



**we share  
solar**

## **Solar Energy Learning Guide**

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EMPOWERING EDUCATORS & STUDENTS TO

*Light the World*



Energy that comes from the sun is called **Solar Energy**. Solar energy helps to grow plants, dry clothes, heat water, warm homes and it can also be captured by solar panels which convert the solar energy into *electricity*.

**Electricity** is the movement of electrons from atom to atom. **Atoms** are the smallest unit of matter. **Electrons** are negatively charged particles that spin around the center of an atom and can travel from one atom to another. Electrons are so small that they cannot even be seen with the strongest microscope, meaning that for now, they are practically invisible. This means that electricity is invisible.

To better visualize electrical concepts we use water analogies to visualize what is happening in an electrical circuit. An **electrical circuit** is the path electrons take from power source to load and back to power source. A **load** is an appliance that consumes electricity and a **power source** provides electricity.

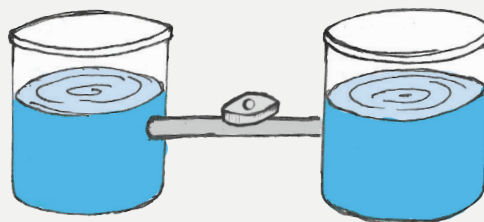
Because electricity behaves similarly to water.

You can think of water molecules as electrons, a water pipe representing electrical wires, and a water valve representing a circuit breaker or switch.

*Why use water to describe electricity?*



If we have 2 tanks of water with a pipe between them, and the water levels are the same, will water flow?



*No, there must be a difference in the levels.*



Electricity acts the same way. There must be a difference in the voltage for electricity to flow from source to load.

**Voltage** is the force of electrical pressure behind electrons, it is also described as “potential difference.” Voltage is measured in **volts** (V).

Waterfalls can also help us to visualize electrical concepts. A high waterfall can be thought of as having high voltage because the difference is great from its height to where it falls.

Voltage is the force, and current is the rate of flow.

*Rate of flow of what?*

**Current** is the rate of flow of electrons through a wire, which is a bit like quantity. Current is measured in **amps** (A).

A wide waterfall with a high volume of water flow can be thought of as having high current or amperage.

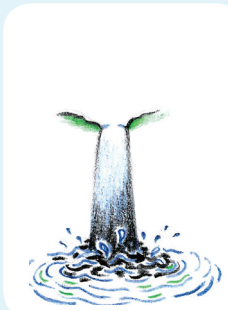


Electricity isn't used as just amps or volts – rather it is consumed as **power** – which is the product of the volts and amps. Power is the instantaneous rate of producing (or consuming) energy.

**Watt** (W) is a unit of measurement of electrical power. *Volts x amps = watts, or  $V \times A = W$ .*

*Let's give these waterfalls electrical values to better visualize the relationship of  $V \times A = W$ .*

$$4A \times 4V = 16 \text{ watts}$$



$$4A \times 25V = 100 \text{ watts}$$



$$25A \times 4V = 100 \text{ watts}$$

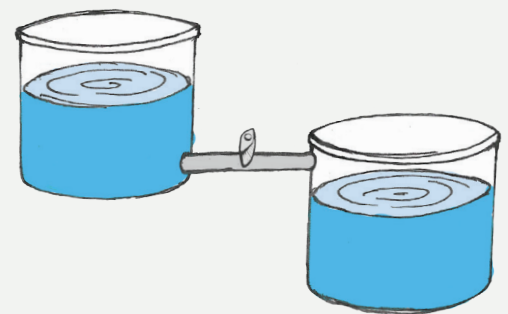


$$25A \times 25V = 625 \text{ watts}$$



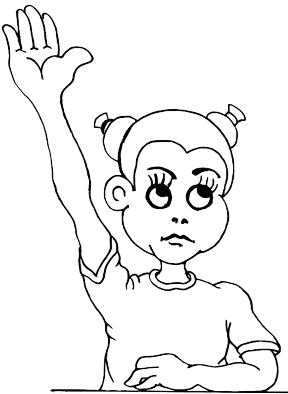
Electricity only flows when a circuit is complete. So with the water tanks, if the valve is turned off, water flow cannot be measured.

In electricity, if the circuit is open or not complete (the switch is OFF) current cannot be measured and there is no quantity of electricity reaching the load from the source.





To find the total amount of energy that a load will consume, multiply the power consumption by the number of hours that they are being used, thus giving you the total watt-hours of consumption. The amount of electrical energy we make or use is measured in watt-hours (Wh). **Watt-hour** is a unit of measurement of energy. For example, a 12 watt light bulb on for 3 hours will consume 36 watt-hours of energy.



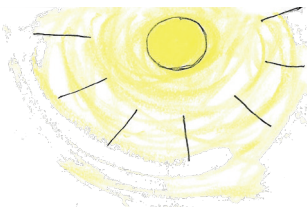
So what is energy?

Energy manifests itself in many different ways. The standard definition of **energy** is the ability to do work, or make a change.

There is motion energy (also called kinetic energy), and there is stored energy (also called potential energy). Energy can be *transferred* from one object to another, and energy can be *transformed* from one form to another form.

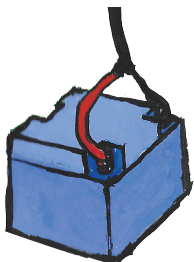
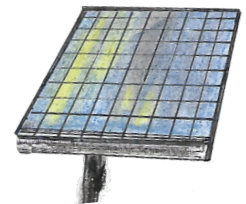
Electricity is one form of energy.

*Let's discover all the forms that energy takes in the Solar Suitcase system.*



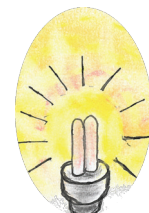
We start with the sun. The sun is an amazing source of energy. We call this solar energy or light energy. The energy in one hour of sunlight shining on the Earth's surface is equal to the amount of energy consumed by everyone on the planet in an entire year!

The solar panel takes the light energy and converts it into electrical energy, however, only during the day when the sun is shining, which is why we need a rechargeable battery to store the energy for use at night.



The rechargeable battery converts the electrical energy into chemical energy. Rechargeable batteries are both a load, meaning that they "consume" electricity from the solar panel (to recharge themselves), and a source, meaning that they provide electricity for appliances to use. Since appliances don't use chemical energy, the rechargeable battery is used because it transforms its chemicals into electricity.

Our appliances take that electricity and convert it again! For example, a light bulb converts the electrical energy into light energy, and the battery in the mobile phone converts the electrical energy back into chemical energy.



## Power and Energy that Various Loads Require

Power tells us *how fast* the electricity is used.

Power is measured in watts.

Energy measures the *total quantity* of electricity used.

Energy is measured in watt-hours.

Written somewhere on most electrical appliances is the information about how much power it uses. Sometimes it says it in watts, sometimes it says how many volts and amps it consumes, which means you have to calculate how many watts it consumes.

Remember how to calculate power:  $\text{volts} \times \text{amps} = \text{watts}$ .

If we look at our LED light bulb it shows 5 W and 12 V. While we know the watts are 5, we may want to know how many amps the bulb uses. When we divide 5 watts by 12 volts = 0.4 amps. Indeed, if we multiply 12 V  $\times$  0.4 A = 4.8 watts, or approximately 5 watts.

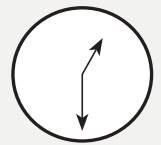
An E-reader uses about 6 volts and 3 amps. When we multiply these numbers together it will give us its power consumption: 6 V  $\times$  3 A = 18 watts.



*How do we know how much energy the appliance consumes?*

That depends on how long it is on.

Remember how to calculate energy:  
 $\text{power consumption (watts)} \times \text{hours used} = \text{watt-hours}$ .



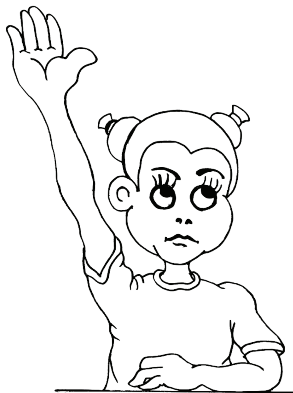
How much energy does the LED light bulb consume if it is on for 5 hours? 5 watts  $\times$  5 hours = 25 watt-hours.

Let's say a smart phone and E-reader both take 3 hours to fully charge. How much energy will they consume?

The smart phone: 5 watts  $\times$  3 hours = 15 watt-hours.

The E-reader: 18 watts  $\times$  3 hours = 54 watt-hours.

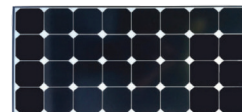




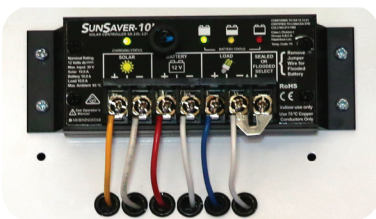
*Why is it important to know how to calculate watt and watt-hours?*

Understanding how to calculate watts and watt-hours can help us know how much energy is available in a solar battery to charge appliances or use lights.

It can also enable us to calculate how many hours it takes to charge a battery from a solar panel.



We Share Solar uses two different types of batteries for solar electric systems, Sealed Lead Acid (SLA) and Lithium Ferrous Phosphate (LFP). SLA batteries are more readily available in the market, less expensive, but also are rather sensitive to being fully discharged. LFP batteries last longer than SLA batteries but, are more expensive and not as easy to find in the market.



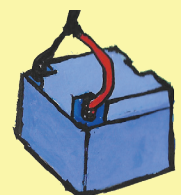
SLA batteries last longer when they are discharged only 50 percent. However, if need be, they can be discharged 80 percent.

How much we discharge a battery is called the **Depth of Discharge**, this is something that the charge controller regulates. Completely discharging an SLA battery can damage it. To protect the battery, our charge controller allows 80 percent Depth of Discharge.

Let's say we have a 100 watt-hour battery.  
We are using a 5 watt light.  
The charge controller allows the Depth of Discharge to go to 80% for this battery.

How long can the light stay on for?

Since we are only using 80% of the battery capacity, we need to multiple  
 $100 \text{ watt-hours} \times 0.80 = 80 \text{ watt-hours}$ . Then we divide 80 watt-hours by 5 watts = 16 hours.  
One 5 watt light can stay on for 16 hours.



While in the previous example we used a 100 *watt-hour* battery, in actuality, batteries are more often rated by **amp-hours** (Ah).



*So, how do we figure out how many watt-hours of energy is stored in a battery?*

To calculate how many watt-hours of energy it has stored we must multiply the number of *amp-hours* by the *battery's voltage*.

For example, the battery commonly installed with the Solar Suitcase is a 38 amp-hour, 12 volt battery.  $38 \text{ Ah} \times 12 \text{ V} = 456 \text{ watt-hours}$ .

Let's calculate how many hours we can power a 5 watt light bulb with a 38 amp-hour SLA battery.

We already figured out that there are 456 watt-hours in a 38 amp-hour battery.

To make sure we don't over-*discharge* the battery, we first multiply  $456 \text{ watt-hours} \times 0.80 = 364.8 \text{ watt-hours}$ . Let's round up to 365 watt-hours.  $365 \text{ watt-hours} \div 5 \text{ watts} = 73 \text{ hours}$ .

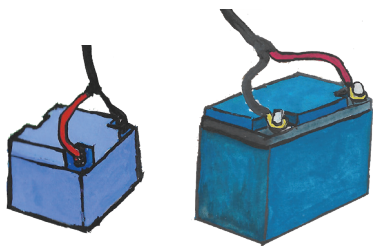
In reality, we don't need one light bulb on for 73 hours.

If many light bulbs were on for 10 hours, how many light bulbs could we power with this battery?

First, let's figure out the total amount of watt-hours each light would take:

$5 \text{ watts} \times 10 \text{ hours} = 50 \text{ watt-hours}$ .

Now we divide  $365 \text{ watt-hours} \div 50 \text{ watt-hours} = 7.3 \text{ lights}$ , which we round down to *7 lights* since we can't have a third of a light.



*Why don't we just get a bigger battery so that we can power more lights?*

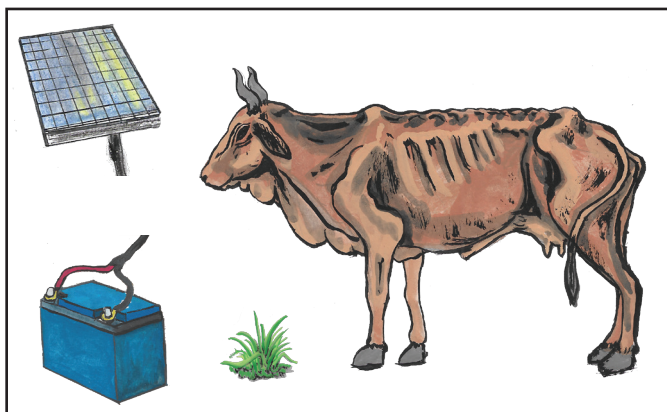
You may get a bigger battery, but you will also need to get a bigger solar panel.

The reason why many solar electric systems fail is because the solar panel is not large enough to fully charge the battery on a regular basis.



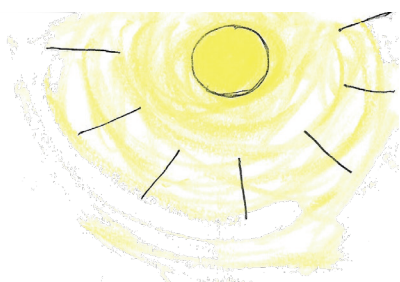
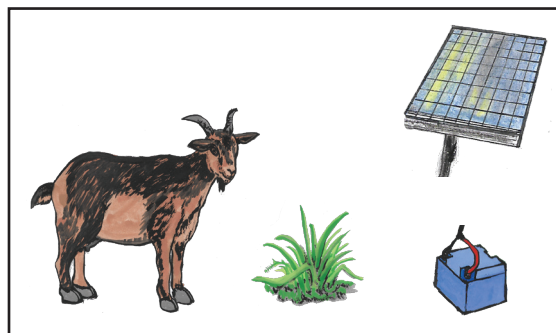
There's another way to think of the relationship between a battery and a solar panel.

Solar panels provide the “food” for the battery. A large battery is like a cow, and a small battery is like a goat. A cow may produce more milk than a goat, but a cow also eats *more* than a goat.



So if you have a small solar panel and a big battery, it's like having a cow but only feeding it half of what it needs. The cow will survive for a while, but it will become smaller and smaller until it dies. This is a common reason that improperly sized solar electric systems fail, because the solar panel cannot provide enough electricity to fully charge the battery on a regular basis.

However, if you have a small solar panel and a small battery, it is like having a goat and feeding it every day. The goat will never be as big as the cow, but at least it will be healthy. The small battery will not be able to power as many lights as a big battery, but it will last much longer.



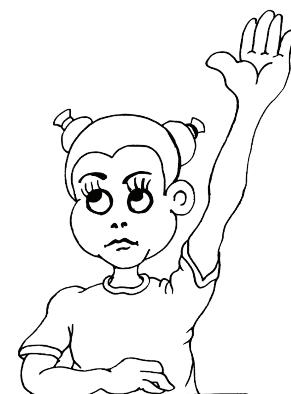
How long does it take to charge the battery?

The key factors determining how long it takes to charge a battery are:

- 1) The capacity of the battery in watt-hours
- 2) The power of the solar panel in watts
- 3) The amount of peak sunlight hitting the solar panel per day.

**Peak sun** is the equivalent of full sun directly shining on the solar panel.

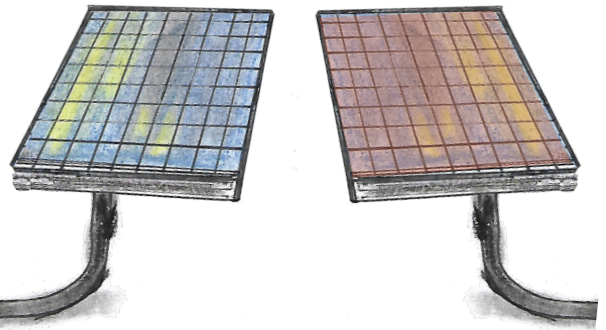
In East Africa near the equator, the approximate amount of peak sun per day is 5 hours.





It is also important to note that a solar panel charging a battery is not 100% efficient.

There are losses due to heat, dust, voltage differences, and transforming electric energy into the chemical energy of a battery.



When we add up all of those inefficiencies we think of a 100 watt solar panel pushing approximately 60 watts of power into the battery.

Therefore, a 100 watt solar panel charges a battery at the rate of about 60 watts, or, in one hour, it provides about 60 watt-hours of battery energy (charged battery).

We can estimate that solar panels charge at 60-80% of their rated output. The range depends on the type of charge controller and how well the voltage is matched of the battery and solar panel.

*So, how long does it take to charge the battery?*



Getting back to the example of the 12 volt, 38 amp-hour battery, which has a capacity of 456 watt-hours: if the battery has been discharged 80%, then to recharge it we need to provide enough solar electricity to restore the battery to 100%. We have already established that 80% of 456 watt-hours is 365 watt-hours.

Given that the 100 watt solar panel recharges a battery at a rate of 60 watts, it will take approximately 6 hours for the solar panel to fully recharge the battery.

$365 \text{ watt-hours} \div 60 \text{ watts} = 6.08 \text{ hours}$

Batteries and solar panels come in all different sizes depending on what the system is designed for.

A small system may be convenient if we only want a single light at night and phone charging ability.

However, someone else may want a larger system to power all the lights in a house, a radio, a fan, a television and a refrigerator.



Let's look at a solar lantern. A solar lantern uses a very small solar panel and a small battery that is usually concealed. This solar lantern has a 2 watt solar panel and a battery that is 7.4 volts and 1.8 amp-hours. The voltage of the solar panel and the battery are more specifically matched than in the larger system, so the loss due to voltage difference is lower. Therefore, we can estimate that the solar panel charges the battery at about 80% its rated output.

How long does it take for the solar panel to charge the battery?

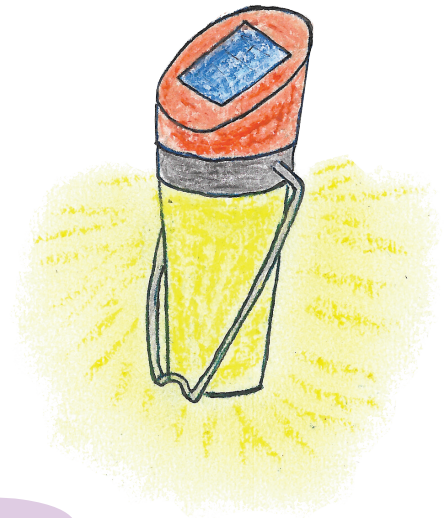
First, we calculate the watt-hours of the battery:

$$7.4 \text{ V} \times 1.8 \text{ Ah} = 13.32 \text{ watt-hours.}$$

Next, we account for inefficiencies of the panel:

$$2 \text{ watts} \times 0.8 = 1.6 \text{ watts}$$

Then, we see how many hours it takes the solar panel to charge the battery in full sun: 13.32 Wh divided by 1.6 W = 8.3 hours, or about 8 hours to fully charge the battery.



*Why is the voltage and amperage different for the solar lantern's battery compared to the Solar Suitcase's battery?*



We all have different needs and means.

The solar lantern is designed to be portable and economical. Its battery may have a short lifespan, and therefore may need to be replaced frequently. However, it may cost the manufacturers less to use. All batteries "die" eventually. The We Share Solar Suitcase is designed to last for longer, power more loads and when the time comes, have a battery that can easily be replaced from the market.

A "12 volt DC system" is the most common "stand-alone" home solar electric system, allowing us to have plenty of options for finding a new 12 volt battery.

*What does "DC" stand for?*

DC stands for *Direct Current*.

A **Direct Current (DC) circuit** flows in only one direction. One side, or pole is always negative, the other pole is always positive.

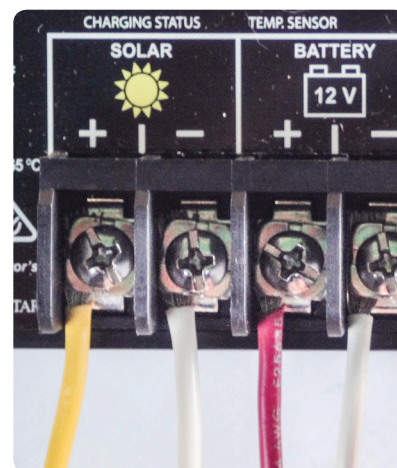
Electrons flow from the negative pole to the positive pole. This is referred to as **polarity**. Correct polarity means that the negative conductor is connected to the negative terminal. Both power source and load have a negative and a positive side.



A wire is often referred to a **conductor** because it acts as a pathway for electricity to flow from one place to another.

Metal is a good conductor; plastic is a poor conductor, which makes it a good insulator! Plastic coating on wires keeps the electricity on the metal pathway.

A **terminal** is a point in which an electrical component is connected.



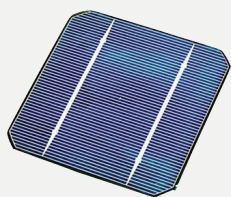
All solar electric systems produce DC current.

The electrical grid produces AC, or Alternating Current. In our daily lives we interact with appliances that use both AC and DC current. For example, mobile phones use DC current. If we charge a mobile phone from an electrical socket in the wall, the charging device will always have a small block that is actually a power adapter changing the current from AC to DC.

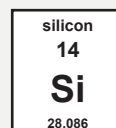
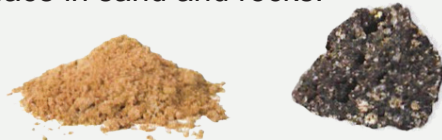
When we charge a mobile phone from the Solar Suitcase, it only needs a USB cord because the Solar Suitcase produces the same type of Direct Current that the mobile phone consumes. While the mobile phone consumes DC current, the voltage it needs is lower, so the USB adapter converts the voltage from 12 volts to 5 volts.

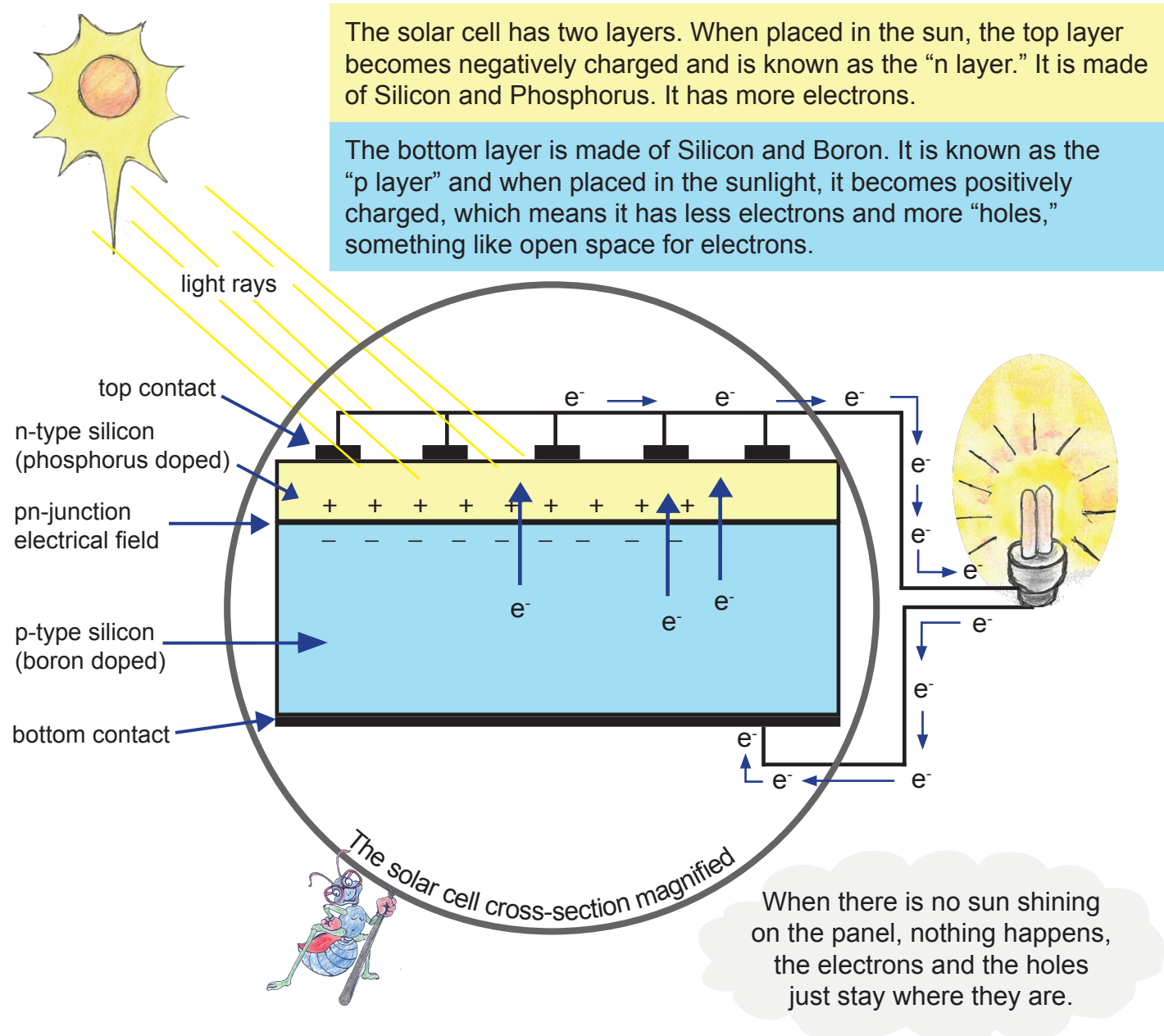
*What are solar panels made of and how do they work?*

The solar panel is made up of smaller units called solar cells.



The solar cell is made mostly of silicon. Silicon is found all over the Earth's surface in sand and rocks.





Sunlight is made up of photons, or tiny particles of light energy. When the cell is exposed to sunlight, the photons break apart electron-hole pairs and this frees up the charged particles to create an electric current.

The n layer likes to “grab” electrons and the p layer likes to “let go” of electrons.

When a load, such as a battery, mobile phone or lamp is connected to the solar cell, the electrons flow from the top of the cell to the load. The electrons complete the circuit by returning to the bottom-side of the solar cell.

While batteries may only work for a few years, solar panels work for over 25 years.

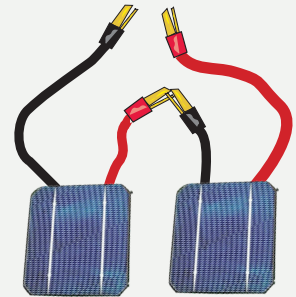
## Parallel and Series Connections

At times, we may want to increase the voltage or increase the amperage in order to match the needs of the device we're powering. Which leads us to another invisible electrical concept to learn about, and that is connecting solar cells, solar panels or batteries in series and/or parallel.

### Series Adds Voltage (SAV)

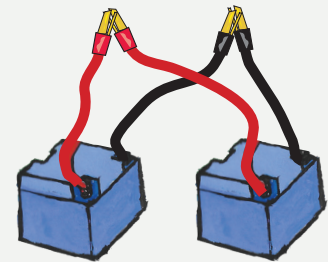
We can make a **series connection** by attaching one positive wire (red) to one negative wire (black). The remaining two wires are then connected to the terminals on the load. The negative wire is connected to the negative terminal and the positive wire to the positive terminal. A series connection increases voltage.

Solar cells are connected in series to make a solar panel.



### Parallel Adds Amperage (PAA)

We can make a **parallel connection** by attaching both positive wires together and both negative wires together. The negative wires are attached to the negative terminal on the load and the positive wires are attached to the positive terminal on the load. A parallel connection increases amperage.



*Why do we need to combine solar cells to make a solar panel?*

The reason we combine solar cells into a solar panel is to increase the voltage.

Each solar cell only produces 0.5 volts. So in order to make an 18 volt solar panel (which is what we need to charge a 12 volt battery), we must wire 36 solar cells in series.

In order to charge a 7.4 volt battery, like found in the solar lantern, we must make a 10 volt solar panel, so therefore we need 20 solar cells wired together in series.

Do you remember why the solar panel needs to have a higher voltage than the battery?

*Because in order for the electricity to flow there must be a difference in the voltage, because voltage is the force of electrical pressure behind the electrons!*

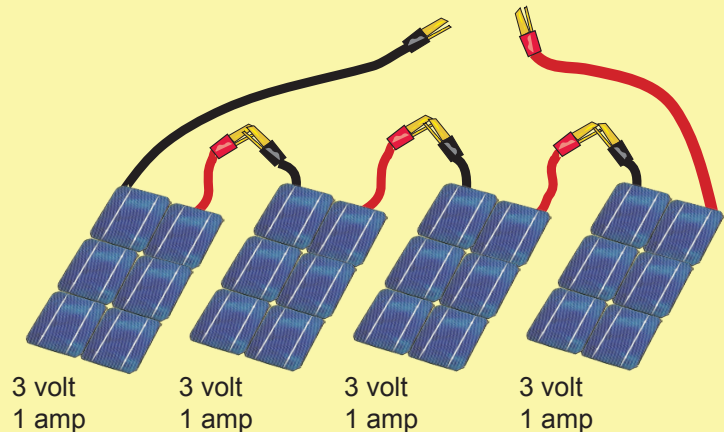




Example 1 – These solar panels are connected in series. In this image, four (4) 3 volt, 1 amp panels are wired in series. When solar cells or panels are connected in series, it is called a **string**.

Because series adds volts, the system will be 12 volts and 1 amp.

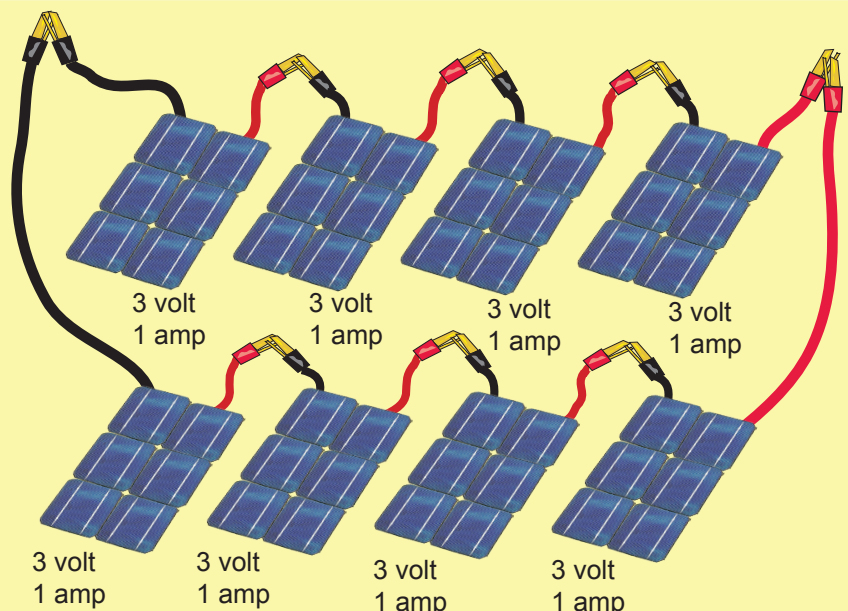
$3\text{ V} + 3\text{ V} + 3\text{ V} + 3\text{ V} = 12\text{ volts}$ ,  
Amps remain the same = 1 amp.



Example 2 – These solar panels are connected in series AND parallel wiring.

In this image, two "strings" of 4 panels each are wired in parallel. The voltage of each string is 12 volts and the amperage is 1 amp. The two strings are wired together in parallel so the voltage stays the same, 12 volts, but the current of each string is added.

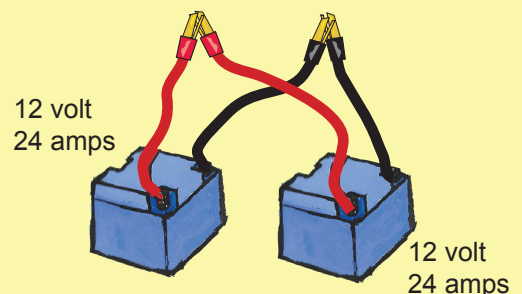
The whole system of 8 panels produces 12 volts and 2 amps.



1st string in series:  $3\text{ V} + 3\text{ V} + 3\text{ V} + 3\text{ V} = 12\text{ volts}$ , 1 amp  
2nd string in series:  $3\text{ V} + 3\text{ V} + 3\text{ V} + 3\text{ V} = 12\text{ volts}$ , 1 amp  
Strings paralleled together:  $1\text{ amp} + 1\text{ amp} = 2\text{ amps}$   
Whole system = 12 volts and 2 amps.

Example 3 - These batteries are connected in parallel wiring. The voltage of each battery is 12 volts and the amperage is 24 amp-hours.

Since they are connected in parallel, the amperage is added together making 48 amp-hours, but the voltage remains the same at 12 volts.



## The Charge Controller

Now that we have learned about solar panels and batteries, let's look at the electrical component that allows them to work together in a way that optimizes battery life, the charge controller.



The **charge controller** has three main functions:

1. *The charge controller regulates the charge from the solar panel to the battery.*

This enables the solar panel to charge the battery, but prevents it from being over-charged. It also measures how much current is flowing from the solar panel to the battery.

2. *The charge controller is an intermediary between the battery and the loads because it regulates and measures the electricity going to the loads.*

If the charge controller determines that the battery is running very low on energy, it will turn OFF the load circuits to protect the battery from complete discharge. This protects the battery from being damaged and maximizes its lifespan.

3. *The charge controller informs us how much energy is available for use.*

This can help us make good decisions about our electrical usage.



As long as the sun is shining, the solar panel will continue to send DC electricity into the system.

As long as there is electricity available, the loads will continue consuming electricity.

The charge controller makes sure the panel doesn't over-charge the battery and that the loads don't over-discharge the battery.



## Flow of Electricity in We Share Solar Suitcase

Electricity only flows when a circuit is complete. Circuits are like roads, or pathways that electrons take to travel from source to load. A **wiring circuit** connects one electrical component to another and has a positive and negative wire.

Wiring circuits must be protected from too much current flowing through the wires. If too much current flows, the wires can overheat causing damage to electrical components or fire. Only one side of the circuit needs to go through a **circuit breaker**. We always connect the positive side to a circuit breaker. For the protection of the battery, each circuit is routed through the charge controller.

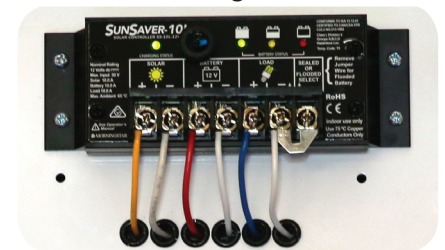
In the Solar Suitcase there are 3 wiring circuits:

- 1) Solar Circuit
- 2) Battery Circuit
- 3) Load Circuit

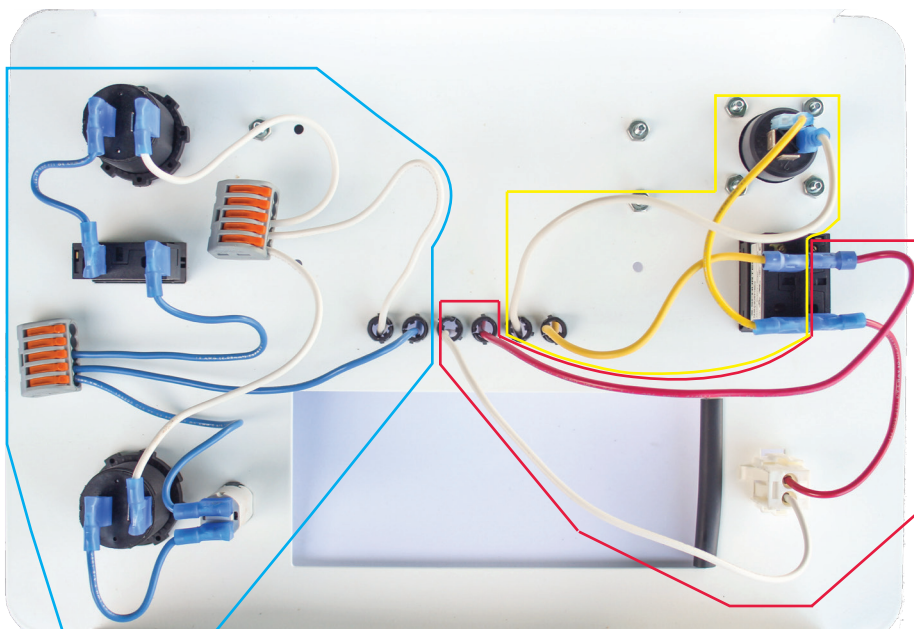
In standard solar electric systems there are usually only two main colors of wires, red for positive and black for negative.

If we look at the wires connected to the charge controller in the Solar Suitcase, we can see 4 colors: white, yellow, red and blue. The unusual color selection was chosen for learning purposes.

Front of Charge Controller



Backside of Main Control Board



In the Solar Suitcase, all of the white wires are negative, and all of the colored wires are positive.

The yellow is the positive wire of the Solar Circuit.

The red is the positive wire of the Battery Circuit.

The blue is the positive wire of the Load Circuit.

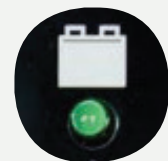
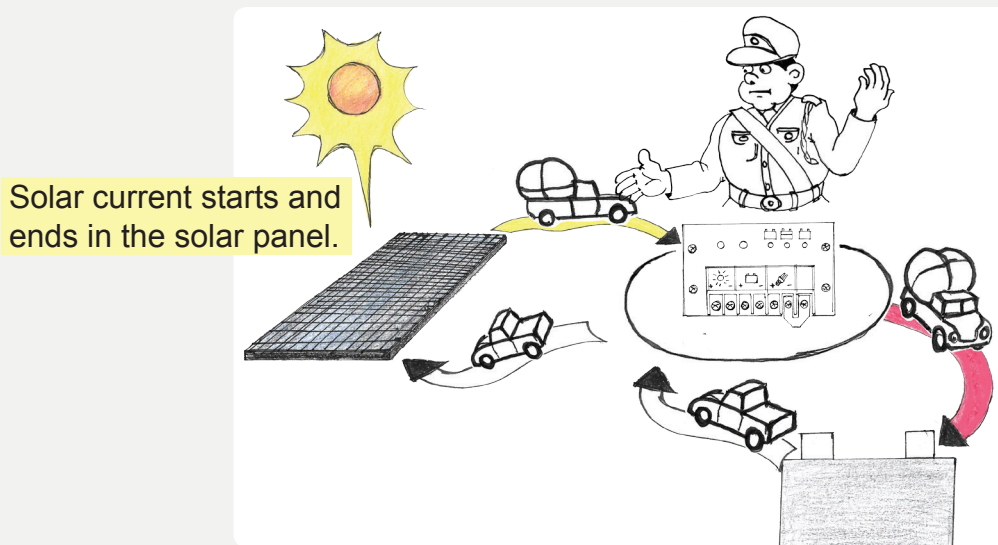
All of the wires pass through to the front side to connect to the charge controller.

In the Solar Suitcase there are two power circuits.

A **power circuit** is when electrical current flows from a source to a load. Power circuits are like the trucks that carry the current from source to load. The battery can be both a source (when it is providing energy for devices to use) or a load if it is receiving energy (to recharge itself).

### 1. Solar current circuit:

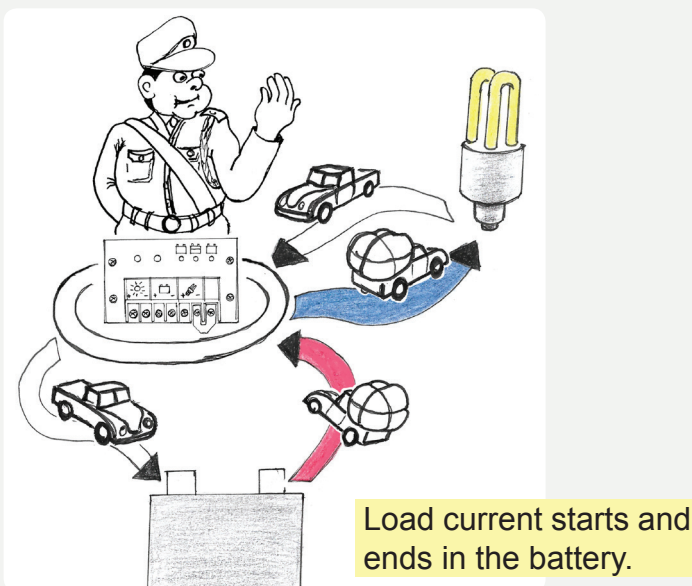
Solar panel (source) to the battery (load).



When the battery is full, the solar current flows almost directly to the loads, just touching the battery's terminal screws on the charge controller.

### 2. Load current circuit:

Battery (source) to loads (loads such as lights).



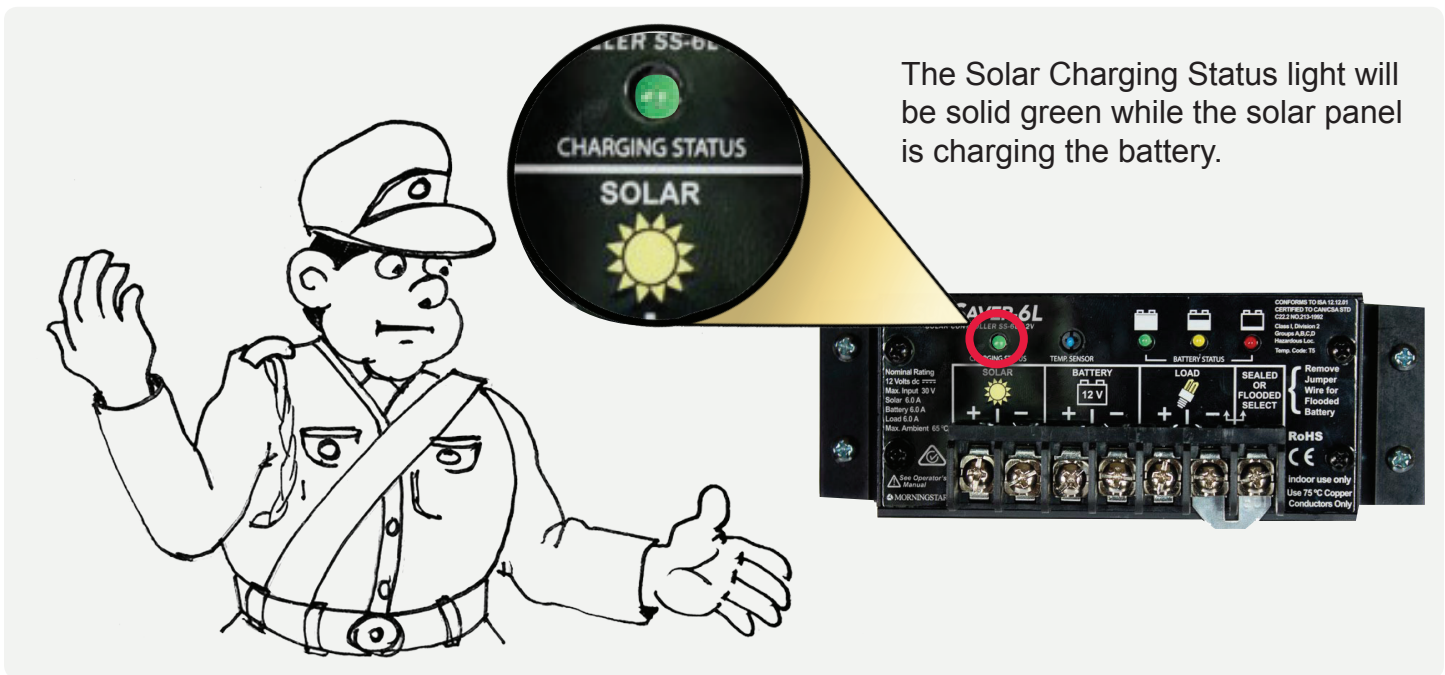
During the day, both power circuits can be engaged.



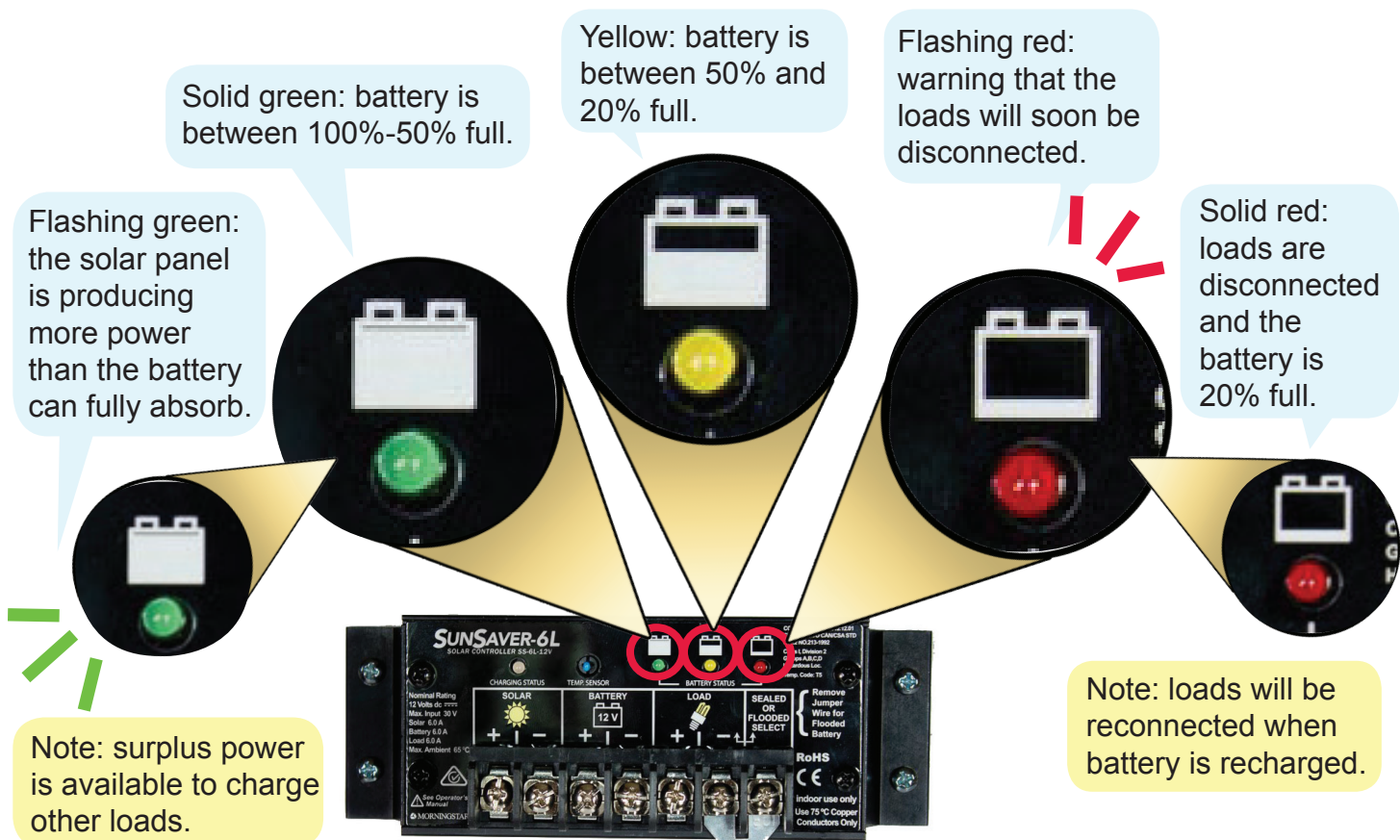
At night, only the load current circuit is operating.



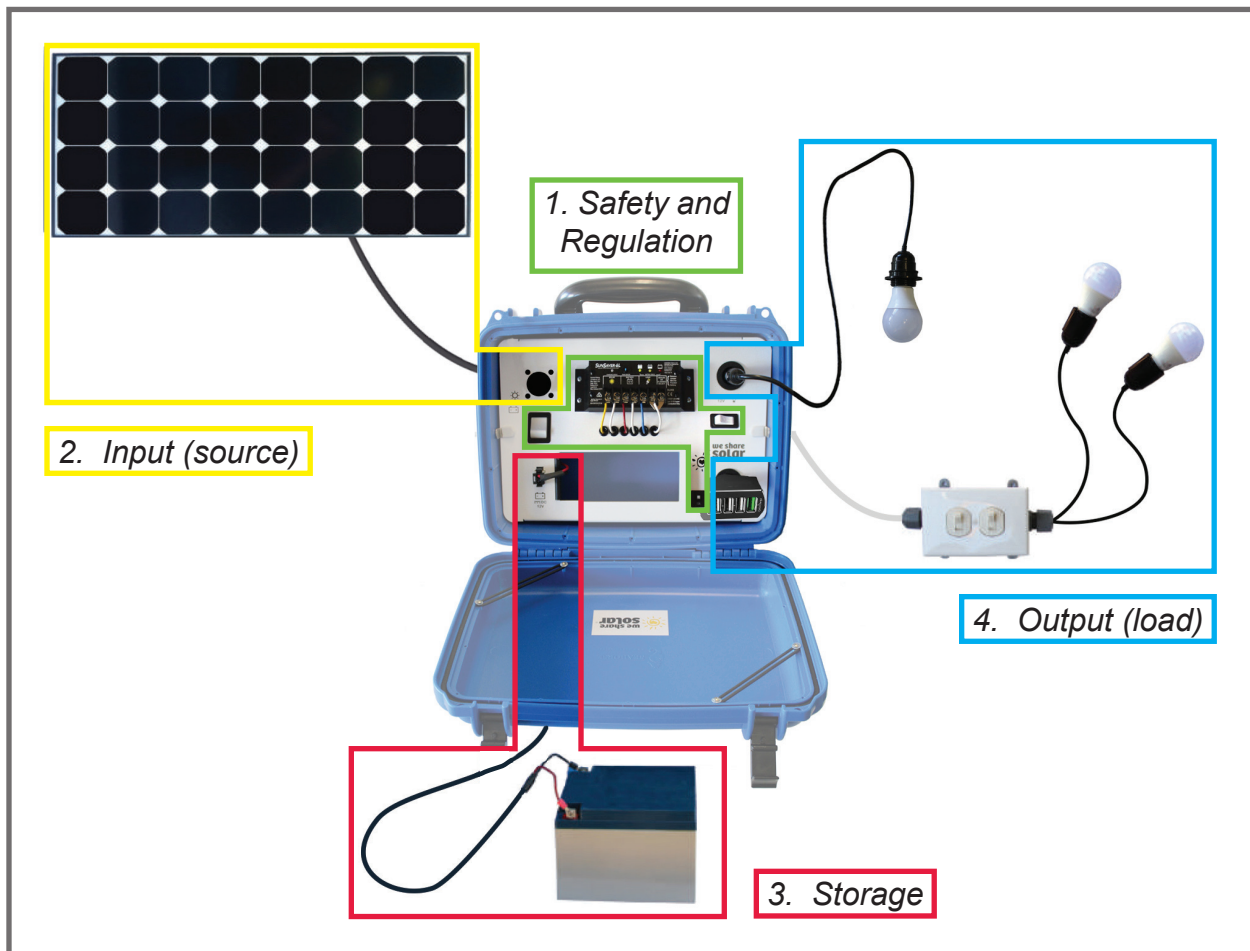
## Analyzing the Charge Controller Status Lights



The Battery Status Lights will indicate the level of charge of the battery.



## Solar Suitcase System Components



The Solar Suitcase is a complete solar electric system.

The system can be divided into four main sections:

- 1) Safety and Regulation
- 2) Input (source)
- 3) Storage
- 4) Output (load)

The white metal board inside the Solar Suitcase is called the **chassis**. When the chassis is populated with switches, charge controller, receptacles and wires it is called the **Main Control Board (MCB)**.



## 1. Safety and Regulation

Safety is essential for all electric systems. Overcurrent and short circuits can damage electrical components and even cause fire.

**Overcurrent** is when there are too many amps flowing in the circuit and through the breaker. A **short circuit** is a connection between two parts of an electrical circuit that are NOT meant to be connected.



The **main switch** is both a circuit breaker and a switch; it turns the whole Solar Suitcase ON and OFF. It does this by breaking (opening) the connection between the solar panel and the charge controller AND between the charge controller and the battery.



On the back of the main switch there are two sets of terminals. One set controls the positive side of the solar circuit; the other set controls the positive side of the battery circuit.

In the off position it “opens” the circuit from the solar positive to the charge controller and from the battery positive to the charge controller. This turns the whole system OFF.

In the event of overcurrent, it will automatically turn OFF (open the circuit) protecting the system.



The **charge controller** regulates solar charging and load discharging to and from the battery. More information about the charge controller can be found on pages 16-19.



The plastic **bushings** are used to “mechanically” protect wires from getting their insulation damaged and to prevent electrical conduction which could cause a short. They protect the wire from the metal edge of the chassis. It is important to protect the insulation of the wire from getting cut as this could cause an electrical short circuit.

The **small switch** controls the flow of current to the DC receptacle that the light is plugged into. It only controls one DC receptacle unlike the main switch which controls the battery and solar circuits.



Because this breaker is also a switch, it allows the user to turn the light on and off without having to pull the plug out.



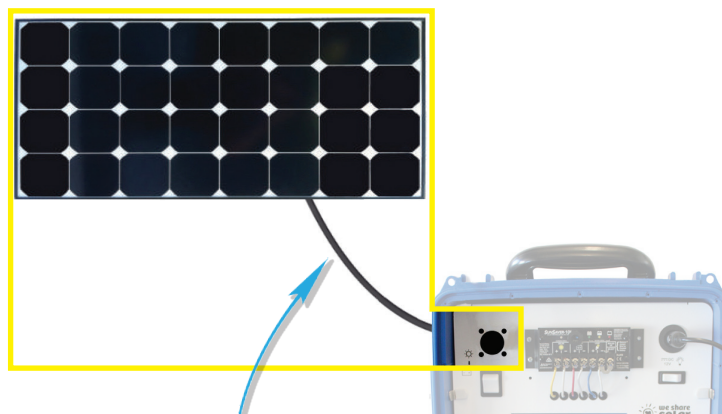
The **pop-up breaker** controls the flow of current to the bottom DC receptacle. It also protects its circuit from too much current. It is resettable after breaking a circuit. The pop-up breaker does not operate as a switch.



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## 2. Input (source)

The **solar panel** collects energy from the sun and converts it into electrical energy. More information about the solar panel can be found on pages 12-14.



The **homerun cable** is used to connect the solar panel to the Solar Suitcase.

It has a positive wire that is first connected to the main switch before going to the charge controller, and it has a negative wire that is connected to the charge controller.

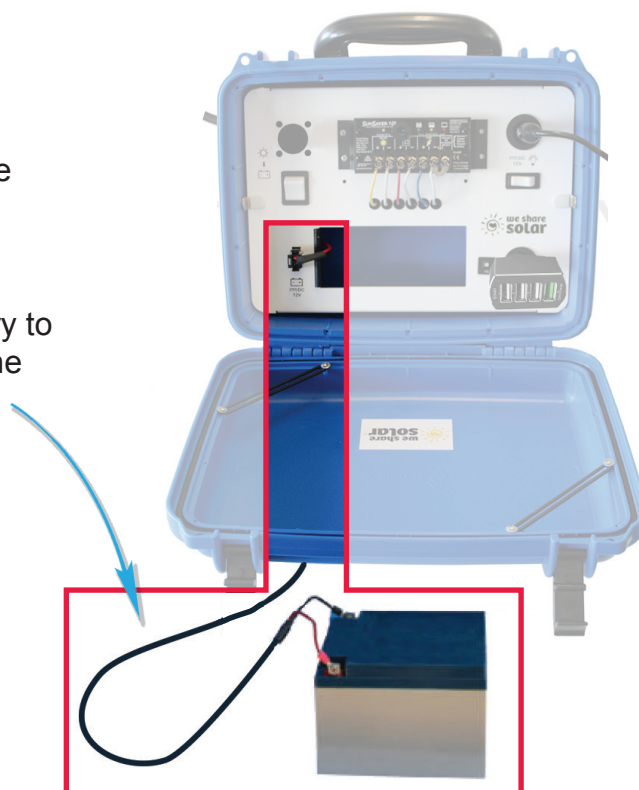
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## 3. Storage

The **battery** stores energy for use at night. More information about the battery can be found on pages 7-11.

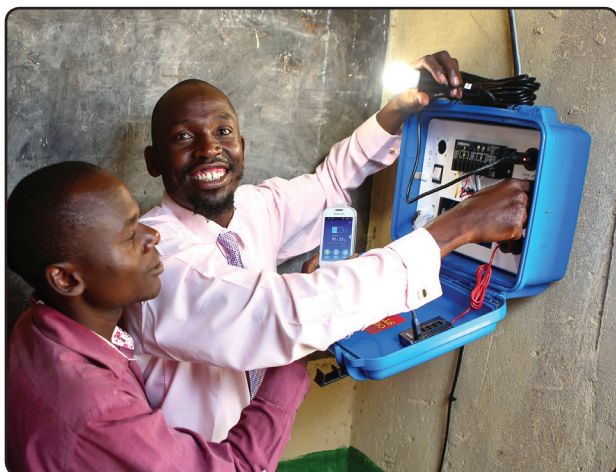
The **external battery cable** connects the battery to the battery cable receptacle on the chassis of the Solar Suitcase.

It has a positive wire that first goes through the main switch before connecting to the charge controller and a negative wire that connects to charge controller.

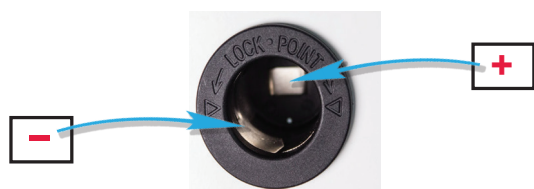




#### 4. Output (load)



The charging ports in the Solar Suitcase are **DC receptacles**. In our daily lives we most often find DC receptacles in cars and other vehicles. The DC receptacles are 12 volts.



Notice that the metal conductor lining the inside wall of the DC receptacle is negative. The metal plate on the bottom, in the center of the DC receptacle is positive.

The positive wires that connect the DC receptacles to the charge controller must first go through the small switch (for the top receptacle) and the pop-up breaker (for the bottom receptacle). The negative wires are connected to the charge controller.

The **lamp cord** fits into the DC receptacle and is specially designed for a 12 volt, DC system.



The light bulb is also a special 12 volt DC light bulb. This light bulb can only be used in a 12 volt DC system and cannot be connected to a regular socket that uses the electrical grid because the electrical grid is either 120 volts or 240 volts, AC Power.

The **switch box** allows for more lights to be connected to the Solar Suitcase.



The **USB adaptor plug** fits in the DC receptacle. It can be used to charge mobile phones, headlamps and any other device that uses a USB cable.



## Worksheet for We Share Solar Suitcase

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Power: volts x amps = watts

Energy: watts x hours = watt-hours

Battery storage: amp-hours x volts = watt-hours

1. The Solar Suitcase is a 12 volt system. Everything that uses its energy must also use 12 volts. This means that the LED lights are also 12 V (and cannot be used in a regular, grid-connected light socket). Eventually, the 5 watt LED light has to be replaced. However, only an 8 watt, 12 volt LED light is available in the market. How many amps of current does it require?
2. Let's consider a 8 watt light that plugs into a regular grid-connected socket. The grid voltage is 240 volts. How many amps of current does the 8 watt, grid-connected light require?
3. How much energy will the Solar Suitcase 8 watt light consume if it is on for 8 hours?  
How much energy will the grid-connected 8 watt light consume if it is on for 8 hours?

There's a Solar Suitcase system with a 120 watt panel and a 40 amp-hour battery and six, 5 watt lights.

4. How many watt-hours of storage does the battery have? (Depth of Discharge is 80%)
5. How many hours of sun does it take to charge the battery if it 100% discharged?
6. How many hours of sun does it take to charge the battery if it 80% discharged?
7. How many hours can all 6 lights stay on at night?

Series and Parallel connections: SAV (Series Adds Voltage), PAA (Parallel Adds Amperage)

8. We have a 6 volt battery that powers a solar light. To charge this battery we need a 9 volt solar panel. If each solar cell has 0.5 volts, how many cells do we need to wire together to make a 9 volt panel? Do they need to be wired in series or parallel?
9. Using 3 volt, 1 amp panels can you make a system that is 24 volts and 5 amps?
10. Using different 18 volt, 3 amp panels can you make a system that is 612 volts and 12 amps?

**Amp-hour (Ah)** - the amount of electrical charge carried by one amp of current flowing for one hour. Batteries are often rated in amp-hours. – 8

**Amps (A)** - (plural of ampere) is the unit for measuring how fast an electric current flows. – 4

**Atom** - the smallest unit of matter. – 3

**Bushing** - used to “mechanically” protect wires from getting their insulation damaged and to prevent electrical conduction which could cause a short. – 21

**Charge controller** - has 3 main functions: 1) Regulating the charge from the solar panel to the battery. 2) Intermediary between the battery and the loads. 3) Providing information about battery charge level. – 16

**Chassis** - metal board inside of Solar Suitcase. – 20

**Circuit breaker** - a device that is installed on the positive side of an electric circuit that protects the wires and components from too much current from flowing into the circuit. – 17

**Conductor** - material that acts as a pathway for electricity to flow from one place to another. Another name for a wire. – 12

**Current** - the rate of flow of electrons through a wire. – 4

**DC receptacles** - 12 volt charging ports in the Solar Suitcase. – 23

**Depth of Discharge (DOD)** - how much a battery is discharged; regulated by the charge controller. – 7

**Direct Current (DC) circuit** - the one-way movement or flow of electric charge carriers (electrons) usually from positive pole to the negative pole. – 11

**Electrical circuit** - a path in which electrons from a voltage or current source flow. – 3

**Electricity** - the movement of electrons from atom to atom. – 3

**Electrons** - negatively charged particles. – 3

**Energy** - the ability to do work, or make a change. – 5

**External battery cable** - connects the battery to the battery cable receptacle on the chassis of the Solar Suitcase. – 22

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**Homerun cable** - connects the solar panel to the Solar Suitcase. – 22

**Lamp cord** - connects to the 12 volt DC receptacles on the Solar Suitcase. – 23

**Load** - an appliance that consumes electricity. – 3

**Main Control Board (MCB)** - the chassis populated with switches, charge controller, receptacles and wires. – 20

**Main switch** - both a circuit breaker and a switch; it turns the whole Solar Suitcase ON and OFF. – 21

**Overcurrent** - when there are too many amps flowing in the circuit and through the breaker. – 21

**Parallel connection** - made by attaching both positive wires together and both negative wires together. A parallel connection increases amperage. – 14

**Peak sun** - the equivalent of full sun directly shining on the solar panel. – 9

**Polarity** - refers to the flow of electrons from the negative pole to the positive pole. The negative conductor is connected to the negative terminal; the positive conductor is connected to the positive terminal. – 11

**Pop-up breaker** - controls the flow of current to the bottom DC receptacle. – 21

**Power** - the product of volts and amps. Power is the instantaneous rate of producing (or consuming) energy. Power is measured in watts. – 4

**Power circuit** - when electrical current flows from a source to a load. – 18

**Power source** - provides electricity. – 3

**Series connection** - made by attaching one positive wire (red) to one negative wire (black). The remaining two wires are then connected to the terminals on the load. A series connection increases voltage. – 14

**Short circuit** - a connection between two parts of an electrical circuit that are NOT meant to be connected. – 21

**Small switch** - controls the flow of current to the DC receptacle that the light is plugged into. A switch is a device that toggles the path of an electric circuit. i.e. opens and closes the electric circuit, also known as a circuit breaker. – 21

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**Solar energy** - energy that comes from the sun. – 3

**String** - solar cells or panels connected in series. – 15

**Switch box** - allows for more lights to be connected to the Solar Suitcase. – 23

**Terminal** - a point in which an electrical component is connected. – 12

**USB adaptor plug** - fits in the DC receptacle. It can be used to charge mobile phones, headlamps and any other device that uses a USB cable. – 23

**Voltage** - the force of electrical pressure behind electrons, it is also described as “potential difference.” – 3

**Volt (V)** - the electrical unit of voltage or potential difference. – 3

**Watt-hour (Wh)** - a unit of measurement of energy. Watt-hours are found by multiplying the power consumption by the number of hours that a load is being used. – 5

**Watt (W)** - a unit of measurement of electrical power. Watts are found by multiplying volts x amps. – 4

**Wiring circuit** - connects one electrical component to another and has a positive and negative wire. – 17

## Answers to Worksheet

1. The LED light uses 0.67 amps and 12 volts, which gives us 5 watts of power.

$$12 \text{ V} \times A = 8 \text{ W}$$

$$A = 8/12$$

$$A = 0.67$$

2. The LED light uses 0.02 amps and 240 volts, which gives us 5 watts of power.

$$240 \text{ V} \times A = 8 \text{ W}$$

$$A = 8/240$$

$$A = 0.03$$

3. Both will consume 64 watt-hours of energy.

$$8 \text{ watts} \times 8 \text{ hours} = 64 \text{ watt-hours}$$

$$8 \text{ watts} \times 8 \text{ hours} = 64 \text{ watt-hours}$$

4. 384 watt-hours.

$$40 \text{ amp-hours} \times 12 \text{ volts} = 480 \text{ watt-hours} \times 0.8 \text{ (Depth of Discharge)} = 384 \text{ watt-hours}$$

5. Approximately 6.5 hours.

480 watt-hours divided by 72 watts = 6.6 hours

Solar panel charging at 72 watts - 60% its rated output ( $0.6 \times 120$  watts).

6. Approximately 5 hours.

$$384 \text{ watt-hours divided by } 72 \text{ watts} = 5.33 \text{ hrs}$$

Solar panel charging at 72 watts ( $0.6 \times 120$  watts).

7. 12.8 hours.

5 watts x 6 lights = 30 watts of power for all the lights.

$$384 \text{ watt-hours of battery storage} / 30 \text{ watts} = 12.8 \text{ hours.}$$

8. 18 solar cells wired together in series makes a 9 volt panel.

Since we need to add (or increase) voltage, we need to use series connections to create a solar panel from individual solar cells.  $18 \times 0.5 \text{ V} = 9 \text{ volts}$ .

9. Wire panels in series in string of 8 panels, then parallel the 5 series strings together.

[illegible]

Parallel:  $1\text{ A} + 1\text{ A} + 1\text{ A} + 1\text{ A} + 1\text{ A} = 5\text{ amps}$

10. Wire panels in series in strings of 34 panels, then parallel the 4 series strings together.

**Series:** 18 V + 18 V = 612 volts ( $612 / 18 = 34$  panels)

Parallel:  $3 A + 3 A + 3 A + 3 A = 12 \text{ amps}$  ( $12/3 = 4 \text{ panels}$ )



## Acknowledgements

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### **Solar Suitcase Learning Guide**

Merritt Eby Gates	Project Manager, Curriculum Developer & Graphic Designer
Bernard A. Mugisha	Illustrations & Technical Drawings
Liz Kamugisha	Photographer
Katie G. Nelson	Field Photographer, Muhuru Bay, Kenya, p 22.
Alli Pemerl	Editing

### **We Share Solar Curriculum Development**

We Share Solar: Hal Aronson, Alli Pemerl, Gigi Goldman, Wendy Cross

Remote Energy: [www.remoteenergy.org](http://www.remoteenergy.org)

Contributors: Molly Naughton, Julian Goldberg, Anna Gomberg, Silvia Debenedetti, Natasha Allen  
Lawrence Hall of Science, UC Berkeley, EPICC Program

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### **We Share Solar® Suitcase Technology**

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Rex Lu and Brent Moellenberg	Design assistance with the WSS 601 Solar Suitcase Kit

For more information, please visit [www.wesharesolar.org](http://www.wesharesolar.org)

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