Guide to back-up power options for resilient households

With increased incidence of fires, floods and severe weather events, it is important that households understand their options and needs when it comes to ensuring electricity supply, especially to critical appliances.

We've drawn on the experience of New South Wales householders who've relied on alternative power sources in a blackout to compile this guide to some of the options available.

About this guide

This guide was created as part of the *Energy Sustainability through Knowledge and Information Exchange (ESKIES)* project by researchers from the *Collaboration on Energy and Environmental Markets (CEEM)* at UNSW Sydney.

We welcome comments, suggestions, questions and corrections on this guide.

For more information, or to contact the research team, please visit our website at www.energy-resilience.com.au.

This is a Bushfire Community Recovery and Resilience Fund (BCRRF) project funded through the joint Commonwealth/State Disaster Recovery Funding Arrangements.

Disclaimer

While the authors have made every effort to ensure the information provided here is correct and useful, we accept no liability for any errors or inaccuracies. Readers are advised to obtain independent advice before investing in solar, batteries, generators or other distributed energy resources.

Although funding for this project has been provided by both the Australian and New South Wales Governments, the material contained herein does not necessarily represent the views of either Government.

Energy resilience

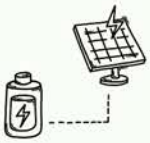
Extreme weather events, such as bushfires, floods and severe storms, can cause grid outages that disrupt the supply of electricity. Energy resilience – the ability to maintain access to energy during these events – can be achieved in different ways. Most of this guide is about *electricity* resilience, but the final section touches on other sources of energy.

Some approaches to electricity resilience – not covered by this guide – work at the level of a community or electricity network. Examples include microgrids, community batteries, emergency relief centres or refuges, and resilient energy centres.

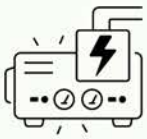
This guide focuses on increasing energy resilience - and particularly electricity resilience - of individual households through the use of Distributed Energy Resources (DER).

DER include:

Rooftop solar (photovoltaics)



Batteries



Generators

Electric vehicles

And less commonly:

Micro-wind generators

Micro-hydro generators

People buy and install DER for a variety of reasons, including to:

Save money

Reduce their carbon emissions

Increase energy independence

There are different types of DER and not all of them will increase energy resilience. This guide describes some things to consider when choosing DER if you want them to provide a reliable energy supply during electricity grid outages.

Generators

Generators, also known as *gensets*, are the most commonly used source of electricity during severe outages due to extreme weather because they are relatively cheap, easy to obtain, and can be mobile.

They may be used for short periods each day (conserving fuel and reducing noise) to charge phones, batteries, etc., or to run continuously if needed for refrigeration or air-conditioning in high temperature conditions, or to pump water for fire-fighting.

They have limitations - including their noise and need for fuel - and there are some important factors to consider before buying.

Generators must only be operated outdoors as they emit toxic carbon fumes. Do not run them in a shed or garage. To minimise risk of fire, never refuel a generator while it is running.

Advantages	Limitations
• Relatively cheap • Easy to obtain • Mobile – can be taken to where required • Work at night / in smoke • Reliable if well maintained • Quick to start – fast response	• Need regular operation and maintenance • Noisy • Can be affected by heat • Greenhouse gas emissions • Fuel storage can be risky • Fuel may be unavailable in emergency situations

Think about...

- Sizing to meet your needs
- Fuel type: petrol, diesel or gas
- Fuel storage
- Starting: manual, electric or automatic
- Fuel capacity and use
- Switchboard connection or extension lead to appliance/s
- Safe outdoor location
- Safe operation to avoid fire and electrocution risks

Using generators for energy resilience

There are three ways generators can be used for energy resilience:

Connected to individual loads or appliances using an extension lead (e.g. a fridge or water pump)

- Make sure the extension lead is not overloaded.
- Computers, mobile phones, tablets and televisions should have surge protection installed to protect the equipment.

Connected to the switchboard to supply a whole property or selected circuits (e.g. lighting, certain power points or water heating)

- *Socket and changeover switch must only be installed by a licenced electrician.*
- Make sure the generator is not overloaded (see *'Designing your resilient household electricity system'* below).
- For a 3-phase grid connection, consider whether you need to supply all phases or just a single phase.
- You may need extra circuit breakers to avoid overloading the generator.

Connected as a back-up for a solar-battery system

- *This should only be connected by a licenced electrician.*
- Some systems start automatically when the grid disconnects (or when the battery charge drops below a set level).

See "Portable generators" below for another option.

Fuel supply for generators

	Petrol	Diesel	LPG Gas
+	• Available in smaller sizes, more portable • Run quieter with fewer fumes • Run better if rarely used	• More fuel-efficient • More reliable with prolonged constant use	• No need to refill a fuel tank, so reduced fire risk • Quiet operation • Fuel doesn't degrade
−	• Run hotter than diesel • More prone to breakdown with prolonged use • Greater fire risk while filling or storing fuel	• Need to be run regularly • Diesel fuel can denature (go stale) over time	• Lower efficiency • Risk of gas cylinders exploding in a fire
=	Good for low-load, occasional or intermittent use	Good for high-load, frequent or long duration use	Good for larger applications

In emergency situations, lack of supply, transport or labour can constrain access to fuel.

$ Expect to pay

• From $500 for a small 2kW inverter-generator to $20,000 for a 35kW 3-phase, water-cooled diesel generator with electric start

• $600 to $1000 for a switchboard connection and changeover switch

Rooftop solar and batteries

Rooftop solar is the most common form of distributed energy resource in Australia, found on one in every three houses. Solar electricity is cheap and clean, and generating electricity where it will be used reduces reliance on the grid.

But most solar systems on their own will not power your home when the grid goes down - and sometimes not even when connected with batteries.

Most grid-connected solar systems are configured to stop delivering power to the home and the grid when there is a blackout, for safety reasons. This is called 'anti-islanding'.

However, an '*islandable*' system will disconnect from the grid during an outage and continue to power your home. Islandable systems usually have batteries but, again, not all solar battery systems will operate in a grid outage. They must be configured to disconnect from the grid and only supply electricity to the house or selected circuits.

There are also a few 'battery-less inverter' systems which are islandable, allowing you to use solar generation in the home during a blackout without a battery. As there is no storage, you only have power when the sun is shining.

(Solar also called photovoltaics or PV; Battery also called Battery Energy Storage System or BESS)

If you are buying solar and batteries for energy resilience, make sure you have a system that will keep delivering power to your home during an outage – not all systems will.

Solar and battery system types

An *inverter* is used to convert between the DC ('direct current') electricity of solar and batteries and the AC ('alternating current') electricity of mains electricity, household appliances and generators.

A solar-battery system may have an inverter for the solar and a separate inverter-charger for the battery (this is called an 'AC coupled' system), which may be fully integrated with the battery as a single unit.

Alternatively, it may have a single 'hybrid' inverter-charger for both solar and battery (a 'DC coupled' system).

Most households with solar and batteries keep their connection to the grid. There are different arrangements for both AC-coupled and DC-coupled systems that determine what happens during a grid outage.

Depending on the technical configuration, a solar-battery system may provide back-up to the whole house or to selected circuits or not at all. The more loads and appliances that are connected, the shorter the back-up duration.

For houses with 2-phase or 3-phase grid connections, most battery systems will only provide back-up for a single phase. 3-phase back-up is possible but is more expensive.

Confusingly, the term "hybrid" is sometimes used to mean DC coupled, sometimes to mean islandable, and sometimes used for any solar-battery system.

Solar and battery system types

The table below compares the resilience provided by different solar and battery configurations

Type of system	Operation in grid outage	Resilience	Other benefits/options
Solar only (non-islandable)	Solar shuts down due to anti-islanding	No resilience benefits	Reduce bills, payback in 3-5 years, reduce emissions
Solar only (islandable)	Solar and special inverter deliver electricity to the house or essential circuits during the day only	Resilience during the day when the solar panels are producing electricity.	Reduce bills, faster payback than battery system, reduce emissions
Solar + battery (no back-up)	Solar and battery shut down due to anti-islanding	No resilience benefits	Reduce bills, increase solar self-consumption, help the grid, may participate in a VPP*
Solar (non-islandable) + battery with limited back-up	Battery supplies individual circuits or single socket, but does not recharge from solar.	Resilience against short outages	Reduce bills, increase solar self-consumption, help the grid, participate in a VPP*
Solar + battery (fully islandable system) with back-up	Solar and battery supply house or individual circuits	Resilience against longer outages (but not extended periods of low generation)	Reduce bills, increase solar self-consumption, help the grid, may participate in a VPP* Add a generator for reliable supply in long periods of cloud or smoke
Solar + battery (off grid)	No change! Solar and battery supply house	Resilience for long periods	No electricity bills but high upfront cost. Often include a generator for maximum security

*Participating in a VPP (Virtual Power Plant) enables a 3rd party to use your battery to benefit the electricity system, in return for payment or reduced costs. There may be a trade-off between VPP income and the available back-up capacity of your battery.

Choose your solar system provider carefully

There are solar sales people, solar system designers and solar installers involved in your solar system. In a small company it could be one person doing all three jobs.

Talk to the system designer to design a system to suit your needs in an outage. Check that they are experienced with systems that provide a back-up during grid outages.

The installer may be a sub-contractor of the sales company. When talking to a seller, ask who will be installing your system.

Be clear about your resilience needs: Know which loads you need backed-up and for how long.

Only use an installer accredited by the Clean Energy Council. You can find the list at: *https://www.cleanenergycouncil.org.au/consumers/buying-solar/find-an-installer*

Get informed, local recommendations from family, friends and neighbours.

Installers that have been around for a while are more likely to still be around if you need something repaired at a later date.

Ask about after-sales service:

- What maintenance is needed?
- Does the system have monitoring?
- What if something goes wrong?

A local company may be better placed to provide ongoing support.

Solar and battery warranties

✓	**The installation warranty covers the installation work and should be for at least 5 years, preferably 10 years**
✓	For good quality solar panels, expect a product or equipment warranty of 10 - 15 years (some are as high as 25 years)
✓	The performance warranty on panels should be for 20-25 years (this means panels should still have 80% of their rated output after this time)
✓	An inverter should be warrantied for 10 years, and you should expect to repair or replace it within the lifetime of the solar panels
✓	Batteries should also have a 10-year warranty, at minimum

Expect to pay

Costs for solar and batteries depend on location, specification and what you need them to do. Expect to pay more for a system that provides a secure back-up supply.

A simple solar system will pay for itself in 3-5 years, but a battery may not pay back its cost in bill savings within its lifetime.

Factors that can increase system costs include:

- High, steep and tiled roofs
- Long distances between the solar system and the meter box
- The use of microinverters
- Living in an isolated area

Example costs	
A 6.6kW solar system could cost	$5,000 - $13,000
Adding a battery system to existing solar could cost an additional	$8,000 - $20,000
8kW solar & 13.5kWh battery hybrid system could cost	$25,000 - $35,000
A comprehensive off-grid system for a house with modern appliances could cost	$40,000 - $50,000 or more

Solar system battery types

The most common home solar batteries are lithium-ion. Lead-acid batteries are also used, particularly for off-grid systems, but are becoming less common.

	Lead acid	Lithium ion
+	• Reasonable efficiency (75-80%) • Mature technology • Can withstand higher temperatures • Easily integrated and well-understood • Simple operation • Low self-discharge (5% per month) • Recycling streams available	• High efficiency (95-98%) • No maintenance • High energy/power density (small & light) • Longer life (10,000+ cycles) • High discharge rate
−	• Low energy density (big & heavy) • Low continuous currents • Sensitive to low temperatures • Requires regular use / maintenance • Low cycle life	• Less mature technology • Needs battery management system (BMS) • Hard to recycle • High temperatures can cause “thermal runaway” – destructive fire

There are ***newer types of batteries*** that are worth considering for resilience applications.

- **Lithium iron phosphate** batteries have a longer life and are less sensitive to heat than lithium-ion.
- **Lead-carbon** batteries can replace lead-acid for off-grid systems, with greater usable capacity and lifespan, but higher cost.

Solar system battery sizes

Battery sizes are described by two factors:

Energy capacity

- Measured in kWh (kilowatt-hours)
- This is the amount of electrical energy stored
- For lead-acid batteries, only about 50% of the rated energy capacity can be used; for lithium-ion, it's around 80%
- For example, a 5kWh lithium-ion battery can run a 1kW load for 4 hours (not 5), or a 2kW load for 2 hours

Power or discharge capacity

- Measured in W (Watts) or kW (kilowatts)
- This is the output power that can be delivered from the battery inverter at a particular time, which limits the number and size of appliances that can be connected at the same time

It gets more complicated: Inverters are sometimes rated on continuous power AND surge or peak power which can be delivered for short periods of time.

Appliances with motors or pumps ("inductive" devices) often need a much higher power to start and then lower power once they are running.

Designing your resilient household electricity system

Essential loads

The first step in designing a resilient household electricity system, whether solar-battery or generator, is to decide which household loads you want to supply during a grid outage. This may depend on whether the anticipated outage is for a few hours, multiple days or several weeks.

You will find the rated power (in Watts or kilowatts) labelled on each appliance. Energy efficient appliances will reduce the level of back-up required, as well as reducing electricity bills.

Carry out an audit of:

☐ The power rating (in Watts or kW) of the appliances or circuits you need to run off your solar, battery or generator

☐ The amount of electrical energy (in KWh) you need to store to get through a grid outage

Essential loads will vary between households and might include:

- Fridge or freezer
- Lighting
- Communications (phone charging / computer / wi-fi)
- Water pumping (for fire-fighting / drinking / washing / toilets)
- Sewerage pumps
- Cooking
- Medical equipment
- Air-conditioning
- Space heating
- Water heating

Factors to consider are:

- Continuous power (kW) of the appliance
- How long the appliance is used for each day
- Energy (kWh) needed each day (Energy = Continuous power x Time)
- When the energy is needed (e.g. day or night-time)
- Instantaneous or surge power (kW): “Inductive” loads that have motors or pumps (e.g. water pumps, air-conditioning, fridges) can have a high surge power, up to 8 times the continuous power
- Generators and solar or battery inverters should be sized to deliver the maximum surge power; batteries are sized to store the energy needed

Estimate how much 'essential' electricity you need per day

Australian households typically use between 8-20 kWh per day, depending on the number of occupants, the types of appliances and how long they are used. You can find your average daily electricity usage on your electricity bill.

However, not all that usage is 'essential', so when assessing what you need in a blackout it's useful to do an audit of your needs.

The total power of the appliances (in kW) used at one time is called 'maximum demand' and determines the size of solar/battery inverter or generator needed.

For example, many hybrid solar-battery inverters are rated at 5kW, so will only supply 5,000W of appliances at one time.

The total electrical energy needed (in kWh) determines the size of battery needed.

Sizing your solar and battery for resilience

Solar and battery systems designed for resilience will be bigger than those designed for maximum financial benefit.

- Size the solar to charge the battery and size the battery to provide the length of back-up supply you need.
- Consider installing solar on East and West facing roofs, as well as North, to give a longer period of generation each day.
- Consider "oversizing" the solar to give enough generation on a dull winter day, or when there is smoke in the air.
- In sunny conditions, a battery must store enough energy to run essential loads overnight. In cloudy or smoky conditions, you may need capacity for a few days. On-grid systems are unlikely to guarantee more than a few days of resilience without a generator.

Consider how the system will be operated. Grid-connected batteries are commonly set up for daily cycling, charging during the day, and discharging in the evening and overnight, to maximise the financial benefits. This can mean that if there is a power outage in the morning, the battery will have very little energy stored.

For resilience, some battery capacity should be reserved for back-up, maybe 20%, 50% or even 100%. Some systems allow the installer or the user to specify this.

Grid connection

Most Distribution Network Service Providers (DNSPs), who operate the electricity network (poles and wires), limit either the size of solar system (peak generation in kW) that can be connected to the grid, or the power (kW) that can be exported to the grid at any particular time.

You can find these limits for most DNSPs on their websites.

For NSW, the limits (as of July 2023) for the 3 DNSPs are shown below. DC size refers to the peak power output of the solar panels; AC size refers to the output of the solar inverter.

		Ausgrid	Endeavour Energy	Essential Energy
Connection Limit	**1-Phase**	10kW AC (13kW DC)	10kW AC (14kW DC)	5kW DC (6.6kW DC) 3kW in rural areas
	3-Phase	30kW AC (40kW DC)	30kW AC (40kW DC)	15kW AC (19.8kW DC) 9kW in rural areas
Export Limit	**1-Phase**	10kW	5kW	5kW 3kW in rural areas
	3-Phase	30kW	30kW	15kW 9kW in rural areas

If your house has a 2-phase or 3-phase grid connection, it could make sense to have the switchboard rewired to group all the essential loads on a single phase which can be connected to your back-up supply.

Fire considerations

There are a number of particular considerations for siting and installing DER if they are needed to provide secure power during extreme weather events:

- There are specific rules about **battery location**, including proximity to inhabited spaces, doors, windows, etc. (specified in AS/NZS 5139:2019)
- **Solar and battery inverters** may need an internet connection (wi-fi or 4G) if you want to monitor their operation
- Installations should avoid locations liable to flooding

In general, **inverters and batteries** should be located away from direct sunlight or heat or extreme cold. Lithium-ion batteries are particularly sensitive to heat and susceptible to thermal runaway. Some Lithium-ion battery management systems will shut down above 50 degrees Celsius.

Batteries and inverters may need protection from extreme temperature and embers. This can be done by:

- Siting away from potential fire routes
- Steel mesh enclosure, allowing airflow for cooling but not ember ingress
- Containerised system with air-con (run from battery) and ventilation

Solar panels are not very flammable but the build-up of leaves and/or embers between panels and roof is a fire risk. This can be reduced by covering the gaps with wire mesh and by regular preventative maintenance - removing leaves, etc.

Siting **generators, inverters and batteries** close to the main switchboard reduces cable runs. Laying cables underground in protective enclosures can reduce vulnerability to fire or, for over-ground cables, composite poles are more fire resilient than timber.

There are fire-risks associated with **generators**. Storing large quantities of **fuel** creates a fire risk, particularly if it's petrol. Filling generators while they are running is particularly high risk and should not be attempted. Gas-powered generators do not need to be filled but gas cylinders are an explosion risk in a fire.

Other DER

Other renewable generators

For some households, the security of the electricity supply can be increased by using different types of generation.

A small **wind generator** added to a solar-battery system can provide power during periods of low solar generation due to smoke or cloud. In most locations, wind turbines need to be mounted at a height where wind speeds are higher and more consistent, and there is less air turbulence. This – and ongoing maintenance costs – make them relatively expensive.

Micro-hydro generation is only possible where there is suitable running water, but can be a good source of consistent generation in some locations. Again, this option has ongoing maintenance costs.

Portable solar generators are an emerging form of household energy back-up. They come with a 'blanket' of solar panels and an all-in-one battery inverter unit. With the solar typically sized at 200W – 2kW, and the battery 200Wh up to 2kWh, they are a highly portable, emissions free, quiet and safe alternative to a portable liquid fuel generator. However, they do rely on sunlight to charge the battery, and cost more to buy (although less to run).

However, a portable solar generator won't create the electricity bill savings or emission reductions that a rooftop solar system will.

Other fuels

Diverse energy sources can increase resilience, although the carbon and particulate matter emissions from burning fuels should be considered.

Gas stoves or barbecues can be used for cooking, and gas or dual fuel fridges for keeping food fresh during grid outages. Wood stoves or fires can provide heating and be used for cooking. Kerosene can provide light, heat, and cooking.

Solar hot water and gas-heated water may or may not be resilient to grid outages as some systems need electricity to power a pump or provide ignition. Solar kettles, barbecues and ovens provide energy services directly, but are time and weather dependent.

Vehicles

The batteries in electric vehicles (EVs) are typically much bigger than household batteries, so have the potential to provide significant back-up power. Vehicle-to-home (V2H) bi-directional chargers enable an EV to power a whole house, but are currently expensive and in short supply.

Vehicle-to-Load (V2L) arrangements allow individual appliances to be powered from the EV, but also have limited availability at present. Inverters are also available that can be connected to the battery of an internal combustion engine vehicle to run individual appliances, but the storage capacity of these batteries is much lower.

Battery-powered and other resilient appliances

Battery appliances can provide specific energy services during an outage, provided of course that the batteries are kept fresh or regularly charged. Wind-up or solar powered devices offer better resilience. Commonly available devices include torches, lamps, radios, phone chargers and combinations of these.