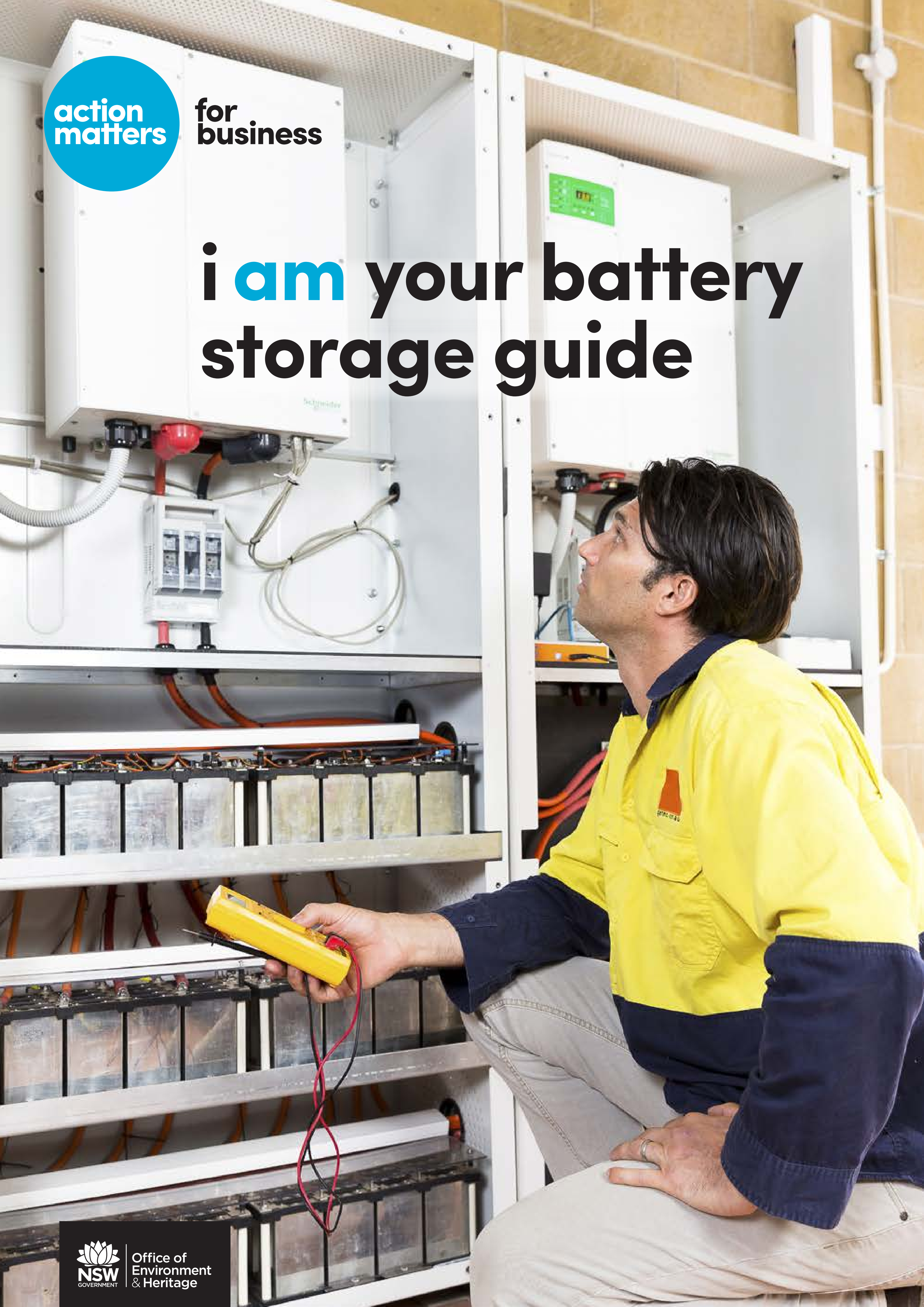
action matters for business

i am your battery storage guide



NSW GOVERNMENT Office of Environment & Heritage

Cover photo: C. Harding/OEH

Dedication

In memory of James Robinson.

OEH staff member, James Robinson, recently passed away from cancer. James worked with OEH since 2011 and was a driving force behind the development of these battery storage resources. He made a large contribution to the emissions-reduction effort, and had a deep commitment to making a difference and changing how the NSW business community value and use energy.

This publication would also not have been possible without input from – Julien Freed (Julien Freed Consulting), Evan Darmanin and Ed Darmanin (ChargeWorks), Samantha Christie, Manuel Weirich and Tim Stock (NSW Department of Industry), Sam Behrens (CSIRO), Richard Collins (Global Sustainable Energy Solutions), Luke Pickles (Clean Energy Council) and Mary Hendricks (Australian Energy Storage Alliance).

Published by:

Office of Environment and Heritage
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: (02) 9995 5000 (switchboard)
Phone: 131 555 (environment information and publications requests)
Phone: 1300 361 967 (national parks, climate change and energy efficiency information, and publications requests)
Fax: (02) 9995 5999
TTY users: phone 133 677, then ask for 131 555
Speak and listen users: phone 1300 555 727, then ask for 131 555
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents

Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
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Contents

List of acronyms and abbreviations

AC	alternating current
DC	direct current
DoD	depth of discharge
kW	kilowatt
kWh	kilowatt hour
KWp	kilowatt-peak
OEH	Office of Environment and Heritage
PV	photovoltaic
SoC	state of charge
UPS	uninterruptible power supply

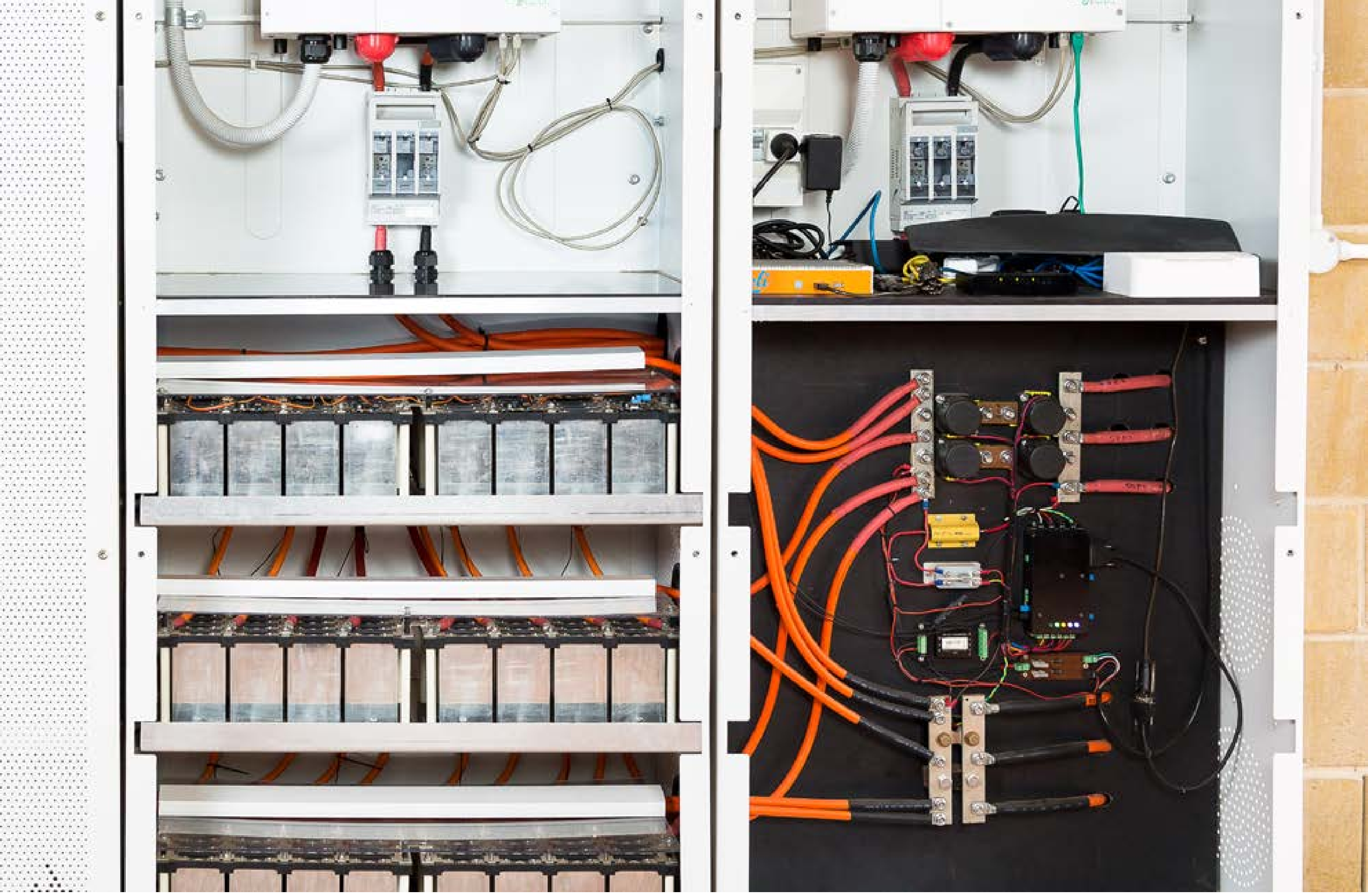


Photo: C. Harding/OEH

About this guide

Resources to help you investigate battery storage

This guide is part of a set of resources designed to help businesses determine whether to invest in battery storage:

- *Battery storage for business: the essentials* – a quick overview
- *i am your battery storage guide* – greater detail about the technology and how it might apply to your business, and a buyer's toolkit
- *Battery storage for business: investment decision tool*
- *Battery storage for business: price estimate template*.

How this guide will help you

i am your battery storage guide will help you decide whether battery storage is right for your business.

It sets out:

- the basics of battery storage systems
- the potential business applications and benefits of battery storage
- a simple framework for making decisions about whether to invest in battery storage at your site.

This guide alone can't identify the best solution for your specific needs. Finding an appropriate solution for your site or project can only be achieved through an individualised and engineered design.

Photo: Shutterstock/OEH

How to use this guide

There are two parts to this guide:

Part 1: About battery storage

This section explains:

- key considerations for businesses
- technical terms used
- basic types of battery technologies available
- applications and configurations, and;
- how businesses can use battery storage to save on running costs or to obtain other benefits.

Part 2: Buyer's toolkit

The buyer's toolkit (Figure 1) contains:

- **information gathering tools** to help you evaluate your needs and identify the possible benefits, savings and payback of battery storage at your site
- **feasibility assessment tools** to help you consider whether battery storage is right for your business
- **buyer's checklists** to help you define the scope of your project and collate the data you will need to obtain a design and quote from potential suppliers/installers.

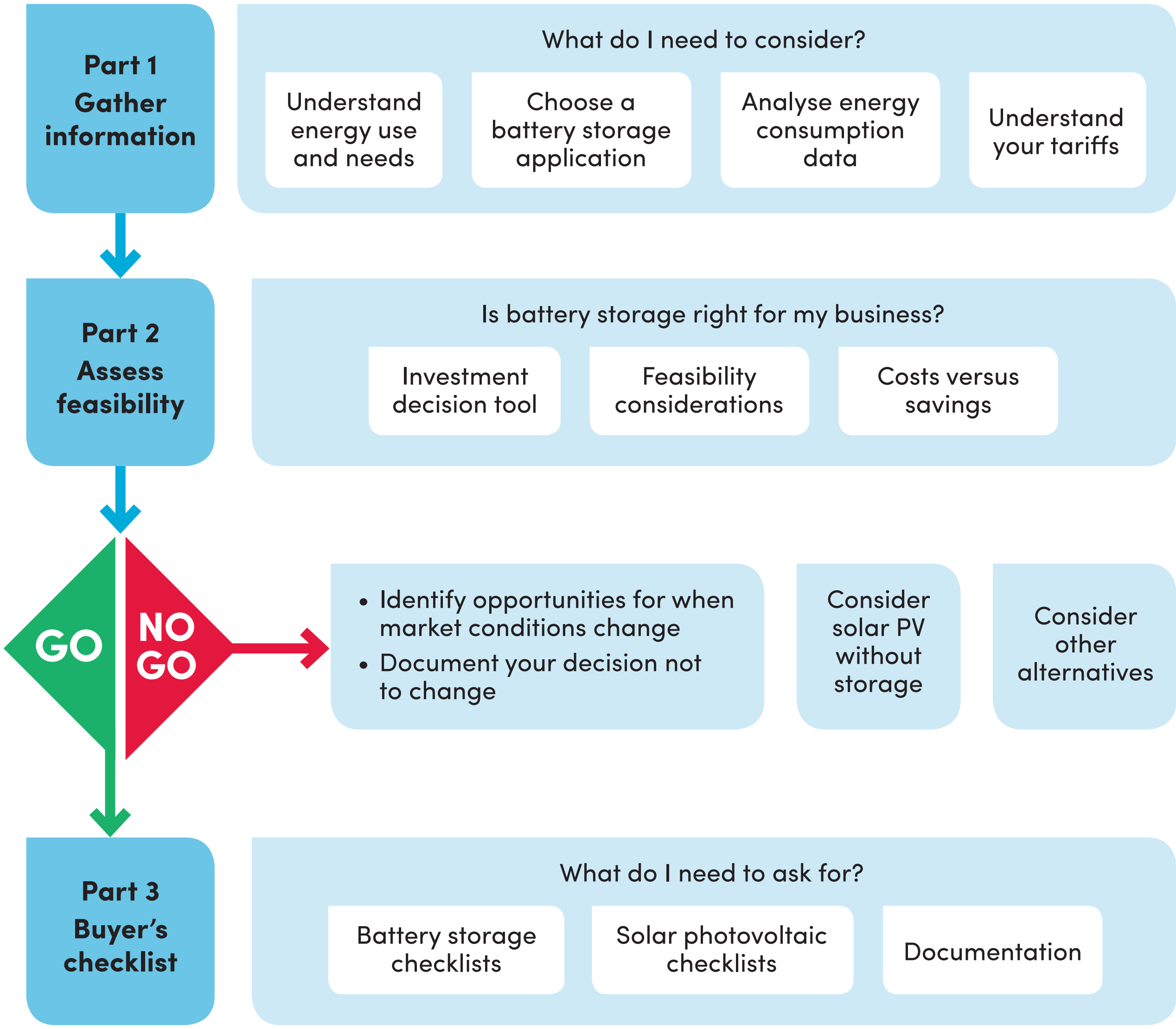


Figure 1: Buyer's toolkit

Further advice

These resources are intended for business people who are interested in understanding the technology and evaluating its applicability to their site. They do not seek to provide any detailed engineering, nor financial analysis of the needs of a particular site.

Every battery installation is unique, and the templates and tools provided in this guide do not substitute for the advice of a qualified engineer or legal counsel. Advice should be sought from suitably qualified professionals to ensure the solution is robust and compliant with all standards and requirements.

We recommend that businesses interested in further investigating this technology attend the NSW Office of Environment and Heritage (OEH) battery storage training course. This training course is designed to help businesses understand potential project feasibility and define the next steps for their organisation.

For more information visit the OEH webpage:
www.environment.nsw.gov.au/business/battery-storage-training.htm

Introduction – is battery storage right for your business?

Businesses in New South Wales can save money by being energy efficient and managing how and when they use energy. The use of batteries to store energy is an advanced stage of energy management that may allow a business to reduce electricity costs by shifting electricity consumption from the grid to time periods with lower associated costs.

Many businesses are also choosing to investigate battery storage and solar photovoltaics (PV) together as a way of significantly increasing the amount of renewable energy they consume. Depending on their consumption and the availability of suitable roof space for PV, businesses can reduce their consumption of grid-supplied energy by up to 80% and use renewable energy generated on site instead.

The feasibility of battery storage depends on how a business uses electricity and how it pays for electricity. A good understanding of both is essential for identifying if battery storage makes sense.

The payback depends on your energy use and energy costs

At the time of publication, a typical battery storage system could realise a payback in 10-15 years due to relatively high battery prices. However, battery prices are expected to decline significantly in the near future. Depending on your business goals and energy costs, batteries may already be feasible.

The challenge for decision-makers is that battery storage and solar PV has a long lifetime, sometimes in excess of 10 years. Businesses considering battery storage need to look at the return on investment over the longer term.

Photo: iStock/OEH

Part 1: About battery storage

What is battery storage?

Key points

- Battery storage is not about energy efficiency, it's about resource efficiency and energy management.
- Battery storage should be just one element of a comprehensive energy management program.

Battery storage involves the use of a battery to store energy for use when required. Technically, it is the conversion of electrical energy into chemical potential energy for storage followed by reconversion of chemical potential energy into electrical energy when desired.

A battery storage system allows a business to obtain electricity at a time when it is relatively inexpensive, store it chemically, and then consume the energy electrically at a time when electricity is relatively expensive or unavailable.

Other than a battery, there are multiple components in a battery storage system that enables the system to function. These include inverters, battery management systems and the installation of the batteries in a secure fire-rated battery room or enclosure.

Why invest in battery storage?

Financial benefits

The primary reason businesses are considering implementing battery storage is to reduce costs through energy management.

Energy management begins by identifying how a business uses and pays for energy (Figure 2). The next stage of energy management involves becoming more energy efficient, optimising the patterns of energy use and considering alternative sources of energy. In the case of battery storage systems the specific component of energy use is electricity.

Understanding how your site uses and pays for energy is critical to making an informed and confident decision about the suitability of battery storage.

The advantage of battery energy storage is that it enables a business to source energy at a lower cost from the grid, from renewable sources, or both. This may achieve cost savings by reducing the amount of electricity purchased when it is expensive, such as in peak tariff periods.

Businesses that face difficulties in the reliability or capacity of their electricity supply can also reap benefits from battery storage. Costly upgrades to power infrastructure can potentially be deferred by using battery storage in addition to the main supply from the grid.

Businesses that require on-site generation of energy using diesel or gas can also benefit from battery storage by optimising fuel consumption and reducing maintenance costs.

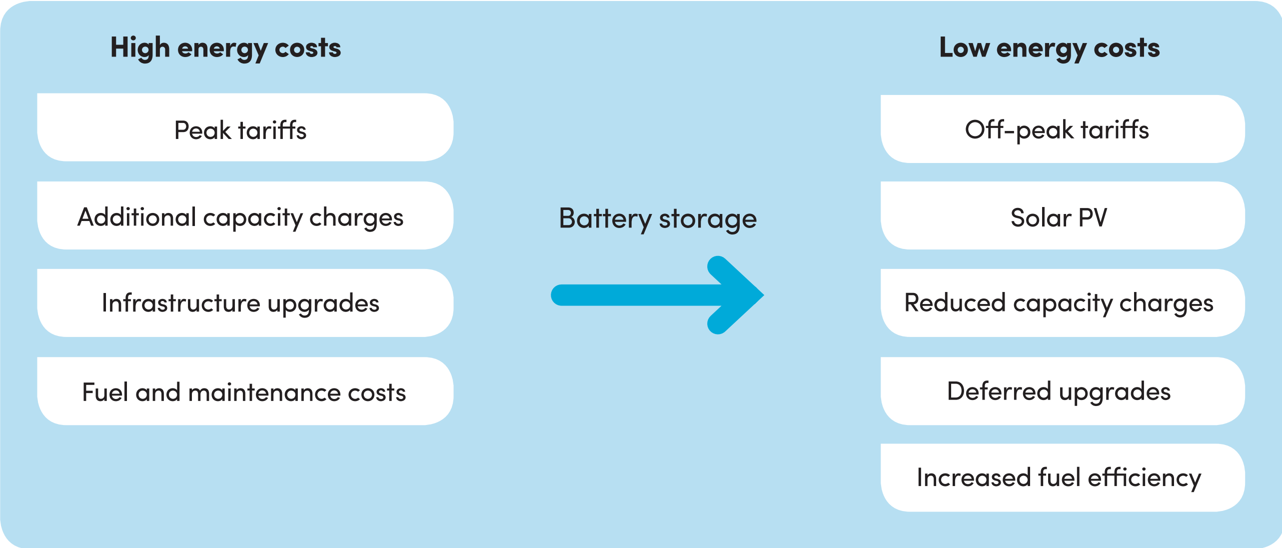


Figure 2: Battery storage can help you take advantage of lower energy costs

Environmental benefits

Solar power in Australia makes sense – Australia has plenty of sunshine. Electricity generated by solar photovoltaics (PV) can directly offset electricity purchased from the grid, which means it can be a good way to reduce energy costs.

The downward trend in the cost of solar panels and the increased cost of electricity means that solar PV systems are now more economical than ever. However, the benefits of solar PV are limited by the simple fact that the sun is only available during daytime and is most effective around midday.

The electrical demand profile of a business will not exactly match the production profile of solar power throughout a day. For example, in the middle of the day (particularly in summer) solar production may exceed electrical consumption and excess solar power is supplied to the grid. On the other hand, early and late in the day (particularly in winter), or in periods of cloud cover, solar production may be less than consumption and electricity must be sourced from the grid. Batteries can get around this problem by enabling excess energy from solar power to be stored for later use.

Battery storage, in combination with solar PV, enables a business to increase self-sufficiency by enabling solar PV systems with excess energy to meet energy needs outside solar PV generation periods. This also increases the overall amount of energy that is consumed from renewable sources.

Larger solar PV systems that produce surplus energy during the day are able to offset a greater component of total daily usage instead of feeding excess power into the grid for a relatively low return. Battery storage makes it possible for businesses to deploy larger PV systems to maximise the environmental benefits of renewable energy and also realise a better financial return by self-consuming more solar power.

Is battery storage a new concept?

The use of batteries for energy storage is actually not new at all. Storage systems featuring lead-acid batteries have been implemented for over a century in applications that include submarines, telephone exchanges, uninterruptible power supply (UPS) systems and off-grid solar power systems.

In recent years consumer interest in battery storage has significantly increased.

Large-scale investment in the development of this technology by several well-known international manufacturers improved the technical performance of batteries, and through extensive marketing transformed a relatively small industry into a highly competitive multi-billion dollar international market.

What has changed lately is the rapid improvement of lithium-ion based battery technology for mass consumption in personal devices like smartphones and tablets. This has led to investments in increased production of batteries for electric vehicles and stationary battery storage for homes and businesses.

Indirectly, the improvements and adoption of solar PV have increased consumer awareness of renewable energy and provided an incentive to store excess energy rather than feed it to the grid for relatively small return.

This widespread adoption creates economies of scale for a dramatic reduction in per-unit costs, not just in lithium-ion, but also for other battery technologies including incumbent (lead-acid) technologies and other options (flow, advanced lead-acid and others).

Battery storage is now more versatile

Technical enhancements and the reduction in cost have now made it possible for businesses to consider battery storage for a range of applications that had previously been unfeasible.

Photo: Shutterstock/OEH

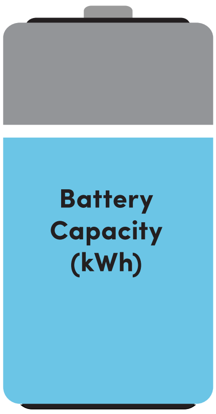
Battery storage terms and concepts

There are a number of concepts that are critical to understanding battery storage, for example the difference between energy (kilowatt hours) and power (kilowatts).

Battery terms

A battery is a device that stores and releases energy.

How much energy a battery can store is referred to as its energy capacity or battery capacity (Figure 3). The more battery capacity it has the longer it can supply a load.



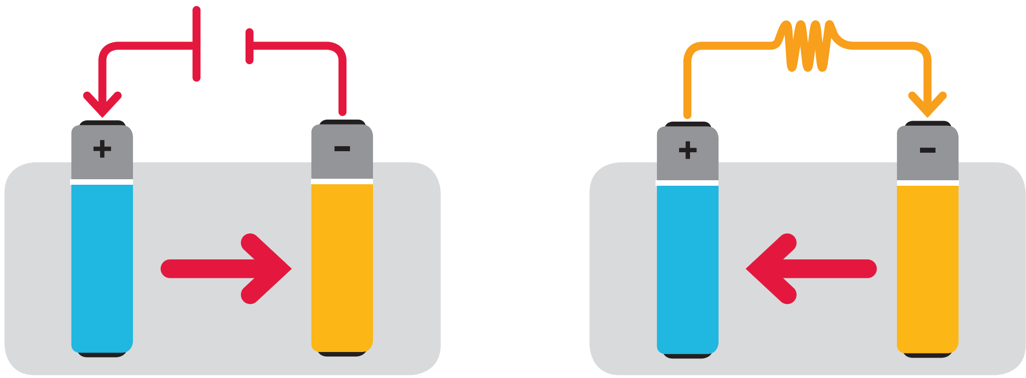
Battery
A device that stores and releases energy

Battery capacity
The total energy that can be stored in a battery

Unit: kilowatt-hours (kWh)

Figure 3: Battery capacity

A battery is charged by applying an electrical current, and discharged by allowing electrical current to flow through a circuit (Figure 4).



Charge
The process of storing electrical energy in the form of chemical energy.

Discharge
The process of converting chemical potential energy by allowing the flow of electrical energy.

Figure 4: Battery charge and discharge

Power and energy terms

To compare different battery storage solutions you need to be familiar with the key battery concepts of power (kilowatts) and energy (kilowatt hours).

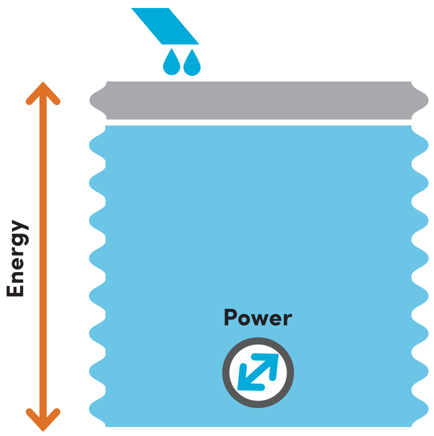
The power output and power consumption of electrical equipment is usually expressed in kilowatts (kW). For example, an electrical kettle draws about 1.2kW when boiling water. The power output of a battery is also expressed in kilowatts. Power is the amount of flow of energy the battery can support at any one time. The maximum amount of power that can be delivered at any one time is expressed as the kilowatt-peak (kWp).

Energy capacity is measured in kilowatt hours (kWh) and this is the unit in which energy is purchased from the electricity network. The energy capacity of a battery is how long it can supply energy to a certain load before running flat and depends on both power and time.

These two concepts can be compared to a simple water tank.

The nominal energy capacity of a battery (kWh) is similar to the amount of water that a water tank can hold.

The peak power that a battery can deliver (kWp) is similar to the size of the outlet on the side of a water tank (Figure 5). The larger the size of the outlet, the greater the flow and the more power it has.



Energy
The ability to do work. A battery stores and releases an amount of energy.

Unit: kilowatt hours (kWh)

Power
The rate of doing work. Power is also the rate at which a battery releases (or stores) energy.

Unit: kilowatts (kW)

Rated power
The maximum allowable power that can be continually supplied by a system.

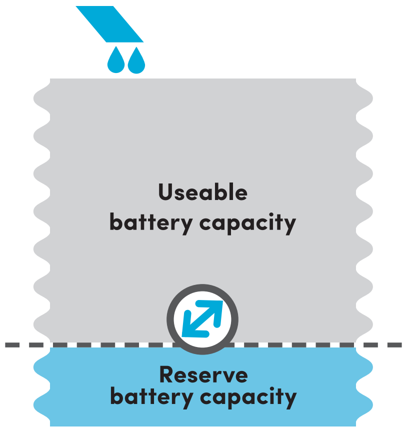
Ampere hour (Ah)
Just like the kWh, the Ah is another common way to express battery capacity. It is a unit of energy equal to one amp continuously supplied for one hour at the battery's nominal voltage.

Figure 5: Battery energy and power

However, it is important to understand that most batteries are not normally discharged (emptied) completely, in order to improve their lifetime performance.

Extending the analogy above, the outlet of the battery is not located at the bottom of the water tank, but part way up the side.

The ‘usable’ capacity of a battery is the volume of the water in the tank above the outlet, where the height of the outlet represents the minimum recommended state of charge of the battery (Figure 6).



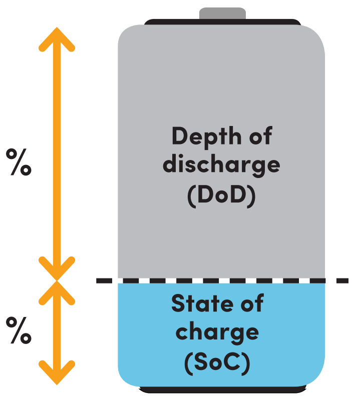
Usable battery capacity
The recommended amount of energy that can be discharged without adversely affecting the battery.

Unit: kilowatt hours (kWh)

Figure 6: Usable battery capacity

State of charge (SoC) and depth of discharge (DoD) are terms for referring to how much usable battery capacity remains in a battery when it has been partially discharged (Figure 7).

These terms are complementary. The SoC and DoD percentages add together to equal 100%.



Depth of discharge (DoD)
The proportion of the battery that has been discharged.

Unit: % of total capacity

State of charge (SoC)
The proportion of the battery charge remaining.

Unit: % of total capacity

Figure 7: State of charge and depth of discharge

Cycles and cycle life

A battery cycle refers to the alternation between charging and discharging of energy from the battery (Figure 8).

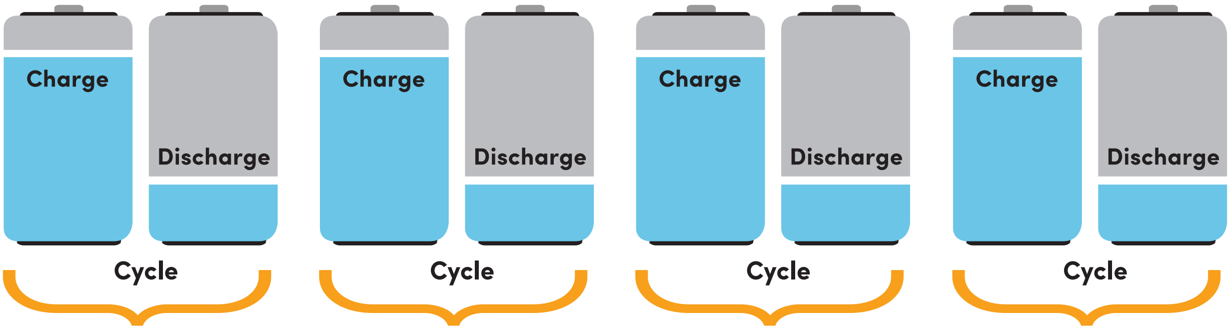


Figure 8: Battery cycles

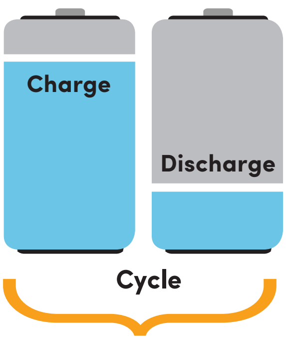
Modern batteries that have been designed for daily cycling applications typically have a usable lifetime of 10 years or more (i.e. 3650 cycles).

The degradation in performance over that lifetime is affected by five elements:

1. how many charge and discharge cycles are completed
2. to what depth of discharge the cycle is occurring
3. the temperature of the battery in its operation
4. the rate the battery is charged and discharged at
5. activities to maintain the chemistry in the battery, if required.

The greater the number of cycles and the more energy that is cycled into and out of the battery the more quickly a battery deteriorates (Figure 9). Deeply discharging some types of batteries can be very damaging to their lifetime performance and can diminish available capacity over time (see Types of batteries).

The operating parameters of different batteries over their lifetime and the associated degradation should be considered when comparing batteries, as different battery types and manufacturers will achieve different levels of performance depending on how they are used.



Cycle
The process of completely charging and discharging a battery in its usable range.

Battery life (cycles)
The number of cycles that can be expected before the battery can no longer effectively store energy.

Unit: number of cycles

Battery warranted life
The number of cycles or fixed number of years a manufacturer guarantees.

Unit: number of cycles or years, whichever comes first

Battery warranted capacity
The remaining usable capacity a manufacturer guarantees after a certain number of cycles.

Unit: kilowatt hour (kWh)

Figure 9: Battery cycle terms

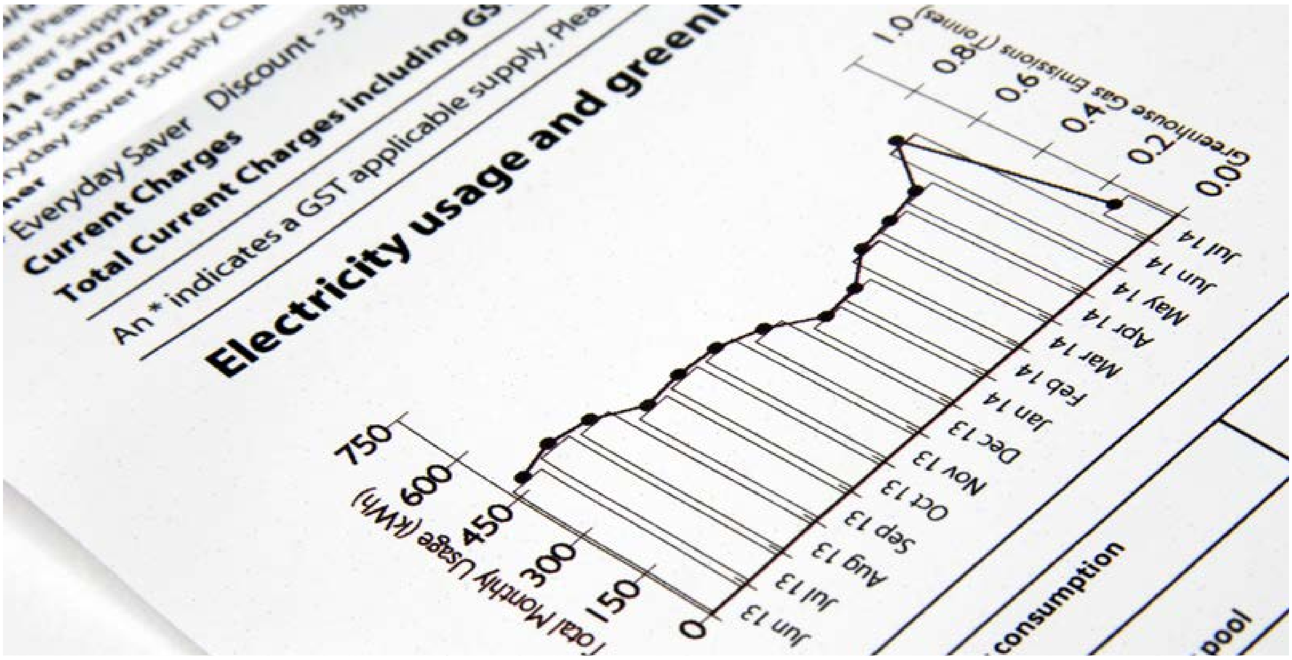


Photo: Shutterstock/OEH

How businesses pay for electricity

Key point

Businesses must understand how they are charged for electricity before they can properly evaluate the value of battery storage.

Time-of-use tariffs

A business pays for electricity per kilowatt hour consumed. However, the rate paid per kilowatt hour usually depends on the time the kilowatt hour was purchased and this arrangement is referred to as a time-of-use tariff.

The times when these periods occur vary and depend on the arrangement between a business and its electricity retailer.

The periods are generally referred to as:

- peak period
- off-peak period
- shoulder period.

Electricity rates can vary significantly between these periods. All electricity supplied by the electricity network is paid per kilowatt hour.

$/kilowatt hour
Rate paid for electricity.

Peak tariff
The rate paid for electricity usage in peak time periods.
Unit: $/kWh

Off-peak tariff
The rate paid for electricity usage in off-peak time periods.
Unit: $/kWh

Not all businesses are on time-of-use tariff structures, however, and it's important to know which tariff you're on so that you can make decisions about how a battery system can benefit you.

Another common example of a tariff structure is known as a 'block' tariff. This is where electricity is charged at a tiered rate, and the rate you pay changes as your business hits certain usage thresholds. Businesses on this structure cannot use a battery for tariff optimisation.

Capacity charges

Capacity charges (also known as peak demand charges), on the other hand, are fees calculated based on maximum power usage in a given period, usually for the previous month or previous 12 months.

Capacity charge
Rate paid for the maximum power provided to a business in a period regardless of other usage.
Unit: $/kilo volt-amp (kVA)

Depending on the tariff, once a peak capacity is recorded, the amount that a business needs to pay for capacity charges each month may not reduce for up to 12 months.

For example, a business may reach an isolated peak of energy use, and the capacity charge will remain at that peak level for 12 months, irrespective of how much energy is used during the rest of the billing period.

A business pays capacity charges based on the cost of providing the availability of their peak usage requirements regardless of when they occur. This means that a business pays the grid operator to have the capacity to meet their peak demand, even if it is rarely reached. It is not uncommon for capacity charges to be the largest component of a business's monthly electricity bill.

Photo: iStock/OEH

Businesses applications for battery storage

Key point

Before investing in a battery storage system a business needs to identify the battery storage application that best applies to their specific situation.

Businesses can reduce their running costs by using battery storage:

- to get maximum benefit from a solar photovoltaic (PV) system
- to optimise usage in relation to time-of-use tariffs
- to reduce capacity charges.

Businesses can also use battery storage to provide back-up power, to avoid paying for an expensive upgrade to grid infrastructure, to trade energy on the wholesale market or as part of an off-grid power supply system.

The Buyer's toolkit in Part 2 of this guide explains how to work out which application will best suit your situation.

Batteries have a long lifetime and the cost savings over the life of the system make sense for some businesses. The increased ability to use renewable solar energy is an attractive bonus.

Multiple applications?

It may be possible that you can use the same battery storage system for different specific applications. However, caution should be applied as the different applications often require different performance characteristics. The chosen battery may compromise one or more of the selected applications.

Time-of-use tariff optimisation

Tip

This is applicable only for businesses that source energy at different prices at different times of the day.

Batteries can be used to exploit the different cost of energy at different time periods. Energy can be sourced from solar PV or from the grid during off-peak tariff periods and consumed during peak tariff periods.

Figures 10 and 11 show how one business (a registered club in this example) avoids using grid energy in peak periods by using a battery.

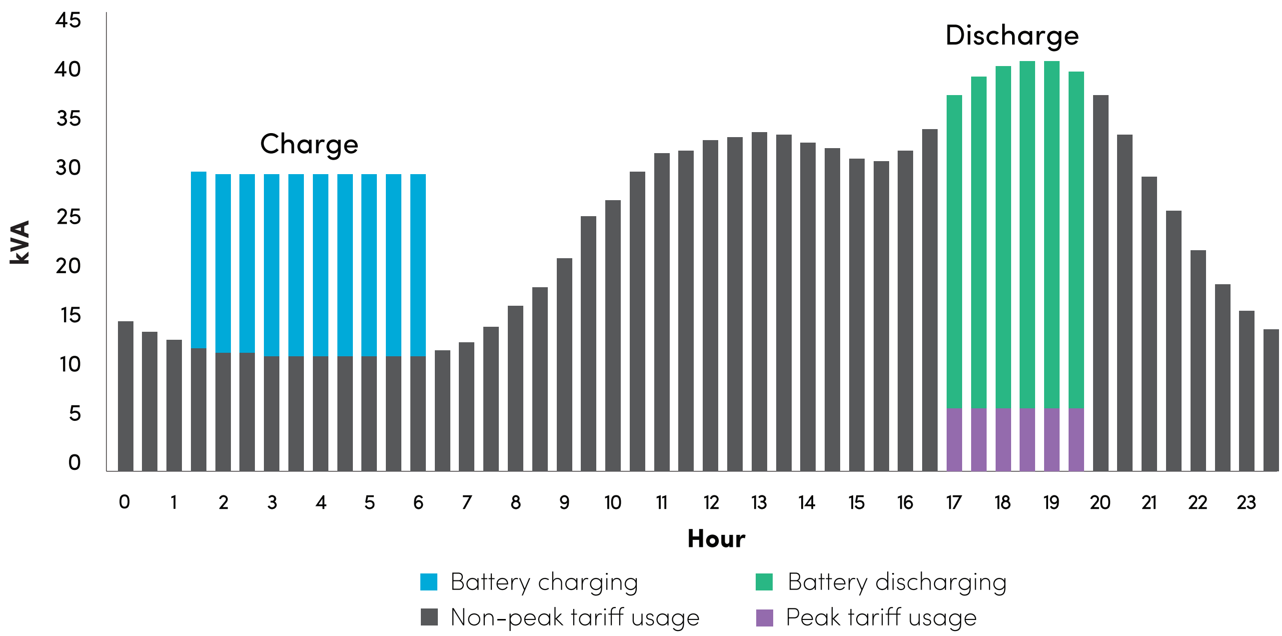


Figure 10: Charging from the grid off-peak/discharging in peak

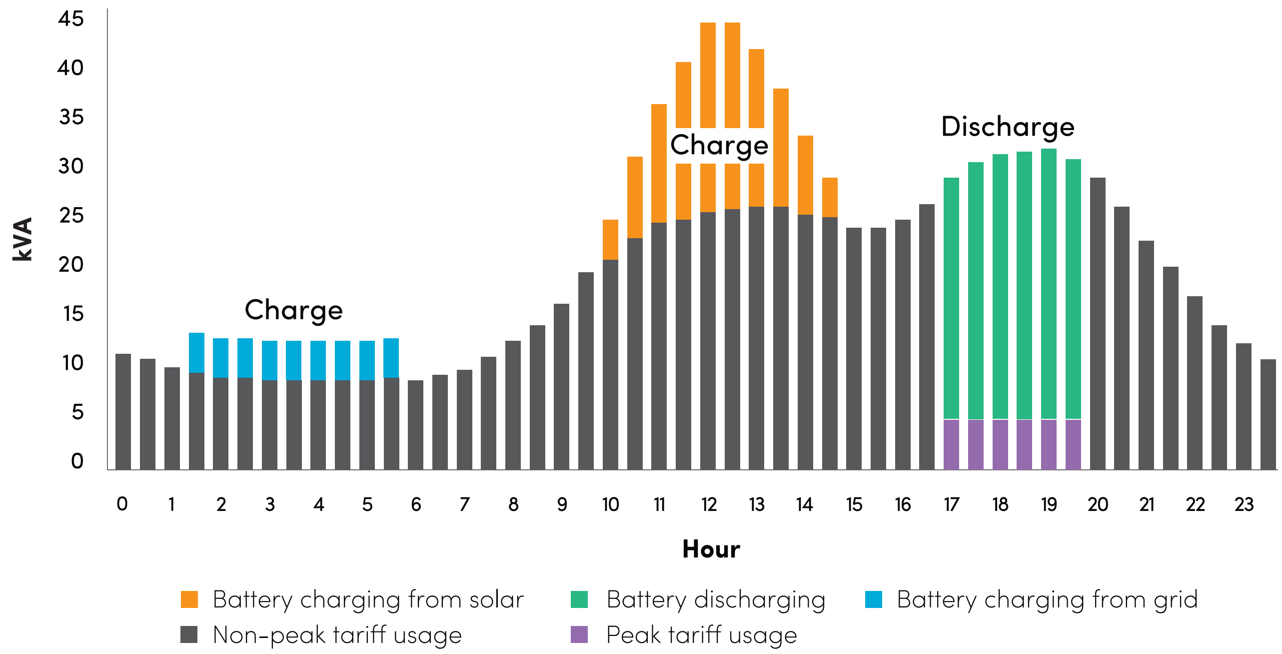


Figure 11: Charging from both solar PV and from the grid off-peak/discharging in peak tariff period

Application notes

- Power for battery charging can be sourced from any source, solar or otherwise.
- This approach is most effective when the peak tariff rate is high and the alternative source of energy is inexpensive.
- Larger energy users may find tariff optimisation is ineffective because they are charged much less for energy than smaller energy users.

Reducing capacity charges

Tip

This is applicable only for businesses that pay capacity charges.

Batteries can be used to avoid excess electricity being sourced from the grid when total usage approaches a maximum threshold. This is sometimes called ‘peak lopping’ or ‘peak shaving’.

Figure 12 shows a business avoiding a higher capacity charge by using a battery and grid energy together to supply maximum power usage. The battery system needs to be sized to discharge and reliably ‘shave’ the peak to a certain chosen level at all times, not just on one day.

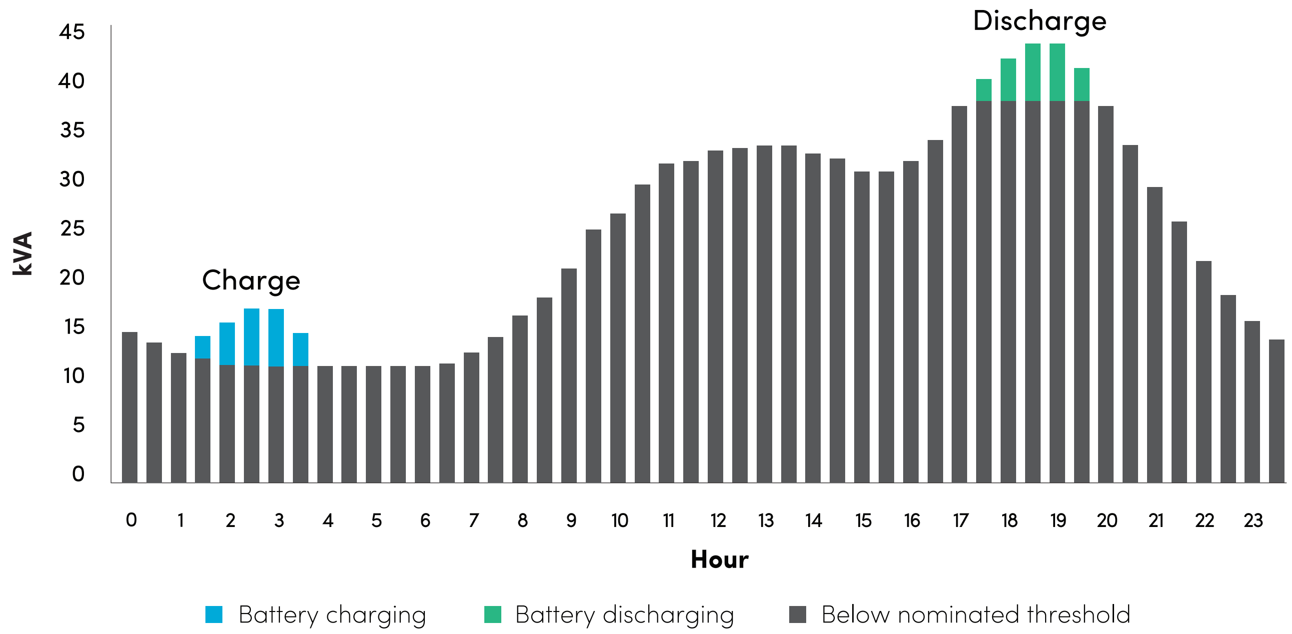


Figure 12: Peak shaving to reduce capacity charges

Application notes

- This is suitable for larger energy users on applicable tariffs.
- Good knowledge of historical power usage is required for the system to be effective. The battery system needs to be specified to provide enough power to 'lop the peak' at all times of the year.
- Power for battery charging can be sourced from any source, solar or otherwise.
- This is most economical when high power usage occurs for short durations.

Maximising solar photovoltaic system

Tip

This requires detailed load analysis and system sizing.

Batteries can be used to enable businesses to self-consume more solar power by storing energy for when solar power is not available.

This approach is used because solar energy is typically inexpensive compared to purchasing energy from the grid but energy usage can occur in times when solar is not available.

Figure 13 shows a business with enough solar power to supply its daytime loads and charge a battery. In the evening, the business discharges the battery, thereby using the excess solar power.

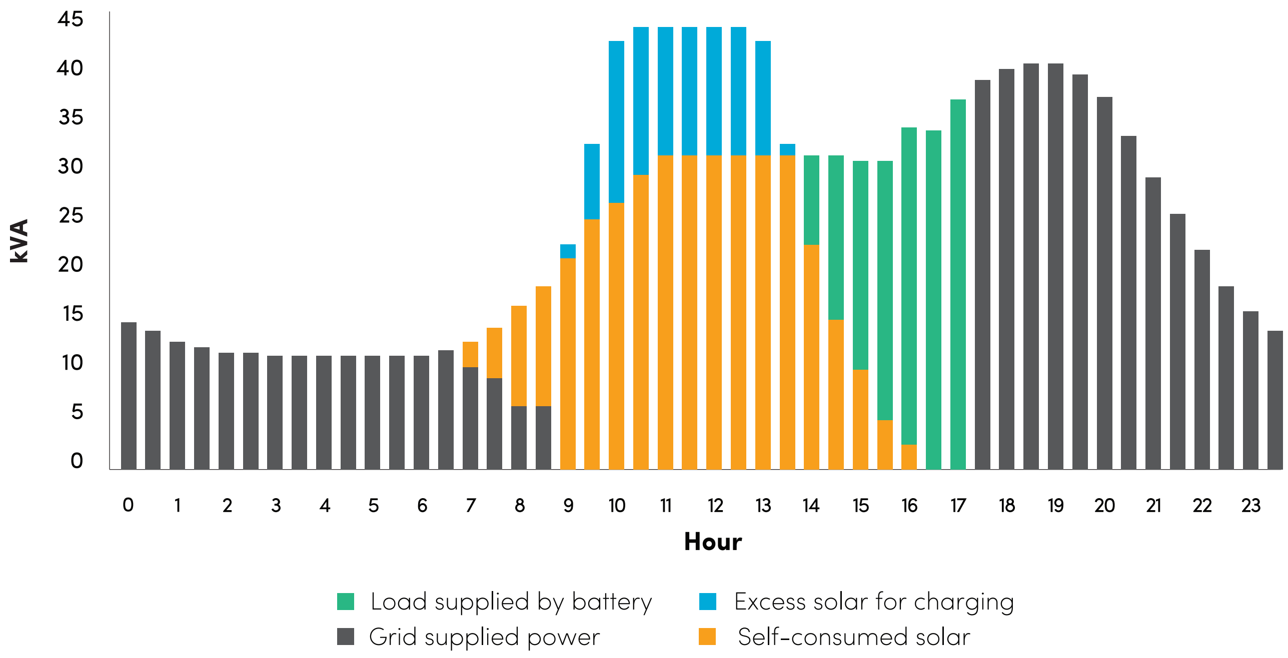


Figure 13: Increased self-consumption through battery charging

Aside from the cost advantages of using more solar power, coupling solar PV generation and battery storage technology also provides businesses with the less-tangible benefits of consuming clean energy and improving self-sufficiency.

The trade-off to consider when seeking to increase self-sufficiency is that larger systems for year-round performance will result in time periods when the capacity of solar PV and batteries is not fully used. Small increases in battery size (and associated costs) enable a relatively large increase in the self-consumption of solar PV, particularly in the summer months.

The downside is that the return on investment is not as effective in winter because the reduced availability of solar energy means that a battery system may not be able to be fully charged and will be under-used.

On the other hand, during summer if a battery is too small it will not be able to capture all of the surplus solar PV generation. System components and capacities are highly dependent on what the owner wants to achieve; professional guidance is recommended.

Application notes

- This application is most economical for small to medium energy users.
- This is suitable for businesses interested in increasing the proportion of energy they consume from renewable sources, and for businesses interested in increasing their self-sufficiency.
- The system requires surplus solar PV generating capacity.

Basic back-up

Tip

This requires additional switching controls and equipment.

A business whose operational continuity is important during a blackout or power failure may choose battery storage to help avert significant losses or opportunity costs.

In this scenario a business may need to continue production when power is unavailable from the grid. There are specific requirements for the connection of batteries in this manner, primarily to ensure the battery does not back-feed onto the network.

Any system that uses this type of back-up will need to be properly designed as such. There is a long-standing precedent for this kind of application where back-up generators or uninterruptable power supply (UPS) are used.

Application notes

- This applies to businesses who obtain value from being able to switch to a temporary alternative energy supply if the grid is not sufficient.
- There will be a delay while cutting over from one power system to another.
- The requirements of this system are specific to the nature of the business.

Uninterruptable power supply (UPS)

Tip

This is a highly specific application requiring additional switching controls.

Distinctly different from basic back-up, a business whose operational continuity must not be interrupted at all can consider a specifically designed uninterruptable power supply.

This is not typically a feature of the battery storage scenarios covered in this guide. The emerging technologies covered in this guide have largely not yet emerged within the UPS market.

Application notes

- UPS is not a feature of most battery storage systems.
- UPS requires electrical energy to be continuously converted between alternating current (AC) and direct current (DC) and back to AC at all times, which has negative implications for energy efficiency.

Network constrained businesses

Tip

This is useful for businesses faced with electrical upgrade costs to improve energy supply.

Businesses that cannot service all of their power needs from the grid (e.g. due to premises expansion) may be faced with infrastructure upgrade costs. Battery storage may be a more economical alternative.

Battery storage potentially provides an alternative option of charging batteries with power from the grid in periods of low usage and drawing on both grid and batteries in periods of high usage.

Application notes

- Appropriately sized battery solutions may be a cost-effective alternative to infrastructure upgrades and allow a business to save money in this way.
- Professional advice for designing this system is essential.

Off-grid systems

Businesses that source part or all of their power needs off-grid, whether normally provided by wind, solar or fossil fuel-based generation such as diesel, can benefit from introducing an optimised battery storage system.

Power generation from wind and solar sources is by nature variable. Periods of darkness or low wind speed mean that power must be provided by alternative generation or battery storage, or both, for reliable power to be provided.

The business case for introducing new or additional battery storage will depend on existing power generation and battery storage infrastructure and measures for controlling consumption loads.

There may be a viable business case for some off-grid systems if battery storage can be shown to be more economical than installing additional generation capacity.

Configurations of off-grid systems vary based on whether the solar PV and battery system is the primary power source or complementary to a fossil fuel generator (table 1). Each has different design parameters that need to be considered.

Table 1: Off-grid power configurations

	Configuration	Advantage	Disadvantage
1	Solar photovoltaic (PV) and battery storage used as the primary power source with generator back-up	Very high renewable energy self-consumption	A generator might be required in the event of extended bad weather
2	Solar PV and battery storage in parallel with generators which are the primary power source	Reduced fuel usage and maintenance	Requires generators at all times
3	Battery storage to facilitate the purchase of a smaller generator. The two power sources work together to service peak loads and the generator recharges the battery during periods of low usage	Reduces capital cost for generators Improves fuel efficiency of the generator	Requires good load management to ensure the battery can supply power when required

Sell power and ancillary services back to the grid

A business may make arrangements to sell services from the battery back to the electricity grid. These services might include exporting power during high price periods or providing 'ancillary services' such as frequency support and reactive power support.

Tip

Requires appropriate electricity network connection arrangements.

Application notes

- Businesses will need to make agreements or contracts with outside organisations such as electricity retailers, electricity network businesses or other third party service providers in order to access this use of a battery system. A business may agree to let the outside organisation control their battery during specified situations and receive payment for this service.
- Ancillary service applications are not yet widespread but may become more common in the future.
- These applications will require particular design characteristics for the battery management system and inverter, and will require an appropriate connection to the electricity network.

Photo: C. Harding/OEH

Solar photovoltaics and battery storage

Solar photovoltaics (PV) and battery storage are often considered complementary technologies. This makes sense because one produces electricity from a variable source and the other stores it for use when most beneficial.

The daily and seasonal variability of solar production is an important element of the design and implementation of battery storage systems that use solar PV as an energy source.

Financial considerations of solar photovoltaics with battery storage

The financial benefit of solar PV depends on the cost of purchasing electricity from the network. Solar PV by itself is most cost effective if the price of electricity during the middle of the day is relatively high compared to the levelised cost of the solar panels.

Excess energy generated by solar PV can be fed back into the grid for a small credit, however, this is often less financially effective than self-consumption. For example, a credit of 6c / kWh exported is not as valuable as avoiding paying 24c / kWh during a peak tariff time when the sun is not shining.

A correctly designed and specified battery storage system means that a business can increase the size of solar PV and self-consume through storage. In this way, the overall proportion of total energy consumed on site from renewable sources can be significantly increased.

Levelised cost of energy

Levelised cost of energy (LCOE) is a way to express the average cost of an energy source, taking into account lifetime costs, economic factors, and the lifetime energy output of the system. It is expressed in $/kWh.

Performance considerations of solar photovoltaics with battery storage

The amount of available energy produced by a stationary solar panel varies considerably depending on the time of day and the month of the year.

The graph below shows the comparison of solar energy on a flat surface in Sydney between summer and winter.

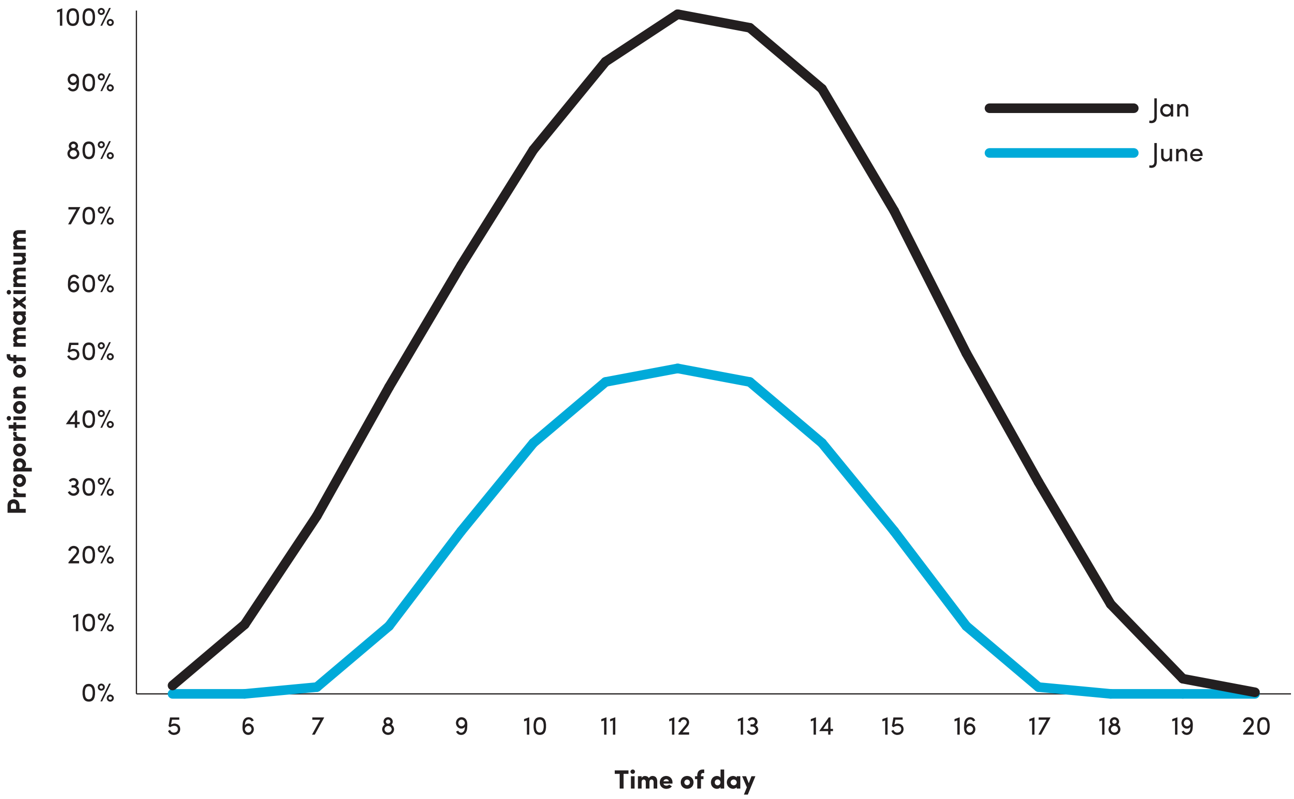


Figure 14: Typical solar energy on a horizontal surface (Sydney)

Midday solar energy per square metre on a horizontal surface is much greater than at other times.

The energy available for a horizontal surface is approximately double in summer compared to winter (Figure 14). This can be improved by tilting panels to optimise how much they face the sun throughout the year.

The best year-round tilted angle is equal to the latitude of the site's location (in Sydney this is 34 degrees) facing due north. Figure 15 shows that the solar energy on a surface can be improved significantly in winter for a small reduction in summer.

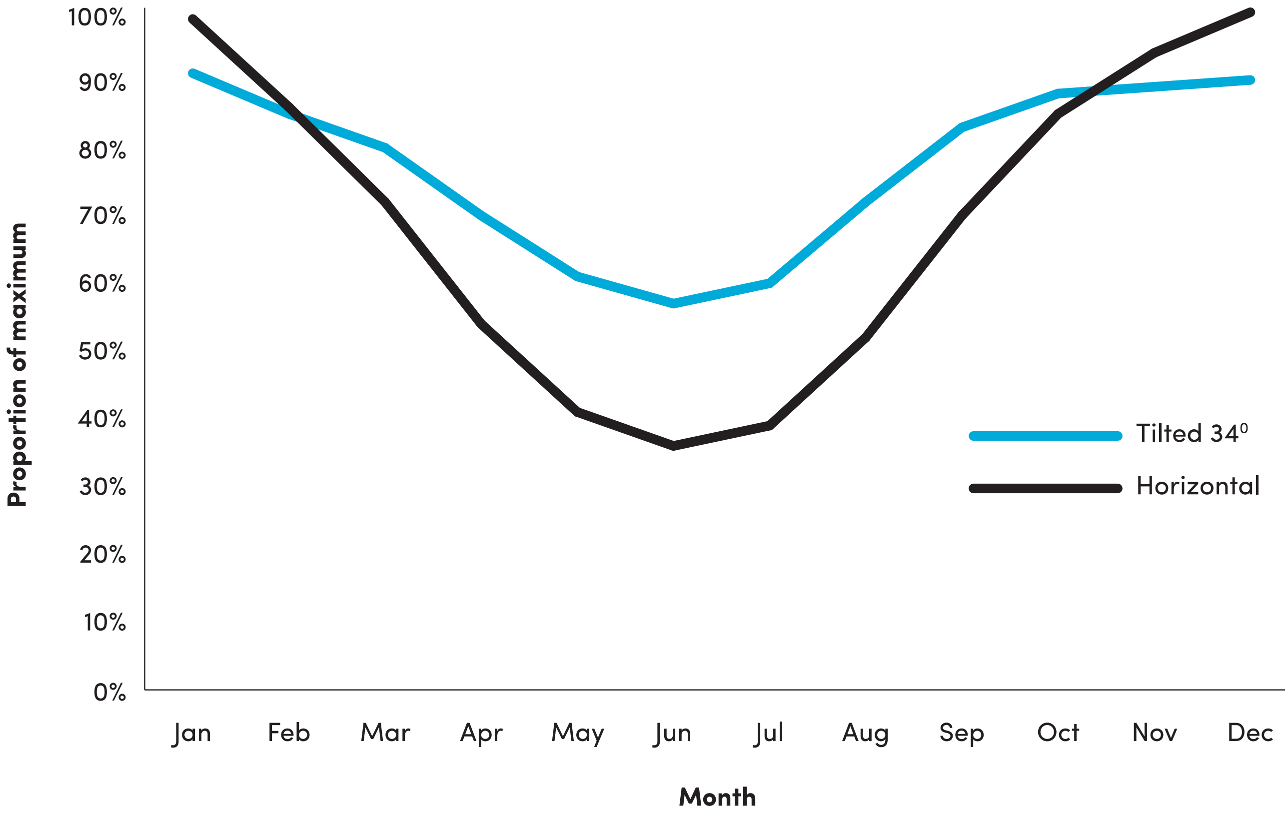


Figure 15: Typical solar energy on a tilted vs horizontal panel (Sydney)

The overall yearly generation from a solar panel is improved by approximately 10% when tilted.

The winter production is improved most significantly, by 46% compared to a horizontal position.

The concepts of daily variation, seasonal variation and the impact of solar array tilt are important for a business to understand when considering solar PV and batteries because of the fluctuation in daily and monthly production.

It is important to include this seasonal variation information in the business's plans for solar self-consumption versus consumption from the grid and the associated tariffs to fully assess the financial benefits of solar PV and the incentive for using battery storage.

For example, a business that uses most electricity during hot summer days is a candidate for considering only solar PV (without batteries) because the load closely matches production. On the other hand, a business that has low daytime usage but high evening usage (such as a restaurant) may not realise much benefit from solar, but with the addition of a battery can realise these benefits.

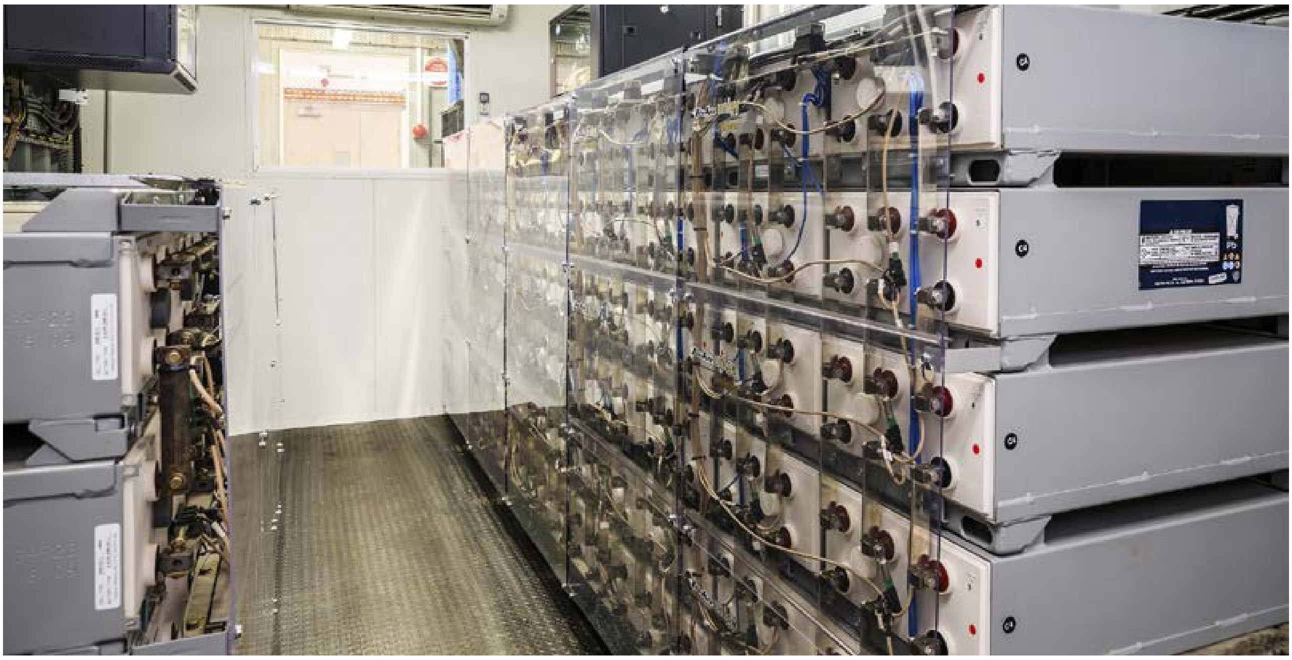


Photo: CSIRO/OEH

System configurations and components

Key point

There is no single answer on how to apply battery storage to your site. You need a holistic understanding of all of the interrelated components of a complete system.

A battery is one component of a storage system and can be arranged either with solar photovoltaics (PV) or separately.

Grid-connected business with battery storage

A battery storage system can be integrated into the electrical infrastructure of a typical grid-connected business in the following way.

Electricity is usually supplied to businesses in New South Wales at 230 volts AC single-phase or 400 volts three-phase.

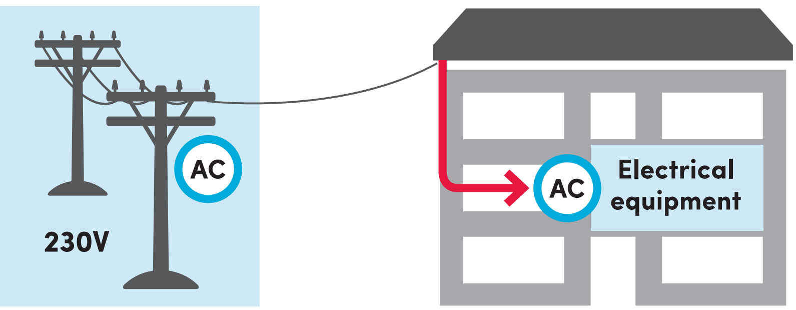


Figure 16: Typical grid connection

A battery system converts AC electricity, via an inverter, into DC electricity that charges a battery.

Inverter/rectifier/battery charger

The devices that operate a battery, including the conversion of AC to DC (rectification) and DC to AC (inversion), as well as the management of the battery to ensure its correct charging and discharging (battery charger), are typically integrated and referred to as 'inverters'.

When the industry refers to 'inverters', these may include any or all of the above componentry.

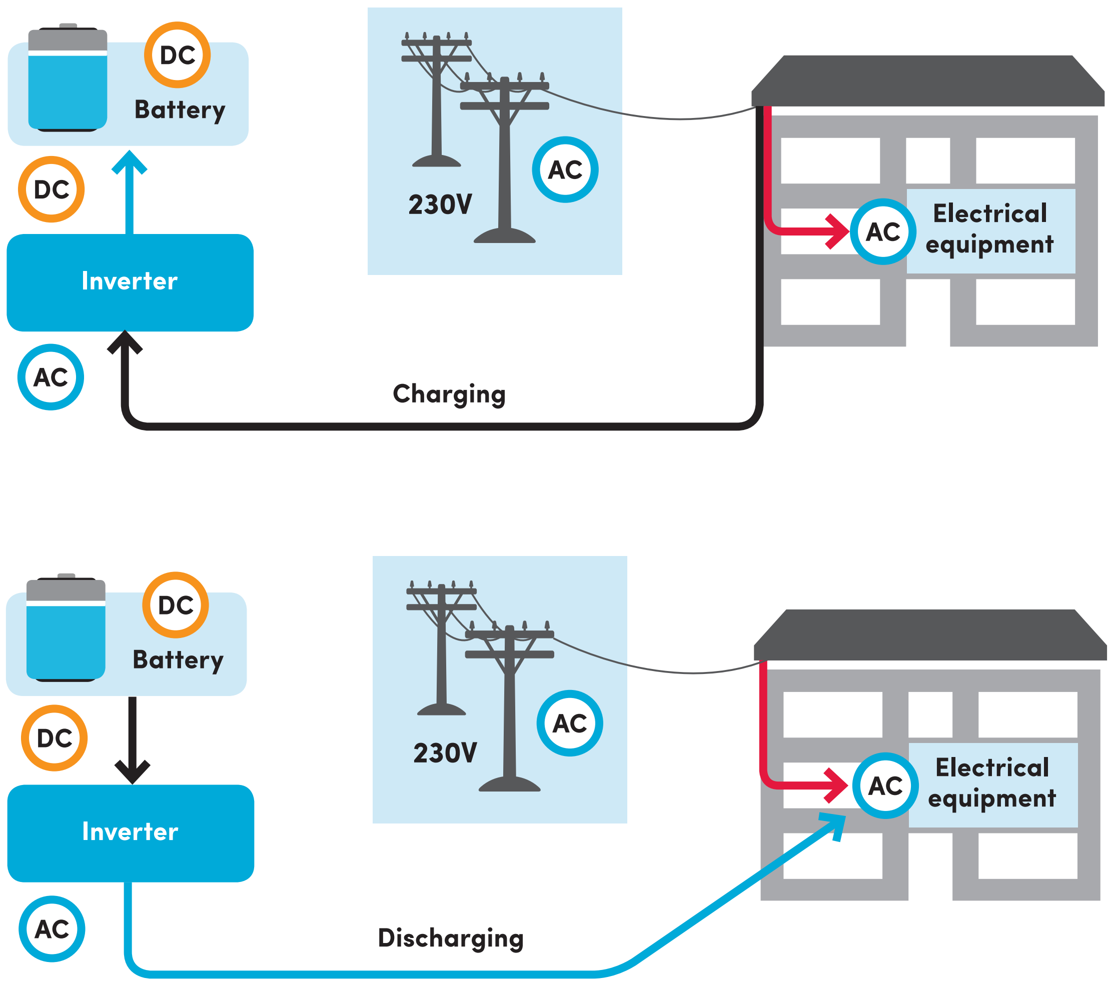


Figure 17: Grid connection with battery storage

A grid-connected battery storage system (Figure 17) is designed to cycle between storing energy (charging) when the cost to do so is low and using the energy (discharging) when the benefit is high, for example, when the price of electricity is relatively high.

Grid-connected business with battery storage and solar photovoltaics

A battery system can function with or without solar PV, but together, businesses can optimise the use of low cost renewable energy at times that produce the greatest financial benefit.

Solar PV converts sunlight directly into electricity. Solar power is instantaneous – it needs to be used at the moment it is generated, either by your business or by the grid. A battery allows excess solar power to be stored for consumption at a later time.

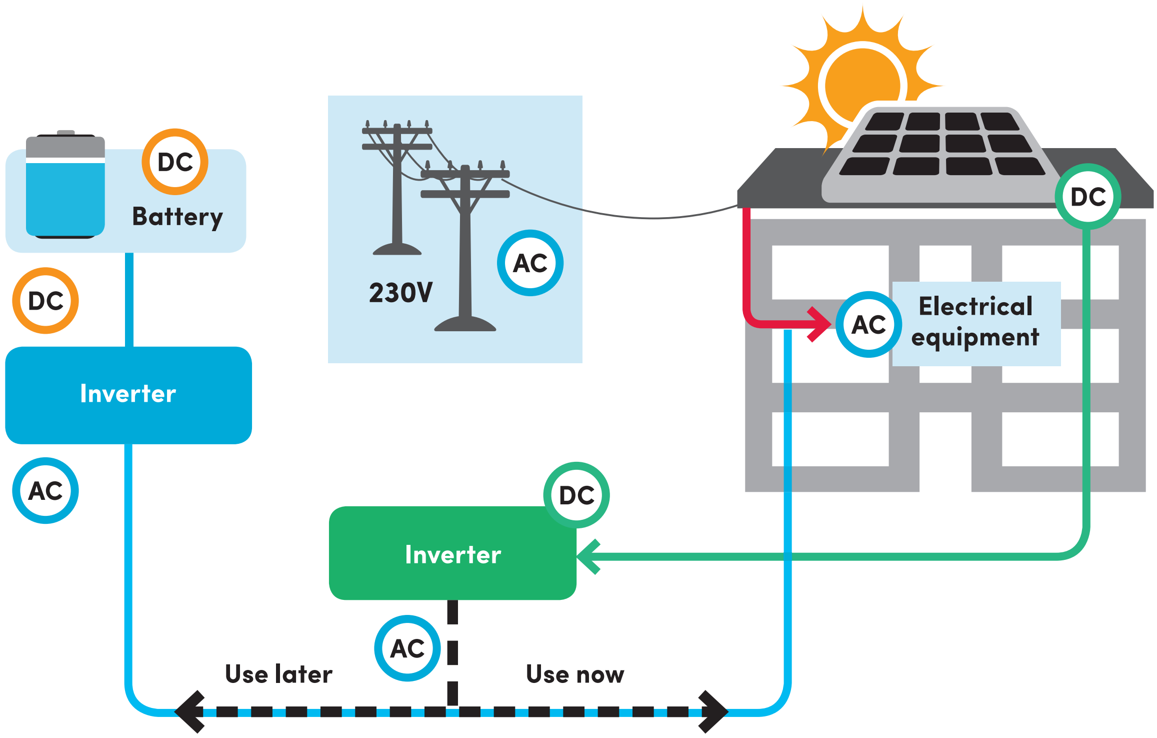


Figure 18: Grid connection with battery storage and solar PV

The configuration in Figure 18 shows an AC-coupled system with two separate inverters: one for the battery and one for the solar PV. Some inverters, known as hybrid inverters, can perform the function of both a solar inverter and a battery inverter. This employs a configuration which is known as DC-coupling.

Other components in battery storage systems

A battery storage system requires more than just the battery or batteries.

Inverters

An inverter converts direct current (DC) electricity into alternating current (AC) electricity. Some inverters, particularly those used in the battery storage industry, can also convert AC electricity into DC electricity. Inverters are designed either to supply single-phase loads or three-phase loads.

All batteries store energy as DC, and in order to power AC devices, it requires a battery inverter that manages the transformation and the output voltage. A battery inverter must be able to charge and discharge a battery according to the operating parameters of the battery and loads.

A solar inverter is similar in that it converts DC electricity into AC electricity; however, there are no circumstances where power is required to go the other way.

Most systems have separate solar inverters and battery inverters that are coupled on the AC side. Some inverters, known as hybrid inverters, are capable of managing both solar and battery electricity.

An inverter will have a rated peak power output which is the maximum power that it can deliver. When choosing a set of inverters you need to make sure it is capable of delivering the required amount of power to match both the business operational load and the battery charging load.

For systems operating from batteries only (no grid), the batteries and inverter must be capable of supplying both a maximum continuous power supply and also sufficient starting current for devices containing motors, to allow them to start.

Battery management system

A battery management system (BMS) is required to control how and when a battery is charged and discharged and needs to be set up to ensure the system targets the goals of the business. It also protects the batteries from overheating.

A battery management system will monitor the state of charge of the battery and ensure that it works within the operating parameters. More recently, some battery brands are being developed with in-built battery management systems and sometimes also include inverters as an all-in-one device. Some batteries require a maintenance cycle to prolong their usable life and this is implemented by the battery management system. A maintenance cycle means for a period of time – up to a day – the battery is unusable because it is performing self-management checks and won't allow discharge past a certain rate for a period. It is important that all components are approved for use with each other, preferably by direct communication to control charge and discharge. We recommend that responsibility for correct selection of components be placed on the suppliers/installers. We also suggest that the end user seeks the advice of a suitably qualified person to verify that all components are properly matched.

Monitoring

Monitoring devices are critical for managing the operation of a battery system, especially one coupled with solar PV. The use of monitoring, especially visualisation of daily production and consumption, is a very useful tool for energy management and helps decision-makers to better manage loads to improve the system's performance.

For example, a business may monitor the production of solar power to choose to run processes when there is abundant solar generation.

A business investing in this technology may use monitoring to ensure the system is functioning as intended. Furthermore, most billing information lacks the detail required to make informed energy management decisions that system monitoring can provide.

Battery storage with monitoring has the effect of increasing user awareness of energy consumption on their site. The benefits of the battery system is enhanced by other energy management strategies, such as load shifting and more energy efficient behaviours. Monitoring can provide users with feedback showing the impact of these activities.

Installation requirements, risks and safety

There are a number of potential hazards associated with battery storage, including electrical and fire hazards. Best practice calls for a dedicated, secure, fire-rated battery room or enclosure.

The Clean Energy Council and the Australian Energy Storage Council have issued installation guides and battery guides recommending methods of battery installation to minimise risks to businesses, ahead of Australian Standards being made available for all battery chemistries. (See Useful links)

The Clean Energy Council has identified the following hazards relating to battery storage:

- electric shock hazards
- energy hazards
- chemical hazards
- explosion and flammable emission hazards
- fire hazards
- gravitational hazards.

Other factors that should be considered in planning for battery storage include:

- theft
- heat, cold and humidity
- corrosion
- water ingress
- dust ingress
- physical impact
- vermin
- external fire.

The presence of these factors may increase the risk of the hazards.

Risk management

A business needs to manage risks presented by any technology, including battery storage.

A secure, fire-rated battery room or enclosure is one way that a business can manage a number of the risks identified above.

Life expectancy vs warranty

Currently we are not aware of a single testing methodology that is used by all battery manufacturers to establish the performance and lifecycles of their products. Predicting the life expectancy of a product is likely to be inaccurate and most likely inconsistent between different manufacturers.

Many organisations will refer to the manufacturer's warranty to establish the period that the manufacturers feel comfortable supporting their product. The drawback with this approach is that the manufacturers place many complicated caveats on the warranty and long term performance of their batteries, making comparison difficult.

It would be rational to establish some criteria that relate your site conditions to the advertised performance of a battery. For example, if your particular project requires a large number of cycles per year (say three cycles per day for the year), then you would require a battery that will deliver a large number of cycles over a long period of time. This battery may be more expensive than one advertised to operate for fewer cycles. However, the cheaper battery may represent a false economy as it might not last long enough to be viable for your project.

Conversely, where you have a project that requires a small number of cycles per year, a cheaper battery that is not required to deliver a high number of cycles may better suit your application.

The way in which you compare battery offers for a particular project can be developed once the particular characteristics of the site have been established. This will determine the most important criteria for battery performance and create a level playing field for comparing different products.

If we simply view the warranty information provided by manufacturers, the following becomes the only metric by which comparison can be carried out.

Most batteries in the market today offer a warranty of up to 10 years. Within this 10-year period, some batteries offer warranties with 3650 cycles (one cycle per day), while other batteries have warranties of 8000 cycles or more (if used more than one cycle per day).

It can be argued that batteries designed for high numbers of cycles could potentially last longer than the 10-year warranty period if cycled only once per day. In this case a battery warranted for 8000 cycles will not have reached even half the designed number of cycles (3650 out of 8000).

Battery degradation

Battery degradation defines the useful life of a battery. A manufacturer will specify the warranted battery performance over a number of years and will include the details of battery degradation. For example, a battery may only be warranted to provide 80% of its nominal kilowatt hour capacity after three years, and 50% of nominal kilowatt hour capacity after five years.

This degradation needs to be considered when evaluating performance and benefit of the battery storage systems that are being compared.

Photo: Shutterstock/OEH

Types of batteries

Key point

Understanding the type of battery and how it may work within your business is an important aspect of the overall process for choosing a suitable battery storage solution for your site.

There are four battery chemistries that are typically put forward by suppliers for the applications discussed in this guide.

Which chemistry for which application?

- Any of the chemistries currently on offer are capable of providing appropriate performance in each application. However, some chemistries perform some functions more effectively than others.
- Your system design process needs to include an assessment of the unique characteristics of your site so you can identify and specify the chemistry which will provide the best performance.

Which is best for your business?

This guide alone can't identify the best solution for your specific needs. Finding an appropriate solution for your site or project can only be achieved through an individualised and engineered design.

Lead-acid and advanced lead-acid batteries

Lead-acid batteries are the most established battery type in the industry (Figure 19).

Chemistry

A lead-acid battery consists of a positive cathode, a negative anode, and an electrolyte. In its charged state, a lead-acid battery has the potential for a chemical reaction between these three components.

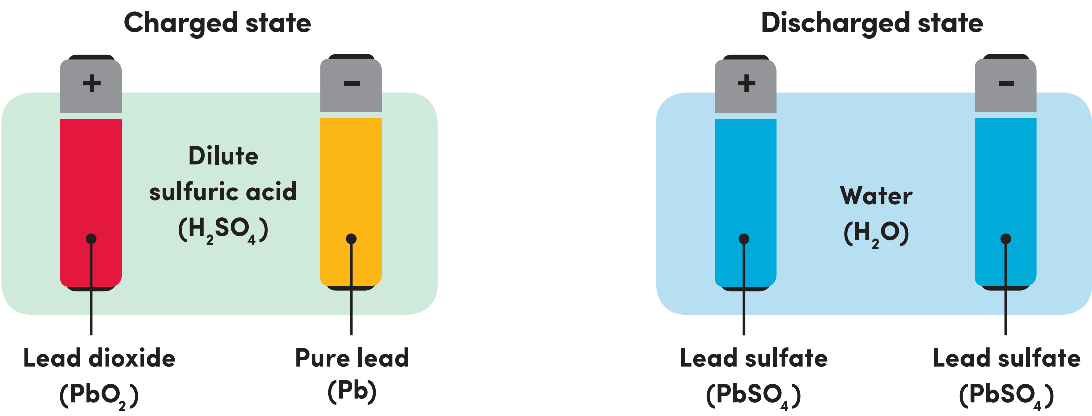


Figure 19: Lead-acid battery

Connecting the battery into a circuit to power a load allows electrons to flow and the chemical reaction can occur. When the reaction is complete the two electrodes are the same material.

The battery is re-charged by applying a voltage which forces the reaction to be reversed.

Background

Lead-acid batteries have been used extensively in uninterruptable power supplies (UPS) and other storage applications for decades.

Because these batteries have been used for a long time there are formal Australian Standards for the installation of battery storage using this battery chemistry.

Current Australian Standards for lead-acid batteries

- AS2676 – Installation and maintenance of batteries in buildings (1983)
- AS3011 – Secondary batteries installed in buildings (1992)
- AS4509 – Stand-alone power systems (2002)
- AS4086 – Secondary batteries for SPS
- AS4777 – Grid connection of energy systems via inverters (2005)
- AS62040 – Uninterruptable Power Systems (UPS) (2003)
- AS3000 – Electrical installations (AS/NZS Wiring Rules - 2007)

Characteristics

Lead-sulfate can accumulate on the electrodes over time and can be difficult to remove. The battery cannot rapidly alternate between charging and discharging without affecting lifetime performance. This is a significant drawback for this battery type because the load profile of a business may require erratic charge and discharge.

Advanced lead-acid batteries feature a large capacitor to mitigate this disadvantage. The capacitor performs the short-term charge and discharge duty while the lead-acid battery provides the energy storage capacity and longer term charge and discharge power.

Lead-acid batteries have the ability to supply high current relative to their overall capacity and in comparison to other battery chemistries, generally are able to supply high power. This can make them more appropriate where the specific site characteristics call for a substantial amount of power over a short period of time without the need for a large storage capacity.

There are well established Australian Standards, understood hazards and procedures to deal with fires, personal injury, etc. are in place with authorities. Recycling supply chains are generally well-established. There is usually no cost to dispose of the lead and rebates for recycling are sometimes available.

Lead-acid batteries require stringent management of their state of charge, charging and discharging by a battery management system specific to the chemistry. Battery life can be significantly diminished by inappropriate management of these operating parameters. Furthermore, the expected battery life can be a trade-off to the desired usable storage capacity, i.e. choosing a greater depth of discharge range will result in fewer cycles as a component of operating life.

Lead-acid batteries are heavier and larger than lithium-ion batteries per kilowatt hour, and this needs to be considered as part of their installation requirements. The potential risk of hydrogen emission and cell leakage means that ventilation and containment also need to be considered.

Future outlook

Lead-acid is likely to be overtaken by new types of battery technologies that are being rapidly improved and becoming more affordable and are marketed heavily.

Advanced lead-acid batteries, which feature a large integrated capacitor, present an opportunity for this technology to remain competitive.

Lithium-ion batteries

Lithium technology development and the marketing of lithium-ion battery products has created great interest in energy storage. There is a rapidly growing suite of lithium-ion products available in the market.

Chemistry

A lithium-ion battery consists of a positive cathode that is a type of lithium-metal (figure 20). The exact material used can differ between different manufacturers and each has associated advantages and disadvantages. The variations available in commercial batteries include:

Chemistry	Lithium nickel manganese cobalt oxide	Lithium iron phosphate	Lithium manganese oxide
Frequency	Most common	Alternative	Least common
Key characteristics	Potential for thermal runaway, high energy density	Stable and longer life, less energy density	Stable, high power density, less energy density

Lithium-ion batteries feature a negative anode of graphite carbon, and an electrolyte.

In its charged state, a lithium-ion battery has electrical potential due to the accumulation of lithium-ions at the anode.

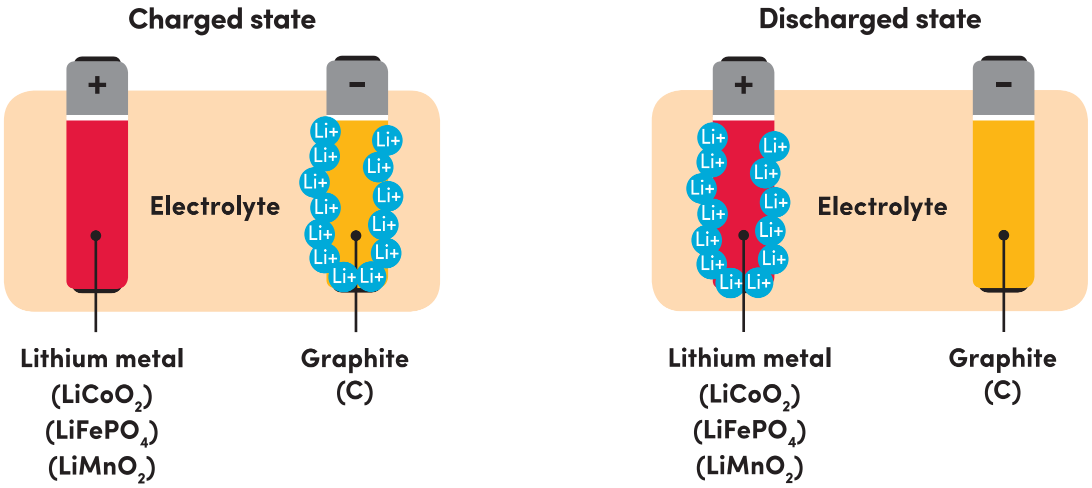


Figure 20: Lithium-ion battery

Connecting the battery into a circuit to power a load allows electrons to flow and the positively charged ions can migrate to a lower potential in the lithium metal.

The battery is re-charged by applying a voltage which forces lithium-ions to the anode.

Background

Lithium-ion batteries are rapidly improving in performance and price.

Large automotive manufacturers developing electric vehicles, and the associated development and widespread marketing of lithium-ion batteries, have significantly increased the awareness and demand for battery storage.

Since this type of battery has not yet been used extensively for stationary power storage, there are limited installation standards.

Characteristics

Lithium-ion batteries are able to operate at a lower state of charge compared to lead-acid batteries, however, completely discharging the battery can adversely affect its operating life.

This chemistry also requires stringent battery management to ensure that the battery's overall longevity is maintained. The relationship between useful operating life and operating conditions (including depth of discharge, rate of charge/discharge and temperature) varies significantly between manufacturers. In principle, lithium-ion batteries have characteristics better suited to high cycling applications than the other chemistries discussed in this guide. This statement is based on the information provided by manufacturers about their own products.

Most lithium-ion batteries on the market are unable to deliver the same high power relative to their overall capacity as lead-acid. Where an application requires high power characteristics, a brand or model of lithium-ion battery may be available to meet that need but the documentation should be scrutinised.

Lithium-ion batteries are lighter and smaller than the other technologies presented in this guide per kilowatt hour of storage. The risks associated with thermal runaway from short circuiting, incorrect charging and discharging or puncture require specific installation considerations. Some lithium-ion batteries have particular temperature sensitivity and, depending on the site characteristics, this may also have implications for battery selection and management.

At the time of publication, the existing Australian Standards do not cover the specific characteristics relevant to emerging technologies. However, standards are due to be published in relation to these technologies and their application.

The methods for dealing with fire and other safety hazards are not clear at this time, however, there are best practice guides from industry bodies that address some of these issues (See Useful links). Recycling practices are not well established in Australia for this battery chemistry. Lithium-ion batteries present challenges in disposal because their salvage value is currently less than the cost of processing.

Future outlook

There are predictions that the prices of batteries, particularly lithium-ion batteries are set to fall dramatically over the next few years.

Mass production of lithium batteries for electric vehicles is expected to increase production to a level that can create economies of scale to reduce production costs and drive global prices down.

Flow batteries

Flow batteries are an alternative battery type in the industry (Figure 21).

Chemistry

Flow batteries consist of two large separate tanks containing a liquid electrolyte. The battery operates by pumping the two separate electrolytes through a cell to allow ion transfer between the two liquids. A membrane prevents the two liquids from mixing.

The two most common types of flow batteries are similar in design but use different electrolytes:

- zinc bromide flow batteries
- vanadium redox flow batteries.

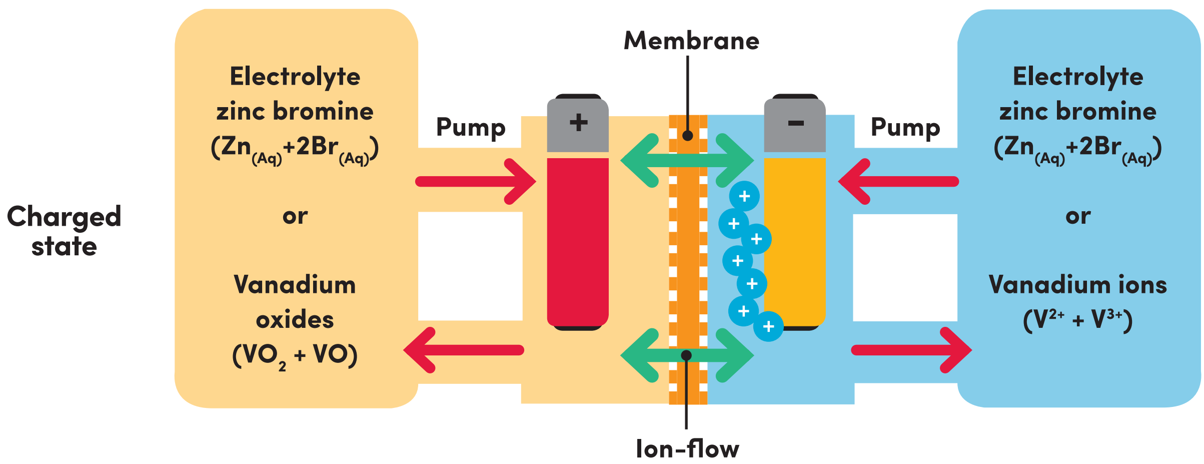


Figure 21: Flow battery

Background

There are relatively few flow battery manufacturers. An Australian manufacturer has developed a flow battery which features a zinc bromide chemistry.

A different type of flow battery, using a vanadium redox chemistry was developed in Australia in the 1980s. It has recently become available commercially as batteries have become more desirable to consumers.

Characteristics

Flow batteries have a 100% usable depth of discharge range, which means their operating life is not adversely affected if the battery is completely discharged. The chemicals used in flow batteries are able to be processed to recycle the liquid for re-use. The liquids used are inherently more stable than lead-acid and lithium batteries and the chemicals themselves do not present a fire hazard.

Since the storage medium is a liquid, the storage capacity can simply be increased by increasing the tank volume. Liquid storage has the potential risk of chemical leakage and due consideration should be given to containment, either included as part of the battery itself, or as an additional component of installation.

Flow batteries are limited in the amount of current supplied relative to their overall capacity, and in comparison to lead-acid batteries will supply less power. Flow batteries have characteristics well suited to high cycling applications compared to lead-acid and are comparable to some lithium-ion batteries. This statement is based on information provided by manufacturers about their own products.

At the time of publication, the existing Australian Standards do not cover the specific characteristics relevant to emerging technologies including flow batteries. However, standards are due to be published in relation to these technologies and their application.

Future outlook

The commercial efforts of local manufacturers in developing and marketing zinc bromide flow batteries for home and business storage has created demand for this technology in Australia.

This technology is in relatively early stages of development compared to other battery technologies. Improvements in storage capacity, power delivery and cost of manufacturing may occur in the future.

Salt-water batteries

Salt-water batteries (also known as sodium-ion batteries) are an alternative battery type in the industry.

Chemistry

Salt-water batteries are very similar to lithium-ion batteries because sodium shares many properties with lithium (Figure 22). Both are metals and can join the structure of graphite in a process called intercalation.

An electric charge forces sodium-ions to intercalate into a battery's anode and creates a potential.

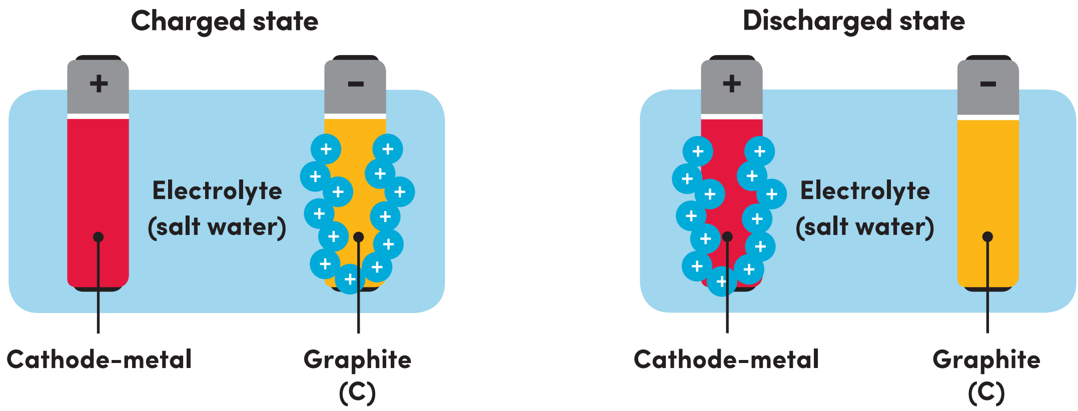


Figure 22: Salt-water battery

Connecting the battery into a circuit to power a load allows electrons to flow and the positively charged ions can migrate to a lower potential in the cathode.

Background

The salt-water battery was invented in 2008 and has only been in commercial production for a few years. Since then it has seen applications in both home storage and large grid-scale batteries.

Characteristics

Salt-water batteries are limited in the amount of current supplied relative to their overall capacity and in comparison to lead-acid batteries will supply less power. Salt-water batteries have a 100% usable depth of discharge range, which means their operating life is not adversely affected if the battery is completely discharged.

The materials used are inherently more stable than lead-acid and lithium batteries and the chemicals themselves do not present a fire hazard. The chemicals within these batteries are highly recyclable and non-toxic.

Salt-water batteries are heavier and larger than the other technologies per kilowatt hour, including lead-acid, and this should be considered as part of their installation requirements. The potential risk of hydrogen emission means that ventilation also needs to be considered.

At the time of publication, the existing Australian Standards do not cover the specific characteristics relevant to emerging technologies, including salt-water batteries. However, standards are due to be published in relation to these technologies and their application.

Future outlook

The development and marketing of a salt-water battery for home and business storage has created demand for the technology in Australia, as it's made from highly abundant materials and is easily recycled.

This makes salt-water batteries an appealing alternative provided that key performance criteria for specific projects can be met.

Salt-water battery chemistry is relatively new, but it has the potential to improve in performance significantly.

Photo: iStock/OEH

Part 2: Buyer’s toolkit

- Gathering information
- Assessing feasibility
- Buyer’s checklists and template

Gathering information

Key point

Developing a system for gathering and documenting information about your site will help you to communicate your requirements to potential suppliers/installers.

Step 1: Understanding your energy use and needs

The best place for a business to start when considering battery storage is to understand how and when it uses energy, and to think about what changes it would like to make. Table 2 sets out key considerations in regard to energy use and objectives. You could use this as a starting point to help define your energy objectives and the scope of a battery storage system for your business.

Table 2: Energy objectives

	Key considerations	Example responses
Motivation	What is your reason for considering battery storage?	• Reducing electricity bills • Shift consumption to renewables • Need more power than the grid can supply
Current energy use	How much energy does your site consume? (e.g. in kWh/year)	• Financial year 2015/2016 the site used on average 500 kWh per day (183,000 kWh per year)
Current power use	What is your site's demand profile? (i.e. its maximum demand in kVA or kW)	• The kVA charges for the past 12 months are based on 80kVA
Future view	Any changes that may increase or decrease electricity consumption in the future?	• Future usage is expected to be similar to current usage • Future usage is expected to be 20% more than current usage
Seasonal variation	Does your business observe large changes in power usage depending on the time of year?	• The business pumps water only in summer • The business has a high heating load in winter
Load balance	What is your site load/energy balance (i.e. the percentages used by different systems)?	• HVAC represents 50% of our energy use • There are significant 24/7 lighting loads • Electric forklift charging once per day
Aspirations	Is there a business objective to source a proportion of this energy from renewables?	• We want 50% of the energy we use to be generated on site by renewables

Step 2: Choosing a battery storage application

You may already have an idea about the type of battery storage system you need, and the scope of the system's design. The decision tree in Figure 23 can be used to help you investigate the best application of battery storage for your business.

For more information see Business applications for battery storage.

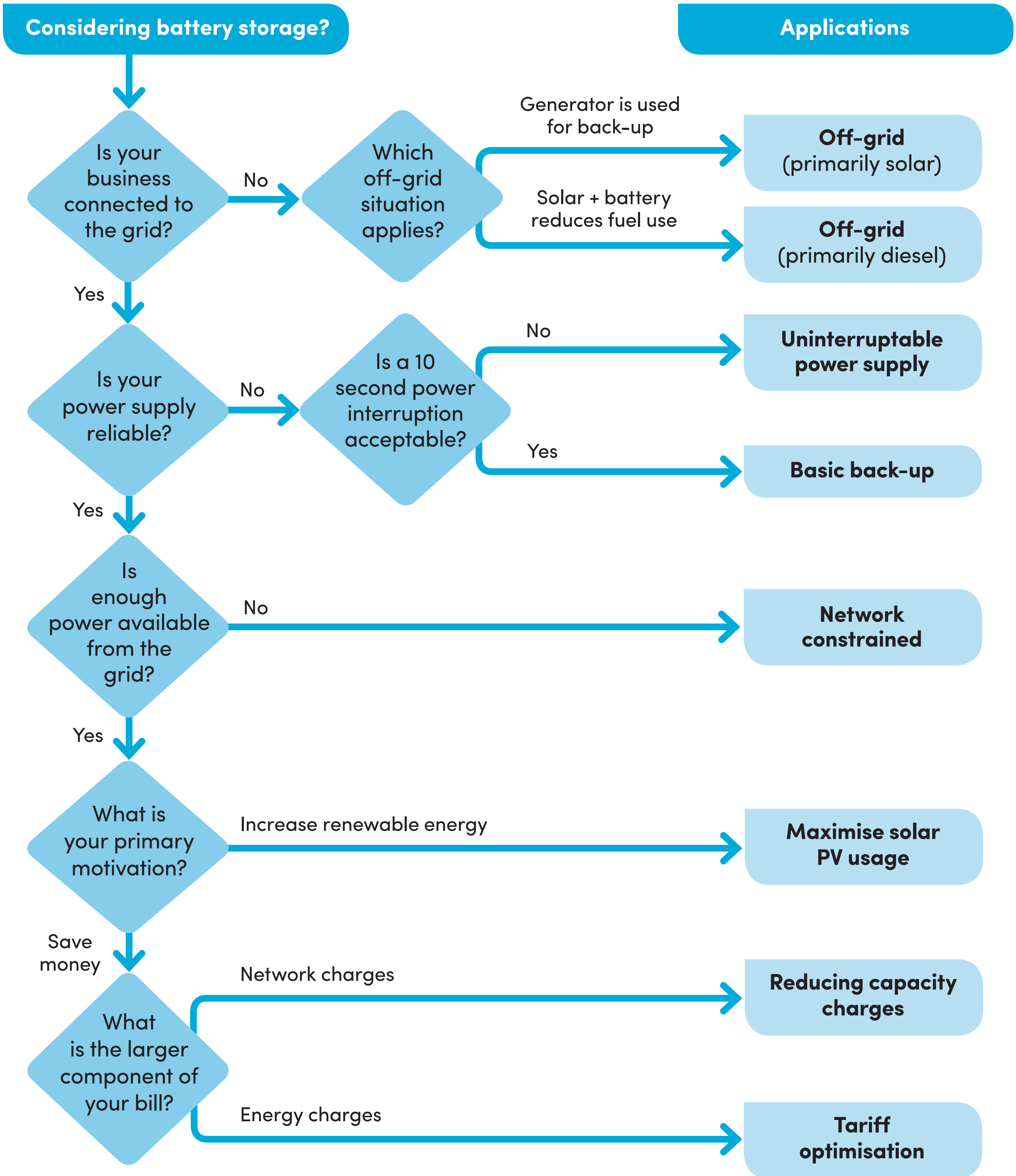


Figure 23: Battery storage application – decision tree

Step 3: Analysing your energy consumption data

Tip

Consider at least 12 months' worth of electricity consumption data, preferably 24 months.

Detailed energy usage information is vital for deciding how battery storage can be applied to your site. You will need to obtain an accurate picture of how you use electricity either through monitoring or by asking your electricity retailer, or both.

Ask your electricity retailer for 15 or 30-minute interval electricity consumption data, if available, for each electricity meter installed on site. You will need to provide the National Meter Identifier (NMI) for each meter when you ask the retailer for electricity consumption data.

Once you have obtained your usage information you may be able to identify what opportunities or constraints for battery storage may apply to your site. Table 3 lists some factors to consider when analysing your usage data. You should address each focus area and list your high-level findings.

Table 3: High-level energy data analysis considerations

Focus area	Key considerations	Example findings
Daily variation	Is usage mainly daytime or at night?	• Daytime usage is much higher than night time. • There is a 5kW base load at all times
Weekly variation	Is usage constant or does it vary significantly from day to day?	• The highest power usage of the week is always on Saturday night • Energy usage is constant 24/7
Seasonal variation	Is there much fluctuation in winter and summer?	• The usage in winter is much greater than other times of the year because of winter heating
Peak demand charges	What days, months and hourly periods represent your highest energy demand?	• The highest annual peaks usually occur in June/July between 6–8pm up to 100kW
Solar generation	Is there on-site solar power generated and not self-consumed?	• All solar power is self-consumed • The gross feed-in scheme means all solar power is exported

Step 4: Understanding your tariffs

Once you have an idea of your business energy usage, you need to understand how your business is charged for electricity:

- How much energy is used per year?
- How much does your electricity cost (i.e. in $/kWh and $/kVA or kW)?
- Does the business pay peak demand charges? If so how much?
- Does the business pay based on the time of use of energy?
- How much is paid per kWh in each time period?

You can use the tables provided here as templates to help identify the important elements of your tariff structure.

Although your bill may consist of both energy usage charges and network charges, these need to be separated to understand how your business could use battery storage.

In the previous step, you analysed the different opportunities or constraints for battery storage that may apply to your site due to your energy usage. Table 4 is a template for a more detailed analysis that will help quantify this usage and should match your bill.

Use this table to document your energy and power information and identify how much energy storage capacity you may require to meet your objectives. Product and service providers typically need this information to be able to provide an accurate proposal.

Alternative tariffs

Some businesses are on a flat rate or block tariff that does not vary based on the time of use. If you are on this tariff, simply fill in the 'Total consumed' column only. **Note:** tariff optimisation using off-peak electricity cannot be achieved on this tariff.

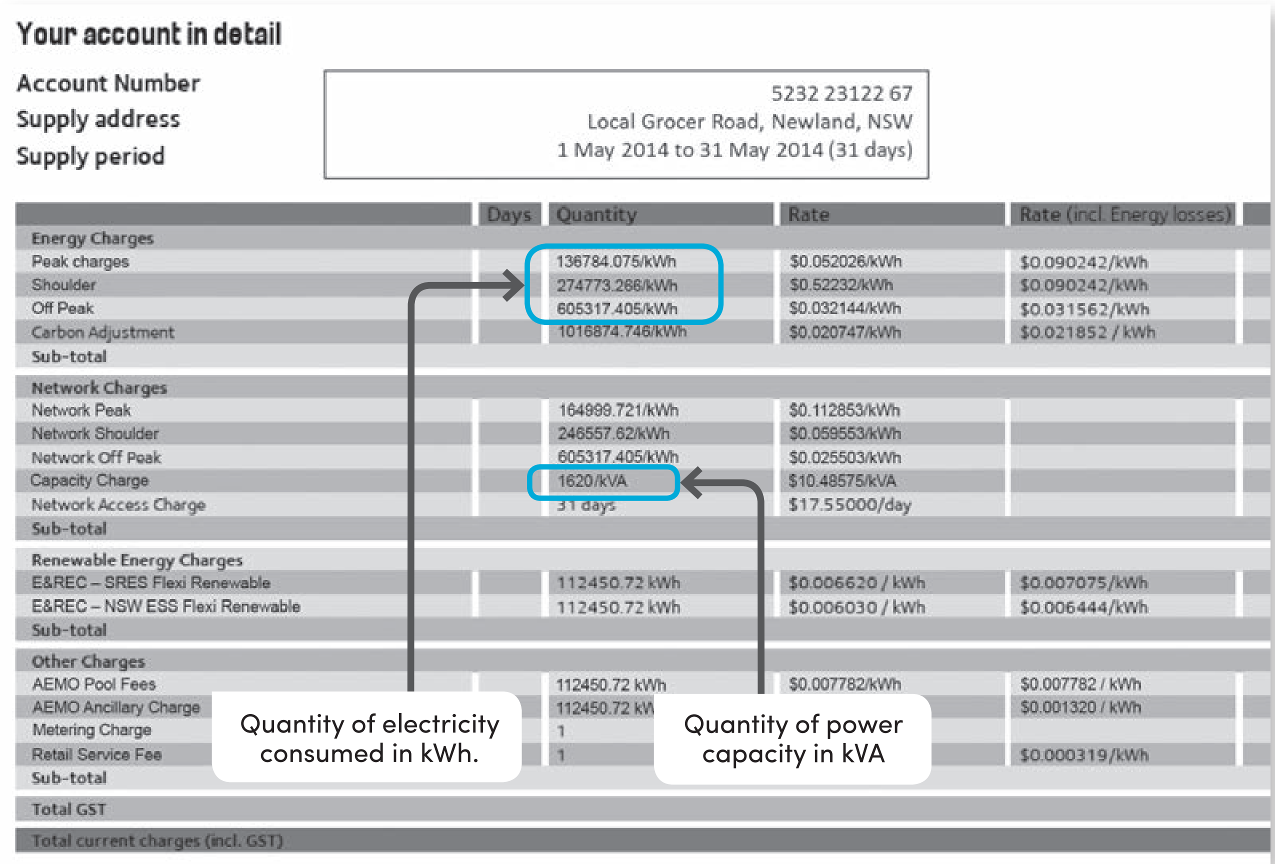
Some businesses do not pay capacity charges. If you are on a tariff without capacity charges, simply leave this column blank. **Note:** Peak shaving cannot be achieved by businesses that don't pay capacity charges.

Table 4: Energy consumption summary

Month	Peak quantity (kWh)	Shoulder quantity (kWh)	Off-peak quantity (kWh)	Total consumed (kWh)	Capacity charges (kVA)
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Total					

Note: kWh = kilowatt hours.

Figure 24 shows a typical electricity bill, and where you can find this usage information.



Your account in detail

Account Number 5232 23122 67
Supply address Local Grocer Road, Newland, NSW
Supply period 1 May 2014 to 31 May 2014 (31 days)

	Days	Quantity	Rate	Rate (incl. Energy losses)
Energy Charges				
Peak charges		136784.075/kWh	$0.052026/kWh	$0.090242/kWh
Shoulder		274773.266/kWh	$0.52232/kWh	$0.090242/kWh
Off Peak		605317.405/kWh	$0.032144/kWh	$0.031562/kWh
Carbon Adjustment		1016874.746/kWh	$0.020747/kWh	$0.021852 / kWh
Sub-total				
Network Charges				
Network Peak		164999.721/kWh	$0.112853/kWh	
Network Shoulder		246557.62/kWh	$0.059553/kWh	
Network Off Peak		605317.405/kWh	$0.025503/kWh	
Capacity Charge		1620/kVA	$10.48575/kVA	
Network Access Charge		31 days	$17.55000/day	
Sub-total				
Renewable Energy Charges				
E&REC – SRES Flexi Renewable		112450.72 kWh	$0.006620 / kWh	$0.007075/kWh
E&REC – NSW ESS Flexi Renewable		112450.72 kWh	$0.006030 / kWh	$0.006444/kWh
Sub-total				
Other Charges				
AEMO Pool Fees		112450.72 kWh	$0.007782/kWh	$0.007782 / kWh
AEMO Ancillary Charge		112450.72 kW		$0.001320 / kWh
Metering Charge		1		
Retail Service Fee		1		$0.000319/kWh
Sub-total				
Total GST				
Total current charges (incl. GST)				

Figure 24: Typical electricity bill

You will also need to know when the peak, shoulder, and off-peak periods occur. This will be in the contract or the terms and conditions document from your electricity retailer. Table 5 is a template that can be used to identify the important timing elements of your tariff.

Table 5: Tariff period information

Item	Example information
Time of peak periods	Weekdays 7am–9am and 5pm–8pm
Time of shoulder periods	Weekdays 9am–5pm
Time of off-peak periods	All other times
Number of peak periods in a week	10

Reading your bill correctly

It's important to add all components of your bill that contribute to the cost of energy per kilowatt hour.

Use Table 6 to add up all of the components that contribute to the cost per kilowatt hour for each tariff period.

The rate paid for energy in each period is critical for calculating potential savings.

Table 6: Tariff rate information

Item	Energy charges ($/kWh)	Network charges ($/kWh)	Other charges ($/kWh)	Total rate ($/kWh)
Peak	A	D	X	
Shoulder	B	E	X	
Off-peak	C	F	X	

Note: kWh = kilowatt hours.

Figure 25 shows a typical electricity bill, and where you can find this usage information.

You also need to know how much you pay for capacity charges per month:

Table 7: Capacity rate information

Item	Capacity charges ($/kVA/month)
Capacity charge	Y

Your account in detail

Account Number	5232 23122 67
Supply address	Local Grocer Road, Newland, NSW
Supply period	1 May 2014 to 31 May 2014 (31 days)

	Days	Quantity	Rate	Rate (incl. Energy losses)
Energy Charges				
Peak charges		136784.075/kWh	$0.052026/kWh A	$0.090242/kWh
Shoulder		274773.266/kWh	B $0.52232/kWh	$0.090242/kWh
Off Peak		605317.405/kWh	$0.032144/kWh C	$0.031562/kWh
Carbon Adjustment		1016874.746/kWh	$0.020747/kWh	$0.021852 / kWh
Sub-total				
Network Charges				
Network Peak		164999.721/kWh	$0.112853/kWh D	
Network Shoulder		246557.62/kWh	E $0.059553/kWh	
Network Off Peak		605317.405/kWh	$0.025503/kWh F	
Capacity Charge		1620/kVA	Y $10.48575/kVA	
Network Access Charge		31 days	$17.55000/day	
Sub-total				
Renewable Energy Charges				
E&REC – SRES Flexi Renewable		112450.72 kWh	$0.006620 / kWh	$0.007075/kWh
E&REC – NSW ESS Flexi Renewable		112450.72 kWh	$0.006030 / kWh	$0.006444/kWh
Sub-total			X	
Other Charges				
AEMO Pool Fees		112450.72 kWh	$0.007782/kWh	$0.007782 / kWh
AEMO Ancillary Charge		112450.72 kWh	$0.001320/kWh	$0.001320 / kWh
Metering Charge		1	$1.0031503/day	
Retail Service Fee		1	$40.50000/month	$0.000319/kWh
Sub-total				
Total GST				
Total current charges (incl. GST)				

Figure 25: Typical electricity bill

At the completion of this step you should have the following information:

- a list of business objectives
- a battery storage application category
- a high-level analysis of your energy usage data
- a detailed summary of your energy consumption
- a list of the tariff periods that apply to your business
- a list of the tariff rates that you pay for energy.

Photo: TransGrid/OEH

Assessing feasibility

Key points

Using the tools in this guide and the Battery storage for business: investment decision tool you can develop a high-level business case for battery storage based on your specific site conditions.

A detailed analysis of your needs should be carried out by a suitably qualified engineer before you make an approach to suppliers or installers.

Battery storage for business: investment decision tool

The companion tool for this guide is the OEH Battery storage for business: investment decision tool. This tool can be used by grid-connected businesses that are considering tariff optimisation or reducing capacity charges (peak shaving). It helps to identify the expected payback periods for these battery storage applications.

Tips

- The investment decision tool is used to identify showstoppers and potential payback periods. It does not assist in sizing a battery storage system.
- The investment decision tool does not address off-grid or back-up power solutions. These will require detailed analysis by a suitably qualified engineer.

You may download the tool and use it to assess the feasibility of battery storage applications.
www.environment.nsw.gov.au/business/battery-storage.htm (See Useful links section)

Feasibility considerations

Table 8 lists items for consideration that may be obstacles for battery storage.

Table 8: Key battery storage project showstoppers

Focus area	Key considerations
Payback expectations	• Be aware that battery storage rarely pays back in less than 10 years (as at November 2016) • Battery storage systems have a long lifetime and the returns on investment occur over this longer term. The expected payback period may be longer than the warranty period. • Any electricity price increases in the future will impact payback calculations.
Business objectives	• Be aware that businesses that have aspirations other than purely financial return are more likely to identify batteries as feasible. • Goals such as increasing renewable energy use and improving the reliability of power may reduce the focus purely on payback.
Budget constraints	• Be aware that batteries and associated electronics are initially capital intensive and provide benefits over a long lifetime. • Will your business be able to afford the upfront cost or will you require finance?
Physical constraints	• A secure fire-rated battery room or enclosure is best practice or mandatory in some cases for installing battery storage. • Do you have space and permission to construct this room or enclosure? • If solar PV is also under consideration you will require sufficient suitable roof space in terms of direct sunlight, orientation and structural integrity.
Electrical services constraints	• A battery storage system will need to integrate with your existing electrical infrastructure. • Leased buildings may prohibit substantial changes to electrical infrastructure. • Do you have permission to modify your electrical infrastructure?
Regulatory constraints	• The Building Code of Australia (BCA) as part of the National Construction Code (NCC) and various Australian Standards will need to be complied with. • The electricity network provider will need to be consulted for any grid-connected battery storage system and will most likely stipulate any requirements specific to your site.

Understanding costs versus savings

Use the following steps to calculate the potential savings from battery storage:

1. Identify the business objective.
2. If your objective has a financial component you need to quantify the possible savings.
3. Quantify these savings per year and multiply this by what you consider the minimum number of years for simple payback.
4. For the system to be feasible, the total installed cost and forecast maintenance costs must be less than this amount.

Tip

Understand what your business is prepared to accept in terms of payback duration. Consider focusing on the lifetime benefit of batteries rather than the short-term payback.

The following examples provide detailed steps on how to calculate the potential savings from the two most common applications of battery storage for businesses.

Calculating the potential savings from time-of-use optimisation

1. Identify the difference between the high price of energy and the low price of energy per kWh.
2. Calculate the difference between these two values to find the maximum saving per storage cycle per kWh.
3. Identify the number of times the battery can be cycled in a week.
4. Calculate the total number of cycles that will occur in a year.
5. Multiply this number by the rate difference found in Step 2 to find yearly savings per kWh.
6. Compare this value to the average cost per kWh to purchase a system.

Working example:
Calculating the potential savings from time-of-use optimisation

The site owner estimated that batteries could save the business $101 every year per kWh of storage installed using the following calculations:

Step 1	Peak tariff rate	$0.26/kWh
	Off-peak tariff rate	$0.07/kWh
	Solar feed-in rate	$0.06/kWh
Step 2	**Savings per cycle per kWh (off-peak)**	**$0.19/kWh**
	Savings per cycle per kWh (solar)	**$0.20/kWh**
Step 3	Peak period 7–9am, 5–8pm weekdays	2 peaks per day
	Charge off-peak/discharge peak cycles	5 cycles per week
	Charge from solar/discharge peak cycles	5 cycles per week
Step 4	**Cycles per year**	**520 cycles**
Step 5	Savings per year per kWh (off peak)	$49
	Savings per year per kWh (solar)	$52
	Savings per year total	**$101**

Note: kWh = kilowatt hours.

This business decided the longest duration it is willing to accept for simple payback is 10 years.

The business identified a number of batteries in the market with a warranty of 8000 cycles, (or 10 years, whichever comes first). Since the battery will be cycled an estimated 5200 times over 10 years, it is possible the battery's usable life will exceed the warranty by 5 years.

Based on this calculation a 50% return on investment is possible.

Step 6	Maximum payback duration	10 years
	Savings per year	$101/kWh
	Maximum price for system	**$1010/kWh**
	Assumed lifetime (cycles)	7800
	Assumed lifetime (years)	15 years
	Total expected benefits	$1515/kWh
	Net expected benefits	$505
	Return on investment	50%

Tip

This method is a simple payback method. Your business may require different financial metrics such as return on investment to evaluate feasibility.

Calculating the potential savings from reducing capacity charges

1. Identify the maximum expected peak in kVA.
2. Identify the rate paid in terms of $/kVA.
3. Compare this peak to other periods of usage.
4. Referring to usage interval data, identify a threshold value which is rarely reached and will be the point at which batteries will begin to supply power.
5. Calculate the difference between the peak value and the threshold value.
6. Multiply this number by the rate difference found in Step 2 to find yearly savings if the peak is reduced to the threshold value.
7. Calculate the amount of energy consumed above this threshold to estimate the battery size.

What if tariffs change in the future?

These calculations assume constant electricity tariff price and conditions for many years.

Although electricity price rises may increase the savings of battery storage, price falls or tariff restructuring with higher fixed-charge components may reduce the expected returns.

Be aware of the risk that if the tariff rules change significantly in the future, some strategies for battery storage may become ineffective.

Working example: Calculating the potential savings from peak shaving

The site owner estimated that batteries could save the business $18,000 every year per kWh of storage installed using the following calculations:

Peak capacity charge	1620 kVA
Rate per kVA per month	$12.50
Threshold value	1500 kVA
Difference in peak and threshold	**120 kVA**
Savings per year	**$18,000**
Length of peak	1.5 hours
Energy needed to be supplied by battery	180 kWh

This business decided the longest duration it is willing to accept for simple payback is 10 years.

The business identified a number of batteries in the market with a warranty of 3650 cycles, or 10 years, whichever comes first. The business estimated it will need the battery to lop approximately 50 peaks per year, mainly in winter. It estimated the battery will last a long time past the warranty since the number of cycles will be small, but decided 15 years is a reasonable estimate.

It therefore estimated it can realise a 50% return on investment.

Maximum payback duration	10 years
Savings per year	$18,000
Maximum price for system	**$180,000**
Minimum usable battery capacity at end of life	180 kWh
Maximum price for system	**$1000/kWh**
Minimum lifetime	15 years
Total expected benefits	$270,000
Net expected benefits	$90,000
Return on investment	**50%**

Tip

This method is a simple payback method. Your business may require different financial metrics to evaluate feasibility.

Photo: C. Harding/OEH

Buyer's checklists and template

Key point

Asking suppliers/installers the right questions is the most effective way of ensuring your needs will be properly met.

Battery storage for business: price estimate template

The companion template for this guide is the OEH Battery storage for business: price estimate template. This template and the following checklists can help you define the scope of your project. Including what you need to ask for to obtain a design and quote for the supply and installation of a battery storage system from potential suppliers. We recommend you attend the OEH Battery storage for business training course as this will give you the opportunity to go through the template step by step with a technical expert. Visit the OEH webpage for more information (see Useful links).

Consider the following checklist items as part of your procurement process. Not all of these elements will be required but the more information you can provide about your requirements, the better the response will be from the market.

Table 9: Lifetime and warranty checklist

Focus area	Key considerations	✔
Battery chemistry	Do you have a preference for a particular battery chemistry?	
Operating voltage	Do you have a preference for a particular battery operating voltage?	
Energy capacity	Do you know how much storage capacity you need (kWh)?	
Power capacity	Do you know the minimum amount of power output you need (kWp)?	
Degradation	Do you know how much degradation you can accept over time?	
System warranty	Do you know how long you require the total system to be warranted for?	
Battery warranty	Do you know how long you require the battery to be warranted in years?	
Battery warranty	Do you know how many cycles you require the battery to be warranted for?	
Lifetime expectation	Other than warranty, how long do you want the system to last in years?	
Lifetime expectation	Other than warranty, how many cycles do you want the system to deliver?	
Operating temperature	Do you have maximum operating temperature conditions?	
Storage temperature	Do you have maximum storage temperature conditions?	

Table 10: Battery inverter checklist

Focus area	Key considerations	✔
Power capacity	Do you know the minimum amount of power output you need (kWp)?	
Product warranty	Do you know how long you require the inverter to be warranted in years?	
Operating temperature	Do you have maximum operating temperature conditions?	
Zero export conditions	Do you require the inverter to limit power export to the grid?	
Grid charging	Do you require the inverter to charge batteries from the grid?	
Programmable control	Do you require the inverter to charge/discharge based on specific criteria?	
Peak demand trigger	Do you require the inverter to deliver peak shaving functionality?	

Table 11: Solar photovoltaic checklist

Focus area	Key considerations	✔
Solar capacity	Do you know the amount of solar power capacity you need (kW)?	
Watts/panel	Do you require high efficiency panels to save space?	
Degradation	Do you know how much degradation you can accept over time?	
System warranty	Do you know how long you require the total system to be warranted for?	
Performance warranty	Do you know what level of performance warranty you require?	

Table 12: Solar inverter checklist

Focus area	Key considerations	✔
Power capacity	Do you know the minimum amount of power you need (kWp)?	
Product warranty	Do you know how long you require the inverter to be warranted in years?	
Operating temperature	Do you have maximum operating temperature conditions?	
Zero export conditions	Do you require the inverter to limit power export to the grid?	

Table 13: Documentation checklist

Focus area	Key considerations	✔
Standards compliance	Have you nominated standards to which the system must comply?	
Data sheets	Have you requested technical data sheets for all system components?	
System control	Have you requested confirmation that the proposed battery inverter/ management system will communicate with the solar inverter?	
Battery management system	Have you requested confirmation that the proposed inverters are approved for the battery technology/management system?	
Warranty statements	Have you requested warranty statements for all system components?	
Warranty conditions	Have you nominated an installation warranty period?	
Warranty conditions	Have you specified the conditions for replacing failed equipment?	
References	Have you asked the installer to provide relevant references?	
Exclusions/ inclusions	Have you specified any other desired inclusions or exclusions?	

Glossary

Alternating Current (AC)	An electric current, where the flow of electric charge periodically reverses direction.
Ampere hour (Ah)	A unit of energy capacity equal to one amp continuously supplied for one hour at the battery's nominal voltage.
Battery	A device that stores and releases energy.
Battery capacity	The total energy that can be stored in a battery. Unit: kilowatt hours (kWh)
Battery life (cycles)	The number of cycles that can be expected before the battery can no longer effectively store energy. Unit: number of cycles
Battery Management System	An electronic control system that monitors and controls the charging and discharging of the battery
Battery storage	The reversible conversion of electrical energy into chemical potential energy for later use.
Battery system	A complete system of components needed to operate batteries, including inverters, BMS, circuit protection, etc
Battery warranted capacity	The remaining usable capacity a manufacturer guarantees after a certain number of cycles. Unit: kilowatt hours (kWh)
Battery warranted life	The number of cycles a manufacturer guarantees or fixed number of years. Unit: number of cycles or years, whichever comes first.
Capacity charge	Rate paid for the maximum power provided to a business in a period regardless of other usage. Unit: $/kVA
Charge	The process of creating chemical potential energy using electrical energy.
Cycle	The process of completely charging and discharging a battery in its usable range.
Direct Current (DC)	An electric current, where the flow of electric charge is only in one direction.
Depth of discharge (DoD)	The proportion of the battery that has been discharged. Unit: % of total capacity
Discharge	The process of releasing chemical potential by allowing the flow of electrical energy.
Dollars/kilowatt hour ($/kWh)	Rate paid for energy.
Energy	The ability to do work. A battery stores and releases an amount of energy. Unit: kilowatt hours (kWh)

Flow battery	Battery chemistry that features two tanks of electrolyte separated by a membrane to facilitate ion transfer.
Inverter	An electronic device that converts DC power to AC power. Colloquially an inverter refers to a device which includes the inverter itself and multiple other components including a rectifier and (sometimes) a BMS.
Kilowatt (kW)	The rate of doing work equal to 1000 joules per second.
Kilowatt peak (kWp)	The maximum amount of power that can be supplied by a system.
Kilowatt hour (kWh)	A unit of energy equal to the amount of work one kilowatt does in one hour.
Lead-acid battery	Battery chemistry that features lead, lead-dioxide and sulfuric acid to form an electrical potential.
Levelised cost of energy ($/kWh)	The average cost of energy calculated by dividing the total system cost by the lifetime energy output.
Lithium-ion battery	Battery chemistry that features the intercalation of lithium-ions on graphite to form an electrical potential.
Off-peak tariff	The rate paid for energy usage in off-peak time periods. Unit: $/kWh
Peak tariff	The rate paid for energy usage in peak time periods. Unit: $/kWh
Peak lopping or shaving	When a battery system supplies electrical energy after total usage approaches a maximum threshold.
Power	The rate of doing work. Power is also the rate at which a battery releases (or stores) energy. Unit: kilowatts (kW)
Rated power	The maximum allowable power that can be continually supplied by a system.
Rectifier	An electronic device that converts AC power to DC power. In the context of battery storage this device is usually integrated into the inverter.
Salt-water battery	Battery chemistry that features the intercalation of sodium-ions on graphite to form an electrical potential.
State of charge (SOC)	The proportion of the battery charge remaining. Unit: % of total capacity.
Thermal runaway	An uncontrolled reaction where an increase in temperature (usually through over or under charging) causes further increases in temperature, which may ultimately lead to destruction of the battery.
Usable battery capacity	The recommended amount of energy that can be discharged without adversely deteriorating the battery. Unit: kilowatt hours (kWh).

Useful links

Office of Environment and Heritage – Battery storage for business training course
http://www.environment.nsw.gov.au/business/battery-storage-training.htm

Office of Environment and Heritage – Battery storage for business resources (Price estimate template and investment decision tool)
http://www.environment.nsw.gov.au/business/battery-storage.htm

Australian Energy Storage Council
https://www.energystorage.org.au/

Australian Energy Storage Council – The Australian battery guide
https://www.energystorage.org.au/the-australian-battery-guide/

Clean Energy Council
https://www.cleanenergycouncil.org.au/technologies/energy-storage.html

Clean Energy Council – battery storage installation guidelines
http://www.solaraccreditation.com.au/installers/becoming-accredited/battery-storage-endorsement.html

Clean Energy Council – Installer accreditation guidelines
https://www.solaraccreditation.com.au/installers/compliance-and-standards/accreditation-guidelines.html

Clean Energy Council - Battery storage safety
http://fpdi.cleanenergycouncil.org.au/reports/storage-safety-study.html