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Solar Power for the Digital Fieldworker

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This article discusses the technical aspects of a solar power setup for remote field situations. It guides the reader through estimating power consumption and setting up a basic solar kit. The authors address picking a solar panel, using a charge regulator, and choosing a battery based on estimated power consumption and availability. They discuss two different types of power adaptors, how to connect the equipment, and the benefits and drawbacks of using multi-meters. They address the use of rechargeable batteries and finally, caution against too heavy a reliance on solar power.

1. INTRODUCTION.[1] The modern fieldworker is increasingly carrying digital equipment into the field to conduct research. Digital devices open up an exciting world of possibilities, potentially allowing a fieldworker to collect more and higher quality data and to use and build upon this data in ways that were previously laborious or impossible. On the other hand, this new workflow introduces a whole new set of problems for the fieldworker, not the least of which is how to power these devices in remote field settings. This article will present a simple solar setup for the modern digital fieldworker.

2. ESTIMATING POWER CONSUMPTION. In order to effectively set up a solar system, to estimate power consumption, and to troubleshoot in the field, it is important to understand something about electricity. The first and most important feature of electricity is that it is dangerous and testing and troubleshooting electrical equipment should be approached with caution. Two types of power will be discussed here: AC[2] and DC power. In general, AC comes from the wall socket or a generator, and DC comes from a battery and sometimes from a generator. Apart from a little addition and multiplication, there is only one mathematical formula important in estimating power consumption:

Watts = Volts x Amps

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1 The information presented here is based on the authors' own fieldwork experiences. One of the authors conducted fieldwork during late 2005 and early 2006 on the language Fas, spoken in a remote area in north-western Papua New Guinea and the other author throughout the majority of 2006 on the language Dupaningan Agta, spoken in the far northern Philippines. Both fieldworkers entered the field intending to record large amounts of audio and video data, both planned for remote situations without access to grid power, and both used solar setups to power their field equipment. The authors, however, entered the field with radically different budgets and encountered quite different field situations. Both perspectives are incorporated into the subsequent discussion.

2 Technical terms are defined in a separate glossary at the end of this paper.

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Watt Hours is a measure of how much power you have to use. Eighty watt hours means that you can deliver 80 watts for one hour, or 40 watts for two hours. If you have a 40-watt lightbulb and an 80-watt-hour power source, then you will have light for two hours.

Ideally, the researcher should have all the field equipment gathered and tested before purchasing the solar panels. In reality, fieldwork and equipment grants are often given at the last possible moment, and fieldworkers will be buying and testing equipment on the fly. Nevertheless, the method discussed below should help even the impoverished fieldworker estimate power consumption.

The first step is to decide which devices will be using the power gathered from the solar panel (as opposed to, for example, running on disposable AA batteries). This equipment will need to be budgeted into the power-consumption plan. To estimate how much power each device will consume, check each power adaptor (see FIGURE 1 below).

FIGURE 1: Power Adaptor

These adaptors take AC power (from the wall socket) and convert it to DC power. Some equipment may not include an AC to DC converter such as the one above, but generally most portable devices use DC power. The power adaptor pictured above outputs DC power at 12 volts, 2000mA (or 2 Amps). This is an indication of what the adaptor is capable of, not what is actually used, but to be on the conservative side, we recommend using this number to calculate the estimate. The point where the plug enters the equipment might also have voltage information (see FIGURE 2 below).

Figure 2: Power-In

This is probably more useful and accurate if available. The manual for the device might have power consumption information as well, and this will be the most accurate (unless it says something like "this product will run for up to 20 hours!"). There may be an acceptable range of voltage which the device can operate within (if it is around 12 volts, then it was probably designed for use with a 12-volt battery).

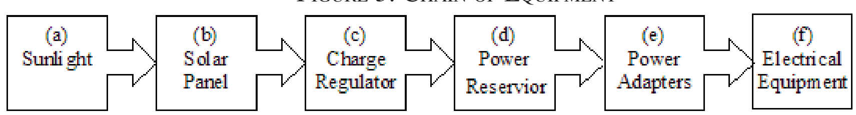
To estimate the power consumption of the equipment, figure out the watts consumed by each device (remember, watts = volts x amps). For the device above, 12 volts x 2 amps (2000mA) is 24 watts. Multiply that number by the number of hours you estimate you will need the device each day. Add together the numbers for each device. This will not be very accurate, so double it for a rainy day (or triple it to be extra cautious), and that is the number of "watt hours" you will need each day. The power storage reservoir (battery) must be big enough to supply that for several days (in case it rains), and the charging method (in the context of this article, the solar panel, but this would also apply for generators) must be able to supply that amount of power in half a day (again, in case of a less-than-perfectly sunny day).

Keep this number in mind when looking at solar panels. Depending on the latitude and the season, the peak time for collecting solar power is roughly from 10 am to 3 pm. The panel will collect more power if it is angled towards the sunlight throughout the day (rather than just laying it flat on the ground, or on a rooftop). Ideally, then, the solar panel will collect power for five hours a day. So a 30-watt solar panel will produce roughly 150 watt hours of power a day (this is approximate; charging the battery results in a loss of about 33% of power). So if you use the top 35% of a standard car battery (~144 watt hours), a 30-watt solar panel is going to fill up the battery again in roughly a day (see Section 3.4 below for a discussion of batteries and why you would only use the top 35%).

After calculating the amount of electricity that all the digital devices will need to consume in the field and investigating solar panels that meet that power requirement, the fieldworkers will see that they must budget electricity consumption, especially if planning to use a laptop in the field. Even top-of-the-line solar panels cannot provide the amount of power that a modern researcher is accustomed to having—powering a laptop and several other electricity-consuming devices throughout the day. In reality, calculating electrical consumption is a give-and-take process. Fieldworkers must first calculate their desired electrical consumption, then look at the price of solar panels, then re-calculate their electrical consumption to fit a solar panel and battery that meet their budget. The daily power usage will be high if a laptop and video camera are used every single day, but probably will be quite reasonable if just charging AA batteries for a flashlight and an audio recorder.

3. A BASIC SOLAR KIT. There is a long chain of equipment in a solar kit. Some components in this chain are critical, while others are optional. The basic chain is illustrated in Figure 3 below.

Figure 3: Chain of Equipment



Each part of this chain will be discussed below. Where a part is not critical to the chain of equipment, this will be mentioned along with the implications of this change.

3.1 SUNLIGHT. It goes without saying that sunlight is critical to a solar setup. Do not, however, assume that if you are in the tropics that you will have ready access to sunlight. Frequent rainstorms and heavy foliage can drastically reduce charging time, and daylight hours vary depending on time of the year.

3.2 SOLAR PANELS. The solar panel the researcher buys will depend on how portable the panel must be, what devices need to be powered in the field, and the fieldwork budget. In general, there are two kinds of solar panels: rigid and flexible.

Traditional, rigid solar panels are much cheaper than flexible models, but can be heavy, awkward, and delicate. It is possible to reduce the bulkiness of a rigid panel setup by purchasing several smaller panels and wiring them in parallel to produce greater amps, or in series to increase the voltage to the point needed to charge your power supply.[3] These would fit nicely into a sturdy and portable case, which some companies sell ready-made.

Flexible solar panels are small and lightweight, are either folded or rolled up, and can fit inside a backpack. They are also purportedly more durable than rigid models, but they are still rather delicate, and advertisements that they can withstand bullet holes should not be taken literally. Another caveat is that the rolled panels cannot be rolled inside out—this will damage the panel irreparably.

3 See the glossary at the end of this article for brief information on serial versus parallel circuits. Each panel *must* have a blocking diode if you hook them up in series.

A good solar panel will have a blocking diode built in. During the day, when the solar panel is generating power, this power will flow into the battery, but at night, the blocking diode stops that from power flowing back into the solar panel and damaging it.

It is a good idea to have a sturdy case for your panel(s). While some panels are supposed to be very sturdy, this is perhaps the most critical piece of equipment in your kit.

3.3 CHARGE REGULATORS. A charge regulator, or charge controller, regulates how much charge goes from the solar panels to the battery. This is a noncritical piece of equipment for the solar setup, but it can be quite useful, and they are neither very expensive or very bulky.

At certain times in the charging cycle for a lead-acid battery, it is important to deliver different amounts of power to ensure that the battery is fully charged. A charge regulator will do this for you.

It is also important not to overcharge the battery. Overcharging will at best damage the battery over time, but at worst could be dangerous to you. A charge regulator will reduce the power to a trickle charge for the last segment of charging, which will ensure that the battery will be absolutely full, but not overcharged.

A good charge regulator will include indicator lights to tell you when the battery is charged and when you have drained the battery to the point where you should recharge it (see section 3.4 below for more on this topic). It may even cut the power when you get to this point and may include a blocking diode as described above.

When purchasing a charge regulator, check the maximum amps and voltage that the charge regulator can take. If the solar panel outputs higher amps or voltage than the charge regulator can handle, the charge regulator will be damaged.

It is important to note that if the charge regulator is damaged in the field, it is possible to connect the panel directly to the battery, but it can be dangerous if the battery gets overcharged. If the panel does not have a blocking diode, and there is no charge regulator, then it should be unplugged in the afternoon before the sun goes down to prevent the charge from the battery leaking backwards into the panel.

3.4 BATTERIES. For most applications, the solar setup will require a reservoir, such as a battery, to store the electricity generated by the solar panels. Having electricity stored in a battery allows the researcher to work at night or on cloudy days. Moreover, most solar panels do not produce enough electricity at once (amps) to charge a computer directly, so for those setups powering a computer, the electricity must instead be stored and redispersed at a higher amperage.

Choosing a battery for the solar setup will depend on estimated power consumption (as discussed above), weight limits, portability requirements, length of stay, and availability. Ideally, fieldworkers should choose a battery that can supply their desired daily watt hours and be fully charged within a day (preferably half a day).

Since bringing a battery on an airplane in the twenty-first century is highly discouraged,[4] most fieldworkers will need to choose a battery that is available in their destination country.

4 Depending on the origin and the country of destination, it can be done though. Call the airlines well in advance to check on this. If it is possible, you will need a Material Safety Data Sheet (MSDS) from

This will usually be a lead-acid battery. These come in sealed, maintenance-free form, and the more common vehicle batteries that require periodic simple maintenance. Vehicle batteries are likely to be more widely available in third-world and remote locations. They come in various sizes; generally, the larger the vehicle, the larger its battery. Larger batteries weigh more but can hold more power.

Lead-acid batteries come in different voltages: 6, 12, and 24, and different storage capacities: 1 amp hour up to 120 amp hours. A twelve-volt battery will probably be most versatile, as most adaptor equipment is designed to operate at this voltage, and most solar panels are designed to charge 12-volt batteries. A typical car battery is a 12-volt, 35-amp-hour, unsealed lead-acid battery. Two or more batteries can also be run in parallel for more power storage, but must be the same voltage and capacity and charged to the same amount before wiring them in parallel.

Lead-acid batteries are quite temperamental. Their ability to take a charge varies based on the ambient temperature, and they discharge faster in extremes of heat or cold. They operate best at room temperature (defined as 20 to 25˚C, 68 to 77˚F).

Although a battery may be rated at 35 amp-hours, to prevent damage, only the top 30 or 40% of the capacity should be used. Over time, it will become increasingly difficult to charge a battery that has been overdrained. So, a battery rated at 35 amp-hours only contains about 12 amp hours of usable power, which is important to consider when purchasing. On the other hand, if the fieldworker does not intend to keep a particular battery for a long period of time (as with a short fieldwork stay), it may be acceptable to drain the battery more deeply.

Deep-cycle lead-acid batteries, in contrast to standard lead-acid batteries, are designed to be deeply drained and then recharged. They are less widely available, however, and may be more expensive than vehicle batteries, making them more appropriate for long-term stays, where the benefits of such a battery outweigh the expense and hassle of obtaining one. Deep-cycle batteries are often used on boats, so if you are in a coastal location, you should be able to find one.

A third option, which is rapidly dropping in price and increasing in capacity is Nickel Metal-Hydride (NiMH) batteries. These are the rechargeable AA or D sized batteries that can often be used directly in your portable equipment. There are some chargers available that charge these batteries using power direct from a solar panel. Alternatively, the batteries can be wired in series and charged directly from the solar cell (you need roughly 1.41 volts per NiMH cell). If the amperage of the solar cell is below one tenth of the capacity of the NiMH cell, the batteries will not overcharge (extra power is dissipated as heat). Note however that it may take two days or more to efficiently charge your batteries this way, so this option is best suited to an ultra light-weight kit and to those with some electronics savvy.

3.5 POWER ADAPTORS. Having established a power source and storage, you must then get the power from the battery to the devices that they want to power. In general, you need

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the manufacturer of the battery. Take several copies and have it handy when you head to the airport. Expect delays when your luggage goes through the x-ray machine.

an adaptor to convert the DC 12-volt power from the battery to a form that can be used by your equipment.

3.5.1 INVERTERS. Whether the devices ultimately use DC or AC power, most will have standard plugs that utilize the AC power from wall sockets (DC devices take the AC power from the wall and change them to DC using converters such as the one pictured in FIGURE 1 above). Since the battery uses DC power, the fieldworker must deal with both the plugs and the conversion of DC power into AC power (but see Section 3.5.2 for a discussion of bypassing that conversion for devices, such as laptops, that already use DC power).

One way to deal with both the plugs and the conversion is to use an inverter. An inverter changes the DC electricity output by the battery into AC electricity used by most electrical devices (Colborn 1999). The inverter has a standard socket (AC) on one end and a DC plug (such as a cigarette lighter plug) on the other. The standard wall-socket plugs can then be plugged into the inverter, and the inverter plugs into the battery.

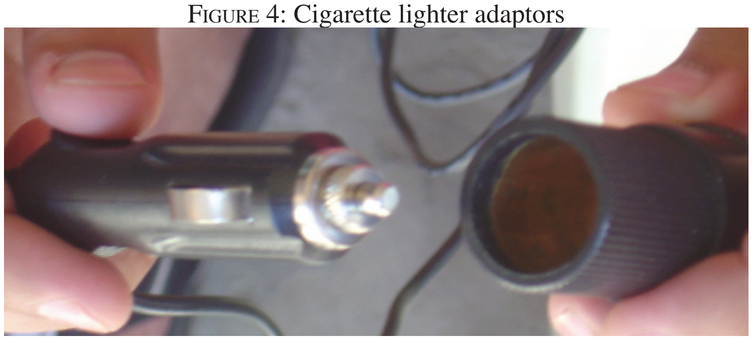
Since different countries have different AC voltages, it is important to purchase one that is appropriate for the devices to be powered (American and Canadian wall outlets produce 110 AC volts, while European and Australian ones produce 220 to 240). On the other hand, many devices, such as laptop computers, are designed to handle a range of voltages (check the technical information on the adaptor for input voltages) and so would work with either a 110 or a 220 to 240 inverter.

It is also important to calculate how large the inverter needs to be in order to handle the maximum wattage that it will be asked to invert at any given time. For example, to power a 100-watt television and two 40-watt light bulbs at the same time, the inverter should be able to handle at least 180 watts.

In terms of weight and energy efficiency, an inverter is not the ideal field setup. Most portable equipment uses DC power, and the conversion to AC wastes power (especially if it is converted back to DC), and with DC to DC adaptors, one has the option to leave all the traditional power adaptors (with wall socket plugs) at home, saving weight (although these are quite useful should grid power become available).

3.5.2 12v DC EQUIPMENT ("CIGARETTE LIGHTER ADAPTORS"). In order to bypass the need for an inverter, the fieldworker may create a setup that utilizes DC cigarette lighter sockets and plugs (also known as automotive adaptors; see FIGURE 4 below).

FIGURE 4: Cigarette lighter adaptors

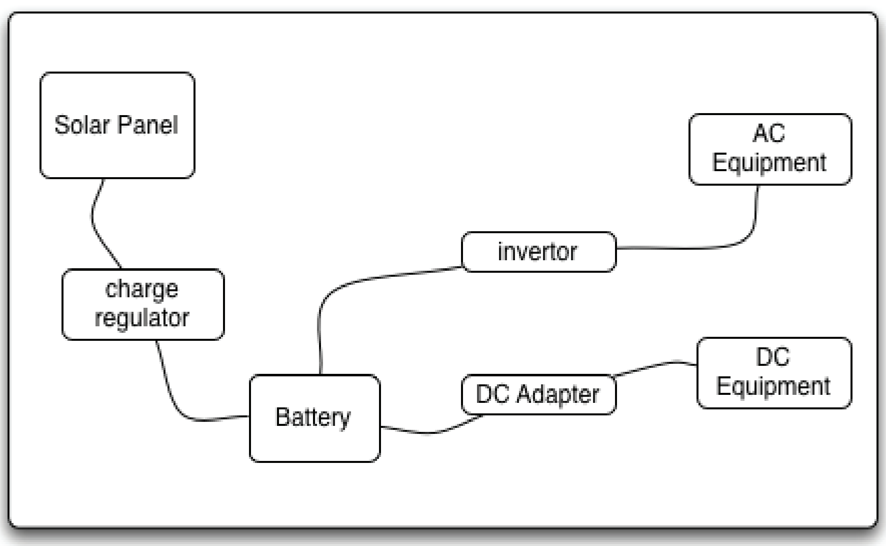


One can either purchase separate automotive adaptors for each device or purchase a multi-purpose adaptor, which can cut down the number of adaptors, but can also destroy equipment if the fieldworker does not completely understand the device. In general, a multi-adaptor will work with any device that has a "DC IN" plug, indicates the polarity of the plug, and has a socket that fits one of the plugs provided. If the device requires a voltage other than 12V, the fieldworker must ensure that the multi-adaptor matches the voltage and is capable of supplying the necessary amps for the device. Laptops, for example, often require a high amperage. If you choose to go down this path, we strongly recommend talking with the salesperson at your hobby electronics store about using this equipment. Purchasing separate car adaptors from the manufacturer for each device is far more reliable for the fieldworker without electronics savvy.

In the tip of the car adaptor (and usually within the inverter as well), there are little glass fuses. They can usually be found by unscrewing the end of the adaptor. The fieldworker should carry extra fuses for each device in case a fuse blows in the field. It is also important to know which fuse goes with which adaptor, as the wrong fuse could result in destroyed equipment or may burnout if it is too weak.

4. PUTTING IT ALL TOGETHER. The setup is wired in parallel, which means connecting the positives (reds) to the positives and the negatives (black) to the negatives. Do so in the chain indicated in the picture below.

FIGURE 5: The solar setup



The red (positive) cable from the solar panel connects to the 'positive in' on the charge regulator, and the black (negative) cable connects to the 'negative in' (there may only be one negative terminal on your charge regulator). If the solar panel is exposed to rain and it is positioned above the regulator and battery, rain may drip down the cable and damage the equipment. To avoid this damage, put a simple loop in the cable so that the water drips somewhere innocuous.

The 'positive out' on the charge regulator connects to the positive terminal (red) of your battery and the negative to the negative terminal (black). Depending on your charge regulator, it may include a 'power out' option, where it will limit the power drawn from the battery so you don't damage it. If this is the case, connect your inverter or DC adapter (cigarette lighter plug cables) to the regulator, positive to positive, negative to negative. Finally, connect your AC or DC equipment to their respective adapters (you needn't worry about polarity, these both have special plugs).

If you wish to hook the solar panel up directly to the battery (i.e. without a charge regulator), then connect it in parallel.

5. MULTI-METER. Some people recommend taking a digital multi-meter into the field. It is cheap and lightweight and, among many other uses, can measure the voltage on the battery, which is a way to see how fully charged the battery is. As a battery is charged, its voltage increases, and as it is discharged, the voltage decreases. The voltage operating range varies from battery to battery and depends on the ambient temperature, but typically, it will be in the range of 12–13.8 volts (see the battery documentation for more specific information).

Although a multi-meter can be quite useful to someone who knows how to use it, an incorrectly used multi-meter could short circuit the battery and cause a lot of harm (it may even kill you). It is important either to become familiar with the multi-meter under supervision before entering the field, or to rely instead on a charge regulator with a battery-capacity indicator.

6. BATTERIES FOR PORTABLE DEVICES. Another important source of power in the field is AA or D Cell batteries. These may be either disposables or rechargeable batteries that are charged via the solar setup. Using disposable batteries for devices such as digital cameras can relieve the demand on the solar setup and help the fieldworker budget limited power resources.

Rechargeable batteries have a lower voltage than the disposable (usually alkaline) kind. This means that if the device is not expecting rechargeables, then it either will not work, or the batteries will seem to drain much faster than usual. Mag-lite (flashlights), for instance, are designed to work only with alkaline batteries. Some digital cameras are designed specifically to work with either and have an option to switch between them, but it is important to set this option, or the camera might suddenly switch off. Audio equipment made by Marantz and Nagra is designed to work with both, and Nagras have a built-in charger (which cuts down on equipment). For a long fieldtrip, you will probably need extra batteries for the microphone. If you are using rechargeables in the microphone, it is important to make sure that it runs properly on the lower voltage. In the end, it is often easier to carry in a few high-capacity disposables for the microphone, as they consume power very slowly. For flashlights, many LED-based ones work well with rechargeables.

Read the back of the box to check. It is worth while to spend a bit of extra money to get high quality rechargeable batteries.

The best power-to-weight ratio battery is the Nickel Metal-Hydride (or NiMH) type. Its capacity is measured in milli-amp hours (or mAh's): the higher the better. At the time of writing this article, ~2700mAh is the highest quality available. For both rechargeable and disposable batteries, it is best to be wary of cheap brands. Many disposable batteries in the third world are of notoriously poor quality, and rechargeable batteries everywhere in the world are of inconsistent quality. It is crucial to charge and use rechargeable batteries before leaving for the field to check their quality.

7. REALITY. In reality, neither of the authors used their solar setups effectively in the field. One solar panel simply melted in the tropical midday sun, failing within the first week of fieldwork. The fieldwork team was forced to develop inventive sources of electricity, including the extensive creative use of D-cell batteries and a second solar cell that had too low a voltage to charge a lead-acid battery (Honeyman 2006). In the other case, the author found that although the field site itself did not have electricity, there was electricity relatively nearby where a battery could be charged for a nominal fee, and this ended up being the primary source of electricity because it was much more reliable than the sun. Even in this latter case, the solar panel that claimed to withstand bullet holes eventually broke when it was used as a sleeping mat.

8. CONCLUSION. While solar technology allows researchers to employ a digital workflow that would not have been possible in previous decades, the modern fieldworker must understand a bit about electricity and solar technology to make use of these advances. The solar setup described here includes not only solar panels, but also a battery, a charge controller, and power adaptors. The owner of these tools must understand how they work to deal with the inevitable problems that will arise in the field. Finally, modern fieldworkers must understand that solar technology is not infallible, and in the end, they must understand how to conduct good-old-fashioned analogue fieldwork in case the unspeakable happens. It usually does in field situations.

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Appendix: Glossary of Terms

AC (alternating current) – the kind of power that typically comes from a wall socket.

amps (ampere, amperage, A) – the amount of electricity that flows at a particular time; Amps = Watts/Volts.

amp hours (AH) – see watt hours.

blocking diode – a means of preventing backflow of electricity so that when the power source is no longer charging up the power storage, the power will not flow back into the power source.

charge regulator (also known as a charge controller) – a device that monitors the amount of electricity that flows from the solar panels to the battery, preventing the battery from overcharging, and preventing the loss of electricity through backflow into the solar panels; some charge regulators also prevent the user from overdraining the battery.

DC (direct current) – the kind of power that typically comes from a vehicle battery; this is also the kind of power utilized by many electronic devices such as laptops, which have built-in adaptors that convert AC electricity into DC.

deep cycle battery – a durable battery designed to be drained of the majority of its charge each cycle.

fuse – a small glass tube containing wires that burn out before a dangerous current reaches the device, thus preventing an electrical device from being overcharged.

inverter – a device that converts DC electricity into AC.

lead-acid battery – a standard battery, such as a car battery, that should be drained only of thirty to forty percent of its charge.

milliamps (mA) – 1 amp is equal to 1000mA.

multi-meter – a handheld device that can measure volts and amps.

parallel circuit – a circuit in which the parts are wired together in a bunch. All positives are wired together and all negatives are wired together, thus increasing the amperage of solar cells, or the available amps for batteries.

polarity – the positive (+, red) and negative (-, black) ends of a powers source.

serial circuit – a circuit in which all the parts are wired in a continuous line, negative to positive to negative to positive, thus increasing the voltage of a power source.

volts (voltage, V) – a measure of electrical potential or force. It is roughly analogous to the idea of water pressure, where the electricity is the water, and the voltage is the water pressure; Volts = Watts/Amps.

watts (W) – a measure of how much power a device uses (or produces) at any given time; Watts = amps x volts.

watt hours (Wh) – a measure of how much electricity a power reservoir has or can store. Divide by volts to convert to amp hours.