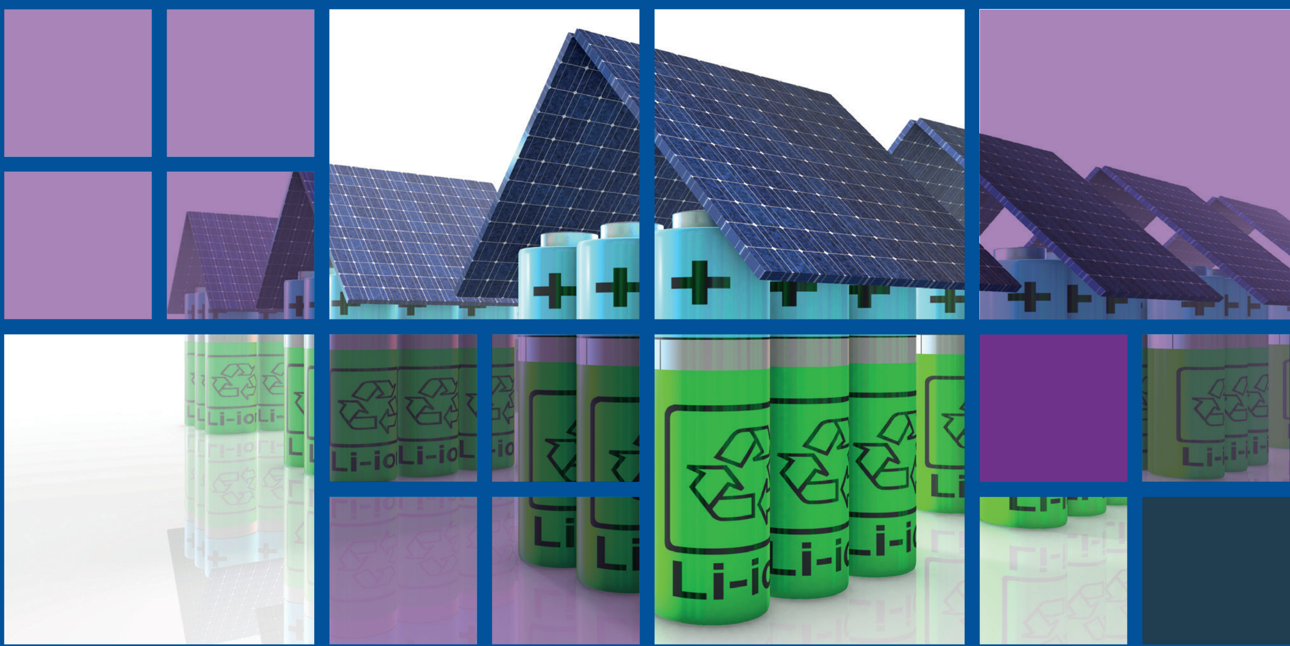
Watts in store?

Introduction to energy storage batteries for homes



Guide

NHBC Foundation
Housing research & guidance

NF83

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This guide is a general introduction to the subject, and does not remove the need to comply with all relevant standards, regulations, codes of practice and health and safety advice.

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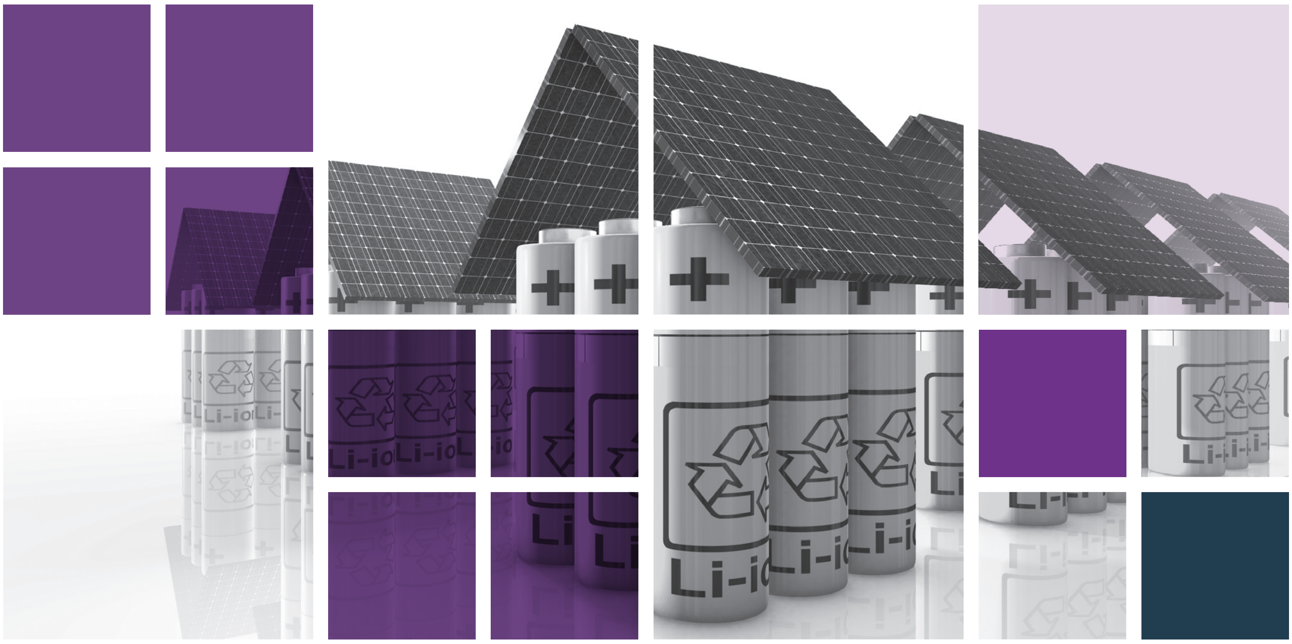

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The NHBC Foundation

The **NHBC Foundation**, established in 2006, provides high-quality research and practical guidance to support the house-building industry as it addresses the challenges of delivering 21st-century new homes. To date, it has published more than 80 reports on a wide variety of topics, including the sustainability agenda, homeowner issues and risk management.

The NHBC Foundation is also involved in a programme of positive engagement with the government, academics and other key stakeholders, focusing on the current and pressing issues relevant to house building.

To find out more about the NHBC Foundation, please visit **www.nhbcfoundation.org**. If you have feedback or suggestions for new areas of research, please contact **info@nhbcfoundation.org**.

NHBC is the standard-setting body and leading warranty and insurance provider for new homes in the UK, providing risk management services to the house-building and wider construction industry. All profits are reinvested in research and work to improve the construction standard of new homes for the benefit of homeowners. NHBC is independent of the government and house builders. To find out more about the NHBC, please visit **www.nhbc.co.uk**.

Contents


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Foreword

As the UK moves towards greater reliance on renewable sources for its heating and power, energy storage is an ever more important consideration. Energy storage has huge potential, not only by reducing peak load on the National Grid, but also because it can buffer the inevitable day-to-day fluctuations in wind or solar energy supply, and so make greater investment in renewables a more secure regional or national strategy. Advances in battery technology have been rapid in recent years, and household systems are likely to become an important part of future energy infrastructure alongside major community-scale battery installations.

This latest guide from the NHBC Foundation offers a timely introduction for UK house builders who are considering the installation of battery systems in their new homes, either at the request of buyers, or because of perceived marketing advantages. It illustrates in simple terms the key aspects of battery choice, and explains that great care is needed in specification and installation to ensure that key occupant expectations are met. Buying the cheapest battery off the shelf is not a sensible option, as it carries the risk of customer dissatisfaction and reputational damage.

In Germany there has been long-standing and extensive adoption of photovoltaics (PVs), and more recently a government-incentivised scheme to install household batteries to enable each home to store its generated power. The result has been a dramatic reduction in the installed cost of home battery systems (down by 60% between 2014 and 2016). A similar cost trajectory in the UK market could make battery storage very attractive, whether linked to PV or as a standalone option which enables occupiers, through smart technology, to use a greater proportion of their electricity at low tariff rates.

It is hard not to be excited about the potential of battery storage in homes, whether one has an eye on national energy strategy or the benefits for individual homeowners. For those tempted to adopt it, I hope this guide will help you to make the right decisions for your customers and to play your part in the successful application of this emerging technology.

Rt. Hon. Nick Raynsford
Chairman, NHBC Foundation

1 Introduction

All of the current political and technological indications are that the UK is gradually moving to an energy infrastructure based on electricity. Such an infrastructure will improve the security of supply and provide flexibility into the future. Ultimately the expectation is that our homes, vehicles and industries will all be powered and heated by electricity from a resilient national grid, supported by a wide range of energy sources: solar energy when the sun is shining, wind power when available, biomass where available, and coal, gas and nuclear when needed. In conjunction with Government policies that encourage the renewable component of energy generation, this will help us to reduce our greenhouse gas emissions and our reliance on fossil fuels.

However, a major issue in moving to an all-electric society, including the increased demand as electric vehicles become commonplace, is that the capacity of the electricity grid will need to be significantly increased (a process known as 'grid reinforcement').

A further challenge is that the UK's most prevalent forms of renewable energy generation tend to be more intermittent than traditional generation, starting and stopping as weather conditions change and daylight comes and goes. Consumers' energy demand is also intermittent, but their pattern of demand is often different to the present pattern of renewable generation. So to enable the increasingly fluctuating grid generation to reliably meet our varying demand, and in the worst case to avoid unexpected interruptions to the national electricity supply, the grid needs to incorporate energy storage. This is already done at the industrial scale using a variety of large-scale grid-based technologies, but there is an increasing opportunity for imaginative solutions at the local, household scale to help match energy supply and demand.

Where electricity is mainly generated from coal-fired, biomass and nuclear power stations, which have a relatively constant output, electricity suppliers encourage consumers to shift their household energy demand to match the available supply by charging a higher price per unit at times of peak demand and a cheaper price at the times when demand is low (for example overnight, as with the traditional 'Economy 7' tariff). With these tariffs many consumers deliberately ran their higher-powered appliances such as washing machines and dishwashers during the cheaper period by using simple time switches. However, this kind of supply/demand matching becomes more complex as the supply becomes variable, increasingly so as the proportion of wind and solar renewable generation increases.

It is now becoming common for new-build homes to incorporate their own electricity generation in the form of roof-mounted solar photovoltaic (PV) panels, but even at this household level there is usually a mismatch of electricity supply and demand.

Straightforward electronic systems are available that can divert surplus generation (during periods of low demand and/or high generation) to an immersion heater in the home's domestic hot water cylinder. This amounts to a very simple method of storing electrical energy on-site, in the form of heat. An increasingly common alternative is to use batteries to store surplus electrical energy and release it later when needed, as shown schematically in Figure 1.

Figure 2 summarises the ways in which a typical household might benefit from an electric infrastructure incorporating battery energy storage.

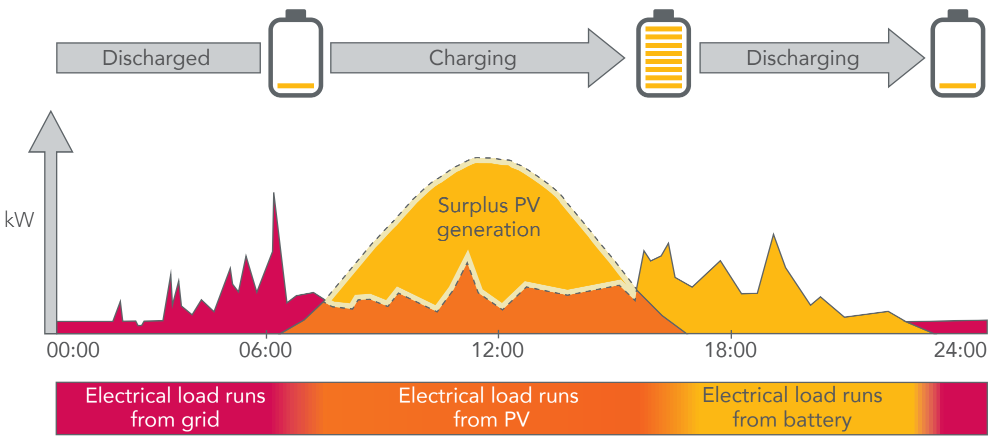
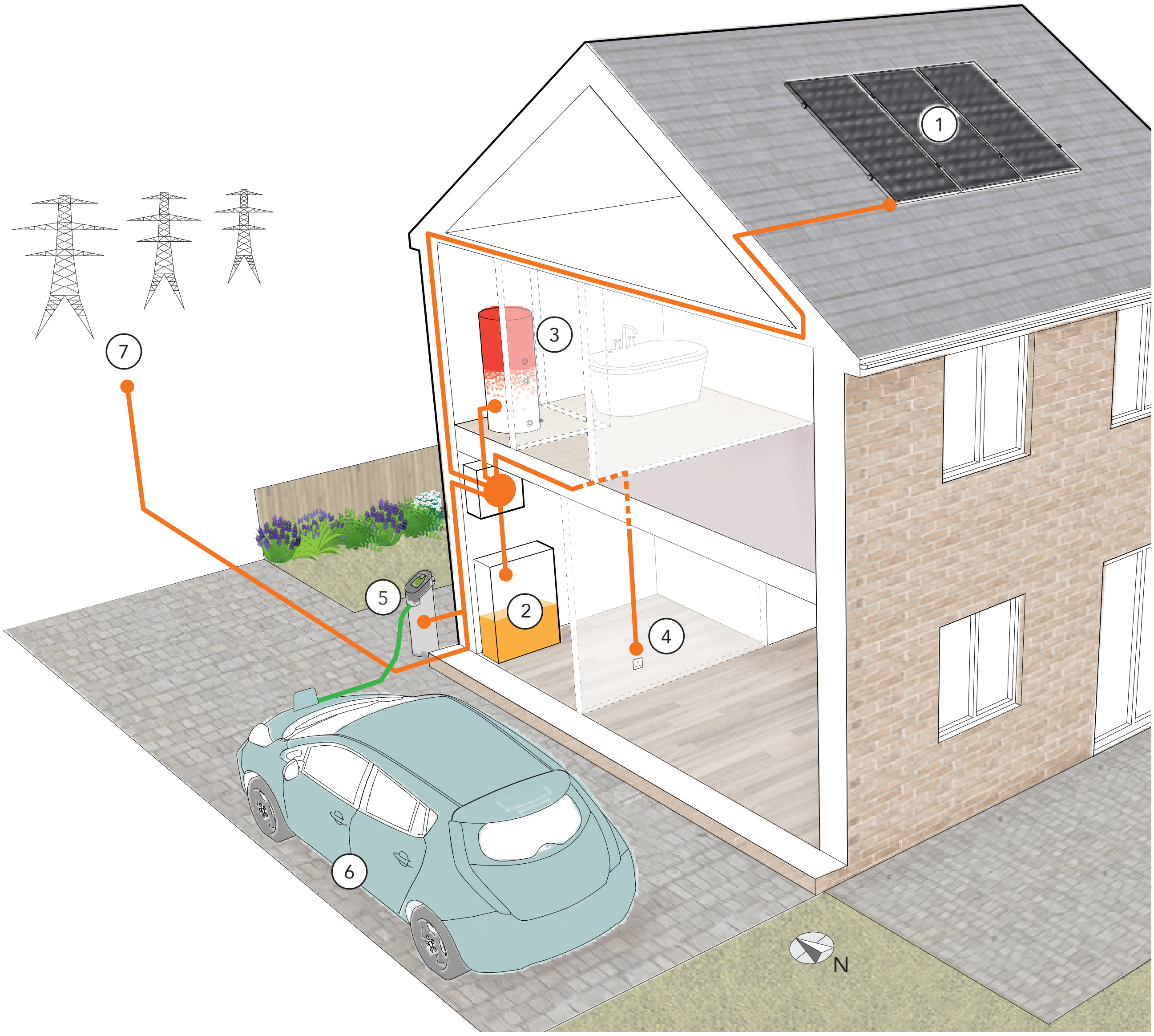


Figure 1 Schematic showing operation of battery energy storage coupled with PV power generation

It is interesting to observe the current growth in the rate of battery installations and their dramatically falling costs. Worldwide battery energy storage capacity doubled between 2014 and 2016, while in Germany the installed cost of household-scale battery systems fell by over 60% between 2014 and 2017. By 2030 the installed cost could fall by a further 50%-60%[1].



Key: opportunities and benefits

1. Photovoltaic panels generate 'free' renewable energy for the home
2. Battery storage system captures surplus PV generation for later use
3. Domestic hot water immersion heater can also run off surplus PV generation
4. Battery storage system may be able to act as backup for the home during power cuts
5. Electric vehicle charges either from the grid, the PV panels or the battery storage system as available
6. Electric vehicles may possibly act as an integral part of the home battery storage system
7. Any electrical energy surplus to the home's requirements is exported to the grid, potentially providing an income for the residents

Figure 2 Emerging domestic electric infrastructure

2 What can batteries do (and not do)?

There are many benefits to residents of having a battery storage system in the home, not all of which depend on the home having photovoltaic panels as well. House builders can benefit from associated marketing advantages, but it is important to ensure that the benefits are not exaggerated.

2.1 Benefits of battery systems linked to PV panels

Daily and seasonal operation

Due to the longer hours and greater intensity of daylight in the summer, PV panels can generate more electricity than the home's appliances require for a few months of the year. Conversely, the shorter, duller days in winter often mean that PV panels are unable to generate all of the electricity required by the appliances at that time of year. The size of both PVs and battery are critical to a system's effectiveness.

The surplus electricity generated in summer and on other brighter days can be very significant. It may be exported to the grid or made use of in other ways in the home, for example to heat the home's hot water. In this common technical configuration, the operation of a combined battery and hot water storage system will vary from day to night, and also at the different times of the year. A typical system's operation over 24-hour periods in both summer and winter is shown conceptually in Figure 3, showing when energy is generated and how it is stored efficiently in the battery and hot water cylinder. Note that household battery systems are not currently expected to store and deliver energy from one season to another, due to the very large size of battery system that would be required.

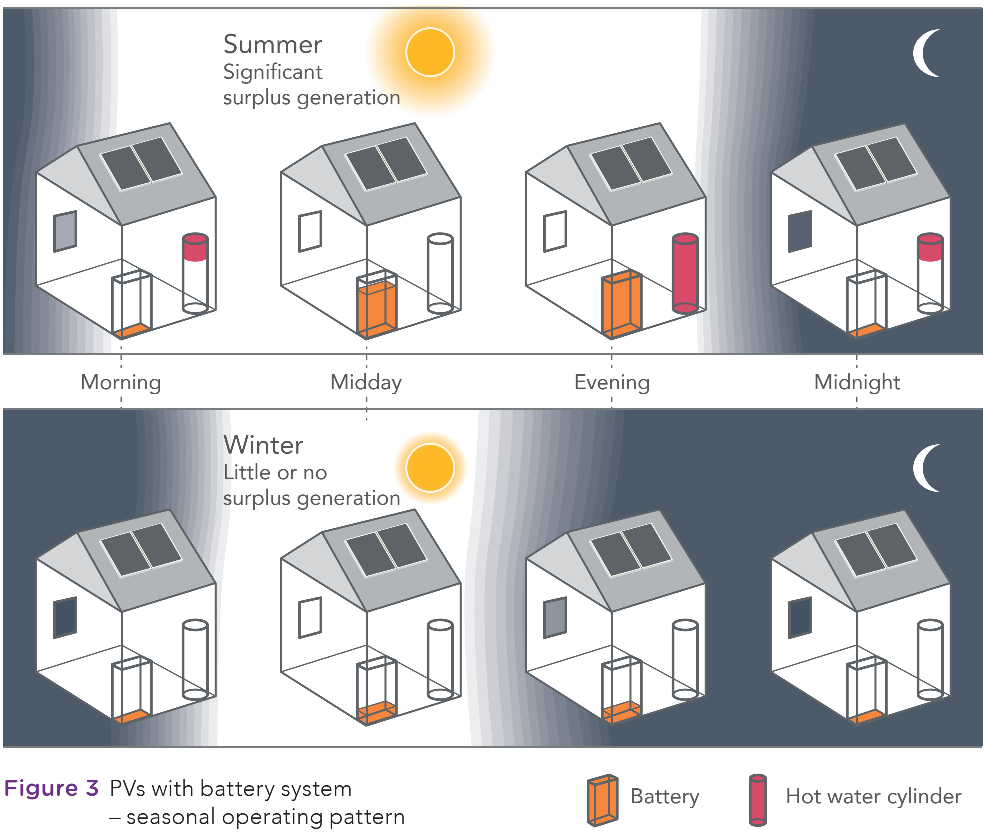


Figure 3 PVs with battery system – seasonal operating pattern

Feed-in tariffs

Feed-in tariffs (FITs) have been offered by all of the major energy suppliers in recent years, supported by government energy policy. At the end of March 2019 the feed-in tariff arrangements for PV-generated electricity are expected to end. FITs offered residents the following major benefits:

i) Payment for the total electricity that their PVs generated, which was metered

ii) Payment for the surplus electricity that they exported back to the grid, which was unmetered but deemed to be 50% of that generated, regardless of whether or not it was actually exported.

Once FITs are abolished, the first payment listed above will no longer apply, and the second payment will be significantly reduced since it will now effectively be metered. House builders will therefore need to adjust their promotional material where it relates to FITs.

The future of FITs

The feed-in tariff is controlled by central government and relates to market transformation/take up of both PV and battery systems. While the current government plans to abolish FITs in Spring 2019, future government policy may re-introduce FITs to stimulate uptake of PV and battery technologies. The timing of any re-introduction and the exact operation of a future FIT mechanism cannot be predicted. In the meantime, house builders and residents should not use the current FIT mechanism as a basis for investment decisions, except in cases where FIT arrangements are expected to be in place before April 2019.

2.2 General benefits of battery systems (whether or not linked to PV panels)

Time-of-use tariffs

'Time-of-use' (ToU) tariffs, also known as 'time-of-day' (ToD) tariffs, are becoming increasingly available. These tariffs can provide financial and environmental benefits whether or not the home includes PV panels.

ToU tariffs are a modern development of the historical Economy 7 tariff. They divide the day into a number of periods each having a different electricity cost to the consumer. The costs in each period are based on the price of wholesale electricity, which in turn reflects the intermittency of grid-based renewable generation at the national level. The costs are also designed to encourage residents to move their demand to when the national grid has more generation than it needs.

Some battery storage systems can exploit ToU tariffs to give residents additional savings. In this instance the residents would charge their batteries from the grid in the periods when grid energy is cheapest, then use that stored energy in the home when grid electricity is at its most expensive. If there is more energy in the batteries than the residents need, it could be exported when it is most needed by the grid, at which point the ToU tariff could be paying more for export.

This individual behaviour, multiplied up to a national level, can make a significant contribution to the overall grid balancing process. The current programme of rolling out smart meters is a key enabler, because it is the smart meter which effectively communicates the varying cost of electricity to the home; without this information the home could not take advantage of the tariff's pricing structure.

ToU tariffs also have the effect of reducing home CO_2 emissions, since the higher-cost periods also tend to reflect a higher CO_2 intensity of grid electricity at that time.

The picture is essentially the same if the home incorporates PVs as well, except the mechanism by which the combined system is controlled becomes more complex: the decisions about when to import, export or store electricity now involve the local generation as well as the grid, battery and ToU tariff itself.

> It is important to realise that the timing of export, import and storage of energy is controlled automatically to take full advantage of prevailing tariffs, and the residents need not play any active part in optimising their energy use if they do not wish to.

Backup during power cuts

Some, but not all, battery storage systems can provide the home with backup power in the event of a power cut. The duration of backup under normal loads may be limited, and special safety arrangements are required. This is discussed in detail in section 4.6.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3 What does a home battery storage system look like?

Neither house builders nor residents need to understand the technical details of a battery storage system. However, house builders do need to understand what their customers will be getting in functional terms, and ensure that they have asked their system designers and installers the right questions.

3.1 Types of battery

There are many different types of battery. Those most commonly used in domestic installations include lead acid (similar to conventional road vehicle batteries) and lithium ion batteries. The system provider will normally choose the specific battery type depending on the required power and capacity of the system, its ability to accept and deliver energy, any weight constraints and the available space.

Lead acid batteries are likely to remain lower cost in the short to medium term, although lithium ion types have better energy density and are gaining more of the market as their costs continue to fall. In the medium to long term, new technologies are likely to emerge which will replace even lithium ion as the most cost-effective option. Chapter 6 briefly discusses some less common storage technologies that are likely to begin appearing in domestic installations in future.

> Because the choice of battery type is made by the provider of the system, the house builder can focus instead on the broader questions of required performance, installation and price.

3.2 Look, feel and location

Household batteries are packaged in a metal case which is typically 1m or more tall and is either wide and shallow (typically 750mm x 150mm) or has a squarer footprint (typically 500mm x 500mm). They are commonly floor-mounted and fixed against a wall for stability, or free-standing (sometimes with wheel casters). Fully wall-mounted options also exist, for use where the load-bearing capacity of the wall is adequate. Where more than one battery is installed for the purpose of increasing capacity, the units might be stacked front-to back or side-by-side depending on their dimensions and the space in which they are being installed.

A separate electronic interface with the grid is also supplied, although this is often integrated within the main case, along with the inverter/charger (see 3.3). The case may also include fan-driven or liquid-cooling components.

Battery systems are very heavy, weighing typically 100 to 250 kg each, and for this reason they are most often installed downstairs. They can operate at ambient air temperatures from -20°C to 50°C depending upon the manufacturer, but it is preferable that the surrounding air temperature stays above 0°C so that the battery does not have to use its own power to ‘keep itself warm’. The ambient air temperature would also ideally remain below 25°C to limit the amount of cooling energy needed. Noise levels are similar to that of a domestic fridge.

Batteries obviously need to be installed where there is access to the home’s electrical wiring. A wi-fi or hard-wired internet connection is usually required for monitoring and control purposes.

For all of these reasons the ideal location is a kitchen, separate utility room, garage or other outbuilding – although they can be installed in any habitable area if required. Certain models can be installed entirely outdoors, but this is not recommended due to the risk of vandalism and theft.

3.3 Connection to the home

Batteries connect to the home's wiring through an inverter/charger, a device which converts the direct current (DC) of the batteries to the alternating current (AC) of the home and grid - and vice-versa. Figure 4 shows a typical, simplified battery connection arrangement for a home without a PV system.

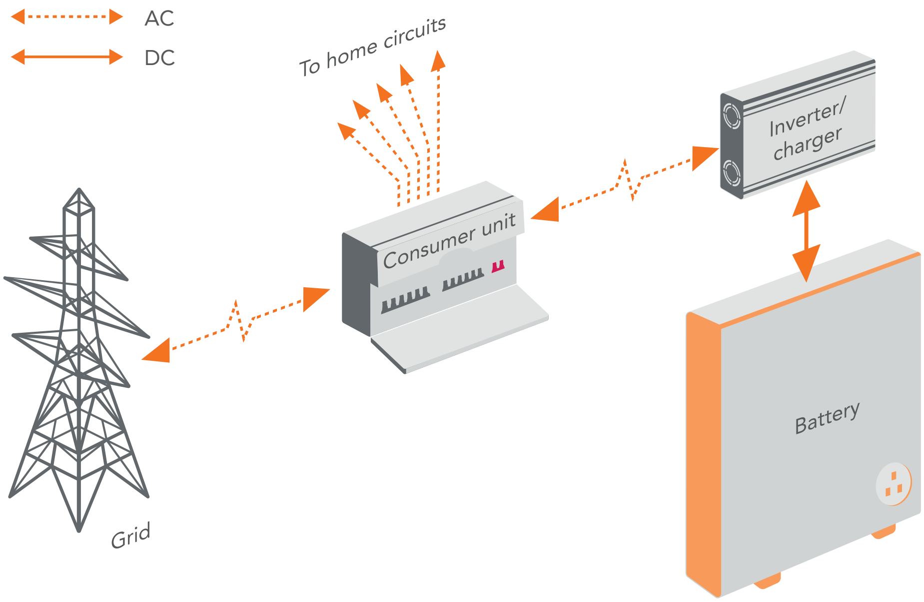


Figure 4 Typical battery connection arrangement – without PVs

In the situation where the home also incorporates photovoltaics, the battery and PVs may be connected to each other using a shared inverter/charger (a configuration known as 'DC coupled', shown in Figure 5) or using an inverter plus a separate inverter/charger (a configuration known as 'AC coupled', shown in Figure 6). Table 1 highlights the differences between the DC and AC coupled configurations.

Note that Figures 4-6 (and Figure 11 in section 4.6) are schematic diagrams for illustrative purposes only. A full system would include isolators, control boxes and other items that are not shown here. For clarity the inverter/charger is shown separately, however it may be incorporated within the battery casing by some manufacturers.

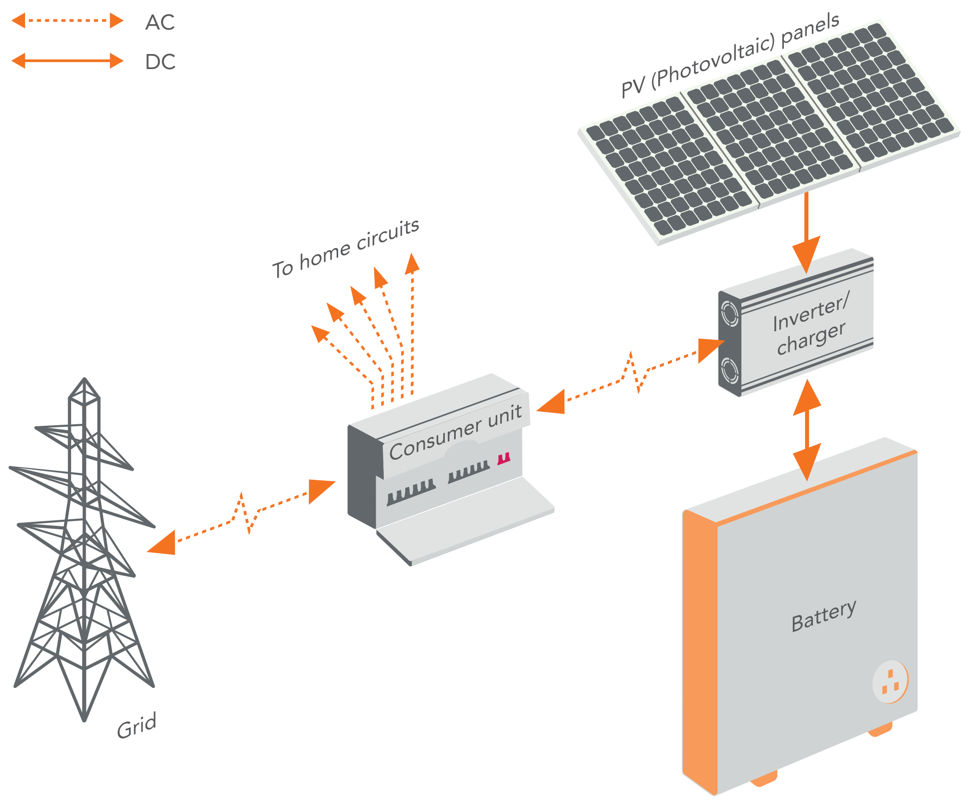


Figure 5 DC-coupled PV and battery – typical connection arrangement
(Battery connects to the PV system using DC)

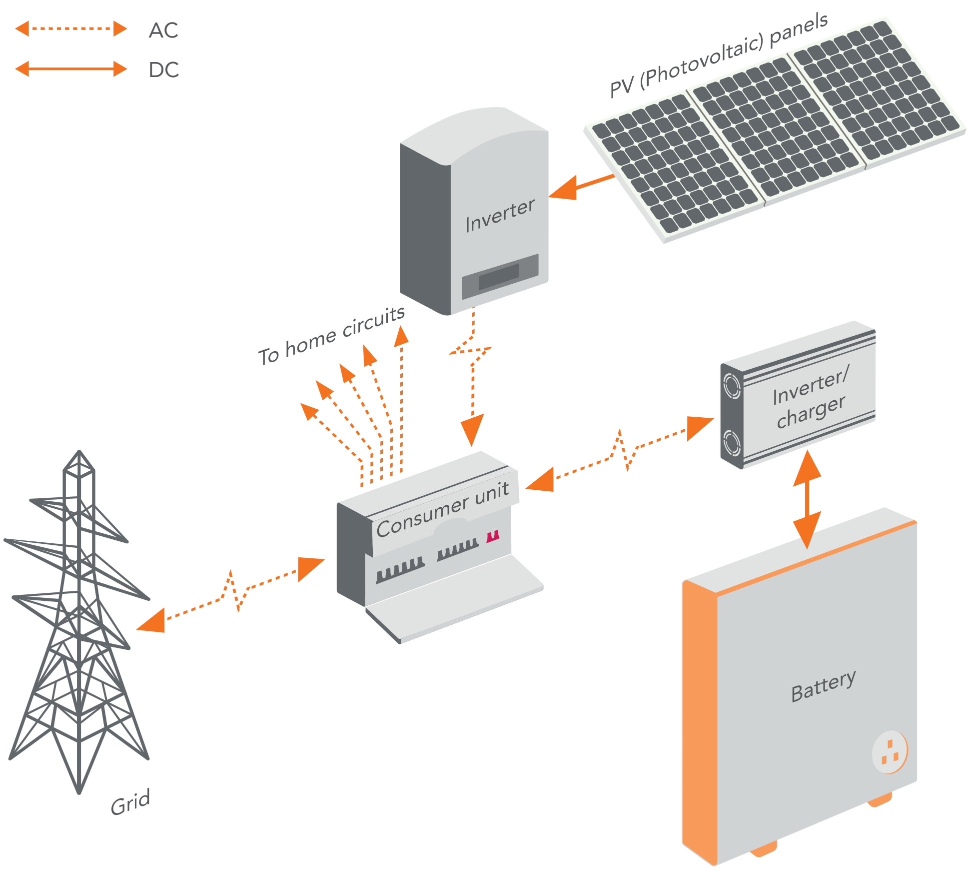


Figure 6 AC-coupled PV and battery - typical connection arrangement
(Battery connects to the PV system through an AC link)

Features of a DC-coupled system	Features of an AC-coupled system
Common when PVs and batteries are installed at the same time.	Common where the PVs and batteries are installed at different times.
Usually simpler to install, and cheaper.	Greater number of components to purchase and install.
Battery should be located near the PV inverter, which may be in the loft. In this instance there are likely to be structural implications (see Section 4.9).	Greater choice in battery location, because it need not be sited near the PV inverter.
Some types cannot operate during a power cut.	Many types can operate during a power cut.
Lower losses, because the PV's DC output is used directly to charge the battery.	Higher losses, because the PV's DC output is converted to AC then back to DC to charge the battery.
FIT income was affected, because the amount of generation is metered at the consumer unit after the battery has absorbed some of it[2].	FIT income was unaffected, because the amount of generation is metered at the consumer unit before the battery absorbs any[2].

Table 1 Features of DC and AC coupled battery/PV systems

3.4 Controllers

Battery storage systems include a controller which may be integral with, or separate from, the battery itself. The controller governs the flow of energy to and from the battery, controls its charging/discharging pattern, ensures that the battery is operating safely and at the correct temperature, and automatically keeps it in good condition. Many controllers can also communicate with the manufacturer and/or resident via the internet, to enable remote monitoring.

4 The technical considerations

Issues such as size, weight and location have been discussed in chapter 3. This chapter outlines the main technical factors affecting the selection, installation and operation of battery storage systems in the home.

Understanding the many parameters involved and correctly selecting the right battery system for the specific home is the job of specialists, and it is essential that house builders use appropriately qualified system designers and installers when specifying battery storage systems (see chapter 5). It is nevertheless important that the house builder understands the basics, and ensures that the important questions have been asked on behalf of the purchaser.

4.1 Power

The power, or output level, of a battery storage system is expressed in kilowatts (kW) and is the total household electrical load that the battery can supply at any point in time. The higher the power, the more electrical appliances that can be supported by the battery before grid electricity is needed. For context, typical kettles and tumble driers may have a power consumption of 2.5kW, electric cookers around 1.0kW, fridge-freezers just less than 0.1kW and smartphone chargers only 0.005kW; this means that a typical battery storage system with an output level of 5kW would be able to power a kettle, cooker, fridge-freezer and as many smartphone chargers as one is likely to have in the home, but not at the same time as a tumble drier.

4.2 Capacity

The capacity of a battery is the amount of electrical energy that it can store. It is commonly expressed in kilowatt-hours (kWh), although a variety of technical units such as amp-hours (Ah) and C-rate ('Cx' or 'xC') are also used in slightly different contexts. The choice of which units to use is a matter for the manufacturers and specialists, but it is very important when comparing battery systems that the units are the same in both cases – you should only ever compare Ah with Ah, C-rates with C-rates or kWh with kWh. For simplicity this guide uses kWh throughout; a more detailed discussion of the different units is contained within reference 3.

The capacity required for a particular home depends on a number of factors including the size of the connected PV array (if present), the household composition (number of people), their pattern of appliance use and whether or not power cut backup is required (and for how long). The capacity of a battery storage system is therefore largely dictated by what features are required by households, and because capacity also affects price a compromise is often necessary.

If a battery is undersized in terms of capacity, it will not be able to store all of the surplus PV generation. In that situation, while the unstored PV generation will be successfully exported to the grid, the amount of energy stored will be less likely to meet household needs (see Figures 7 and 8). If, on the other hand, the battery is oversized then its cost will be higher than necessary, and it may not be able to charge/discharge optimally.

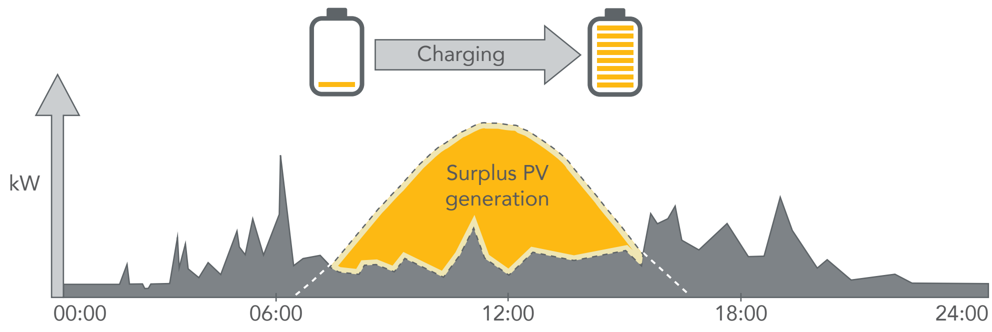


Figure 7 The operation of a correctly-sized battery: all of the surplus generation is stored

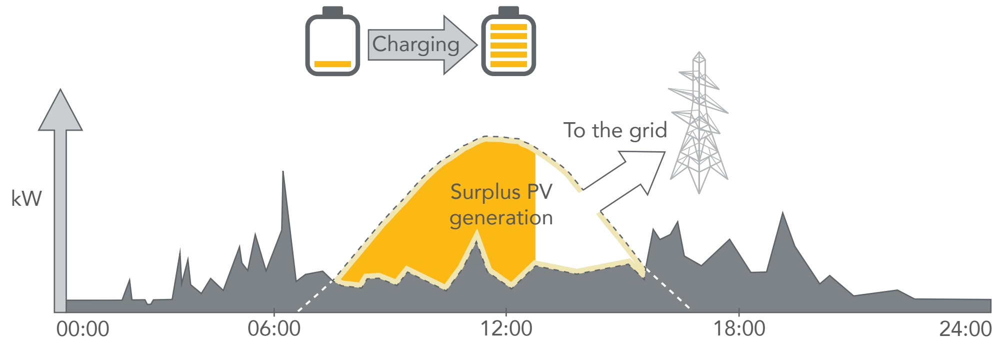


Figure 8 The effect of an undersized battery: surplus in the white area of the generation profile cannot be stored and has to be exported

Usable capacity

Many batteries retain some charge to keep themselves in a 'healthy' condition, and cannot be discharged fully. This retained charge may serve to power the maintenance of the battery and/or to avoid battery deterioration caused by deep discharge. To protect a battery's performance, manufacturers therefore recommend a maximum depth of discharge (DoD) for their batteries. This means that the amount of battery capacity available to the resident (its usable capacity) is less than the full capacity of the battery, and in some cases significantly less.

Figure 9 explains the terms full capacity and usable capacity for a hypothetical battery type with a recommended/programmed depth of discharge of 80%.

To ensure satisfactory performance of the battery system and manage the expectations of home buyers, builders should always check that storage capacity quoted by manufacturers is the usable capacity and not the full capacity.

In some cases manufacturers may offer improved warranty periods if batteries are programmed to operate with specified lower depths of discharge (and consequent lower usable capacities).

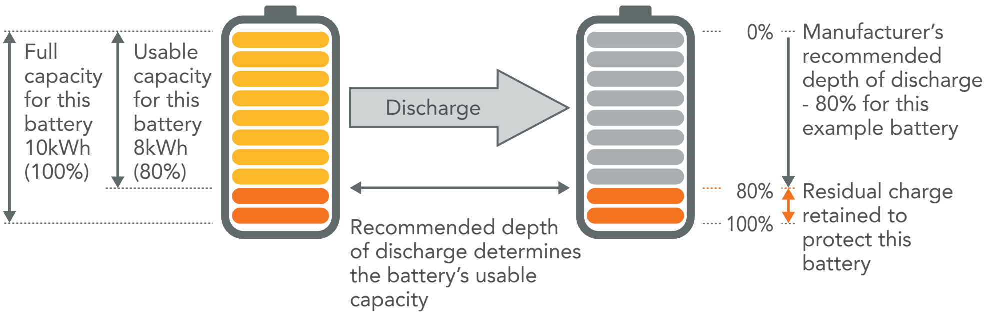


Figure 9 Relationship between full capacity, usable capacity and depth of discharge. Example is a hypothetical battery with a full capacity of 10kWh

Note: The recommended depth of discharge varies markedly between different battery types.

4.3 Understanding the relationship between power and capacity

Power and capacity are both of critical importance when selecting a battery system for a particular household. The ability of a battery to fully power a home for any specified period of time, without the need for grid electricity, depends critically on a resident's pattern and extent of use of their electrical appliances. In order to be certain that the battery can meet the needs of the home, it is necessary to consider the rated power of the individual appliances, the times at which they are used, and both the output power and usable capacity of the battery.

Figure 10 introduces how a home might require power during an evening and how the use of successive appliances gradually draws on the capacity of the battery, until it is exhausted. This chart should not be used for selecting a battery system, however it gives a reference point for judging how a battery might perform against a reasonable occupant expectation: for example, that a fully-charged battery would provide all or most electricity for one evening.

The horizontal orange bars in the top part of Figure 10 indicate the times that an example household might use its electrical appliances during a typical evening, with the thickness of a bar representing the appliance's rated power. The vertical blue bars shown in the lower part of Figure 10 show the resulting peak electrical loads across the evening in kW (ie. within each half hour interval, the highest sum of power ratings for appliances in use at any point in time). Ideally the peak load would not exceed the maximum output power of the battery, although this does inevitably occur at certain times for many batteries on the market today. When it does occur, the system automatically draws on the grid, with an associated purchase cost.

The numbers shown in the column on the right hand side show the energy (in kWh) consumed by each appliance in the course of the evening, with the grand total shown at the bottom. If this grand total energy consumption is no greater than the usable capacity of the battery, then the battery alone can provide all of the home's electrical energy for that evening (provided that it starts the evening fully charged and also that its power output is not exceeded by peak electrical loads at any time).

If, however, the total energy consumption over the evening were to exceed the usable capacity of the battery system, then the additional energy would be automatically imported from the grid, again with an associated purchase cost.

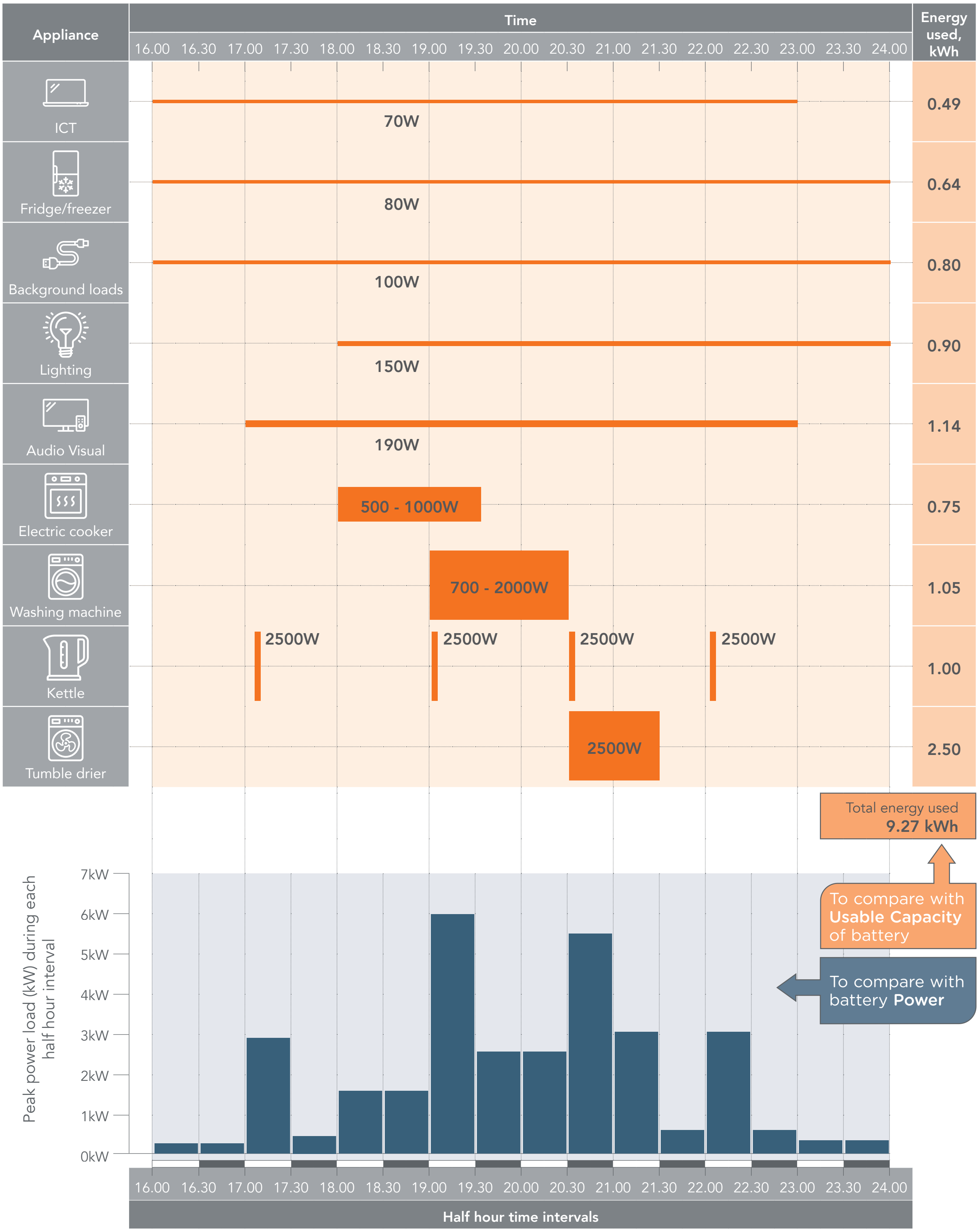


Figure 10 Matching household loads to battery capacity (top) and power (bottom)

Note: This profile is one example of how a household's electricity demand might vary over an evening, and how much electrical energy would be used in total as a result of the shown pattern of appliance switching. The example uses realistic figures for appliance power ratings, but is intended for illustrative purposes and does not represent any specific household composition or type of home. The figures in this diagram should not be used for sizing battery storage systems or electrical circuits, nor for obtaining installation quotes. Expert advice should always be sought when making technical or financial decisions related to battery systems.

4.4 Grid (or network) charging

Under certain circumstances a battery may periodically need to be charged by grid electricity in order to be maintained in good condition. The control system will manage this automatically, and no action is needed from the house builder or resident.

4.5 Round-trip efficiency

The type of battery and the coupling of the system (described in chapter 3) affect the amount of energy that is lost during a 'fully-charged to fully-discharged and back to fully-charged' cycle. The ability of the system not to lose energy during this cycle is expressed as its 'round-trip efficiency' (expressed as a percentage), the higher the figure the better. In practice there is little that the house builder can do to influence this, but it is worth checking that the system designers/ installers have maximised the system's round-trip efficiency.

4.6 Power cut backup

Certain battery storage systems can provide backup for some or all of the home's electrical circuits during a power cut. The system's power and usable capacity will govern the number and type of appliances that can be supported, and for how long. The period during which the batteries alone can supply the home is likely to be relatively short (hours rather than days), and in some cases the batteries may not be able to power all of the home's electrical loads.

One solution is to use separate wiring circuits for essential loads and non-essential loads. 'Essential' loads are those that will be powered by the battery during a power cut (perhaps fridge/freezers, lights, internet routers and smartphone chargers), and non-essential loads are those that will not be needed during a short power cut (typically higher power items such as washing machines and tumble driers). Separation of the circuits is commonly achieved as shown schematically in Figure 11, by installing two separate consumer units and an isolator switch that automatically disconnects the battery from the non-essential loads and the grid during a power cut.

The essential loads can be wired as either DC or AC circuits (not to be confused with the DC or AC coupling described in chapter 3), although in practice today's new homes will generally be wired for AC loads throughout, as shown schematically in Figure 11. Special earthing arrangements are required for power cut backup[3,4 and 5].

House builders should not exaggerate the benefits of power cut backup to their customers if an installed system has been sized, for example, to keep just fridge/ freezers, smartphone chargers and internet routers running but not allow heaters or dishwashers to be used. The likelihood of power cuts (more likely in rural locations), and the importance of keeping at least part of the home powered during a power cut will determine whether or not the additional expense of providing power cut backup is warranted.

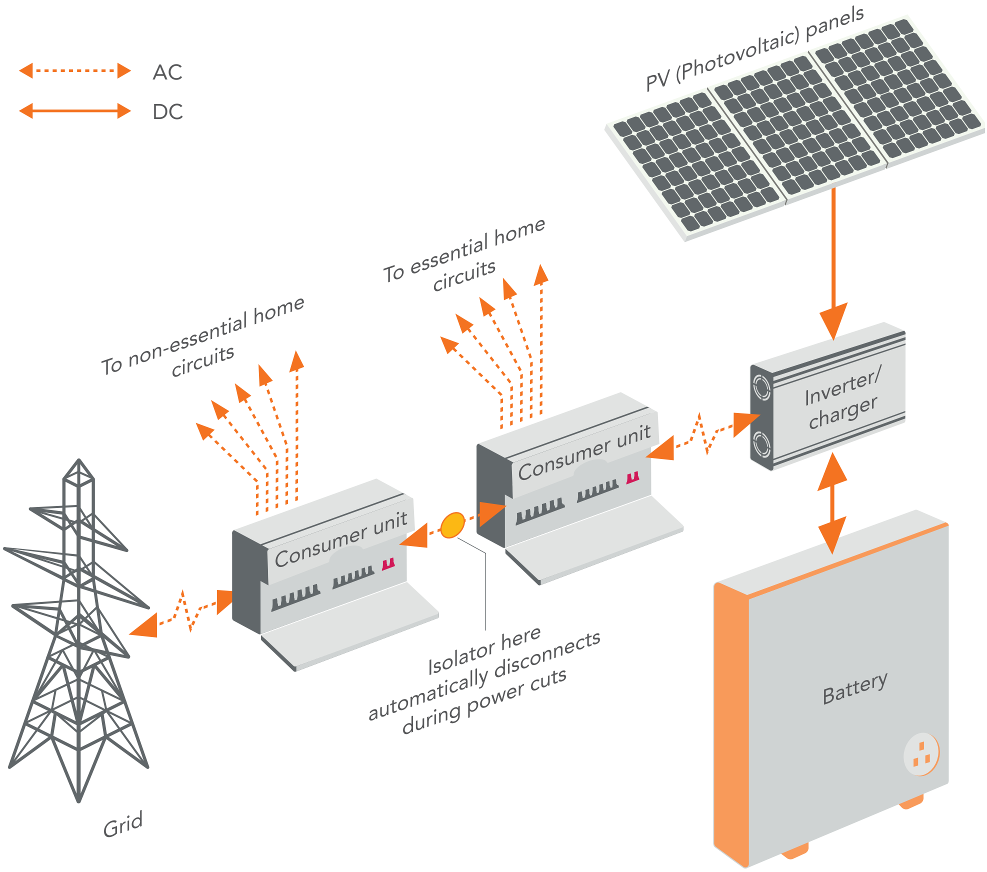


Figure 11 Wiring of essential and non-essential loads for power cut operation. This shows an arrangement suitable for a DC-coupled PV and battery

Safety and power cut backup

In order to avoid injury to operatives working on the grid, there are strict regulations about how (and how quickly) battery systems which operate during power cuts must be disconnected from and reconnected to the grid. There are also regulations on how the home must be earthed whenever it is isolated (referred to as 'islanded') from the grid.

Three key documents with which designers and installers should be familiar are listed in the references[3,4 and 5].

4.7 The future of consumer units (distribution boards)

Today's consumer unit technology provides reliable circuit protection and has served its purpose well for many decades. In future, when a home might include PV generation, battery energy storage, electric vehicle charging, increased levels of home automation and with surplus electrical energy flowing back into the grid, a traditional consumer unit would not be able to accommodate all of these features within the existing design.

The traditional consumer unit can be mounted in various locations in a current new-build home, but future installations will require extra connection points and the associated circuit protection to accommodate the new functions. This could easily double the size of the consumer unit, which means that the physical location of the unit needs careful consideration.

Moreover, residents are unlikely to install all of the new technology at once, in which case the expansion of the consumer unit will occur gradually. Future consumer units will therefore need to be able to accept additional modules which can be integrated into the design while maintaining the necessarily high levels of quality and safety. The integration of new circuitry in this way also means that the consumer unit must, from the beginning, be located where it is possible to add additional cabling over time.

4.8 Safety

Batteries have occasionally been known to leak, catch fire or even explode, and there can be a significant amount of energy stored within them. They may contain toxic substances, and can emit flammable gases. Batteries must have appropriate isolators, correctly rated cables and over-current protection. Systems should be designed and installed according to the manufacturer's recommendations, and must also be in accordance with all applicable standards, regulations and codes of practice (see in particular references 3, 4 and 5). The correct hazard signage should also be put in place.

Construction site managers should ensure that site briefings cover the presence of battery storage systems, and house builders' legal teams should check that their builders' insurance covers the implications for the site and its operatives. Sales staff should always recommend to residents that they inform their household insurers that the home contains a battery storage system; Home User Guides (HUGs) should also contain this advice, along with a dedicated section on the safe operation and maintenance of the battery system.

4.9 Installation, commissioning and maintenance

House builders' contracts departments should check that all designers and installers commissioned to carry out battery work are appropriately qualified, and have undertaken any specific training provided by the manufacturer of the system in question. Normal site practice regarding workforce induction and supervision also applies.

As noted in section 3.2, battery systems are heavy. A design check should therefore be carried out to ensure that they do not exceed the loading capacity of the structure that supports them. This applies to all floors and ceilings which are intended to support the battery, or any wall on which they are mounted (including brackets or fixings). A home's design may need to be refined or modified to support batteries in specific locations.

Some batteries are tall and require vertical restraint to prevent them toppling and causing injury or damage. The installer is responsible for providing the vertical restraint system and for anchoring securely to a suitable structural element.

Locating a battery system in an attic is likely to require adaptation to cope with the load of a battery system. Even ground floor screed floors may be overloaded by heavier loads, eg. from an installation of two or more heavy batteries together.

Following installation, site managers should ask installers to provide verification that the battery storage system has been commissioned according to the manufacturer's recommendations (which will vary from system to system). Generic guidance on what should be carried out during testing/commissioning/handover is given in reference 3. This includes standard electrical tests and advice to check for the correct functioning of the following items (where applicable):

- thermal management systems
- ventilation systems and controls
- fire detection and management systems
- ancillary equipment such as pumps, valves, etc
- data acquisition and control systems, including internet connectivity
- displays and alarms
- wet chemical status, eg. hydrometer checks on lead-acid batteries
- the basic charging and discharging of the battery.

Systems designed to provide power cut backup will usually have further commissioning requirements including those relating to the speed and effectiveness of isolation from the grid, the backup earth connections and their islanded voltage and frequency. Installers should follow the manufacturers' instructions and standard electrical installation guidance[3,4 and 5].

Sales staff should ensure that the Home User Guide states that maintenance must be in accordance with the manufacturer's recommendations, and explains any maintenance or safety issues that are the responsibility of the resident. If applicable, the HUG should also describe how particular battery systems automatically maintain themselves and report alarm conditions to the manufacturer and/or resident via the internet.

4.10 Lifetime and warranties

The lifetime of a battery depends on several factors such as the number of charge/discharge cycles undertaken, the typical depth of discharge and the temperatures to which it has been subjected. Many of these factors are governed automatically and are outside the control of the house builder, although it is important to note that incorrect sizing by the designer or installer can lead to a shorter battery life.

Battery manufacturers typically make assumptions on these key factors and guarantee the battery for a fixed period of time. The guarantee may be in the form of a reducing capacity (eg. 'guaranteed to provide 60% of original capacity after 10 years or 2,000 cycles, whichever comes sooner').

End-of-life issues are important. Lead acid batteries are over 95% recycled.

Lithium ion batteries, on the other hand, are not currently recycled in any great numbers. This is partly because of the economics, but also because not many installed lithium ion batteries have yet reached end of life. Battery manufacturers nevertheless have to meet stringent regulations such as the Waste Electrical and Electronic Equipment (WEEE) regulations and the Waste Batteries and Accumulators regulations.

Home User Guides should advise residents of the need to deal with expired batteries appropriately.

4.11 Electric vehicles

With the advent of the electric infrastructure described in chapter 1, electric vehicles (EVs) will become commonplace. This is also being driven by the government's intention (at the time of writing) to ban the manufacture of petrol and diesel cars and vans from 2040.

The charging of an EV at home can have a very significant impact on how much of a household battery's stored electricity is available for use within the home itself. A typical small family car has a 40kWh battery, which is much larger than the capacity of most home battery storage systems. The corresponding fast home charger would have a power output of around 7kW, which also exceeds the power available from many household battery systems. As a result, charging an EV will have a major impact on the usage profile shown in Figure 10. If car charging is a priority, existing household battery systems may not be able to fully charge an EV overnight but could provide a useful top-up. Designers could increase the capacity and output power of the household battery system if it is known that an EV charging point will be specified.

'Vehicle to grid' technology (see chapter 6) is developing rapidly at the time of writing. This opens up new opportunities for residents but further reinforces the need for house builders to take expert advice when specifying battery storage systems in a home that also contains a car charging point.

4.12 Building Regulations Part L (and devolved equivalents)

The DER/TER compliance method of Building Regulations Part L and the associated SAP ratings and Energy Performance Certificates are, under SAP 2012[6], unaffected by the existence of a battery storage system. There is a proposal that the version to be known as SAP 10 will give some benefit to battery storage systems, but the details were not finalised at the time of writing.

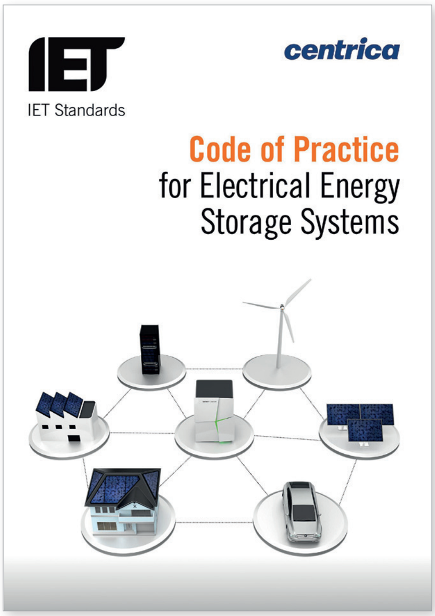
Further detail for designers and installers is given in the Institution of Engineering and Technology's Code of Practice for Electrical Energy Storage Systems[3]

5 Industry standards and specifications

House builders need to ensure that their system designers and installers comply with all relevant standards, regulations and codes of practice. Electrical installers may self-certify their work to meet Building Regulations requirements if they are members of an appropriate government-approved competent person scheme; the schemes currently applicable to electrical work are listed in the references[7].

This chapter and the references show a selection of the applicable standards, regulations and codes of practice, even though the house builder may not need to understand all the detail themselves. For example:

- Design offices and battery installers should act according to the Institution of Engineering and Technology's Code of Practice for Electrical Energy Storage Systems[3]. The code provides the next level of technical detail on many of the issues that are discussed in this guide (and more). Appendix D of the code lists 24 relevant standards with which designers and installers should also be familiar.
- Electrical installers should as a matter of course comply with British Standard BS 7671 which covers the wiring of electrical systems in general. The 2018 edition contains a new Appendix 17, 'Energy Efficiency', which concerns local generation and energy storage[4].
- Electrical installers would also be expected to comply with British Standard BS 7430 relating to earthing arrangements. Consideration of earthing is particularly important if a battery system is intended to provide islanded operation (power cut backup)[5].
- At the time of writing, the government-supported Microgeneration Certification Scheme (MCS) was considering developing a certification scheme for battery storage systems. Such a scheme can provide the protection necessary to ensure that battery systems are specified, sold and installed correctly, helping to ensure satisfactory performance in use. The current status of the MCS scheme can be found at **www.microgenerationcertification.org.**
- There are many more documents with which house builders, installers and designers may wish to familiarise themselves. A representative list is given in the references[8].



6 What's on the horizon?

There are a number of currently emerging technologies, and countless more on the horizon.

The following technologies are already in use in limited numbers, and are set to increase in take-up:

- Owners of battery storage systems will increasingly be able to participate in 'peer-to-peer trading', using their storage system in conjunction with a smart meter to join 'microgrids' and local energy trading schemes. In a similar way residents will be able to participate in demand-side management (DSM) grid balancing schemes run by 'aggregator' companies. Both activities can provide a source of income or additional savings for residents[9].
- Owners of electric vehicles will be incentivised to participate in grid balancing activities at the national scale (known as 'vehicle-to-grid', or V2G, services). Contracted energy suppliers and generators would charge and discharge the batteries of privately-owned EVs at times of their choosing, with some form of guarantee that the vehicle will be fully charged by a specified time of day[10].
- EVs might also be used in principle as an integral part of the battery storage system for the actual home to which they belong, possibly even eliminating the need for a separate battery in the home. The drawbacks are obviously that the vehicle's battery is not connected to the home continually, and that the vehicle might not be fully charged when needed. Some vehicle manufacturers do not recommend this mode of operation.
- Community battery schemes are becoming more common, in which the costs and benefits of PV panels and a large, centralised battery storage system are shared between multiple homes.

In addition there are many novel energy storage technologies, some of which are currently deployed in industrial situations but which may in due course break through to the household market. These include:

Flow batteries, where the energy is stored in liquid 'electrolytes' in external tanks, and is regenerated by pumping the electrolytes through a cell that produces electricity. As a result, flow batteries can be charged and discharged simultaneously. Unlike many conventional batteries, flow batteries contain only non-flammable, non-toxic chemicals, and have potentially limitless lifetimes. They are likely to apply to community-scale developments rather than individual households.

Metal air batteries, in which one of the electrodes is metal and the other is air which is drawn in from the atmosphere. Metal air batteries have the potential to be extremely light, and with an energy density far higher than conventional batteries.

Supercapacitors, which can undergo hundreds of thousands of charge-discharge cycles (as opposed to a few thousand), giving them a long lifetime. They also work at high powers and high load currents, and as a result can achieve a very fast charge – sometimes in seconds. Supercapacitors have a low energy density however, which means that they cannot deliver power for as long as an equivalent conventional battery.

Flywheels, which can be spun up like an electric motor to tens of thousands of rpm using surplus electrical energy, storing the energy as kinetic energy for as long as they remain spinning. To recover the energy the flywheel acts like an electromechanical generator, gradually slowing down as it produces power for the home. Some flywheel energy storage systems originate from the motor racing industry. They have the benefits of being small, light and free of toxic metals and chemicals, but they require strong containment vessels in case of mechanical failure.

Compressed air energy storage (CAES) are a way to store surplus energy by compressing air and storing it under pressure. The compressed air can then be released and run through turbines to generate power when it is needed. CAES plants currently tend to be on the very large scale, storing the compressed air in underground caverns for example, but research is underway to miniaturise the technology.

Heat-based electrical energy storage systems, a number of which are emerging. Smart electric thermal storage (SETS) systems convert surplus generation to heat, which is stored directly in ceramic materials in a similar way to conventional storage heaters, and released to provide space heating when needed. The efficiency is relatively high because there is only one energy conversion – from electricity to heat – although heat losses from the thermal store can offset some of the gains. Another technology, 'heat batteries', use surplus generation to alter the state of phase-change materials, effectively melting a solid to store energy and subsequently recovering the energy as heat when the material re-solidifies. Heat batteries are used to provide hot water for space heating and domestic services.

Hydrogen may also have a part to play in future. It can be produced by using surplus electricity generation to electrolyse water, and is stored in cylinders or pressurised tanks. It is subsequently burnt in a space-heating boiler, or used in a fuel-cell combined heat and power (CHP) unit which provides electricity and heat simultaneously. The challenges of storing and using hydrogen safely may make it more suitable for industrial rather than domestic applications.

Figure 12 Supercapacitor (top), heat battery (left) and flow battery (right).

Glossary and abbreviations

AC	Alternating current.
Battery storage system	An integrated system comprising the battery, its control circuitry and any ventilation/cooling equipment.
Capacity	The amount of electrical energy that can be stored in a battery, in kilowatt-hours (kWh). See also 'full capacity' and 'usable capacity'.
Charger	An electrical/electronic device that converts AC to DC and controls the rate and amount of battery charging.
Coupling (AC and DC)	The two different wiring arrangements for connecting a home's battery storage to its PV installation.
Controller	An electrical/electronic device that governs how battery storage systems and/or PVs operate, including with the home and the National Grid. Sometimes known as a 'gateway'.
DC	Direct current.
Depth of discharge (DoD)	The specified level of discharge that must not be exceeded (in order to protect the long-term performance of a battery or meet warranty conditions).
DSM	Demand side management (or grid balancing) – reducing or increasing electrical loads according to the status of the National Grid.
Essential/non-essential loads	The household electrical loads which are or are not supported by a battery storage system in the event of a power cut.
EV	Electric vehicle.
Energy density	The amount of electrical energy that can be stored per given physical size of battery. Varies by battery type (lithium ion, lead acid, etc). For different batteries with the same capacity, the one with the highest energy density will be the physically smallest.
FITs	Feed-in-tariffs.
Full capacity	The total amount of electrical energy that can be stored in a battery (always more than its usable capacity).
Gateway	See 'Controller'.

Grid balancing	See 'DSM'.
Grid (or network) charging	The situation when a battery is (automatically) charged from the National Grid rather than from PVs. May occur for DSM reasons, or to keep the battery in good health.
Inverter	An electrical/electronic device that converts DC to AC. Used to convert the output from a battery or PVs for use within the home or for export to the National Grid.
Inverter/charger	An electrical/electronic device that combines the functions of an inverter and a charger. Effectively a converter that works in both directions (AC to DC and DC to AC).
Islanded operation	The situation when a battery storage system is operating in physical isolation from the National Grid (ie. during a power cut).
kW	Kilowatts, a measure of power
kWh	Kilowatt-hours, a measure of energy
Lead acid	A common type of rechargeable battery containing metallic lead and dilute sulphuric acid in liquid or gel form. Based on the traditional car battery. Currently cheaper but with lower energy density than a lithium ion battery of the same capacity.
Lithium ion	A newer type of rechargeable battery based on lithium compounds. Does not contain metallic lithium. Currently more expensive but with better energy density than a lead acid battery of the same capacity.
Peer-to-peer trading	Potentially buying and selling electricity directly between households without involving a mainstream energy supplier.
Power	The rate at which a battery can charge or discharge, in kilowatts (kW).
PVs	Photovoltaic panels.
Residual charge	The amount of electrical energy that is left in a battery when it has been discharged (ie what remains after its usable capacity has been depleted)
SETS	Smart electric thermal storage.
Time-of-use (ToU) / time-of-day (ToD) tariffs	Electricity pricing mechanisms that provide an incentive to the end-user to move their consumption to periods of the supplier's choosing.
Usable capacity	The part of a battery's capacity that is actually available for use within the home. Usually less than its full capacity, because many types of battery should not be discharged fully.
V2G	Vehicle-to-grid. Using an EV's internal battery to provide services such as DSM to the National Grid.

Notes and references

1 Electricity Storage and Renewables: Costs and Markets to 2030. International Renewable Energy Agency (IRENA). October 2017.

2 The current FIT arrangements are programmed to terminate at the end of March 2019. At that point the FIT advantage of AC coupling over DC coupling will no longer be a consideration. If FITs are re-introduced in future years the exact mechanism cannot be predicted, so nor can any potential FIT advantage for either form of coupling.

3 Code of Practice for Electrical Energy Storage Systems. Institution of Engineering and Technology (IET). 2017. In addition, Appendix D of this code lists a further 24 pertinent standards.

4 BS 7671:2008+A3:2015. Requirements for Electrical Installations, IET Wiring Regulations. BSI. 2015. This is largely an umbrella standard that also references BS7430 (below). BS 7671 is due for revision 2 July 2018 as BS 7671:2018, intended to come into effect on 1st January 2019.

5 BS 7430:2011+A1:2015. Code of practice for protective earthing of electrical installations. BSI. 2011.

6 The government's standard assessment procedure for energy rating of dwellings 2012 edition version 9.92, dated October 2013 revision June 2014. Department of Energy and Climate Change (now BEIS). 2014.

7 Competent person schemes applicable to electrical work are, at the time of writing, operated by Building Engineering Services Competence Assessment Limited (BESCA), Certsure LLP (trading as Elecsa and NICEIC), NAPIT Registration Limited and Stroma Certification Limited. None of the schemes are specific to battery technologies, although they do include elements relating to microgeneration and renewable technologies.

8 Further publications of interest include:

- BSI committee reports on Electrical Energy Storage in general, ESL 120: **https://standardsdevelopment.bsigroup.com/committees/50254741**
- Energy Networks Association (ENA) guides G59, G83 (due to be re-published as G98 and G99) and G100. These concern export to the grid, and how connections may be more straightforward if installed with export limits: **http://www.ena-eng.org/ENA-Docs/**
- Battery energy storage systems with grid-connected solar photovoltaics, BR514. BRE. September 2017.

9 For examples of pioneering peer-to-peer trading networks and DSM schemes, see **https://sonnenbatterie.de/en/sonnenCommunity** **http://www.moixa.com/ufaqs/what-is-gridshare/**

10 One such V2G scheme is described in **https://www.theguardian.com/business/2017/oct/02/electric-car-battery-savings-nissan-leaf-ovo**

Further information

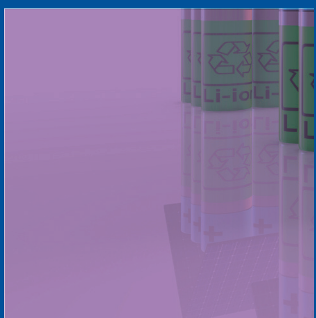
Additional guidance is available from RECC (Renewable Energy Consumer Code)
https://www.recc.org.uk/storage

Watts in store?

Introduction to energy storage batteries for homes

As the UK transforms to an energy infrastructure based on electricity, with increasing reliance on renewable sources, the wider use of battery technology is anticipated. A range of domestic scale energy storage batteries are now available with the potential to reduce energy costs for households and ultimately contribute to the resilience of the grid.

This introductory guide is for house builders considering the installation of a battery system. It highlights the practical and technical considerations when selecting batteries, including the common scenario when coupled with photovoltaics.



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