AfriForum

BASIC PRINCIPLES FOR SOLAR POWER

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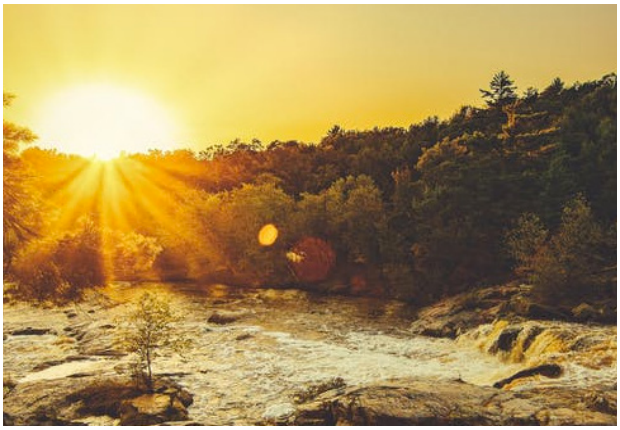


INTRODUCTION

Electricity to end consumers in South Africa has become unreliable and increasingly of poor quality, with the effect that solutions under own control has become an urgent and growing need.

The conversion of sunlight into electricity by way of roof-mounted panels is the most familiar process, but it is often also necessary to store some of this energy for when the municipal network is offline. This requires technical, management and financial judgement. If done sensibly, it is possible to generate your own electricity at better prices with much lower risks, compared to being dependent on the national network.

Although the configuration of the most systems is quite straight forward, it is essential to grasp the basic operational principles. This will enable end consumers to consider the myriad of propositions in a responsible manner in determining solutions that meet the end consumer's needs.

Different types of consumers in the residential, commercial, industrial and services sectors have different needs. This guide presents the basic principles to households to explain how these systems work, how to configure these and how to select service providers.

Trade names and products mentioned in this guide are examples with good reputations and that fosters trust at the time of this guide's publication. There are obviously also other products and trade names.

IMPORTANT TERMS EXPLAINED

AFRIKAANS	ENGLISH
Fotovoltaïese sonpaneel	Solar photovoltaic panel (PV)
Wisselrigterl	nverter
Drywing (Watt)	Power (Watt)
Energie (Watt-uur, W-h, Joules)E	nergy (W-h)
Aangeslane drywing (naamplaatwaarde)P	ower rating (rated power, nameplate)
Gelykstroom(GS)D	irect current (DC)
Wisselstroom (WS)	Alternating current (AC)
Spanning (V)	Voltage (A)

BASIC ENERGY CONCEPTS

Kilowatt (kW)

A kilowatt is the peak energy that an appliance (in this instance electrical) will consume or produce.

Example: A 150 ℓ geyser with a 3 kW element will extract 3 kW at any given time when the thermostat decides that the water's temperature has not yet reached the setting that the consumer selected.

This geyser will withdraw RMS current of 3 000 W/230 V = 13 A

- *1 kW = 1 000 W*
- ***RMS** = root mean square, a concept to qualify the effective AC current value*

Kilowatt-hour (kWh)

The amount of energy that the geysers consume is determined by how long the energy is consumed by the appliance (or generated if it is a PV system).

Example: A 150 ℓ geyser with a 3 kW element requires 3 kW for 2,5 hours to heat this volume of water from 20 °C to 65 °C; this is equal to energy of 3 kW x 2,5 hours = 7,5 kWh. This is displayed as 7,5 "energy units" on the electricity meter.

- *1 kWh = 1 000 Wh*
- *Energy in Wh is the equivalent of 3 600 joules, because 1 watt equals 1 joule/s, and after one hour (i.e., 3 600 seconds) this equals 3 600 joules.*

Appliances on which kVA (kilovolt-ampere) is displayed on the name plate is the apparent power. This is numerically a greater number than the appliance's kW assessment because it also includes the reactive power component (kVar).

$$kVA = \sqrt{kW^2 + kVar^2}$$

HOW CAN FREE SUN ENERGY BE UTILISED?

Free energy from the sun can be utilised photovoltaically converting the sun's irradiation into electric energy (photons become electrons) or by directly capturing the sun's radiant heat in water heaters.

The durability of a solar water heater is determined by the specific appliance, however, as well as by the water quality. A proper system that delivers dependable high-pressure water is usually more expensive.

- This document focuses on the conversion of sunlight into electricity, and therefore the trade term "PV" is used further in this document.

PHOTOVOLTAIC (PV) PANELS

- Photovoltaic panels are known in the industry as PV panels and converts the sun's irradiation into direct current voltage and current.

- A PV panel's name plate specifies the volts (V), current (A) and power (W).

- Electrical current is measured in ampere (after the French physicist André-Marie Ampère, who first described it).

THERMIC SUN ENERGY

Thermic solar water heaters erected on roofs only heat water and do not generate electricity.

Some power stations do use heat from the sun to heat up salt until it liquifies, after which this heat is transferred to water to power steam turbine generators. These systems are enormous and delivers a lot of MW, with one example just outside Upington, visible from afar.

CONFIGURATION AND ENERGY PRODUCTION

- A PV panel in South Africa that is properly aimed north with provision made for the degree of latitude and with no shade from trees and other structures can generate 4,5 kW energy for every kW peak (name plate specification).

-This means that a 500 W panel can generate on average 2,25 kWh per day over 12 months, i.e., 821 kWh energy per year.

- One 500 W panel can theoretically save 821 kWh x R3/kWh = R2 460; however, the sun does not shine every day and all the energy is not necessarily consumed.

Network-linked but without batteries

It is possible to use inverters that synchronise with the municipal network to deliver solar energy locally and feed surplus energy back to the municipal network – this requires a "smart" municipal energy meter to recognise it.

Very few municipalities allow this or buy energy back.

This configuration does not deliver energy during loadshedding or at night.

Stand-alone island power system with batteries

It is possible to create a power system where PV panels recharge batteries sufficiently during the day to enable the inverter to sustainably provide electricity at night.

The battery storage capacity should be adequate and there should be enough PV panels to provide in the daily needs and still be sufficient enough to recharge the batteries for the night's use.

Hybrid PV system

Hybrid inverters deliver electricity with or without a live municipal network.

There is a seamless switch over between the municipal network and the solar power system.

During loadshedding electricity is delivered from the batteries.

Diesel or petrol power generators may be part of the solution to recharge the batteries and provide the house with electricity when the batteries have discharged.

WHEN DO I USE WHICH CONFIGURATION?

Systems that are **only network-linked** can help lower electricity costs, but do not provide enough energy during loadshedding. Large solar farms will sell energy to Eskom in this way. It would be possible, however, to integrate the system with a diesel power generator to decrease fuel costs, because the system can be synchronised with a diesel power generator.

Island power systems require batteries as energy source when the sun does not shine. It is possible to develop a system that is completely off the national grid, but this requires thorough planning and management. Diesel power generators can serve as emergency support when the batteries have discharged.

A hybrid system that is synchronised with the municipal network can deliver energy locally and switch over seamlessly to the batteries during loadshedding. Diesel power generators can serve as emergency support when the batteries have discharged.

The optimal solution for every consumer will differ as a result of the nature of the load (residential, commercial, agricultural, school, old-age home and so forth).

This guide focuses on PV systems for households (residential).

INVERTERS

An inverter uses energy electronics to convert direct voltage to alternating voltage.

Most low-voltage systems deliver 230 V (RMS value) between phase and neutral, and frequency of 50 Hz.

Three single-phase systems can be installed to deliver a single-phase system with 400 V (RMS) between phases.

Hybrid inverters – the most common technology in houses – have built-in battery chargers to enable the battery to recharge from the sun as well as the municipal system.

It also offers the optimisation function of maximum power point tracker (MPPT) and there is no need to buy an additional MPPT.

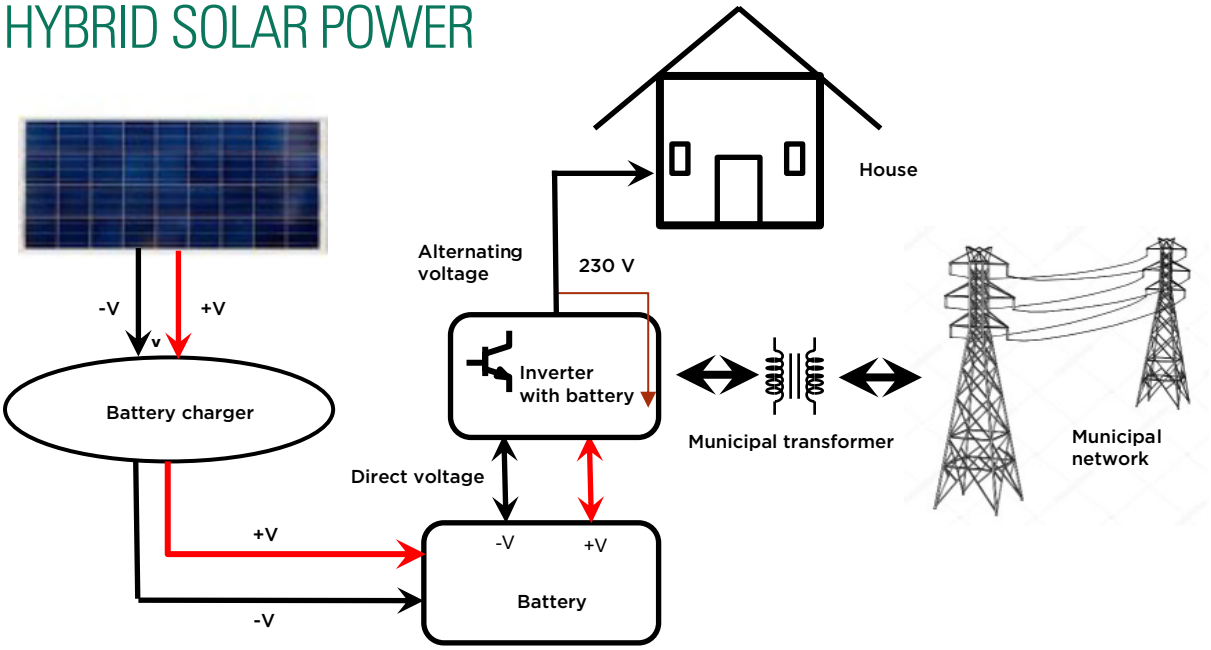
Some inverters are very heavy because the output is fed to the load by a transformer. These models have lots of stored electromagnetic energy and can power motors such as submersible pumps.

Examples are certain Victron and Schneider inverters.

The lighter inverters, although of the same power, are unable to power larger induction motors. They are easy to install, however, and is sufficient for most households.

Examples include Deya, Kodak, Sunsynk, SMA and others.

HYBRID SOLAR POWER



BATTERY TYPES

The battery of choice in 2022 is LiFePO4, because lead-acid batteries, although less expensive, do not last long and have limited discharge capacity.

The number of charge and discharge cycles of lead-acid batteries is up to ten times less than that of LiFePO4 batteries. A major limitation of lead-acid batteries is, although these are deep-cycle, that this is not successful and sustainable.

The electro-chemical process that determines the inherent working principle of any variant of lead-acid battery (including type of gel) degenerates when more than 20% of the stored energy is withdrawn and replaced.

In practice, this means that a 200 Ah lead-acid battery only offers efficient capacity of 20 Ah to maybe last five years. A 100 Ah LiFePO4 battery has 80 Ah available every day and this lasts about 10 years or longer.

It is quite common for a LiFePO4 battery to be guaranteed for 10 years, compared to lead-acid batteries, where the guarantee is seldom more than two years.

Although lead-acid batteries may sound less expensive initially, long-term costs and inconvenience simply do not measure up against LiFePO4 technology.

Make sure of what the service provider offers; there are LiFePO4 batteries termed "second life", meaning these come mainly from old electric vehicles from Europe or the USA. There is limited experience in terms of the number of years and reliability.

WHAT DO I REALLY NEED?

It is possible to measure the current load profile, or make an estimate based on the monthly electricity account, to specify a solar system that matches the historic load profile. It has the potential of being very expensive.

1. Use the minimum electricity

- Use gas stoves with electric ovens that are used only when there is no loadshedding.
- Water can be heated with direct sunlight, or with gas, or with a smart PV system that channels the surplus PV electricity to the normal hot water geyser when the batteries are fully charged and the house's usage is low.
- The swimming pool pump, washing machine, iron etc. can be fed with PV electricity only when there is surplus PV electricity and fully-charged batteries.
- The above "smart" decision-making can be done automatically with a "smart" inverter and installation.

2. Backup to survive loadshedding

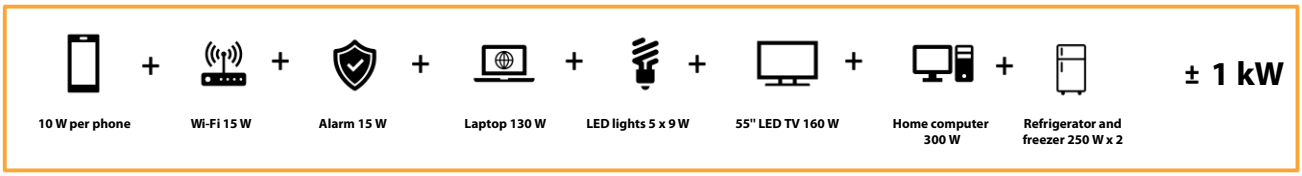
- Internet, security, lighting, TV and garage doors are examples of minimum requirements for most households. A microwave oven requires much power, but the energy is relatively little because it is only used for short periods of time.

3. Adapt your lifestyle to using the minimum energy, and using this as efficiently as possible

- For example, consider using ceiling fans in summer rather than air conditioning with heat pumps.

MOST HOUSEHOLDS WILL BE ABLE TO SURVIVE LOADSHEDDING WITH THE FOLLOWING APPLIANCES

An inverter uses energy electronics to convert direct voltage to alternating voltage.



Remember that not all appliances are switched on the whole time or simultaneously, but – in the worst case – take the total load as 1 kW to determine how much energy to store.

- 2,5 hour backup: 1 kW x 2,5 hours = 2,5 kWh (energy to be consumed in 2,5 hours)
- 4 hour backup: 1 kW x 4 hours = 4 kWh consumed in 4 hours

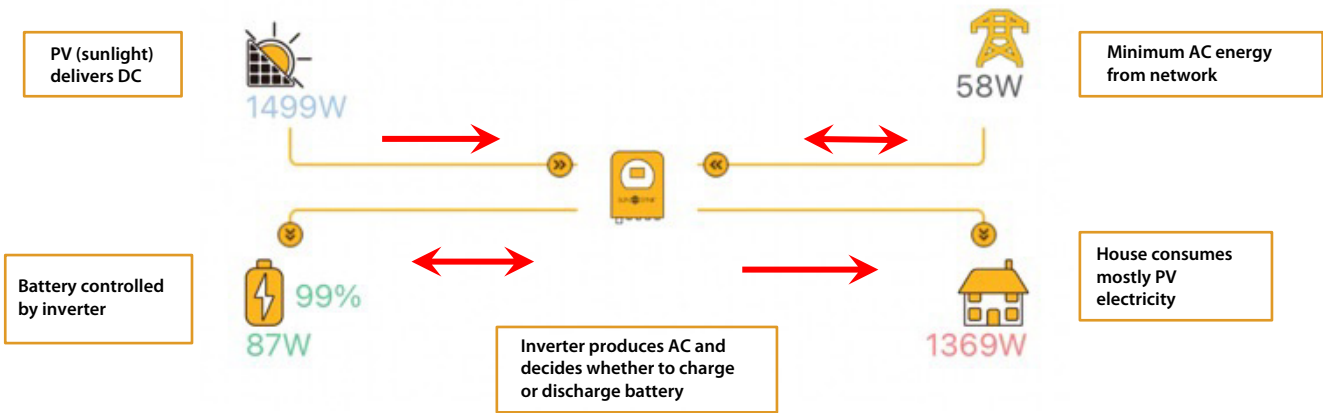
Note: The example above is generous. From experience, we know that most households' load is less than 1 kW, even at night.

SPECIFICATIONS FOR MY INVERTER

Although it may sound as if a 1 kW inverter is large enough, 5 kW is the most common norm and enables you to even use a hair dryer and coffee machine in the morning.

Inverter:

- Consider at least a 5 kW hybrid inverter. It is a popular size where the price per kW offers reasonable value for money. Controlled battery recharge is built-in, with PV panels that link directly to the inverter.
- Compare apples with apples: Cheap Chinese models do not allow the user to monitor or manage the energy consumption properly, and are unreliable. There are indeed good Chinese models available, for example Sunsynk at about R30K.
- The Dutch company Victron's PV equipment is the industry flagship at over R60K.
- Most inverters will allow for smartphone monitoring of daily PV energy generation and consumption from the inverter or from the municipality, and of the battery's condition.



SPECIFICATIONS FOR A LiFePO4 BATTERY

✓ Let us assume that your house requires 1 kW for 4 hours = 4 kWh
✓ It is common to express the LiFePO4 battery's storage capacity in kWh rather than in Ah.

Battery:

- A popular size is around 5 kWh at around R30K.
- Because batteries are expensive components, do not try to save a few rands by buying unknown batteries.
- Names such as Pylontech, Blue Nova and Freedom Won have good reputations.
- Make sure that the provider activates an (at least ten-year guarantee) or do it yourself. A 5 kWh LiFePO4 battery will be able to safely deliver 4 kWh by recharging 80% of capacity daily and putting it back.
- It is possible to later add another 5 kWh because a good battery system allows for parallel connection (e.g., 2 x 5 kWh). 10 kWh will suit larger households better due to more convenience and peace of mind.
- A very good "battery" is a hot water geyser. By not wasting surplus energy in the middle of the day but rather channelling it to the hot water geyser, you prevent the loss of free energy. The geyser can be heated up to 80 °C and can even be stored in the second geyser for tomorrow morning's shower. By linking two geysers in series it is possible to take a hot bath in the evening and a hot shower in the morning without making use of municipal electricity. This may require the automatic switching off of the elements at night so that municipal power is only used when absolutely necessary.

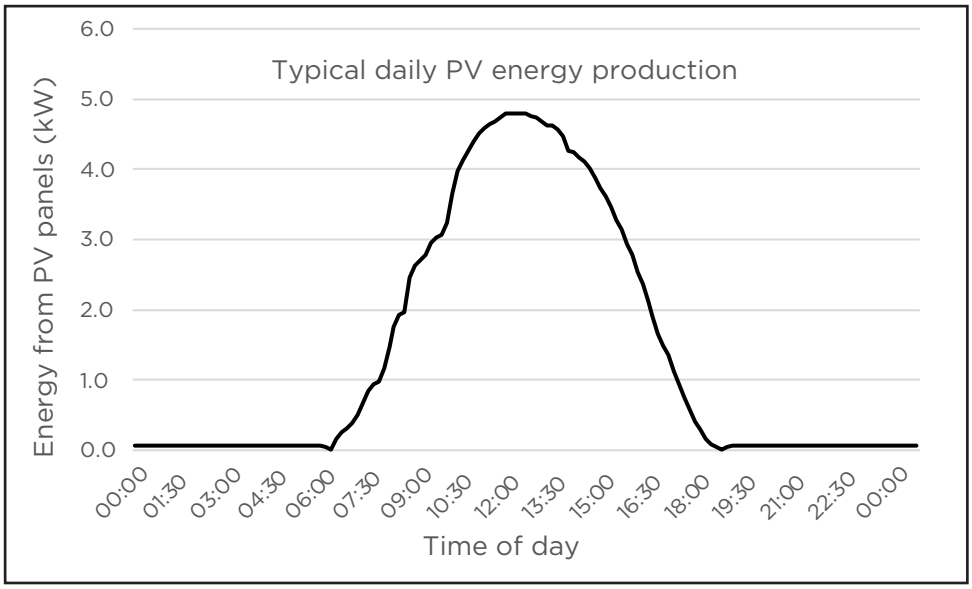
SPECIFICATIONS FOR MY PV PANELS

✓ Let us assume that your house requires 1 kW for 4 hours = 4 kWh and that loadshedding occurs twice a day.

PV panels:

- Thanks to a hybrid inverter the battery can also charge from a municipal network (loadshedding also occurs at night when the sun is down).
- It is important to select panels from reputable suppliers; the supplier will recommend a good brand name. Panels are available up to 600 W and cost about R4K each.
- The average household will already be well away with 4 kW PV panels, but panel linkage for the correct direct voltage that a PV panel needs require an equal number, e.g., six or eight panels.
- 5 kW's panels will allow for the swimming pool pump, washing machine and even an iron in the middle of the day – provided that the sun is shining.
- A 5 kW PV installation will allow you to channel the surplus energy during the day to a hot water geyser.
- Remember that PV panels deliver peak power for a short time of the day; this is when the sun shines properly on and relatively perpendicular to the panels, about 12:00 until 14:00.
- Typical daily production looks like a little bell, as shown below.
- Energy production is the area below the curve.

TYPICAL PV SOLAR POWER PRODUCTION



QUESTIONS AND ANSWERS

1. How much roof area do I need?

- Most houses have enough roof area for a basic solar power system.
- A typical domestic PV installation that delivers 4 kWh peak value requires about 20 m^2 roof space – therefore about 5 m^2 per 1 kWh.

2. In which direction should solar panels be installed in South Africa?

- PV panels convert sunlight into electricity, and if it faces north, it will work in South Africa. The degree of latitude at which the installation is done will determine the angle from the horizontal so that the panels are almost perpendicular to the sun. The installer will calculate the optimal angle.
- If your roof does not face north, you can still generate solar power by facing a part to the west and another to the east. The energy production per panel is now much less than the name plate values, but compensate for this by installing additional panels.

3. Can solar power be installed on any roof?

- There are mounting fittings for every kind of roof in South Africa.
- The weight of the panels requires a good, sturdy roof. The installer will determine whether the roof is sturdy enough.
- The mechanical strength of the construction is important because wind can push very strongly against the panels.
- What does this all mean? Use an installer with a very good reputation.

4. How long do solar panels last?

- Solar panels typically have an energy output guarantee of twenty years. This means that PV panels will still produce more than 80% of the name plate value.

5. What is MPPT and do I need it?

- The maximum power point tracker continuously adjusts the loading from the PV panels as a function of how bright the sun shines to withdraw the most power possible from the panel.
- Modern hybrid inverters have a built-in MPPT and battery charger, so you do not need to buy these additionally.

6. Can the LiFePO4 battery be discharged 100%?

- This situation is usually prevented automatically. That is why most manufacturers will specify a battery for example as 5/4 kWh, indicating that the stored energy is indeed 5 kWh, but that only 4 kWh can be used efficiently to ensure that the battery lasts long.
- Discharge and recharge cycles are managed by an inverter, which prevents the battery from discharging too much and damaging itself.

7. Will the municipality buy my surplus electricity back?

- Mostly not. Some, like Cape Town, do. The expectation is that more and more municipalities will be doing it in future, but only at between 30% and 50% of the price at which they sell it to you.
- **Example:** Cape Town pays a total of R1,03 per kWh. The average price per kWh over a monthly period as provided to households by the municipality is closer to R3 per kWh.
- The same 1 kWh that you sell at R1,03 could have saved you R3. Why then would you want to sell it to the municipality? The answer is not to waste the surplus that you have generated, but rather to use it yourself to ensure a sort of return on your investment.

8. I hear that municipalities will charge monthly levies if I install PV?

- Because municipalities own and have to maintain the supply network, they lose income if households generate electricity themselves. Municipalities may possibly levy a fee to keep the link to the municipal network active.
- PV electricity is a long-term investment and to make it future resistant, design your system for maximum power generation and consumption so that you protect yourself against risks that traditional service providers such as municipalities may pose.

9. Is it worth my while to invest in solar energy?

- From a purely financial viewpoint, it is historically true that electricity prices in South Africa increase more than inflation does.
- Once you have purchased, you have also spent capital and for the next 20 years the returns from the system are reliably predictable with a low risk of having to incur major expenses in future. It may be necessary to replace the batteries after more than 10 years, but the expectation is that batteries will become relatively less expensive in future and, hence, more affordable.
- In future, you will pay less for electricity because the price of self-generated energy does not increase.
- An investment in PV on your home generates a higher annual return compared with government bonds or a fixed investment at a bank.
- It is possible to soon reach a very favourable return and break-even point, but each case is different.
- **IMPORTANT:** The PV system is a reliable insurance policy against future uncertainty over electricity. City councils (and Eskom's) inability to plan, manage and maintain properly is well known.
- PV electricity is of better quality with well-regulated amplitude and without voltage surges that may damage sensitive electronic devices.

10. Must I register my system or apply for approval?

- The municipality must be informed of your PV system, but cannot deny your right to free solar power.
- Few households will operate an island system and the network connection may possibly feed power to the municipal network, which is dangerous for technicians.
- Some city councils, such as Cape Town, have proper documentation and process tracking to be able to allow for prospective and standardised PV solar installations.

11. Do I need an electrician to do the installation?

- Be very careful, as "expert" solar power technicians shoot up like mushrooms.
- Installation requires properly registered electricians to ensure that national wiring standards are adhered to (SANS 1042), so that it is confirmed with a certificate of compliance (CoC).
- This CoC is required by insurance companies or when someone dies because of an electrical shock from your installation.

Note: A proper installation is a safe installation; it is an electrician and consumer who are alive and well.

12. Can I leave the power grid completely?

- Possibly, but it is very expensive.

13. How do I know which providers are reputable?

- AfriForum has compiled a list in cooperation with the Pionier services company (from the AfriForum stable) of recommended service providers to help households to continue with similar projects.
- The use of qualified and accredited providers is of course a great start.
- Visit **www.afrienergie.co.za** for access to examples of these providers.
- The list of recommended providers will be supplemented regularly.