login).
		Power used for other purposes	Power must supply loads (self-supply) and batteries before being sold. Check loads and all **Tile** readings.
		Limited PV size or conditions	Check solar conditions or PV voltage.
		High temperature	Performance is derated in high temperatures. Allow SkyBox to cool, or apply external cooling.
Loads interrupted upon transfer	AC source (grid or generator)	Erratic AC source voltage	Check input AC voltage. If not consistent, the problem is external. AC source voltage may have dipped to a low enough point to disrupt loads before the inverter could take over.
		Loads are sensitive to transfer time	SkyBox features a small but noticeable response time during transfer. Some devices may require an uninterruptible power supply (UPS). Consult the manufacturer of that device for backup power requirements.
		Loads are too large	SkyBox can pass through more power than it can invert. Reduce load size.
		Undersized battery cables	Battery cables smaller than recommended will cause a significant voltage drop when switching to batteries, acting like either an overload or a low-voltage condition. Size all cables correctly.

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