Getting off the Grid

or at least reducing your energy footprint

Jane Harley

ENERGY = POWER x TIME

POWER = AMPS x VOLTS

1 WATT = 1 AMP x 1 VOLT

1W = 1A x 1V

1 kWh = 1 000 W / hour

A = W / V

V = W / A

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My thanks go to:

Robbie Cameron of Midlands Solar, who weathered my dramatics when things didn’t work as I’d anticipated and who has provided unfailingly courteous service;

Neil Windridge and his team, who went the extra mile in installing the various components of my system;

David Harley, who did research on the wind and was still supportive even when I ignored his advice;

Mike and Robin Bamber, my neighbours, who were interested, enthusiastic and involved throughout the process of my (almost) getting off the grid.

Getting off the grid

For reasons that now seem obscure to me, it has been my wish to get off the grid since early in the first decade of this century. Before then, such an idea would not have crossed my mind as I had not yet been exposed to anything more environmentally daring than gardening without pesticides. Despite my desire, however, the cost, the problems, the sheer orneriness of it all, meant that I did nothing about it.

In early April 2011 I became obsessed with the idea. It felt like an imperative. It was still costly, still problematic, still ornery, but it felt necessary.

I was a little bothered about whether going off the grid is in fact an elitist thing to do. After all, it is very expensive and only those with financial resources can afford it. On the other hand, being able to afford it, is this not a more proper way of investing the money than many other ways? Not having fully resolved this issue, I nevertheless sold some (far from green and therefore troublesome) investments and raised the money. I spoke to many people. I spent hours on Google. And at last I made my decision. Despite working from home, I had already reduced my energy requirements to quite a low number (my electricity bill was under R100 a month although this, admittedly, did not include any line costs as my landlords were footing that part of the bill).

I decided to start with a wind turbine because I thought that that would give me the biggest "bang for my buck". I spent a great deal of time speaking to Robbie Cameron (the supplier I eventually settled upon after some investigation) at Midlands Solar, refining my understanding and my needs and finally ordered:

1 x 1kW wind turbine (which came along with its own controller);

12 x 105Ah batteries;

1 x 3kW inverter

My brother, David, had done a whole lot of sums which indicated that the average wind speeds in Pietermaritzburg in April, May, June and July, were not great – but they were averages and I felt that where I live, on a hill outside the city of Pietermaritzburg, was much more windy than in the valley.

Because I made up my mind the week before the dramatic holiday period (only 3 working days out of 11 days) at the end of April 2011, everything was delayed, but eventually a charming chap by the name of Bradley dug the big holes required for the turbine's 6 metre pole, and we were ready to go!

On the 4th of May, Neil Windridge and his team moved in. They:

Dug trenches...

Lifted the paving...

Pulled though cables...

Covered up the trenches...

Attached the turbine...

and its tail...


and its rotors.


They connected batteries


and boxes.

and at last they were ready to raise the turbine into the air. They:


pushed and pulled...


but it was too heavy...


and it was put to sleep for the night.

Nobody had quite understood exactly how heavy 96kg becomes when stuck at the end of a 6m pole. The next day reinforcements were gathered. They:


pushed...


and pulled...


and at last it was up!

The final adjustments were made to the DB board, a switch was switched and, at 11h00 on Friday 6 May, I WAS OFF THE GRID! For three days I worked off the batteries... and waited for the turbine to turn so that some power could feed back in to replace what I was drawing off. I:


waited...


and waited...


and waited...

but the turbine did not move. Robbie came and watched it not moving. Neil came and watched it not moving. My neighbours and I spent hours and hours watching it not moving. Theories abounded and still the turbine sat sullen – even though, in our opinion, the wind was howling. By Monday morning my turbine had still not turned, my batteries were too flat to continue and I, chastened and humiliated, was back on the grid.

Over time I have learned a great deal more about wind turbines and about wind. Firstly, 2.5 metres per second (m/s), which is what is required to start my turbine turning, is quite a lot of wind. Secondly, 8m/s, which is the optimum amount of wind for my particular turbine, is a great deal of wind. Thirdly, as with property, position is everything. Turbulence is a great inhibitor of wind turbines. Even though, where I live, there are some days on which the wind speeds are sufficient, because of turbulence the turbine still does not work properly.

As it happens, there are a number of issues with the positioning of my turbine, the greatest being the very, very tall trees which stand behind it. The prevailing wind comes from the South West, which seemed quite fine when I raised the turbine because from the South West there was a long, uninterrupted stretch in front of it. It had not properly registered with me that obstructions behind the turbine also play a part. When, however, one contemplates this more carefully, it seems fairly obvious –

when the wind has passed the turbine and there is an obstruction, where does the wind go? Clearly, it must start backing up!

This having become plain, my landlords kindly allowed me to cut down some of the smaller trees (one was a guava which was just beginning to fruit and in which the monkeys constantly lurked, so no one was too sad about that), and this certainly had an impact. Now, when the wind blows sufficiently hard, the turbine turns. The large trees are, however, still there, and this means that the turbine tends to "wander" instead of facing straight into the wind. The result of this is that it never quite manages to build sufficient momentum to take proper advantage of the wind and its actual output of current is very small. Because of the massiveness of the trees, felling them is no easy prospect and for now my turbine is a bit of an embarrassment.

I had always recognised that the turbine was not going to be sufficient to keep the batteries fully charged, but had been working off the premise that I would establish first what the shortfall was and would then buy solar panels to make up the difference. Clinging still to my belief that the turbine was going to provide some current, I decided that two 205W solar panels would be sufficient. Well, actually, I decided that two 280W solar panels would be sufficient but there were none available at the time, so 205W it was. Believing in buying locally, I decided on South African-made panels.

I was annoyed to discover that the controller that I already had, which had come with the wind turbine and which had a clearly marked solar input, could only handle 100W of solar input. This meant buying a new controller as well. These were ordered just before election day so, once again, a public holiday caused delays. In addition, when the controller arrived from Johannesburg, half of it was missing and when the solar panels arrived from Cape Town one of them was badly marked and had to go back again. Nevertheless, everything eventually came together and the panels were placed on the roof – although not entirely without incident as a hidden power cable in the wall was hit while drilling holes for the trunking, which put out the lights of half the community and, although no one understands quite how, blew up my telephone connection at the exchange. This was so serious a problem that it took more than two weeks to fix.

As soon as the panels were connected to the batteries, the sun went behind the clouds. My solar controller has a fancy screen which tells me what the charge status is and it varied between saying NIGHT and BULK 0.0A, which meant that nothing was happening. Still no current was flowing into my batteries.

Fortunately, despite the fact that many doomsayers named the 21st of May 2011 the day on which the world would end, the sun still rises each morning and clouds eventually dissipate and after a day or two the skies were clear and my panels were generating current.

It transpires that solar panels are *vol fiemies.* The smallest thing can cause the amperage to drop sharply. Naturally, the sun is moving and so, even if you have been able to place your panels so that they are facing due North, there will be large parts of the day when they are not working optimally. Small shadows and any cloud cover can dramatically impact on how much current is put out. In winter conditions, the output is lower than in summer. On the other hand, if they get too hot, the panels will also put out less. In other words, there is no way that a panel is going to perform to specification on a regular basis.

The general formula for working out the daily output of a panel is to assume six hours of peak sun. What this means is that I should have been getting 205W x 2 = 410W x 6 = 2.5kW per day on a good, sunny day. In actual fact, I was getting a maximum of 1.2kW per day – and this despite the fact that my panels were sitting in full sun, facing slightly off north, free of any shadow, for six hours a day.

Ah, well. I was beginning to feel that alternative energy sucks! But having now invested considerably more in alternative energy than I've invested in my current vehicle, I felt that I had little alternative but to invest even more, because saving half of my less-than-R100-a-month electricity bill is just stupid and embarrassing. I felt that the only way I could legitimise this enormous expenditure was to get off, and stay off, the grid for all time.

So, assuming that 1.2kW per day is the actual output of two 205W panels towards mid-winter in KwaZulu-Natal, I ordered a further six panels.

In the meantime, my batteries filled and I took myself off the grid again. Immediately the sun went behind the clouds and over the next three days a total of 254W was generated by my panels. Such thick cloud cover is most unusual for that time of year, and along with it came cold and lots of rain. Climate change, I assume, in action. On the plus side, we experienced a day or two of high wind and the turbine turned! It turned really fast, and even managed to generate some current, but, given how hard the wind was blowing, much less than I would have anticipated. When I raised the issue, though, I was told "turbulence" and no-one seemed able to see past that issue.

The extra panels first had to be made and then shipped from Cape Town and were finally installed late on the 15th of June.

And what a disappointment that was! Instead of my output increasing four-fold it only slightly more than doubled. I still was not getting in enough power to cover my outgoings.

In July my brother, David, came to visit and spent a day measuring and calculating and investigating. At the end of the day he said that the problem was that the voltage coming off the panels was not high enough for the batteries to absorb the amps that were being produced. The solution was either to replace the panels with higher voltage panels, or rewire the panels so that they were in two series of four (instead of four series of two) so that the total voltage would increase (see later chapters to find out more about this technical stuff), and get a new charge controller to convert the excess volts into amps.

So, with a sigh I purchased a new controller, known as an MPPT controller, had the panels rewired, waited for the several days of mist and rain that immediately set in to pass, and watched my controller with anticipation.

At last! Plenty of amps were coming in, the batteries were charging and I could get through the night without running out of power.

To finish things off I got a solar water heater. When there is sufficient sun, the water gets very hot indeed. Unfortunately, if the sun does not shine all day, the water can be rather too cool for comfort.

Having now gone through a winter and a summer with my alternative energy system it is my considered opinion that it is almost impossible for an individual household to get off the grid and stay off the grid completely and forever. Interestingly, summer has proven harder to get through than winter. My electricity usage went up because the fridge is cycling in more often. Although the clear days are long and sunny, we have an inordinate number of days that are overcast. Mostly we don't notice the lack of sun because the day might still be very warm and there will be breaks in the clouds, but when one is dependent on the sun actually shining on one's panels, one becomes painfully aware that cloud is covering the rays for many hours, even on warm summer days.

If I did not work from home I would require significantly less power and my current system would probably allow me to spend most of the time off the grid (although, as someone pointed out to me, I'd be on the grid at work). However, regardless of how much or how little electricity you are using, if there is no wind and no sun, there is no power coming in and if this situation persists beyond a few days, then the batteries run flat and there is no electricity.

I believe that, unless one has really enormous amounts of money to throw at this, it would be far better to go with a compromise solution – one that allows you to reduce your consumption of electricity, caters adequately for your needs when there are power failures, but does not cost a fortune. There is apparently a pilot being done in the Cape where energy is being fed back into the grid (and paid for at the same rate as energy drawn off the grid) and if this becomes something that can be generally done this will go a long way to making the installation of alternative energy more feasible.

To this end I would suggest that items such as fridges, kettles, etc. be left on a normal Eskom circuit, while lights, computers, televisions, sound systems and so on be transferred onto the alternative system. This relatively small system will not cost a fortune, will go some way to saving electricity and will allow you to have light and entertainment (or to continue working) without interruption regardless of power failures.

Whether you want to get off the grid completely, or just wish to reduce your energy usage, I hope to provide you with sufficient motivation to make the decision and enough information to work out what you need in the following pages.

How much does electricity really cost?

The costs of electricity in South Africa are amongst the lowest in the world so, even as many of us complain about how expensive it is becoming, in world terms (in Europe electricity costs about four times more) it is cheap. The problem is that it is *too* cheap and this means that many people are unable to justify, on a financial level, a change from electricity supplied through the national grid to energy from alternative sources.

Too cheap? How can it be too cheap? Well, the price that we pay does not include those costs that are externalised and are borne by other people. For example, costs that are not included in the price that we pay are:

- The price paid by coal-miners in terms of their health;
- The price paid by coal-miners in terms of their lives;
- The price paid by the environment in terms of acid mine drainage, waste produced in the mining process, land becoming unfit for other purposes, tunnels causing instability, underground fires and other negative consequences of coal mining;
- The price paid by people who live in proximity to coal-fired power stations and who suffer health consequences as a result;
- The price paid by proximate communities (and, indeed, the country at large) for the vast amounts of water that are used and polluted in the process of producing energy;
- The price paid by current and future generations for the waste that is produced by both coal-fired and nuclear power stations;

- The price paid by all the world's plants and creatures for the consequences of global warming caused by greenhouse gases produced through the burning of coal.

There is no way to quantify the actual value of these various prices, but it should be clear that if these costs were included in the price of electricity, the cost of the installation of wind and solar alternatives would be cheap in comparison.

Another energy future is necessary

Electrical power also represents, on some level, personal power. Rich people have electricity while poor people do not. Very rich people can afford to use a great deal of electricity, lighting and heating their homes without a thought, while less rich people need to carefully ration their light and heat. In South Africa, very big corporations have negotiated very secret deals with Eskom according to which they pay, it is believed, less than the cost of producing the electricity. Other consumers must therefore pay more in order to make up the difference.

There are many poor people living beneath massive power lines or near coal-mines and power stations who do not have access to power at all. In some places, where power was once provided, the provision was stopped (sometimes even to the extent of ripping out the pre-paid metres) in an attempt to force people out of the areas.

Pre-paid meters have been put in many (primarily poor) people's homes. Since power will not be provided unless it has been paid for, the risk to the electricity supplier is less than with post-paid electricity but, for some unascertainable reason, the cost of pre-paid power is substantially higher.

The current system of generating power is extremely costly in environmental and social terms. Burning coal produces enormous quantities of carbon dioxide as well as pollutants such as sulphur, mercury and particulate matter. In South Africa, low-grade coal is used which produces less energy and more ash per kilogram than high-grade coal. Large amounts of water are required for cooling and the waste water is polluted.

Recently, the World Bank approved a US$3.5 billion loan to Eskom for the parastatal to build a new power station in a currently “under-polluted” area of South Africa. Once society starts to term less-polluted areas “under-polluted” we have a clear indication that our world view has been severely corrupted.

Rhetoric in both the mainstream and environmental press suggests that wind power and solar power are as problematic as coal and/or nuclear power. In some ways this is true. An entire field of wind generators, or a large plot of desert populated with hundreds of solar panels, do have a great impact on the immediate environment.

We need, however, to stop thinking in terms of our current, centralised system of power generation. To begin with, the current system is extremely wasteful as much electricity is lost in its transmission from power station to end user. In fact, of the energy generated by 1kg of coal in an efficient power station, less than 40% reaches the consumer. Other systems of generation are similarly inefficient.

The South African saying “local is lekker” applies as much to power generation as it does to recording artists. If, instead of trying to emulate the current system of large power generation plants, solar panels, wind turbines and small hydro-electric turbines were placed in a widely distributed manner, their environmental impact would be substantially reduced, as would power loss through distance.

Terms you should know:

What is a watt?

A **watt** is the International System of Units (SI) unit of power, equivalent to one joule per second, corresponding to the rate of energy in an electric circuit where the potential difference is one volt and the current one ampere.

And I hope that that makes it all clear!

If it doesn't, then read on.

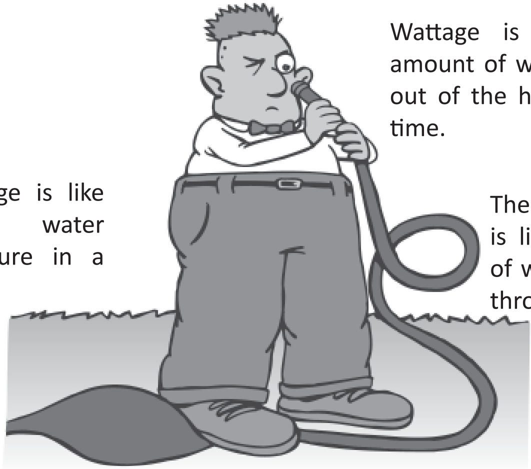
- A **watt** is a unit of power. Power is a function of amps and volts. So, 1 amp x 1 volt = 1 watt. 1 Watt is referred to as 1W. 1000 Watts is 1 kilowatt and is abbreviated as 1kW.

- An **amp**'s proper name is ampere. Simply put, it is a measure of the electric charge that passes a point in a unit of time. It represents the amount of current in a circuit. One amp is abbreviated as 1A.

- A **volt** is the circuit's potential difference, and can be likened to the amount of pressure driving the electricity in a circuit. One volt is abbreviated as 1V.

1 WATT = 1 AMP x 1 VOLT

1W = 1A x 1V



While we often use the terms power and energy interchangeably, they are, in fact, different things.

- **Power** is the *rate at which energy is produced or consumed* and is expressed in watts (W) or kilowatts (kW).

- **Energy** is the *amount of power consumed* and is expressed in watt-hours (Wh) or kilowatt-hours (kWh).

If you look at your electrical appliances, most of them will have a power rating. For example, your kettle might be rated at 1800W, while your energy efficient light bulb might be rated at 11W. 1800W is the amount of power that your kettle uses, or the rate at which your kettle uses energy.

If you were to use your kettle for one hour, you would use 1800Wh of energy. If you were to turn your light on for 10 hours, you would use 10 x 11W = 110Wh of energy.

ENERGY = POWER x TIME

What is the national grid?

When we are talking about power, **grid** is a term used to describe an electricity network that comprises the generation, transmission and distribution of energy. It could equally apply to a small rural installation, or a large country-wide network.

In South Africa the majority of our power is supplied through Eskom and the network of power stations, transmission lines and distribution points is known as the **national grid**.

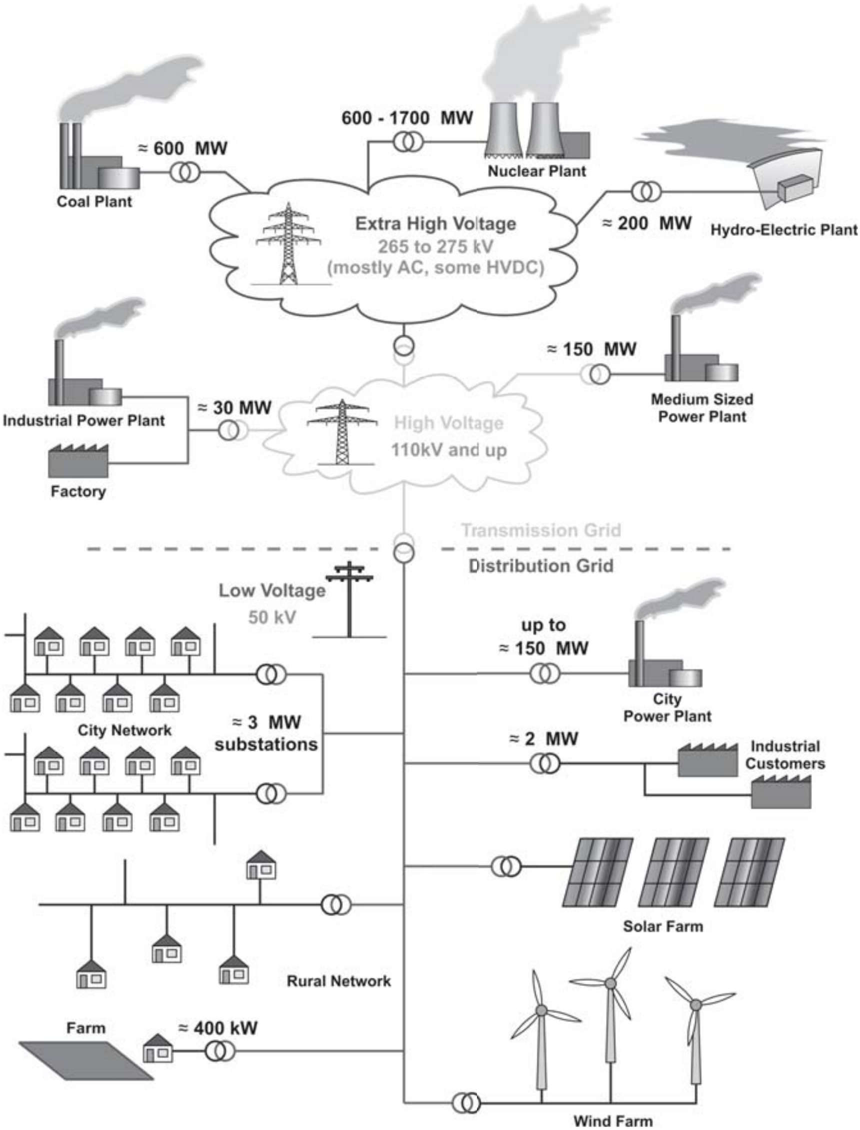
About 90% of all energy in South Africa is supplied through coal-fired power stations. More than ninety million tons of coal are used each year to produce the country's electricity.

Water can be heated by coal, gas, oil and nuclear fuels to create steam. When the steam is released at very high pressure and temperature (over 500°C), it can turn a large turbine that is connected to a rotating magnet. This generates electricity.

A power station generator is made of a very powerful electromagnet coil. This is energised by direct current to produce a magnetic field. It is mounted on a central rotating shaft, called a rotor. The rotor is surrounded by a series of coils, known as the stator. The electrical voltage is generated inside the stator by the rotating magnetic field.

The rotor, which is connected to a turbine, turns about 3000 times per minute, which is about 50 cycles per second. This produces an alternating current with a frequency of 50 hertz.

In order to transmit the power that is generated at the power station, the station is linked to transmission lines and towers, which are known as pylons. The electricity is sent through thick



aluminium and copper wires. Electricity must be at a high voltage (pressure) and low current if it is to be transmitted efficiently and safely. If the current were too high, the cables would get too hot and could melt. If the voltage were too low, the energy could not be carried. The pressure of volts is required to transmit energy over long distances. The generators in the power station produce electricity at about 20 000V, which is raised to between 132 000V and 765 000V before it is sent out.

For local distribution, the electricity is transformed to 11 000V and then further transformed, depending on requirements. For domestic use, the electricity is transformed to 240 (220)V.

Because there is no viable way of storing large amounts of electricity, power stations must generate electricity as it is needed. This means that power stations will produce more or less power at different times, and will be switched into and out of the national grid as required.

When talking about electricity, the load is the amount of power being drawn from the system. In national terms, when the amount of electricity required cannot be produced by the power stations supplying the national grid, some of this load has to be shed. Eskom is not too fond of the term *load shedding* and prefers to use the term *system management*, which is fair enough. Individuals are encouraged to participate in this system management through, for example, television and radio updates which indicate when power requirements are very high. If the load remains too great it then has to be reduced by cutting off sections of the network, prohibiting users from drawing any power at all.

In a way, we have all had to practise our own system management at some point. We know that if we turn on the oven, the stove, the kettle and the heater at the same time, the chances are that our board will trip. This is an indication that the load is too great – in other words, the total watts required by all the appliances is more than the system can supply. When we turn some of the appliances off, we are managing the load.

Doing your own load-shedding

From the preceding discussions it should be obvious that it is desirable, for a number of reasons, to reduce the amount of energy that you consume. Unless they are very rich indeed, most people will have to make some significant life-style adjustments if they are going to come off the national grid, but even if abandoning conventional energy is not your immediate intention there are very real benefits to both you and your environment in reducing your energy consumption.

Here are some ideas for reducing the amount of energy that you use each day:

- If you have not already done so, replace your incandescent or compact fluorescent (CF) bulbs with LED bulbs. CF bulbs are problematic in that they contain mercury. Although each bulb only contains a small amount of mercury, the cumulative effect of the mercury is going to be very troublesome in the future. LED lights use less power than Compact Fluorescent bulbs. They are more expensive, but have an extremely long life (about 15 years).

- Don't leave appliances turned on. Televisions, stereo systems and the like may continue to draw small amounts of power even when in standby mode. Over a year these appliances can use many kWh of energy completely uselessly. While we have become very used to being able to simply press the remote to get everything turned on, it really only uses a few extra seconds to flip a switch. It is worthwhile investing in extension plugs that have individual switches to make things easier.

- Manage your heating and cooling requirements sensibly. Use curtains and blinds to either increase or reduce the effects of the heat from the sun. Invest in thermal socks, hot water bottles and blankets to keep you warm. A small heater will draw about 1500W. The modern halogen heaters draw less, but are still using about 800W an hour, so try not to use heaters.

- If your water is heated by electricity, try to reduce the amount of hot water that you use. Showers use less water than baths do. Take shorter showers and invest in a water-efficient shower-head. Wrap your geyser up in a geyser blanket. Turn the geyser off at times when hot water is not going to be required. Fix any dripping taps. Lower the thermostat to 50°C. Wash your clothes in cold water.

- Dry your clothes naturally. Tumble dryers are exceptionally greedy power users, using between 2kW and 5kW. In addition to being kinder to your clothes, the sun is a natural whitener for cotton and linen. The ultraviolet rays in the sun are a natural antiseptic and help kill bacteria, viruses, moulds and mites that might be lurking in the fabric.

- Change your cooking methods. The oven uses a great deal of electricity, so try to reduce how much you use it. Change to gas. Solar cookers and hot-boxes are cheap and can be used to replace or reduce electricity needed for cooking.

Except in those few areas of the country where it is required to kill off the *goggas* that live in clothes, stop ironing. Ironing is a silly waste of energy – both electrical and human. An average iron is rated at between 1000W and 2400W, which means that it consumes 1kW to 2.4kW for every hour that it is used. If you were to use a 2400W iron for only one hour a week, you would be using a total of 125kW each year!

To put things into perspective, if you really want to come off the grid you are going to need to get your total consumption to below 5kWh per day. One hour of tumble drying might use up this whole allocation. One hour of ironing might use up half the day's allowance and running a heater for two hours will eat up three-fifths of your day's ration. Looking at it differently, one hour's ironing could provide constant light for nine days.

By implementing all of these ideas you will be able to substantially reduce your energy consumption. By doing so you achieve three important things:

1. You will reduce your impact on the world in terms of greenhouse gases;
2. You will reduce the current cost to yourself of electricity;
3. You will be that much closer to being able to get off the national grid.

Further strategies for reducing your electricity requirements are discussed on page 35.

Getting off the national grid

People in remote areas, whether rich or poor, have also been forced to live off the grid. Even before the advent of fancy technologies, wind, water and the sun have been used to create local energy.

Based on my research, in South Africa and the normal suburban set-up, it seems that it is mainly the very rich who have already come off the national grid. It would appear that their primary motivation is less environmental or social than a desire not to have their lives impacted upon by the vagaries of load-shedding and a recent increase in infrastructure failures. High energy bills also play a part.

Many other people have invested in technology that supplements their energy requirements, particularly water heating. Eskom offers a rebate for installing solar water heaters, and this is an obvious place to start. There are also a wide array of outdoor lighting systems that run off solar power and which can reduce energy costs without impacting on, or interfacing in any way with, the rest of one's electrical system.

A grid-tied system links an alternative power input system with the mains system. When insufficient electricity is generated by an alternative source, electricity is drawn from the mains to make up the shortfall. In an ideal world, such systems would be able to sell any excess power back into the grid, while electricity could be bought from the grid should there be a shortfall. At present, however, this is not possible in South Africa, although there is a pilot project running in the Cape in which three householders are participating.

It is not that hard to get off the grid. It is, however, extremely hard to *stay* off the grid! Alternative energy is not completely reliable and a few sunless and/or windless days can leave you in the dark. A grid-tied system is therefore the most feasible option for most people.

Components of an alternative energy system

Whether one goes for a grid-tied system or decides to come off the grid completely, there are certain basic components that you are going to need.

These are:

- Something to generate the power;
- Something to control or regulate the power being generated;
- Something in which to store the power;
- Something to convert the stored power into electricity that can be used by your appliances.

Generating the power

There are two main ways of producing power domestically:

- Sun
- Wind

If you are well-placed and receive sufficient wind at sufficient force, wind is generally the cheaper method. The problem with wind generation, however, is that if there is no wind, then there is no power being generated.

The same problem exists, of course, with the sun. When it is not shining, as at night, no power is being produced and, during the day, if it is cloudy it does not produce the same quantity of power as it would on a sunny day. We can, however, be pretty sure that the sun will rise in the morning and that at least some power will be generated during the day. In South Africa we are fortunate that even in winter our days are long enough and generally bright enough to generate some power from a solar panel every day.

A balance between the two methods is likely to work best, although in low-wind areas investment in a wind turbine is probably not worth it.

Whether we're talking wind or sun, you will purchase the turbine or panel in terms of the watts that it generates.

Wind Turbines

Wind turbines for domestic use start at about 330W and go up to 5kW. If the wind blew all the time, the cost per watt would be considerably less than a solar power watt. In most places, however, the wind does not blow all the time and this is clearly a limiting factor. If the wind blew for an hour a day, a 5kW turbine would produce five times more power than a 1kW turbine. A 5kW turbine will also, however, cost a great deal more.

There is quite a lot of negativity about wind turbines and, when grouped together in large numbers, they certainly are not completely benign. A single turbine in a domestic setting, however, has minimal environmental impact being virtually noiseless, too low and small to create major "flickering" problems (caused by the sun casting shadows through the blades) and too discrete to cause problems for birds. When erected in a windy place, the energy that is used in manufacturing and erecting a wind turbine is generally recouped within three to eight months and, at the end of its lifetime, which is about thirty years, it can be removed, leaving no lasting legacy. During those thirty years it will have produced no pollutants and have used no resource other than the wind.

Determining whether a wind turbine is going to work for you is a very difficult task to do completely accurately. There are many things that can influence the correct functioning of a wind turbine, and moving it a few metres from any given position may make a very real difference (see page 40).

One thing is for certain – our perception of how much wind there is is probably not very accurate. It is most certainly worthwhile investing in a small wind meter and spending several months monitoring the actual wind speeds and duration of real wind before investing in a turbine. Had I done this – as my brother so strongly advised – I would have saved myself not only the cost of the turbine, but the cost of erecting it and wiring it in, a not insubstantial sum.

Solar Panels

Solar panels are rated by watts, although the wattage indicated is misleading as the panels will generally put out more than 12V, 24V or 48V and thus the amperage is lower than might be anticipated. You must be careful to check the full specifications when buying a solar panel.

For example, the rated power of a panel might be 205W, while the rated voltage is 27.4V. 205W/27.4V = 7.50A and it is the amperage that we are really interested in.

The solar technology that is used for generating electricity is different from the technology used for heating water. Electric panels use solar cells while water heating panels use tubes.

There are two main types of solar electric panels at present:

- Silicon based
- Thin film nano

Silicon based photovoltaic panels are the ones that we are most familiar with. These fall into two main categories: crystalline panels and amorphous panels. To create electricity, both convert the photons (heat) produced by the sun into electrons. Crystalline panels are rigid and are more robust than the amorphous modules which are flexible.

Thin film nano solar is a new technology that was developed in 2005 by Professor Alberts of the University of Johannesburg. These panels are more efficient and more cost effective. They do not use silicon but instead use a combination of copper, indium, gallium, selenium and sulphide (CIGS). They are not currently available in South Africa although on the internet there were reports (in 2007) that Sasol would be building a factory to manufacture the panels – and then there is silence. When (if?) these panels do become available it is anticipated that they will need about half the space and cost one quarter of the current panels.

Hydro-electric

If one has a constant source of flowing water nearby, hydroelectric power is apparently quite feasible and relatively inexpensive. Very few people are so lucky, however, and so this source will not be discussed any further in this booklet.

Controlling the power

A *regulator* or *charge controller* is required to look after the power coming into the system. It limits the rate at which the electric current is added to the batteries, preventing overcharging and overvoltage which can limit the batteries' performance and life span. If too much power comes in, the regulator will divert the excess. This is called dumping.

Storing the power

There is no feasible way of storing the power generated by massive power stations but, fortunately, it is possible to store the power generated by wind and solar in the domestic situation. The power is stored in batteries. These are not normal car batteries, which are not designed for this kind of application, but deep cycle batteries. The battery types recommended for use in an inverter system are: Flooded Lead Acid (FLA), Sealed Gel Cells (GEL), Sealed Absorbed Glass Mat (AGM); and alkaline types such as Nickel-Iron (NiFe) and Nickel-Cadmium (NiCad).

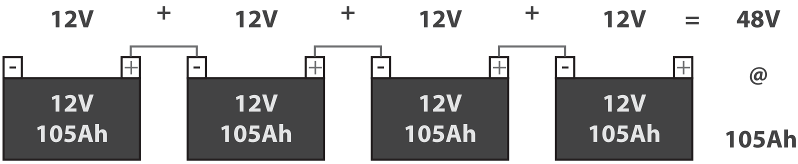
Once again, the way in which a battery is rated can be misleading. Batteries are rated in amperes, and for storing energy for the kind of application that we're talking about here one would generally go for a 105 amp hour (105Ah) battery. What this implies is that if 1A were drawn per hour, the battery would last 105 hours. Because battery life is severely impaired if discharged too deeply, one actually has access to only one half of the rated charge. In other words, with a battery of 105Ah, there is only really 50Ah of usable current.

The way that you configure your batteries will define much of the rest of the system's configuration.

Batteries are generally 12V. They can be linked together in *series* and in *parallel*.

When you link batteries in *series* the effect is to create a new battery that has greater voltage. In other words, if you link two 12V batteries together in series, then you have, in effect, one 24V battery. The current, however, remains the same.

To achieve a series linkage, the positive terminal of one battery would be linked to the negative terminal of the next.

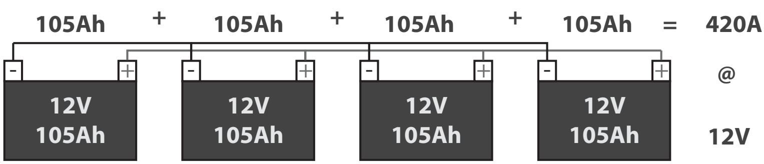


As you might remember from your earlier reading about the national grid, the higher the voltage the more efficient the transmission of power. A 48V system is therefore more efficient than a 12V system and so it is preferable to increase the number of volts available. If we had 12V batteries we would need four batteries connected in series to achieve 48V.

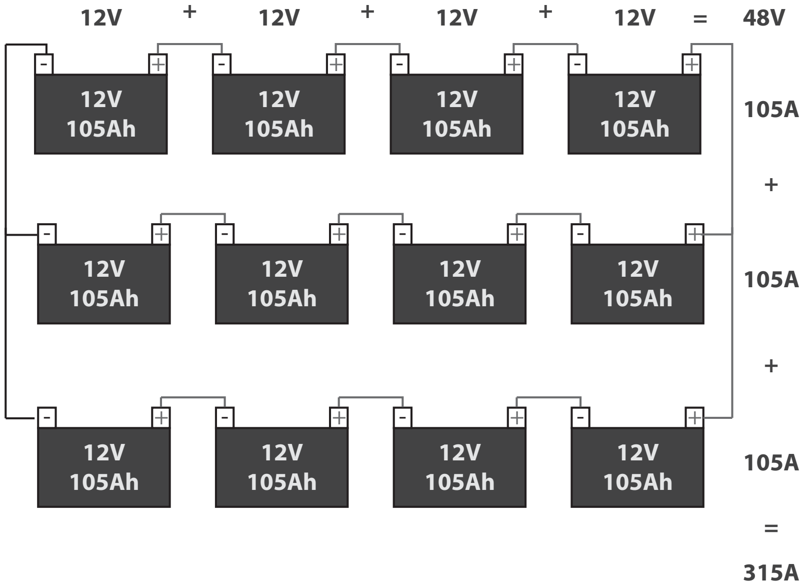
The voltage that you choose for the system is determined by the amount of energy that you intend to put through it. If you are going to be putting through less than 2 000W, then you can run the system at 12V. From 2 000W to 5 000W requires at least a 24V system, while a 48V system should be used for systems of between 5 000W and 20 000W, which is the range into which most domestic installations would fall. Beyond 20 000W a 240V system would be required.

When you link batteries in *parallel,* the current is additive while the voltage remains the same. So, if you were to link two 12V 105Ah batteries in parallel, the circuit would produce 210Ah at 12V.

When linking in parallel, the negative terminal of one battery is linked to the negative terminal of another battery, while the positive terminals of both batteries are also connected.



A *series/parallel* circuit is a combination of batteries linked both in series and in parallel.



In order to increase the amount of current available to the system, we would need to connect batteries in parallel. Our four 12V batteries connected in series are now effectively one 48V battery and so, to increase the current available we would need to link, in parallel, a further four batteries, also connected in series, to our first set.

You need to remember that, having decided to go with a 48V system, you are now tied into sets of four batteries. Each time you wish to increase the current available to the system, you will have to add an additional four batteries.

You must also remember that your power input also has to be at 48V.

Batteries are extremely heavy - about 27kg for a 105Ah battery. They also give off a noxious gas when charging and, if shortcircuited, can burst into flames and so cannot be kept indoors. They cannot be piled directly on top of each other. They need to be as close as possible to the source of the power and to where the power will be distributed.

Converting the DC voltage into AC voltage

Batteries deliver direct current (DC) while the national grid delivers alternating current (AC) at 220V. In order for your appliances to run off the batteries you require an *inverter* to step up the voltage and invert the current.

There are two main kinds of inverters:

- modified sine wave inverters
- pure sine wave inverters

Modified sine wave inverters are cheaper than pure sine wave inverters. They produce an output that goes to zero for a time, before switching positive or negative. Most appliances can be run off such an inverter, although they should not be used with anything that has a capacitor (for example a fridge) or with certain specialised electronic equipment (like some laser printers).

A *pure sine wave* inverter produces a nearly perfect sine wave output that conforms very closely to the power that comes from the national grid. It is therefore compatible with anything that you currently run off your mains electricity.

It is possible to purchase appliances configured for 12V and it would be possible to run these directly from the battery or DB board without using an inverter. Such items range from lights to fridges and freezers.

Doing your homework

Before you can make any decisions you are going to have to do some homework.

How much energy do you require?

To start with, you are going to have to calculate what your current energy requirements are.

The most straight forward way of doing this is to look at your energy bills, but do make sure not to look at the estimates but rather at the actual readings. Alternatively, you could read your meter over a period of days or weeks and get an accurate idea of how much energy your are using. Your energy bill and meter give you your energy usage in kilowatt hours (kWh).

Practically, it will be extremely difficult and very costly to come off the grid if you are going to use more than 5kWh a day.

How can you reduce your energy requirement?

Almost inevitably you will find that your current energy requirement is dauntingly high. If you are currently heating water, heating your home and/or cooking with electricity you are not, unless you are extremely rich and have plenty of money to invest, going to be able to come off the grid. Even if you don't come off the grid, sorting these three issues out will substantially reduce your electricity requirement and your impact on the world.

Alternative water-heating systems

Water heating can be efficiently achieved through a solar water heater or through gas. Since gas (apart from biogas, which is not efficient for heating anything more than a few litres) is a fossil fuel, and is also relatively expensive to run, a solar water heating system is most desirable.

There are a variety of systems available. Some can be hooked to your current geyser while some incorporate the geyser in the solar unit. Eskom offers a rebate on some solar water-heating systems.

Alternative cooking systems

Gas cooking is the most obvious and convenient solution to not using electricity for cooking. A relatively small amount of gas is required for cooking (as opposed to water heating) and so the environmental impact of gas cooking is small. No major adjustments need to be made in terms of how and when one cooks. It is possible to purchase very cheap gas hobs and very fancy, expensive gas stoves with gas ovens.

A variety of solar cookers are available, many made in South Africa. These require an adjustment to the way that one approaches cooking, as obviously cooking has to take place while the sun is shining. They are, however, quite efficient, clean and relatively cheap.

Hot bags can be used in conjunction with any heat source. They are suitable for cooking anything that is generally cooked with water: rice, potatoes, mielie meal, stews, soups, poached chicken, etc. They work on the principle of retained heat, and are only effective once the food has been sufficiently heated by a heat source.

There are also any number of small stoves fuelled by alcohol and gels.

And, although most people might find this a bit drastic, you could, of course, adopt a raw-food diet and do away with the need for cooking altogether.

Alternative heating systems

Once again, gas is probably the easiest and most convenient way to heat your home without using electricity. Gas heaters are easily accessed and used, but not ideal since they are relatively expensive to run and use a fossil fuel.

Solar under-floor heating is a good way of warming the house. It does, however, need to be installed while building a house and is not easily installed at a later stage. Efficient wood-burning fireplaces are also a possibility, although they are expensive to purchase and install and the burning of wood could be viewed as problematic from an environmental point of view.

On a very simple level, wearing more and warmer clothes, and using blankets, shawls and hot-water bottles (not only in bed), are a very cheap and low-impact method of reducing one's need for heat, while insulating the house properly will help to conserve the heat that is generated.

A brief note on biogas

Biogas is produced from animal (including human) waste and vegetable matter. Through a process of anaerobic (i.e. without oxygen) fermentation, methane is produced. On a domestic level, this can be compressed to a limited degree and used to fuel gas appliances. Unfortunately, your normal gas appliances would have to be adapted, so there is neither seamless integration with a current gas system nor the ability to easily switch between biogas and conventional gas.

As the system requires a reasonable "raw material" input, it is not suitable for smaller families. In China, however, 30 million rural households are using biogas digesters for their cooking and are, by the same means, also producing high quality fertiliser and successfully dealing with various wastes. Depending on your approach, systems can be quite cheap or relatively expensive.

What will the most suitable source or sources of energy be?

Unless you have enough wind and a suitable spot to erect your wind turbine, wind is unlikely to be your best source of power. To measure wind speeds you require an anemometer. Finding that your wind speeds are sufficient does not, however, guarantee that your wind turbine is going to be able to work efficiently because if that wind is not hitting your turbine smoothly, then it is not going to turn properly. Turbulence is very difficult to measure, but is caused by obstructions. If a turbine cannot be placed where it is well away, or well above, obstructions such as trees and buildings, it is not going to work efficiently.

Even if a wind turbine is a practical option, most people will also need solar panels.

Solar panels are rated by watts, although the wattage indicated is misleading as the panels will generally put out more than 12V, 24V or 48V and thus the amperage is lower than might be anticipated. You must be careful to check the full specifications when buying a solar panel.

In South Africa six hours of peak sun is generally regarded as average and so, when calculating what a panel will put out, you take the rated wattage times six.

For example, if a panel is rated at 205W you would anticipate that on an average day it would put out 1 230W (1.23kW). As you will discover as you read on, however, there are losses and inefficiencies that tend to reduce the actual output, and so you need to reduce this figure by about 40%, ending up with an anticipated daily wattage output of 738W.

What will the extent of these sources need to be?

Let us assume that you have managed to reduce your daily energy requirement to 5kWh. You would think it obvious that you will need to generate 5kW of power per day. Sadly, however, because of various inefficiencies, this is not the case.

Firstly, there is a loss through battery and inverter inefficiencies, so you need to add 15% to your 5kW requirement, bringing you to 5.75kW. Then you will need to add about 30% for solar or wind inefficiencies, which brings the total that you need to generate to 7.5kW.

So, if you can bank on a wind turbine of 1kW, for example, turning at optimum speed for eight hours a day, then you will have your 7.5kW of power. Except in the windiest of places, this is unlikely to happen. So let us assume that the wind generator will be able, on average, to deliver 2kW of power per day. This means that you require another 5.5kW of power from solar sources.

Solar panels come in all sorts of sizes, but let's assume we will be using 200W, 24V panels. Remembering that we have settled on a 48V system, we have to install our panels in multiples of two. Working on an average of six peak hours of sun (a reasonable estimate in South Africa), one 200W panel will theoretically produce 1.2kW per day, and an array of two panels will produce 2.4kW each day. To achieve our 5.5kW of power, we will need six panels. This would, in fact, give us a bit more than we need, which is a good thing, especially as the wind might not be as reliable as the sun.

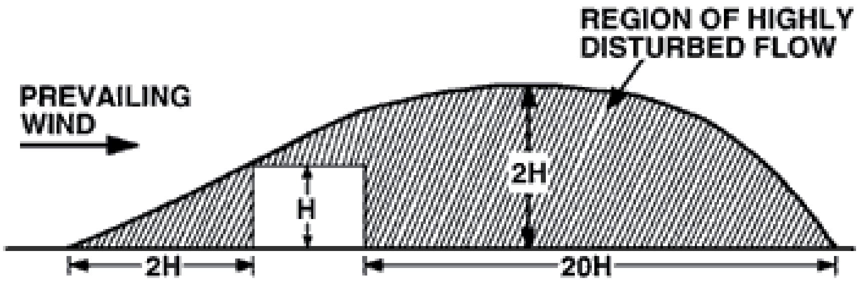
Based on my own experience, however, solar panels are not going to perform quite as well as this, and I believe that you would most likely need eight panels to produce what is required.

Where should the energy sources be sited?

If a *wind turbine* cannot be placed where it is well away from, or well above, obstructions such as trees and buildings, it is not going to work. While a turbine does not take up much space, if you go for a turbine larger than about 600W you are going to require a substantial pole supported with guy-wires, which do intrude on space. People seem to be concerned about the aesthetics of a turbine, but they are really quite attractive and do not intrude in any real way.

Ideally, one would want to position the turbine so that it is able to receive the wind from any direction without any turbulence affecting it. Different turbines can start up at different speeds, but generally a turbine will start turning at wind speeds of above 2.5 metres per second (2.5m/s), which is about 9km per hour, and will reach peak operation at between 8m/s and 15m/s.

Turbulence is a major factor to consider. Turbulence is caused not only by objects in front of the turbine, but also by objects behind the turbine. It is generally recommended that the turbine be about six to eight metres above any object that might be in the way, or at least twice the height of any object in front of or ten times the height of any object behind the object.



Zone of Disturbed Flow Over a Small Building

Solar panels obviously need to be in direct sunlight for as much of the day as possible. In South Africa, they should optimally be placed in a north facing position, tilted at about a 30^o angle. The moment the panel falls into shade it will not generate any further power until next it is in the sun.

You need to watch out for things that will cast a shadow across the panels because even a very small amount of shadow can dramatically reduce the output from the panels. This is because a solar panel is made up of multiple solar cells, which all act upon one another to create electrical energy from collected solar power. If a shadow creeps across the solar panel, power is lost exponentially because one affected solar cell affects all the other solar cells. So, if even 20% of a panel is shaded, your solar output may well reduce to nothing. Keep in mind that if your panels are connected in series, the impact of shadow on one panel will impact on all the others that are connected in series.

Roofs are the traditional place to put solar panels, and in most cases this would be the most practical position for them to be in as they do take up a fair degree of space.

How big a regulator will you require?

The size of your regulator, which controls the current feeding into your system, will depend on how much power you intend to produce. Regulators are relatively inexpensive.

There is a very wide range of regulators available, in a variety of sizes ranging from 5A to 80A. The regulator that you choose must be able to cope with the total number of amps generated. It is important that you don't undersize your regulator because if it is too small any current that is generated in excess of what the regulator can handle will simply be wasted.

How much storage will you require?

Let us assume that you are going to use a 48V system with 105Ah 12V batteries. This configuration implies that you will need at least four batteries (12V x 4 = 48V). Without any power coming in, four batteries will supply you with 48V x 105A = 5040W. But, remember, you can only run your batteries down to 50% without causing damage and shortening their lives, so these four batteries are really only able to supply about 2500W or 2.5Kw.

If your daily power requirement is 5kWh (i.e. 5000 watts are consumed each day), you will need eight batteries to supply you with power for one day without energy coming in. In other words, for each day that you anticipate that you will not be able to put power back into your batteries (because there is no wind or no sun), you will need a further eight batteries.

How big an inverter will you need?

The size of the inverter that you choose will depend on what you anticipate your maximum, or peak, power requirement will be, plus a 20% safety margin. So, if you anticipate using your kettle, your computer, your TV and your lights at the same time, you need to take the cumulative watts that these require and add 20%. In this particular example, your calculation would look something like this:

Kettle	1 800W
Computer	300W
Television	150W
3 x lights	33W
TOTAL	**2 283W**
Plus 20%	2 740W

You would therefore require a 3000W inverter.

By the simple expedient of boiling your kettle on a gas plate or solar stove instead of using electricity, you would reduce this peak to 483W, and could therefore go for a significantly smaller (and therefore cheaper) inverter. Inverters are fairly expensive but it is worth buying a good one which will be adequate for your long-term needs.

Inverters do make a noise (about as much as a high-powered fan). If this is likely to bother you, you will have to place it somewhere where it is not going to intrude too much. By the same token, it should be reasonably accessible as you will want to keep an eye on it.

What else is needed to put it all together?

Whether you are going to be entirely off the grid, or grid-tied, putting everything together will be much the same.

To start with, if you are going to install a wind turbine of 600W or more, you are going to need to dig deep holes, fill them with concrete and embed the pole and guy-rope eyes. Solar panels will need to be fixed to the roof and may well need to be put on angled brackets. Your batteries will need to be housed somewhere where they will be relatively safe from theft and water but will still keep cool, and be able to breathe and safely emit their gases (see the "cage" on the inside back cover). Your controller and inverter will need to be housed inside or somewhere where they will not get wet. Everything needs to be as close as possible to the distribution board in order to reduce both the cost of running cables and the loss of power.

A qualified electrician should connect the entire system to the distribution board. You do have options in this regard. You could choose to place only certain circuits, for example lights, onto the alternative system or you may choose to divert the entire board to the alternative system, with either a manual or automatic change-over to the mains when the batteries reach a certain state of depletion.

In closing

Hopefully, you are now better informed than you were about the vagaries of alternative energy and how to use it. The last few pages are worksheets that will hopefully help you to define exactly what you will need to get off the grid. As time goes by, panels are becoming cheaper and it seems possible that in the not too distant future one will be able to set up a grid-tied system that will self-monitor, switching in and out of feeding into the grid and feeding off the grid, with the household being paid at the same rate when it feeds in as it is charged when it draws off.

For the moment, and as I've mentioned a number of times, it is not necessary to untie yourself entirely from the mainstream of electricity generation. There are many, many ways in which you can reduce your need for electricity and thereby reduce your impact on the world without going the whole hog.

If you do choose to go all the way, may your cloudy days at least be windy.

EXAMPLE WORKSHEET

Table 1 - Determining average daily load

Load	Watts	Hours/ Day	Days/ Week	Weekly watt-hours
Computer	130W	8	6	6 240
Printer	80W	1	6	480
Fridge	480W	12	7	40 320
Fan	45W	8	7	2 520
Television	50W	4	7	1 400
Total weekly watt hours of load				50 960
Divided by days per week				7
Average total watt-hours used per day				7 280
Divided by inverter efficiency (usually about 90%)				/.90 = 8 089
Divided by battery efficiency (75%)				/.75 = 10 785
Divided by wiring & panel efficiency (90%)				/.90 = 11 984
TOTAL average daily input required				11 984

Table 2 - Calculating battery bank size

Average total watt-hours used by per day	7 280
Divided by DC nominal voltage	48
Average amp hours per day	151
Divided by inverter efficiency (usually about 90%)	151/0.9 = 168
Divided by battery efficiency (usually 75%)	168/0.75 = 224
Adjusted amp hours per day	224
Divided by depth of discharge (usually 50%)	224/0.5 = 448
Multiplied by days of autonomy required	448 x 3 = 1344
Battery bank size required	1344
Divide by Ah available per battery (usually 50)	1 344/50 = 27
Batteries required	27

Table 1 - Determining average daily load

Load	Watts	Hours/ Day	Days/ Week	Weekly watt-hours
Total weekly watt hours of load				
Divided by days per week				
Average total watt-hours used per day				
Divided by inverter efficiency (usually about 90%)				
Divided by battery efficiency (75%)				
Divided by wiring & panel efficiency (90%)				
TOTAL average daily input required				

Table 2 - Calculating battery bank size

Average total watt-hours used by per day	
Divided by DC nominal voltage	
Average amp hours per day	
Divided by inverter efficiency (usually about 90%)	
Divided by battery efficiency (usually 75%)	
Adjusted amp hours per day	
Divided by depth of discharge (usually 50%)	
Multiplied by days of autonomy required	
Battery bank size required	
Divide by Ah available per battery (usually 50)	
Batteries required	

The cottage in which the author lives (mostly) off the grid.

Jane lives on a small farm just outside Pietermaritzburg in KwaZulu-Natal. She tries to grow most of her own vegetables and keeps a few chickens for eggs. She runs a small business facilitating authors who wish to self-publish and spins yarn and knits in her spare time.

(www.boutiquebooks.co.za)

Jane Harley shares her experiences with wit and charm, while including extremely useful information too. This is essential reading as we head to a post-carbon future.

Nikki Brighton – Dargle Local Living

This book will appeal to a wide audience - those who are interested in calculations and science and those who want a simpler explanation. My favourite section was "Doing your own load shedding". It gets to the point (honestly!) but in an entertaining way that also serves to help people make this meaningful in their own lives.

Megan Lewis - groundWork

Getting off the Grid **is both entertaining and accessible. It will also be useful to those just getting onto the grid as it will help them to understand where power can be saved in order to contain their electricity costs.**

Gill Addison -
Friends of the Earth South Africa

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