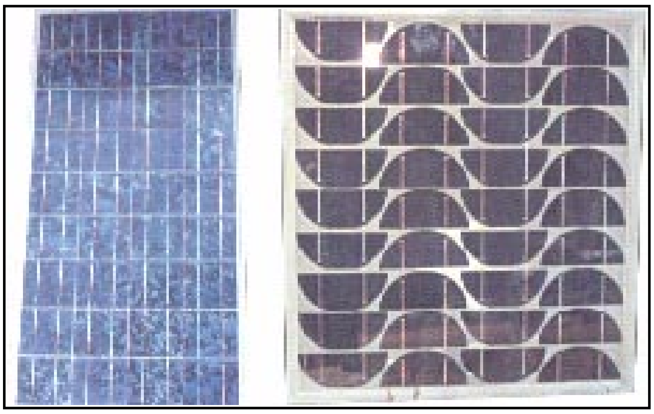
AJ's Technical Tips: Designing a Small Solar PV System Part II: Choosing a Solar Panel for the System



Poly-crystalline (left) & mono-crystalline (right) type of solar panels. See page 5 for a picture of an amorphous solar panel

A big thank you to all of you who wrote me letters. Phillip Kimathi Marete of Meru writes asking for advice about repairing solar panels. He says, "I have installed a number of solar systems and repaired many of them with success. The problem is whereby the positive or negative terminal breaks inside the glass and I have to use clips to hold the metallic wire after breaking the end of the glass carefully with pliers. The biggest problem is when the glass breaks and cuts the wire making no continuity. I have tried to tighten with copper wire round the glass but the outcome is not good. Is there a way you can make a gum e.g. araldite or stik-tight which is a good conductor that can still pass the current and can also join the glass tight?"

In my experience, there are not any good solutions to this problem. The main issue is that once the ends of the glass have been broken on an amorphous solar panel, there is the problem of water leaking into the panel. This water will damage the panel quickly - it might work for a short while but when the rains come the panel will get spoiled. It is very difficult to seal the glass so that the water does not get in once the original seal has been broken. So, unfortunately I do not have any good advice for Phillip - once the terminals break inside an amorphous solar panel there is not much to do, unless it is possible to return the panel under the warranty (sometimes this might be possible).

Simon Nyukuri of Kitale also asked a question about selecting wires for small solar PV systems. I will write about this in the next issue of *Solarnet* in an article that will include details about selecting a battery and wires for a small solar PV system.

Those of you who read the last edition of "Technical Tips" will remember that we completed the first step for designing a small solar PV system - which is the step of calculating the size of the electrical loads for the system. This time we will use the load calculations from last time to calculate the right size for a solar panel for this same system.

The solar PV system that we talked about last time (see *Solarnet* volume 3, number 3) had one 7 watt fluorescent lamp that was used for 3 hours per day, a black and white television (13 watts) that was used for two hours per day, and a 2 watt radio that was used for five hours per day. The total daily energy use for the system was 57 watt-hours. This number - the total daily energy use - is the main number that we will use to calculate the size of the solar panel and, in the next issue of *Solarnet*, the size of the battery. Remember that the amount of energy that can be used by the customer is limited by the amount of electricity that is produced by the solar panel. This means that for this system we need to pick a panel that is big enough to provide these 57 watt-hours per day.

Once we know the daily energy use, the next number that we need is the amount of sun that will hit the solar panel once it is installed. This number depends on three main things:

1. The place where the solar panel is installed - some places are sunnier than others (for example, Kisumu gets more sun on average than Nairobi does)

2. The month of the year - sunny months have more sun than cloudy months

3. The tilt and direction of the solar panel - the amount of sun on the panel depends on which way it is facing and how tilted it is.

In Table 1 I list the amount of sun that is available on a flat mounted (horizontal) solar panel for 10 towns in Kenya and 5 towns in Uganda. For each town I list the amount of sun in a very sunny month, the amount in an average (medium) month, and the amount in a cloudy month. In his book "Solar Electric Systems for Africa" Mark Hankins has more information about the amount of sun available in Africa, including solar data for more Kenyan and Ugandan towns as well as for some towns in Tanzania and several southern African countries.

When you design a solar PV system you should try to find information about how much sun is available at the place you are going to do the installation. You can estimate this from solar energy data for a town that is nearby and that has weather patterns that are similar to the place where you will do the installation. Sometimes it is hard to find information for a town that is very close, but it is also possible to use solar information for a town that is a little bit far away. For example, for towns to the south and east of Mt. Kenya such as Murang'a, Embu, and Meru I use solar data from Nairobi. This is not exact, but it can be close enough in many cases. Let us say that for the solar system we are designing in this example that the installation is for a home near Embu. I will use solar data for the nearest town listed in Table 1 that has similar weather - this is Nairobi.

The next thing to decide is if we want to design the solar system so that it can provide the total daily energy (57 watt-hours per day in our example) during an average (medium) solar month or if we want

Table 1: Solar Energy on a Flat Surface for Some Towns in Kenya and Uganda

Town/Country	Solar Energy in a Sunny Month (sun-hours per day, also kWh/m2/day)	Solar Energy in an Average Month (sun-hours per day, also kWh/m2/day)	Solar Energy in a Cloudy Month (sun-hours per day, also kWh/m2/day)
Eldoret, KN	7.0	6.1	5.0
Kericho, KN	6.8	5.7	4.7
Kisumu, KN	6.7	5.9	5.7
Kitale, KN	6.7	5.9	5.2
Mainei, KN	5.7	5.2	4.5
Mombasa, KN	6.1	5.4	4.5
Nairobi, KN	6.6	5.3	3.6
Nakuru, KN	6.6	5.9	5.5
Nanyuki, KN	6.8	5.4	4.4
Narok, KN	6.2	5.5	4.5
Gulu, UG	5.5	5.1	4.3
Kampala, UG	5.5	5.1	4.6
Kasese, UG	5.2	5.0	4.4
Soroti, UG	6.1	5.5	5.1
Tororo, UG	5.6	5.3	4.7

to be able to provide this much energy even in a very cloudy month. If we want to provide this energy even in very cloudy months, it will be necessary to buy a larger solar panel than would be the case in an average (medium) month. Because people in rural areas of Kenya can usually take their battery to a local charging station from time to time during very cloudy times, I often design the system so that it provides enough energy in an average month. However, it is always important to be sure that the customer understands what he or she is buying. Because of this, I am always sure to explain that designing the solar system for an average month will mean that they can buy a solar panel that is a bit smaller, but that during cloudy periods they will either have to use a little less energy or take the battery in for a charge more frequently.

In this example I will select a solar panel based on solar data for an <u>average month</u>. Since we are using solar data from Nairobi, this number is 5.3 hours of bright sun per day on a flat surface (see Table 1 - also, see Mark Hankins' book for an explanation of how this number is calculated). However, as a practice exercise, you might also want to calculate the panel size that would be necessary to meet the daily energy demand even in a <u>cloudy month</u> so that you can see the difference. Send me your results from this calculation (that is, tell me what size of solar panel is required to meet the load of 57 watt-hours per day in a cloudy month for an installation near Embu) - and I will check your calculations and give feedback in the next issue of *Solarnet*.

You will remember that in addition to the location and the time of year, the amount of sun that hits the solar panel also depends on the tilt and direction of the solar panel. For most locations in Kenya (and other places close to the equator) it is usually best to mount the solar panel so that it is almost flat - with just enough tilt for rainwater to run off of the panel. When the panel is mounted this way (almost flat), the direction is not so important (but if the tilt is greater than 15 or 20 degrees then for locations that are south of the equator solar panels should usually be mounted so that they face north and for locations north of the equator it is usually best for the panels to face south).

When solar panels are mounted so that they are almost flat then it is OK to use the solar data that is given in Table 1. If the panel is mounted with a steeper tilt then the amount of sun on the panel will be different than the numbers in Table 1 - and in most cases in Kenya on average it will be less. This is why it is important to mount the panel with a very small tilt only. In a future article I will give more information about the effect of the direction that the panel faces and the tilt of the panel on the amount of sun that hits a solar panel.

And, of course, it is also always important to make sure that nothing blocks the sun from reaching the solar panel during the day. If trees, buildings, or other things block the sun, then the amount of electricity produced by the panel can be very low - in some cases blocking even a little bit of the panel can cut the electricity produced in half!

For our example of an installation near Embu - which is just south of the equator - I would recommend that the panel be mounted with a 5-degree tilt only (almost flat). This means that we can use solar data from Table 1 for the city of Nairobi for the number of hours of bright sun that will hit the solar panel during an average (medium) month. This number is 5.3 sun hours per day.

Now that we have an estimate for how much sun will hit the solar panel, we can calculate how big the panel should be if it is going to produce enough electricity to meet the daily energy use that we estimated for this system in the last issue of *Solarnet* (that is, 57 watt-hours per day).

The calculation is done in 3 steps:

1. Daily energy use for the load (watt-hours per day) system voltage (volts) = daily load amp-hour requirement for the system (amp-hours per day)

    - For our system this is 57 watt-hours per day 12 volts = 4.75 amp-hours per day.

2. Daily load amp-hour requirement 0.8 (this is the battery storage efficiency) hours of bright sun on the solar panel = required current output from the solar panel in bright sun conditions (amps).

    - For our system this is 4.75 amp-hours per day 0.8 5.3 sun hours = 1.12 amps.

    This means that we want a solar panel that gives about 1.12 amps (or more) under bright sun conditions.

3. This leads to the third step in the process - selecting a high quality but affordable solar panel that will produce the amount of current that we calculated in step 2, above.

There are two stages to selecting a solar panel - one is choosing which type of panel you want to use - that is, the brand of panel you want to buy and whether you want an amorphous type of panel or a crystalline or poly-crystalline solar panel? The second stage is finding a panel that gives the right current output for your system (in our example this is 1.12 amps). The first stage is really a question of reputation and quality.

You want to buy a solar panel that is of high quality and that performs up to the level advertised by the manufacturer. The second stage is connected to the first, as the lowest cost solar panel that is of a good quality and that gives the right current output should work well for the system.

From my experience, all of the three main types of solar panels - amorphous, crystalline, and poly-crystalline - can perform well. The key is to pick a good quality brand, as some manufacturers are better than others in terms of quality. I will talk more about solar panels and quality a little later in this article.

In terms of selecting a solar panel that gives the right current output, one place to find out how much current the panel will give under bright sun is to get the information from the manufacturer's data. This information is usually printed on the back of the solar panel, and you should also be able to get information sheets for the panel from the place where you buy the panel. If the business selling you the panel cannot give you good information about it - including a written sheet with information from the manufacturer plus a written guarantee of performance - then you probably should not buy the panel. See Table 2 for manufacturer's information about some small solar panels that are commonly sold in Kenya (I thank Mr. Henry Watitwa and Mr. Maina Mumbi for helping me to collect this information).

Solar Panel Brand	Solar Panel Type	Rated Power Output (watts)	Current at Rated Power (amps)	Approximate Retail Price (KSh)	Price per Rated Watt (KSh/watt)
Free Energy Europe	Amorphous	12	0.75	4,200	350
Millennia	Amorphous	20	1.3	9,100	455
Unisolar	Amorphous	21	1.27	16,500	786
Solarex SX-20	Poly-Crystalline	20	1.19	12,000	600
Helios	Crystalline	15	0.92	8000	533
Helios	Crystalline	20	1.21	10,500	525
Sangyug	Crystalline	18	1.04	8,400	467
Sangyug	Crystalline	20	1.16	9,300	465

Data Source: Manufacturer's data and Distributor suggested retail prices

Unfortunately, while most manufacturers give more or less correct data about the performance of their panels, some of the solar panels sold in Kenya do not perform as well as they should. From my experience, manufacturers of the following brands of small solar panels give information that is more or less correct: BP Solar, Millennia (BP), Solarex (BP), Free Energy Europe (FEE), Unisolar, Siemens, Kyocera, and Astropower. I consider these to be high quality solar panels. There are some others, such as Eurosolare (made by Agip), NAPS (crystalline), and Shell Solar that I have not tested - but as far as I know these are good quality solar panels. However, some other brands sold in Kenya, including some of the very common types, may not perform as advertised.

Some of the discount crystalline solar panels are not really a bargain as some do not perform as well as advertised. For example, a little while back I bought a 15 watt crystalline solar panel in Nairobi for KSh 7000 because I was curious about its performance. This would seem like a bargain, since the price per rated watt was only 467 KSh per watt (You can calculate the price per rated watt by dividing the price of the panel by its rated power output. For this example this is 7,000 KSh 15 Watts = 467 KSh/watt.) This appears to be considerably less expensive than some of the leading brands, such as Solarex, which sell for about 600 KSh per rated watt. See Table 2 for the price per rated watt for some commonly sold brands of small solar panels in Kenya. However, when I tested the 15-watt panel using a careful scientific test its real output was only 10.6 watts - much less than the advertised performance. This means that the true price per watt is about 660 KSh/watt (I get this from 7000 KSh 10.6 watts = 660 KSh/watt). Thus, what seemed like a bargain was even more expensive per watt than leading high quality brands like Solarex. I have also tested some of the other lower cost crystalline solar panel brands with similar results.

So, if the deal you are getting in terms of the price per rated watt seems too good to be true, it might not be such a good deal. Of course, some of the <u>amorphous</u> panels do cost a lot less than the crystalline and poly-crystalline type panels, and some of these - especially the Free Energy Europe and the Millennia solar panels - are a good deal. I recommend them highly.

OK, now that we have discussed the issue of quality and performance of some solar panels, it is time to pick a panel for our system. Here I want to get a good quality panel that will give enough current but which does not cost too much. We are looking for something that has a rated current output of 1.12 amps (or more) at maximum power under bright sun conditions. According to the manufacturer's data, several panels from Table 2 would work, including 20 watt solar panels made by Millennia, Solarex, Helios, and Sangyug as well as the 21 watt solar panel made by Unisolar (the 15 watt Helios and the 18 watt Sangyug panels are too small - their advertised current output is less than the 1.12 amps that are required to meet the loads). Of these, my first recommendation would be the Millennia 20 watt solar panel - this is a high quality panel that will give more than enough current for our application - and it costs less than the others (9,100 KSh). My second recommendation would be the Solarex SX20 - it costs a bit more than some of the others (12,000 KSh), but I recommend it anyway because of its good quality.

However, there is also another option that can be used that is even less expensive than the 20 watt Millennia module. This would be to use two of the Free Energy Europe (FEE) 12 watt panels. These should be wired in parallel (that is, the positive from both of these panels should be connected to the positive side of the battery, and the negative from both panels should be connected to the negative side of the battery) - when this is done the total current will be two times the current from one panel so we will get 1.50 amps of output. This is more than enough, and the price of 2 of these panels is only 8,400 KSh - which is less than the Millennia. I see this, as the **<u>best option</u>** because the customer will get the best price, and they will also get extra energy because the current output will be even higher than is required to give enough energy for the loads.

This means that the customer will be able to use the lights, television, and radio in their system a bit more than if we had used one of the 20 watt panels (for example, the 20 watt Millennia or the 20 watt Solarex) - and at a lower cost.

Finally, there are some new solar panels that are going to be available in Kenya soon - including a 20-watt Free Energy Europe solar panel. I have not yet tested this panel, but if it performs well and has a low cost this new solar panel may be an even better option than buying two of the 12-watt Free Energy Europe panels. However, we will have to wait until it comes out to know for sure.

To conclude, in this article we have used the information about the daily energy required by the loads from the last article of *Solarnet* along with infor

mation about the amount of sun that is available at the place where the solar PV system is to be installed to pick a solar panel for the system that will be the right size to give enough energy. My first recommendation for this system is to use two 12 watt Free Energy Europe panels wired in parallel - and if the customer decides that it is better to use only one panel then my second recommendation is to go with a 20 watt Millennia solar panel.

In the next issue, I will select a battery for this same solar PV system and I will also talk about choosing wires for the system. Until then, *kwaherini*.

Continued from page 2

Dear Lloyd,

I have given your greetings to Henry, and he sends you a big "hello" in return. In general, it is best not to mix panels of different sizes and types, but it can be done. If you do mix them, you will loose a little bit of performence from the panels. For example, a 20-watt and a 12-watt panel combined do not add up to a 32-watt panel. Instead, they might perform together like a 28-watt panel. Also, if you do mix panels, it is better to combine crystalline types (mono or poly-crystalline) with other crystalline panels and amorphous with amorphous - but combining crystalline with amorphous will give bad results with a large performance loss

Sincerely yours, Arne Jacobson (AJ's Technical Tips)

Energy Efficient Lighting

Lighting is one of the most important and essential loads whether you are working with utility grid connected or off-grid (solar PV) applications. If we want to save energy, it is therefore important to begin with lighting.

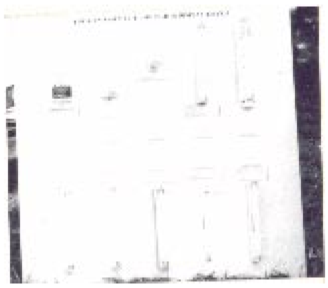
There are four main kinds of lights that can be used in homes, offices and business premises. These are incandescent lamps, halogen lamps, compact fluorescent and standard fluorescent lamps.

Incandescent lamps are the most commonly used type of lighting. This is, generally, due to the low cost of the bulbs they use. However, incandescent bulbs are not very efficient - over 90% of the electricity they use is wasted as heat and only a small part is made into light. In addition to their low efficiency, the bulbs do not last very long - typically each bulb can be used for about 1000 hours of operation.

Halogen lamps are similar to incandescent lamps except that they are a little bit more efficient and the bulbs last about three times longer (that is about 3000 hours). They also have a "whiter" light - which is a light that is closer to the colour of sunlight - than incandescent bulbs. Their low efficiency means that they are not a good choice if high efficiency is needed, but their long life makes them good for certain uses.

Fluorescent lamps come in two forms - compact fluorescent, which can be fitted in a normal lamp socket and the standard fluorescent tubes that are double ended. Both types are more efficient than incandescent and halogen lamps - generally they are 3 to 4 times more efficient, although the exact amount depends on which type of 'ballast' the lamp has (the ballast is the electrical circuit that is built into the fluorescent lamps). Both types of fluorescent lamps last longer than incandescent and halogen lamps - compact fluorescent have a rated life of 10,000 hours, while standard fluorescents have a life of 8,000 hours. However, fluorescent lamps are highly affected by low voltages, which brings about the blackening at the end of the tube in direct current systems and delayed starting in alternating current systems. Finally, fluorescence comes in a range of 'colours', from "cool white" to "warm white" to blue, green and red. On a colour rendering index (CRI) of 1 to 100, with 100 being the best (that is, the closest to true sunlight colour), the "cool white" is rated at 69. For commonly used places, a CRI of 80+ is recommended.

To conclude, if high efficiency is important, one of the two types of fluorescent lamps should be your first choice. This is especially true for off-grid (solar PV) systems, but it can also be true for homes, offices and business premises that are connected to the grid. Of course, other considerations



Examples of fluorescent tube lights, a compact fluorescent light & an incandescent bulb

such as colour and flicker can be important, and different people have different opinions on these issues. These additional issues should also be taken into account when choosing lights. In general, because of their low efficiency and short life, incandescent lamps should only be used when (1) no other alternative is available or (2) for lamps that are not used very much or are only used for short periods of time. Also, both incandescent and halogen lamps may be considered when it is important for the light to come on immediately or when full range dimming is required - and halogens are often preferred in these cases (when available) due to their longer bulb life. For most other applications in homes, offices and business premises either standard or compact fluorescent lamps are probably your best choice.

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