SIZING OF SOLAR PV SYSTEMS

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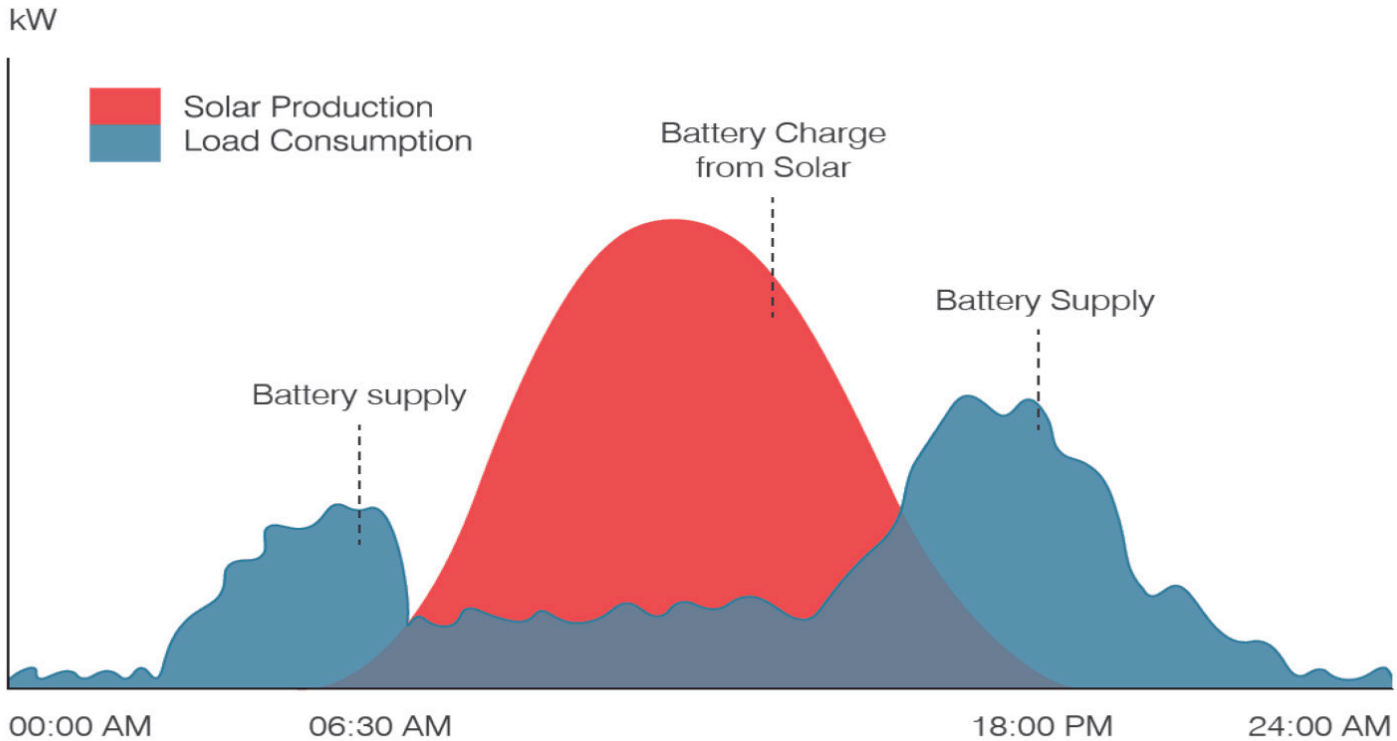
We have used a practical example of a house situated in The Hills Estate, to help users understand how one should go about sizing their solar PV systems. Practical and accurate methods will be shared regarding the number of solar panels required, the size of batteries (independent vs. off-grid) and finally the sizing of hybrid inverters.

Conceptual Understanding

Solar generates power during the day when the residential consumer is not at home consuming this generated power. The only way to harness the midday generated energy is to store it in batteries and to discharge the batteries in the evening/mornings.



CASE STUDY

4 Bedroom House, The Hills, Pretoria

Load description

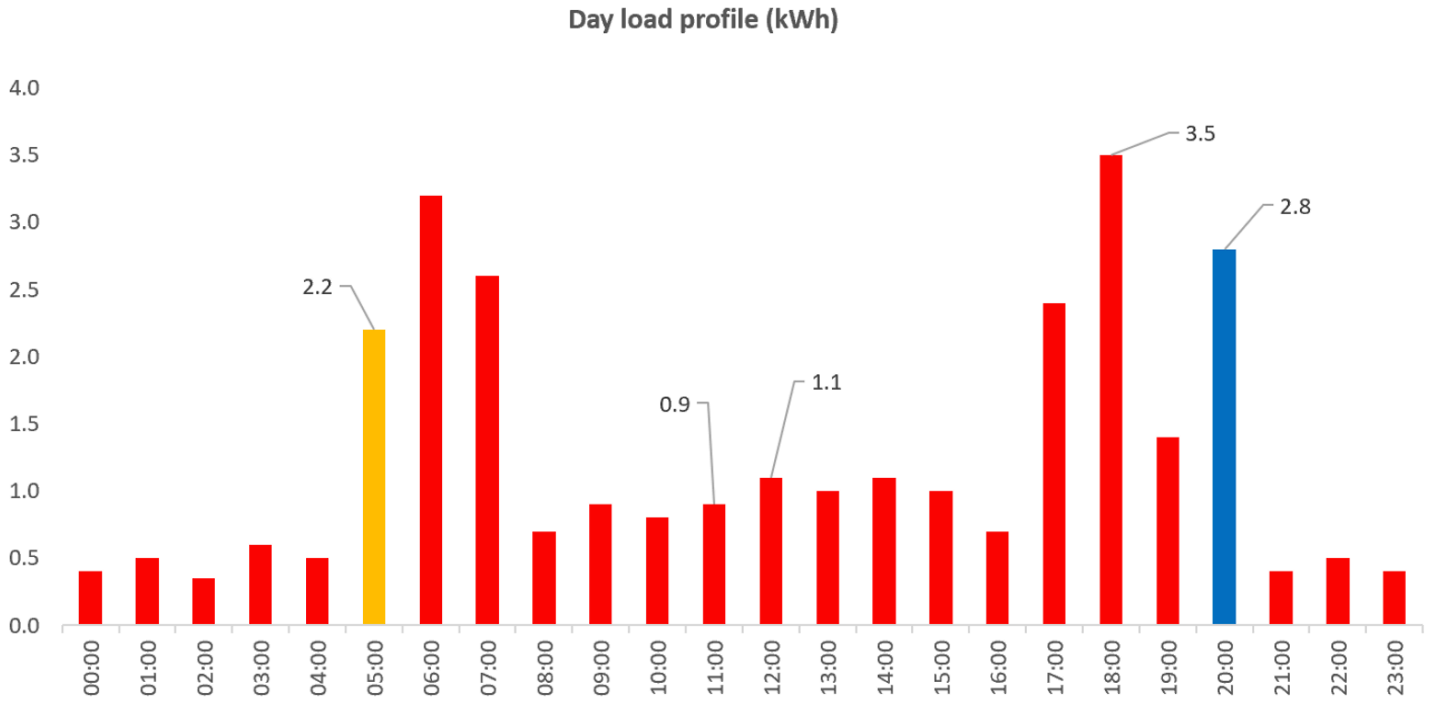
Lights and plug circuits running normal appliances such as fridges, freezers, Wi-Fi, TV etc. Power hungry devices include 2 x Air-conditioners, 2 x Geysers, 1 x swimming pool pump.

Monthly consumption

900kWhper month

Daily Load Profile:

A profile over 24-hours showcasing when power is being consumed.



Solar panel sizing

The size and number of panels depend on two (2) factors.

1. The roof itself plays a significant role in selecting the physical size of the panels. This is due to factors like physical obstructions & limitations, vents on the roof etc.

   It is important to note that the higher output panels require a larger surface area required, For example: 550Wp takes up 2384×1096mm (2.6m^2), and weighs 28.6 kg, whereas a 450Wp takes up 2102×1040mm (2.2m^2) and weighs 24.0kg. Depending on the roof layout, the designer may opt to use lower output rated panels.

2. The number of solar panels needed depends on the consumer's average monthly energy consumption. As a rule of thumb, a 500Wp panel, installed on a 10-degree tilted north-facing roof, generates 2.5 kWh/day. Thus, when consuming 900kWh per month, (i.e. 30kWh per day) 12 panels are required. The maximum output of the solar PV system is calculated as 12 x 500Wp=6kWp.

Cost estimation:

12 x 500Wp Tier 1 rated solar panels (incl. rails) **R60 000**

Hybrid inverter sizing

The hybrid inverter is sized using two (2) factors,

1. The first factor depends on the total output of the solar panels. A hybrid inverter can typically handle 130% of its rated output. So for example; a 5kW hybrid inverter can handle a maximum solar output of 6.5kWp. Thus, considering the solar PV output is 6kWp, a 5kW hybrid inverter would suffice.

2. The second rating, and in most cases, the determining factor, is the instantaneous power requirement the inverter needs to deliver. For example, during the mornings a typical household has a base load of 1000W, the kids need the microwave (2000W), dad is ironing his shirt (2000W) all whilst mom is drying her hair (1000W). In that point in time the house requires 6kW, which will cause the 5kW inverter to trip, leaving the house without power until the inverter has restarted. In this case one should rather upgrade the inverter to an 8kW unit to avoid this unwanted tripping.

Cost estimation:

1 x 5kW Hybrid inverter incl. Wi-Fi dongle **R25 000**

Cost estimation:

1 x 8kW Hybrid inverter incl. Wi-Fi dongle **R40 000**

Battery sizing

The batteries are sized according to the consumer's load during the hours where the solar system is no longer generating enough power (typically after 16h00 and before 08h00) On average this load represents 60-70% of the daily load consumption (i.e. 30kWh x 66% = 20kWh.)

It is important to note, that for the longevity of a battery, one should not discharge a battery more than 80% of its rated output, thus the battery size required is 20kWh / 80% = 25kWh. Furthermore, it is important to note that a typical lithium-ion battery has a yearly retention loss of around 3%. (i.e. 30% over a 10-year warranted period) To ensure that the load can be supported in 10 years' time the battery required is 25kWh / 70% = 35kWh. The most common lithium-ion battery size is a 5kWh unit and therefore seven (7) batteries are required.

Cost estimation:

7 x 5kWh Lithium-ion batteries **R210 000**

A factor to be taken into consideration is that the above costs do not take into account the increase in quantity of solar panels required to recharge the batteries whilst supporting the day load. The day load is estimated to be 10kWh, the battery recharge requirement is 35kWh x 80% = 28kWh, and the solar panels produce 30kWh per day leaving a shortfall of 8kWh, (i.e. another 4 panels are required.)

Cost estimation:

4 x 500Wp Tier 1 rated solar panels incl. rails **R20 000**

Conclusion

This method, albeit correct, ends up giving the consumer an understanding of how to become totally grid independent (bar bad weather days etc) and is often referred to as being "off the grid". However, this term is incorrectly used as it implies that there will be no other source of power other than

the solar hybrid PV system, and as a result, costs will increase dramatically to overcome the previously mentioned bad weather / rainy days. Thus, we refer to a percentage of independence instead. The above example is a case of being 100% independent, bar the bad weather days.

Item	Cost
16 x 500Wp Tier 1 rated solar panels incl. rails	R 80 000
1 x 8kW Hybrid inverter incl. Wi-Fi dongle	R 40 000
7 x 5kWh Lithium-ion batteries	R 210 000
Cabinets, trunking, accessories, and sundries	R 20 000
Installation, approvals, and certification	R 40 000
TOTAL	**R 390 000**

Recommendation

As can be seen from the table above this option does not make financial sense for a household with an average monthly electricity bill of R2500pm (900kWh), as it will take a good 10+ years to recoup the investment. Therefore, it is recommended to rather split the distribution board into essential loads (fridge, kettle, lights etc) and non-essential loads (power hungry devices).

Essential loads are connected to the backup (battery) of the hybrid inverter, this will ensure an uninterrupted supply during power outages such as load-shedding. However, during the day, when the solar system is generating enough power, the more power-hungry devices (non-essential loads) such as geysers and air-conditioners will be powered.

It is also recommended to move evening loads to daytime loads (e.g. geysers, swimming pool pumps etc) This will reduce the battery requirement and number of solar panels needed.

See diagram below

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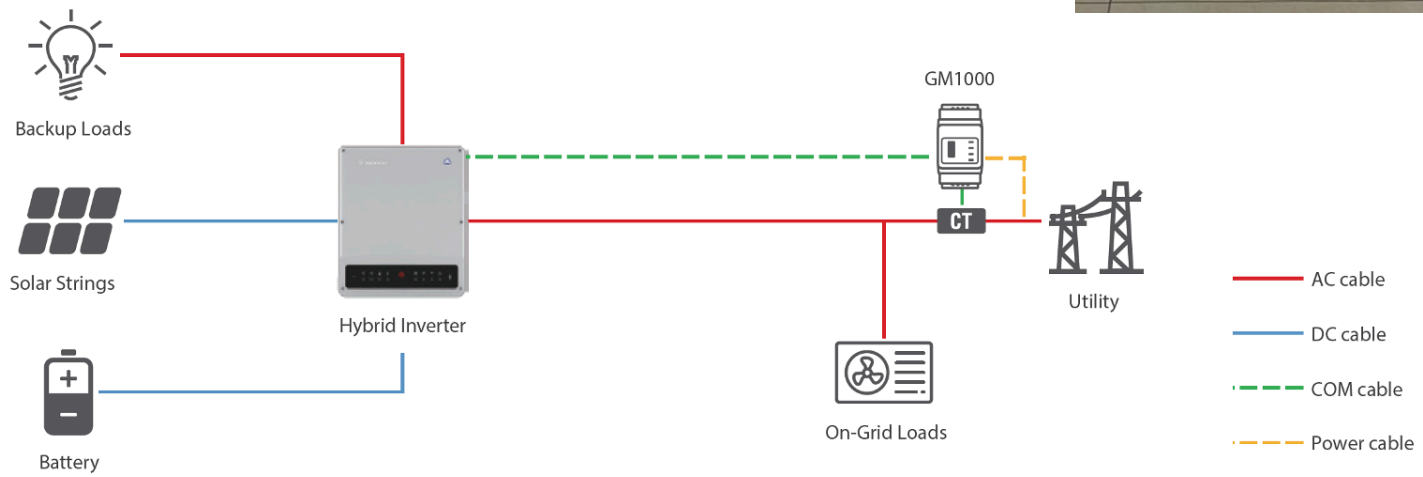
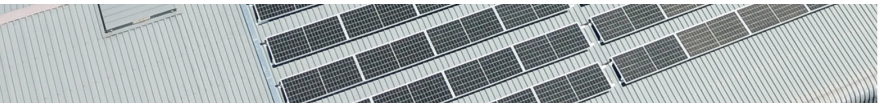
Typical solar hybrid PV system wiring:





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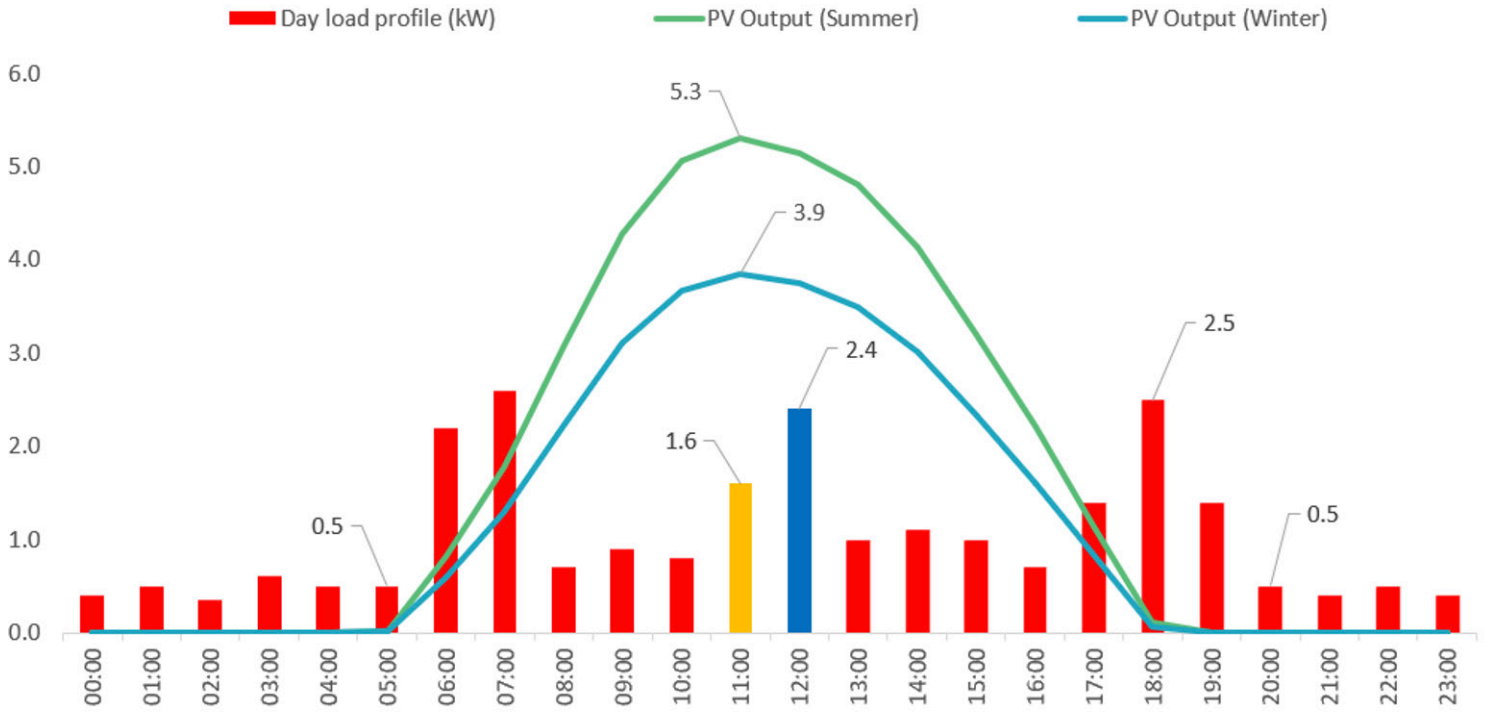
Shifted day load profile:



The above changed results in

1. The total consumption from 16h00 – 08h00 has reduced to 11kWh. Thus, the battery requirement reduces to 11kWh / 80% / 70% = 20kWh.
2. The number of solar panels now reduces from 16 down to 12 due to the reduction in the battery requirement from 20kWh x 80% = 16kWh.
3. These changes also ensures that the consumer will also have certain level of independence during the winter months when the solar system about 20-30% less than in summer

CONCLUSION

It is recommended to work towards a system that either fits the client's budget or that aims to achieve the total independence, bar bad weather days, by splitting the loads and shifting night-time loads to the day. By doing this a hybrid solar PV system will normally pay itself off within 6 years, without considering the asset value it brings to the home.

Item	Cost
12 x 500Wp Tier 1 rated solar panels incl. rails	R 60 000
1 x 8kW Hybrid inverter incl. Wi-Fi dongle	R 40 000
4 x 5kWh Lithium-ion batteries	R 120 000
Cabinets, trunking, accessories, and sundries	R 10 000
Installation, approvals, and certification	R 30 000
TOTAL	**R 260 000**