Can I save money by using PV Solar?

– a Guide for Home Owners V2.8

Eon de Koker, Pr.Eng, M.Eng.,MBA

1. Introduction

As everyone was struggling with intermittent electricity (partly due to load shedding but also due to the inability of municipalities to provide services), I decided to compile this guide to provide home owners with information on the selection of components and equipment, from an unbiased source. Unfortunately, there are many opportunistic service providers.

While the initial drive to implement alternative sources of electricity was due to load shedding, the continued increases in electricity costs have has now become the driver.

This guide is accompanied by an Excel model which enables the system size and cost to be estimated. In Version 2.1 we have added costs in R/kWh as well as costs of operating generators. We also added VAT to the component costs.

2. Viability of using PV Solar

In the last 2 years alone, the City of Tshwane increased electricity rates by more than 35% to R3.32/kWh as of 1 Jul 2024. During the same period, the cost of solar panels, batteries and inverters dropped by nearly 50%. Our model shows that the effective electricity cost from an off-grid PV Solar system for an average household is R1.35/kWh which includes installation and finance which amounts to a 60% saving on the electricity compared to the municipal rates. Our model does not include the impact of any rebates. The average household can save more than R1,000 per month by implementing off-grid PV solar. This savings will increase with the planned NERSA increases in the future. This is the by far the best investment any home owner can make.

We are fortunate that South Africa is the second-best rated country on the planet for solar power. Not only do we have the second highest intensity of sunlight but the solar irradiation difference between winter and summer is about 20% in Pretoria and 50% in Cape Town. Other countries such as Germany has snow in winter and the solar power output drops by 80% for up to 4 months. This is why both Europe and the USA need to use gas, nuclear or other sources of power to survive the winter. Unfortunately, the fact that other countries have to rely on coal and gas in winter is being used as an excuse to motivate the use of coal and gas in South Africa, which is unfounded.

The cost of electricity in the City of Tshwane in 2022 was about R2.40 per kWh. NERSA approved a 18.3% increase for Eskom that will be implemented in April 2023 and the cost escalated to R 2.85. NERSA also approved another 12.74% increase for 2024 that pushed the unit costs to R3.32.

In 2020, PV solar became the cheapest way to generate electricity on the planet. In the latest bids for renewable energy projects issued by the South African Department of Energy (Oct 2022), the unit cost of solar and wind were less than R0.50/kWh. Unfortunately, the South African Government did

not proceed with these projects despite load shedding. The reason given was that there is insufficient network capacity available (and not enough time, money or interest to build it).

As a matter of interest, just the cost of coal peaked at a rate of USD 225/ton which translates to R2.16/kWh. The cost of coal is 120 USD/ton and can be found here: https://markets.businessinsider.com/commodities/coal-price. This means that the cost of electricity per kWh from an off-grid PV solar system at domestic scale is about the same as the just the cost of the coal per kWh used by a utility scale thermal power station. If one then adds the operational and finance cost of Medupi and Kusile, the energy generation cost become more than R50/kWh.

So, it becomes a no-brainer to decide in investing in PV Solar as home owners will pay less for electricity while the impact of loadshedding is reduced. As can be seen from the Spreadsheet Model, the finance cost is based on a 20-year financing term. Lithium batteries and Inverters typically have a 10-year life. Solar panels typically have a 25-year life.

The fuel cost of generators varies between R8 and R12 per kWh which is nearly 6 times more than the cost of PV solar. Users currently paying for fuel should rather use the money to pay for the PV solar system.

3. Viability of Wind Power

There is a good article here: https://mybroadband.co.za/news/energy/483827-why-home-wind-power-is-useless-for-most-south-africans.html

This provides many reasons why wind power is not suitable for residential power generation in South Africa. Some of the main reasons are high installation costs, high maintenance costs, damage due to high wind speeds, wind energy having an availability factor which is 50% less than solar and the capital outlay being nearly 3 times that of solar. Solar panels come with warranties of 10-20 years while wind turbines only have warranties of 2-10 years. Some wind turbines (typically the vertical ones) can turn in the wrong direction and then have to be manually stopped and the direction reversed.

4. Basic Steps

The first and most important step is to first reduce energy consumption by selecting more efficient energy options. This has a substantial impact on reducing the initial system capital cost.

Hot Water Options

The biggest energy consumer in the home is the hot water geyser. These are the options to reduce the energy consumption:

a) Retrofit solar tubes to existing geysers. This is more efficient and less costly that using PV solar power for the geyser as PV panels are only about 20% efficient. You can buy a 20-tube solar water heater unit for about R8,000 and a circulation pump for about R800.
b) Consider using gas for cooking and hot water heating, especially if hot water is only required occasionally such as for guest rooms. You can buy a Bosch 18L gas geyser for about R8,000 or a Rinnai 28L for R14,000. The Rinnai is made in Japan and has an electronic controller making it more energy efficient.
c) Consider using a heat pump. This uses only 30% of the electricity of a geyser element for the same output. So, a heat pump with 3kW heat output only uses 1kW which results in a 67% energy saving.

You can buy a 3.5kW (output) heat pump for about R12k and then add a circulation pump for R800.

Stove

Each stove plate uses 1-2kW. The oven itself is another 2kW per element (bottom or top). With the oven and 4 plates on at the same time, it can draw 4-6 kW. Some stove plates use induction heating which heats faster but the power usage is still 1-2kW per plate. It is therefore advised to rather use gas for cooking. A 48kg gas cylinder cost about R1,600 to refill and will last more than 18 months. The cost therefore is about R90 per month.

High Consumption Appliances

The appliances that are the biggest energy consumers, are the ones having heating elements:

- Tumble Drier (2-3kW)
- Oil heaters (2-3kW)
- Aircon (2-3kW)
- Dishwasher (1-2kW)
- Washing machine (1-2kW)
- Iron (1-2kW)
- Pool pump (1-2kW)

In most households, it is not necessary to run all these appliances simultaneously. The PV system capital cost can be substantially reduced by installing timers and having these appliances on different timeslots.

Appliances used at night

The next step is to consider which appliances are required at to run night. It is important to minimise the energy usage at night as this directly impacts the battery size which is an expensive component. Some options are:

- Ensure all appliances used at night such as fridges have an A++ energy rating
- Use only LED light bulbs
- For outdoor lights, consider the ones with movement sensing
- Run dishwashers, washing machines, driers and pool pumps during the day

One of the appliances consuming energy at night is air-conditioning units. Some options are:

- Ensure roofs have sufficient insulation
- Paint roofs white to reflect more sunlight
- Use canopies and/or sun blocking film on windows

5. Generators

For comparison, we have added the cost of generating electricity with a generator.

From the table, it can be seen that a generator is nearly 6 times more expensive to run than PV solar. With 5 hours of loadshedding per day, the fuel costs alone amount to more than R1,500 per month.

Also interesting is that a diesel generator remains less expensive than petrol or gas. Also, despite many companies advocating gas to be substantially cheaper to run, our model shows only a slight reduction compared to petrol.

Despite the high cost of generators, it is advised to have a generator as a standby option in the case where the weather remains overcast for many days and the grid is not available. The generator is not likely to be used for more than 5 days in a year.

When comparing generators, check the kW rating for continuous load. For example, some generators are listed as 10kVA but with a power factor of 0.8. This means it can only provide 8kW at peak and only about 7kW continuously. Also verify the ratings of both the engine and the alternator.

Ideally, the generator should be able to charge the batteries as well.

Item	**LPG**	**Diesel**	**Petrol**
Fuel cost (see notes)	1,660.00	23.00	22.00
Fuel Cost R per Gallon	72.63	87.40	83.60
Energy Content (BTU)	91,452.00	137,381.00	120,238.00
Engine Efficiency %	22.30	27.00	19.30
Capital Cost for 10kVA unit	18,000.00	40,000.00	16,000.00
Prime Rate	0.12	0.12	0.12
Finance Cost R/m over 5 years	300.88	668.62	267.45
Fuel Cost R/kWh	**12.15**	**8.04**	**12.29**
Notes - The R/kWh running cost is for fuel only and excludes capital and maintenance - The fuel of LPG is for 48kg - The fuel price for petrol and diesel is per liter			
The fuel cost to run a 5kVA generator for 6 hours is	**72.90**	**48.24**	**73.75**

6. PV Solar Component Choices

1) Inverter Choices
   There are 3 choices: grid tie, off-grid and hybrid: Globally, most rooftop solar installations use grid tied inverters with a Feed-In-Tariff (FIT) Scheme as this is the most efficient and lowest cost. Unfortunately, the electricity networks in South Africa have deteriorated to such an extent that even the current renewable energy projects recently awarded will not be able to feed their energy into the grid due to insufficient capacity. As a result, the most likely choice for home owners is between an off-grid system and hybrid. We have added a separate section on Hybrid Inverters.

2) Batteries
   Lithium Iron
   Currently, the most economical battery option in terms of cost per cycle is a Lithium-Iron battery with the latest chemistry being Lithium Iron Phosphate or LiFePO4.

   Some important points to look out for are the following:
   - The number of Cycles specified. One cycle per day totals 365 cycles per year or 3650 cycles in 10 years. High quality batteries specify more than 6,000 cycles rated at a 90% depth of discharge. Lower quality batteries typically have only 2,000 cycles or less at 50% depth of discharge. The price difference between high quality and low-quality batteries are surprisingly small, so ensure you verify the number of cycles on the datasheet.

- The peak power that the battery can deliver is expressed as C. For example, a 1C 5kWh battery can be charged/discharged at 5kW in 1 hour. Most of the high-quality batteries are 1C or more.
- Unlike the old lead acid batteries, all the Lithium-Iron batteries are intelligent and has an internal battery management system (BMS). High quality batteries have a BMS port that connects to the inverter which enables it to optimise battery charging and discharging.
- The BMS protocol is not standardised so it is important to ensure that the selected inverter supports the battery BMS protocol of the selected battery. We do not advise using a battery and inverter without the BMS connection as this will reduce the battery life.
- The price of a reputable 5kWh battery is about R20,000 ex VAT
- As the battery is a substantial investment, it is important to ensure that there is a reputable local company that can repair it and can offer a warranty. Most suppliers provide 10-year warranties. However, this is model dependent so ensure that it applies to the battery model you select.

Lead Acid/Gel/AGM

Lead Acid batteries (both flooded and gel) are mainly designed for standby use. Even the ones being sold as "Deep Cycle" batteries can only handle 20-30 cycles at 100% discharge before failing. With level 6 load shedding you will need to cycle daily so to last 12 months, the battery must be capable of 365 cycles. Most lead acid batteries only have warranties for 12 months. If you decide to go with lead acid, at least ensure that the manufacturer provides a graph showing the number of cycles as a function of the DoD (Depth of Discharge). As an example, some of the high-quality lead acid batteries are manufactured by Trojan, a US company. Here is a comparison between their different product lines: https://www.trojanbattery.com/pdf/TrojanBattery_SOLAR.pdf.

The only Trojan product line that can offer more than 6,000 cycles is the Solar Industrial Line and then only at 30% DoD, which means that you need a battery capacity of nearly 3 times more than the equivalent Lithium Iron. We have not found any Lead Acid batteries that is cheaper than Lithium-Iron when comparing on a cost per cycle basis.

3) UPS/Power Backup Systems

We have seen a number of trolley type UPS/Power Backup systems on the market, that are typically rated at 1-2kW and can power equipment (laptops, TV and router) during load shedding. While the equipment is cheap, it has a number of drawbacks:

- Most units have lead acid batteries
- Most unit use low-cost inverters which do not have the ability to cut off the battery before it is fully discharged and therefore it is not possible to comply with the DoD specifications. This ruins the batteries quickly and, in most cases, they don't last 12 months which result in a costly replacement.
- These units do typically do not support solar panels

If you are considering a power backup system, the better option would be to use a good solar inverter with a compatible Lithium-Iron battery. Then you can add the panels later. Just bear in mind that you will still be paying your full municipal electricity bill until you add the panels.

Solar Panels

It has been shown that monocrystalline panels have better performance in low light and is therefore recommended. Most panels are designed for a 25-year life. Most panels on the market today are in the 500-600 W size, typically 1m X 2m in size. Most are made in China. The average

price is about R2.85 per Watt (ex VAT). Panels should be installed on north facing roofs, preferably at a 30-degree angle. There is good calculator here: https://pvwatts.nrel.gov/pvwatts.php. This calculator shows the impact of roof angle on the system in both winter and summer months. For flat roofs, it works out cheaper to add a few panels instead of incurring the costs for the structure to install the panels at an angle.

7. Example

The following is an example of a home with no pool and no aircon where all the above recommendations have been implemented. The total monthly energy consumption is around 600kWh or 600 units. The average total daily energy consumption is 600/30=20kWh. The average consumption at night is about 4kWh or about 20% of the daily total.

Inverter Selection

- A 5kW inverter can be used, however, this will require the High Consumption Appliances to be on timers, to prevent them from being switched on simultaneously. The price of a reputable 5kW off grid inverter is about R7,000 incl VAT
- An upgrade to this would be a 7.2kW which cost around R10,000 incl VAT.

Battery Selection

- As indicated, the night consumption is about 4kWh. Bear in mind that one can typically only use 90% of the Lithium-Iron battery capacity. So, a 5kW battery would actually only have 4.5kW usable capacity. This will be sufficient for summer but there would be no reserve for the longer winter nights. The recommended size to also cover winter nights is therefore 6-7kWh.
- The Lithium-Ion batteries also come in fixed increments of typically 3kWh. So, we would need 3kWh x 2 which works out to 6kWh at a cost of about R24,000 ex VAT.

Panel Selection

To calculate the panel size, we consider the daily consumption of 20kWh. We need to design for winter so then the sun rises at say 8:00 and sets at around 16:00. So, we can work on about 8 hours of sun. Then the capacity required is 20kWh/8h=2.5kW. However, this assumes that the solar intensity is the same at 8:00 as at 12:00 which is not the case. Also, we have to take into account that when it is overcast or rainy weather the output is reduced to 20%. Then we also need to take system losses into account.

There is good calculator here: https://pvwatts.nrel.gov/pvwatts.php. This shows that for Pretoria/Johannesburg we need a minimum panel size of 4.5kW to get to 600 units in June when the solar irradiation is the lowest. To compensate for the cloudy days and system losses, 6kW or more would therefore be recommended. The estimated cost is R3.50/kWh x 6kW = R21,200 (ex VAT).

However, in Cape Town, the calculator shows that 6kW will not be enough for the month of June. The minimum is therefore 7kW and the recommended size is 8kW or even 9kW. The estimated cost is R3.50/kWx9kW = R31.500 (ex VAT).

It is not a problem to have 9kW panels powering a 5kW inverter as the inverter will only supply the load up to the maximum of 5kW. But this will enable the inverter to supply 5kW of power over a longer period in the day as it will start generating earlier in the morning and work later in the afternoon as well as enable the system to generate power on overcast and rainy days.

8. Hybrid Inverters

The main reason why off grid systems are more expensive than grid tied is because of having battery storage. But it is also more expensive because of waste. In the case of an off-grid system, when the battery is fully charged and there is no load to absorb the generated power, the solar power goes to waste. If this could be connected to the grid, the unused power could be supplied to the grid. The hybrid inverter accomplishes this. It provides the same functionality as the off-grid system but with the additional feature of being able to also feed energy into the grid. Unfortunately, a typical hybrid inverter is 40-50% more expensive than the equivalent off-grid system.

Most municipalities have yet to implement an attractive Feed In Tariff (FIT) scheme. The City of Cape Town is already purchasing power from residents at a rate of R1.12/kWh. The CoC has also removed the restriction to which limited home owners from being paid should they feed in more than the value of their municipal account.

As it is not clear for what period the City of Cape Town will be paying this tariff, it is not possible to confirm if it is viable to invest in a more expensive hybrid inverter. And it is also not possible for home owners that have already purchased off-grid inverters to determine if it is viable to replace them with Hybrid inverters.

One can also use the spreadsheet model to estimate the viability of selling to the grid, such as in the case of CoC. By setting the price of the battery =0 and increasing the inverter price by 50%, the unit generation cost amount to R0.77. This means that a home owner would be making R0.35 per kWh for the energy sold to the CoC.

In the City of Tshwane, the draft bylaw on SSEG (Small Scale Energy Generation) indicates a FIT rate of R0.10. The bylaw on SSEG has been in Draft status since 2017 with no progress.

It is unfortunate that CoC has been the only municipality which realised that they have an alternative to Eskom on their doorstep and can purchase electricity from home owners cheaper than they are paying Eskom without having to incur any capital investment.

9. Future Trends

The declining trend in the prices of PV solar components is set to continue into the future. This is driven by the global demand as well as improvements in technology. Recently, a breakthrough was made in batteries, to replace Lithium with Sodium. This not only improves performance but also reduces the price substantially while making it environmentally friendly. The first batteries are already in production and used in electric vehicles and for large container size battery storage systems.

Currently, despite the billions that Eskom spent which has basically bankrupted South Africa, it now produces less power than 20 years ago. At the rate which PV solar is being adopted by businesses and home owners, Eskom might soon find that their market has declined to such an extent that it would not justify running the big power stations any longer.

Local municipalities have been caught asleep and unprepared for both load shedding and escalating electricity prices. They still have not realised that their income from electricity sales is disappearing. Municipalities are pricing themselves out of the market. For example, let's assume that CoT buys electricity from Eskom for R1 and sells to residents for R2. Now, let us assume that NERSA increases the rate by 10%. This means the price Eskom charges goes up to R1.10. But the municipality

increases their rates also by 10%. So then the price to residents becomes R2.20. The municipality is now making an additional R0.10 (equal to 10%) on the sale of electricity, without any justification.

With the cascading number of increases, municipalities have increased electricity prices to levels that is not affordable in the current economic climate, making rooftop solar the most viable option for most home owners and businesses.

Another key factor that municipalities overlook is the Time of Use. Eskom charges municipalities based on Time of Use. As an example, one of the municipalities we analysed were paying up to R3.50/kWh during peak hours and only R0.50/kWh during off-peak, typically at night. However, municipalities in South Africa charge residents a flat rate for domestic use.

With the development of utility scale container size BESS (battery storage systems) it is possible for municipalities to do arbitrage – charge the batteries using off peak Eskom rates and/or renewable energy sources and then supply from the batteries to the grid during peaks. These systems (called Peakers) are already financially viable and are used globally in this application.

In most countries where Small Scale Embedded generation is implemented using Rooftop solar, the metering is not only bidirectional but the tariff scale is also based on Time of Use. This rewards generators that feed into the grid in peak periods and penalises consumers using the grid in peak periods.