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Batteries and Solar Power:
Guidance for domestic and small commercial consumers

BRE NATIONAL SOLAR CENTRE

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RENEWABLE ENERGY CONSUMER CODE

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Principal Author: Sue Bloomfied, RECC

Secondary Authors: Chris Roberts, Poweri and Martin Cotterell, BRE National Solar Centre

Editors: Chris Coonick and Jonny Williams, BRE National Solar Centre, Virginia Graham, RECC

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If you have concerns about a particular solar installation, please contact RECC via www.recc.org.uk

Cover images are from Fronius and Victron (image of domestic solar storage system at BRE Innovation Park at BRE, Garston, Watford, see www.ipark.bre.co.uk)

Image: Schneider Electric, a domestic installation for a large house or small commercial application

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1. Introduction

Batteries designed to capture surplus electricity generated by your solar PV system allow you to store solar electricity for use later in the day. This guide sets out the main features you might need to take into account when deciding if a battery storage system is suitable for you and your solar PV system. Included are 20 questions to ask your installer should you consider a battery system.

Potentially batteries can help you use more of the electricity generated by your PV system, saving you money on your electricity bill. But they're not for everyone, as you generally need to be generating 'surplus' solar electricity to store. It is also important to note that, contrary to expectations, some battery storage systems are not designed to work during power-cuts. In addition they are not cheap: at today's prices, poorly designed systems may not repay their initial investment (in what they save on electricity bills). But prices continue to fall and the technology is also improving, meaning that battery storage is becoming a viable economic option for some households and businesses.

1.1 This guide

This guide is designed to help you decide if a battery storage system makes sense for you. It covers:

- the basics of battery storage for solar PV systems

- what you need to consider to work out if they are for you

- where you can find more information and

- the questions you need to ask any prospective installer.

NB There is no MCS standard for battery storage systems so you won't find an MCS-certified system. But UK technical and installation standards are currently being prepared.

In the meantime, you should make sure any installer of storage batteries for solar PV systems is a qualified electrician. If they're installing your solar PV too, check that they are MCS-certified - http://www.microgenerationcertification.org/consumers/installer-search

For more technical information please refer to the BRE National Solar Centre publication "Batteries and Solar Power: A Technical Guide" and the forthcoming publications from IET on battery storage systems.

2. Storage for solar PV systems: the basics

2.1 Your solar PV system

The solar PV system on your roof will generate electricity during the day that you can use in your home. Without a means of storing that solar electricity, any surplus energy that you don't use is 'exported' to the local electricity grid. During times when the panels are no longer generating (or not generating enough for your needs), you need to buy electricity from your electricity supplier.

2.2 Solar PV plus storage

'Energy storage' lets you store the surplus solar electricity, instead of exporting it. Battery storage lets you use more of your solar PV system's output (in the jargon, it 'increases 'self-consumption'). This reduces the amount of grid electricity you need to buy, saving you money on your electricity bill.

During the day :

- the solar PV system generates solar electricity
- the battery storage system will check if all the generation is being used to power your lights and appliances
- if you're not using all the electricity that the solar PV system is generating, then the system will ensure that any surplus energy is used to charge the battery
- once the battery is fully charged, if there is still more solar electricity being generated, this will be exported to the grid (or in some systems, will be diverted to other uses e.g. to an immersion heater)

In the evening or at time of low solar generation:

- the solar PV panels have a reduced or zero output
- the battery system can discharge the stored electricity, providing you with renewable-generated electricity at no additional cost
- once the battery is discharged, if you need to use more electricity, you buy it from your electricity supplier

3. Storage for solar PV systems: the batteries

3.1 Battery types

The two types of batteries most commonly offered for solar PV storage in the home are lithium-ion and lead-acid batteries.

Some of their key features and differences are set out here:

Lithium-ion batteries (commonly found in electronic devices such as laptops and mobile phones)	**Lead-acid batteries** (used in cars)
• More expensive • Increasingly common in domestic grid-connected solar PV storage systems • Lighter • Require integrated controller, that manages charge / discharge • More efficient • Can discharge more stored energy • Longer expected lifetime	• Cheaper • Typically used for off-grid properties where more storage is required • Heavier and larger • Need good charging and discharging routine to maintain battery health • Less efficient • Shorter expected lifetime

Examples of battery systems from Enphase and Wattstor (Lithium Ion and Lead acid based systems)

Batteries and battery systems can vary considerably in shape, size and weight. The greater the battery capacity, the greater the battery size and weight. Typical domestic systems vary from being the size of a small computer to the size of a washing machine.

3.2 Battery capacity

Battery storage systems are often provided with a power rating in kiloWatts (kW). Storage batteries for a grid connected solar PV storage system are typically around 1kW to 7kW. This is the capability of the battery to provide power.

A battery's stated electricity capacity, as expressed in kilowatt-hours (kWh)[1] is generally larger than the battery's actual useable capacity, because:

- all batteries lose some energy in charging and discharging, though some have better 'charge-discharge efficiency' than others.
- most batteries are not designed to be routinely fully discharged (can reduce battery life). Some have deeper discharge capability than others.

Typical Lead-acid battery systems may be setup to limit the 'depth of discharge' to around 50%, Lithium-ion systems to 75% or more.

'Nominal' vs useable capacity

6kWh lead-acid battery, 50% 'depth of discharge' = useable capacity of 3kWh

6kWh lithium-ion battery, 75% 'depth of discharge' = useable capacity of 4.5kWh

1 Electrical capacity can alternatively be given in Amp-hours (Ah); where Ah x Voltage = kWh

Safety note: Batteries can pose a fire and explosion risk if mistreated. They can also be heavy and difficult to move. They must only be installed in suitable locations for safe battery operation and out of the reach of children.[2]

3.3 What a battery storage system could power

A fully-charged medium-sized system could store sufficient energy to power during the evening your lights and lower-powered items like your fridge-freezer, TV and laptop. Over four or five hours, all of these together will use at most a few "units" or kiloWatt-hours (kWh), of electricity.

However, the battery will quickly run out if you put on heavy energy users like the washing-machine or tumble-dryer: these can consume 2 - 3kWh in a single use.

And in winter, the battery might not store enough to provide for even the lower-powered items for many hours (see Section 4.1 'Winter mode').

3.4 Battery lifetime

A battery's efficient lifetime depends on the technology and the way the battery is used - significantly on the number of 'cycles' (complete full battery charge and discharge) that they undergo.

Manufacturers generally give an expected lifetime in years and/or in 'charge-discharge cycles'. For example:

• 'Life expectancy = 10 years or 10,000 cycles, whichever is the sooner'

Lithium-ion batteries last longer than lead-acid: you may see a 10-year lifetime expectancy claimed and this is improving all the time.

Normally the battery storage system will monitor the battery performance and should give you an indication when your batteries need replacing.

Some battery system manufacturers operate a battery leasing and/or replacement scheme for worn-out batteries and arrange for the safe disposal/recycling of the battery.

NB Solar PV panels can last 25 years or more. The storage battery is likely to need replacing in the lifetime of your PV system

3.5 Warranties and Insurance

As with many electrical products, a warranty for a battery is normally for a shorter period than its lifetime expectancy: for example a 5 year warranty on a battery expected to last 10 years. If you install a battery storage system you must notify your provider of your building and contents insurance as they will need to know.

4. Storage and solar PV systems: how they fit together

The batteries in a solar PV storage system work like any rechargeable battery: they charge direct current (DC) from an external source (e.g. your solar PV system) and discharge DC when energy is required.

4.1 'Winter mode'

Solar PV panels generate far less energy in winter (in the UK, around 4 times less in December than in June), so the system may not generate enough surplus solar electricity to fully charge the battery during the winter months.

Leaving a battery sat partially discharged for long periods can reduce its lifetime. This is particularly the case for lead-acid batteries.

To maintain battery health, the system may have a 'winter mode' setting that during the winter puts the battery to sleep, reduces the discharge from it or charges it from the mains.

4.2 Mains-charging

Repeated incomplete charging can impact on the life of the battery. So most systems will occasionally use 'mains-charging' (drawing electricity from the grid) in order to complete the charge cycle.[3]

2 For example, the unsealed type of lead-acid battery MUST be placed in a location with ventilation.

3 If you have economy 7 or another favourable off-peak tariff, it might be possible to programme the system to top when your electricity is cheaper.

4.3 Solar PV systems without storage

Put very simply, a grid-connected solar PV system works like this:

Solar PV panels generate direct current (DC) → **A solar inverter converts this DC to alternating current (AC)** → **The generation meter records the kWh generated** → **The AC is used in the home or is exported to the grid**

Batteries also store and discharge DC, which similarly has to be converted to AC by an inverter.

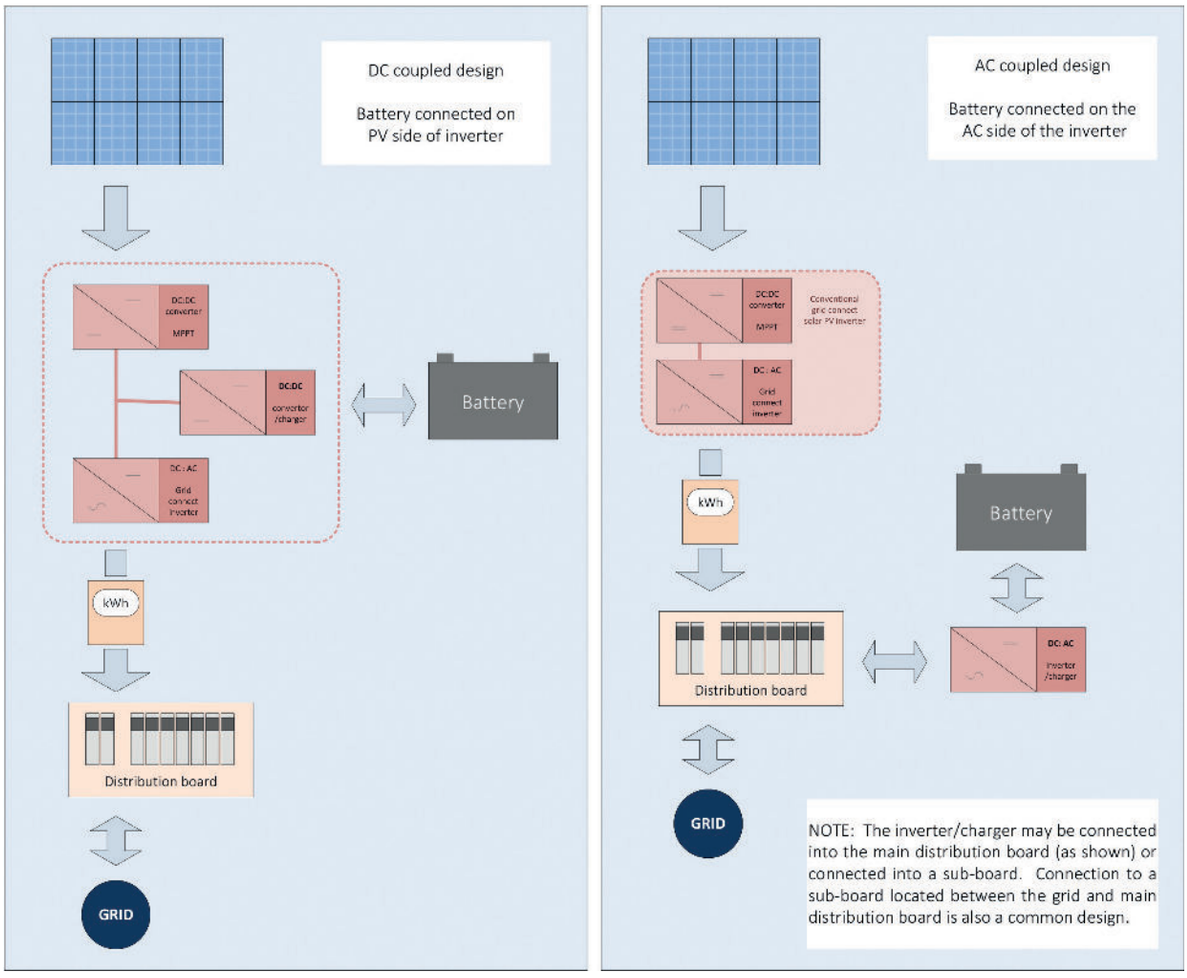
4.4 DC and AC coupled

There are two main ways of linking a battery storage system into such a system:

- DC Coupled: the batteries are installed on the same side of the solar inverter as the solar PV panels, they charge from the panels, and their DC is only converted to AC when it's used ('DC-coupled')

OR

- AC Coupled: the batteries are installed on the grid-side, where the solar PV's DC has already been converted to AC ('AC-coupled'). A separate inverter converts the AC back to DC for storing in the battery. When the battery discharges, the same separate inverter converts the DC back to AC.



Copyright: IET, Code of Practice for Grid Connected Solar PV Systems, 2015.

You're more likely to be offered an AC-coupled system if you're looking to add a battery storage system to an existing solar PV system (they're more suited to such 'retrofit' applications).

For retro-fit applications, the installer will need to verify that the new equipment being installed is compatible with the existing equipment. DC coupled systems can be installed as a retrofit but more equipment will need to be added or replaced.

You're more likely to be offered a DC-coupled system if you're installing a solar PV system and a battery storage system from scratch. Many DC-coupled systems will not operate in a power-cut (see below) and it may affect your Feed-In tariff income (see Section 5.2 'The impact on your Feed-in tariff income from solar PV').

4.5 Power-cut operation

Despite expectations, some storage systems will not provide power during a power-cut.

Some battery storage systems however do have an 'off-grid' functionality, providing a limited amount of power to your home, or to essential equipment (such as your fridge-freezer, lighting etc). But a battery may run out of power before the power cut ends – or have already run out of power if it's been discharging all evening and the power outage starts late at night or early in the morning.

If you require your battery storage system to provide power during power-cuts it is important to talk this through with your storage installer from the outset as the system will need to be carefully designed and set-up to your specific requirements.

5. Storage for solar PV systems: things to consider

If having read this far, you think storage may be for you, then there are lots of questions you should ask any prospective installer to ensure you have the correct information. There's a list of suggested questions at the end of this Guide. But before you get to that point, you might want to weigh up a few things.

5.1 Your 'load profile': how much of your solar PV generation you use/are likely to use

You may use (or already use) most or all of the electricity generated by your solar PV system during the day, for instance if:

- you are at home during the day and/or
- you set energy-intensive appliances on timers to run during the day and/or
- you divert some of the electricity, for example to an immersion heater to heat hot water.

In this case, your 'self-consumption' of the solar PV electricity is already high. And your 'load profile' – when you use electricity and how much you use – means you won't have much (or any) surplus electricity from your solar PV system to store in a battery. Information on how much solar electricity you export to the grid at different times of the year is useful to have when considering these points.

5.2 The impact on your Feed-in tariff income from solar PV

Currently, the UK Government encourages the take-up of solar PV with financial incentives, the Feed-In Tariff (FIT) scheme. There is no incentive scheme for installing a battery storage system. In fact, a battery system may reduce your actual or potential FIT.

The generation FIT is paid for every kWh generated by your solar PV system, as measured by your solar generation meter. In addition, the scheme estimates (or 'deems') that half of this will be exported back to the grid and pays an export tariff on that 'deemed' 50%.

In 'DC-coupled' battery storage systems (the arrangement most likely if you're installing solar PV and storage together), the solar electricity that goes to charge the batteries isn't registered by the generation meter at the time, but only when it is subsequently discharged by the batteries or when the batteries are full[4]. Since all batteries lose energy in the charge-discharge cycle, some of the original solar PV output will be lost in the process. This will impact on your FIT payments.

4 In an AC-coupled system, the battery effectively sits further down the chain. The generation meter registers all of the solar PV output before any goes to charge the battery.

Your FIT export tariff income will currently be unaffected if you store, rather than export, surplus solar electricity. It is paid on the 'deemed' 50% of your solar PV system's output, regardless of how much electricity you actually export. This may change in future. Smart meters are being rolled out to every home over the next few years. These meters will be able to measure how much you actually export so export payments could instead be paid on that, rather than a 'deemed', amount[5]. In those circumstances, every extra unit that storage lets you use at home is one less unit for export and one less export tariff payment. However the savings available through buying less electricity will still be significantly greater than the loss of export tariff.

5.3 Costs v benefits

You can weigh up the substantial costs of the battery storage system against the potential benefits.

In purely financial terms, you can compare the cost of the battery system with your estimated benefit in savings.

On the cost side, you need to take into account:

• the full cost of the system, including any running costs

• the cost of replacing the battery at least once in the lifetime of your PV panels.

On the benefits side, every kWh you use from the battery is a kWh you don't have to import from the grid and pay your electricity supplier for. How much YOU will save over the course of a year depends on your circumstances, including: your solar PV system, your 'load profile', the battery concerned, your electricity tariff per kWh.

In working out savings, remember to factor in:

• The cost of any mains-charging

• Whether your FIT generation or export tariffs are affected

• The savings won't be the same in the winter months as in the summer.

Comparing total costs with net benefits per year will show you how many years it would take for the system to 'pay for itself' or 'payback'. This is an approximate calculation only. It assumes a constant level of annual benefit over the years and does not take into account any inflation, or changes in usage, electricity prices or export tariffs.

Payback

Total cost in ££s/annual benefits in ££s = no. of years to payback.

Eg cost £3000; benefits worth £200 p.a

Payback = £3000/£200 = 15 years.

if the expected lifetime of the system is 15 years or more, the system will payback.

If it's less than 15 years, the system will have worn out before it can payback.

6. Further help and next steps

For technical information about battery storage systems for solar PV, see:
BRE National Solar Centre's "Batteries and Solar Power: A Technical Guide"

For advice, contact the Renewable Energy Consumer Code on info@recc.org.uk

If you do decide a battery system makes sense for you, it's a good idea to get several quotes, either for the battery system alone (if you are 'retro-fitting' to an existing solar PV system), or for a package of solar PV-plus-storage (if you don't already have solar PV).

- Try to make sure you're comparing like with like.

- Don't be afraid to ask lots of questions: there are 20 key things you need to know in the following section.

5 When the Government consulted on changes to subsidies for renewables in 2015, it said it intended to 'end 'deemed' exports for all FITs installations and see the entire scheme moved to export tariff payments based on actual meter reads on the completion of the smart meter roll-out'. At the time of writing (January 2016) it has said that it is not proposing to make any change to the export tariff for now but will consult on it 'in future'.

20 questions to ask your installer

With thanks to Chris Roberts of Poweri and the Solar Trade Association

1 **What battery technology does the system use?**

2. **Why are you recommending it for me?**
Advantages/disadvantages can include charge/discharge efficiency, weight, size, life expectancy, safety considerations etc.

3 **Are there any special considerations in terms of battery management / maintenance or storage location I need to be aware of?**
For example, due to their weight, some types of battery should only be located on the ground floor. Some will need ventilation as well.

4 **Does the system require replacement of my existing solar inverter? [if you have one]**

5 **Will the batteries need mains electricity to charge at any time?**
Ask for an estimate of annual demand and cost. And, if applicable, whether the system can be programmed to charge from cheaper off-peak electricity.

6 **What is the predicted lifetime of the batteries? How is this calculated?**
How many charge-discharge cycles? How many years?

7 **How will I know that the batteries are nearing the end of their life?**

8 **What guarantees apply to the system/the batteries?**

9 **How would I safely dispose of used batteries at the end of their life?**

10 **What's the cost of replacement/additional batteries?**
The batteries are likely to need replacing at least once in the lifetime of the solar panels.

11 **Can I buy replacement batteries from anywhere or do I have to buy a special type from the original system manufacturer?**
You may be able to get better value batteries if you have more options and can shop around.

12 **What is the useable storage capacity in kilo-watt hours (kWh)?**
The useable storage capacity is not the same as nominal capacity because most types of battery should not be 100% discharged as this shortens their life.
If the figure is quoted as Amp-hours (Ah), what's the voltage? Ah x V = kWh.
500Ah at 12V sounds better than 200Ah at 48V, when it is actually smaller (500 x 12 = 6kWh; 200 x 48 = 9.6kWh)

13 **What does this mean in practical terms?**
Your installer should be able to indicate what type of appliances could be operated and for how long. For example a 3kWh battery operated with an allowable depth of discharge of 80% outputs 2.4kWh (80% of 3kWh) – enough to supply 200W of lighting for approximately 12hrs.

14 **What is the charge-discharge efficiency?**
All battery systems lose some energy in the charge-discharge cycle but some technologies lose less than others.

15 **Can I add more batteries at a later date to increase the storage capacity?**

16 **Will the system give me power during a mains power-cut?**
Some systems, such as those integrated or connected to a solar inverter, will not operate during a power-cut.

17 If the system does provide power during a power cut, how will this work in practice (will I have to re-wire the house to achieve this)? And what will I be able to run?

18 Will the system affect my generation meter reading/FIT income at all?

19 Does the system incorporate a means of monitoring electricity in and out?
This could help you get the most from the system or identify if more batteries would benefit you (assuming the system can be expanded).

20 Do I need to get any permissions/notify anyone before having a battery storage system installed?
For example, your Distribution Network Operator will require notification of the battery storage system install. Others such as Ofgem and the local council may require notification.

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BRE National Solar Centre,
Eden Project,
Boldeva Road,
St Blazey,
Cornwall
PL24 2SG

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