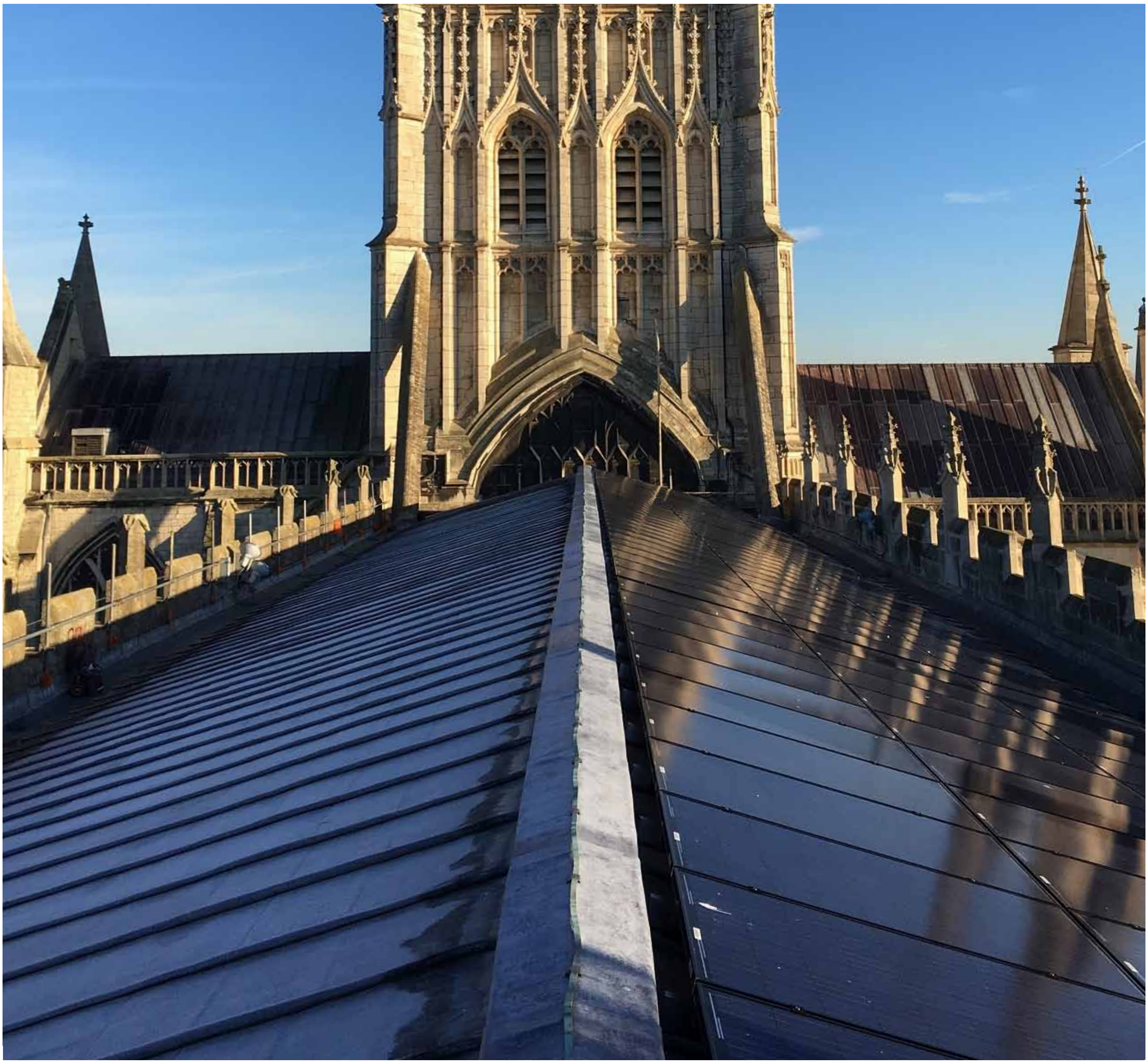
Historic England

Energy Efficiency and Historic Buildings

Solar Electric (Photovoltaics)



Summary

This guidance covers the issues associated with installing solar photovoltaic (PV) panels on a historic building or on the land of a historic site. It describes the different options available and how they work. Advice is also provided on how to minimise the potential damage to the fabric and the visual impact of a renewable installation on the character and appearance of the building or site.

This guidance note is aimed at providing advice for building owners and occupiers who are considering installing solar PV panels to generate their own energy. It will also be useful for architects, surveyors, building contractors or similar building professionals who need to make the appropriate selection of equipment and method of installation to work within a historic building.

Before installation of renewables are considered, steps should be taken to cut energy consumption. Historic England has a wide variety of guidance on improving energy efficiency in historic buildings. This document forms one of a series of notes covering the installation of renewables and low carbon technologies such as heat pumps, solar thermal and hydroelectric.

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Front cover:
Roof-mounted photovoltaic installation on Gloucester Cathedral's south nave. The solar panels are hidden from ground view by the parapet wall and crenellations, and fixed to a rail system that is weighed down by ballast above the lead roof.
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Introduction

The installation of any renewable energy source should be seen as part of a 'whole building approach' to improve the energy efficiency of a building. Taking a whole building approach is a logical process which enables the best possible balance to be struck between saving energy and reducing carbon emissions, sustaining heritage significance, and maintaining a healthy building.

The whole building approach involves creating an energy plan that takes into account all the factors relevant to a particular building and its context. It deals with specific situations as opposed to generalities. A site-specific approach considers the interrelationship between building fabric, engineering services and people. In this way it ensures that energy saving measures are appropriate, proportionate, properly integrated and cost effective and that the risks of unintended consequences are reduced. Historic England's Energy Efficiency and Historic Buildings: How to Improve Energy Efficiency provides detailed advice.

High-quality design can play a key role in minimising any adverse effects of projects. Fundamental to achieving high-quality design is a sound understanding of the character and importance of the historic asset involved, whether at the scale of individual buildings and sites or more extensive historic areas and landscapes.

The location will have an effect on what kind of microgeneration you choose: it will greatly influence what type of renewable energy source is appropriate. Issues such as the amount of sunlight reaching the roof slopes or whether there is sufficient space around the building to install a ground source heat pump will need to be considered.

Given the rapidity with which renewable energy technologies are evolving, renewable energy projects and their associated infrastructure should aim to be reversible where possible.

It is important to weigh up the cost of the installation against potential savings in energy use.

Before installing solar photovoltaics it is worthwhile considering:

- the potential visual or physical impact on the buildings historic fabric
- carrying out an assessment of all renewables to ensure that photovoltaics are the right solution for your application
- what energy you require – heating or electricity?
- the amount of energy that could be generated and what the payback period would be
- any technical risks associated with the measure
- whether you need consent: consent will most likely be needed if the installation is located on or near a listed building or within a conservation area

For historic buildings a balance needs to be achieved between generating your own energy and avoiding damage both to the significance of the building and its fabric.

1 What is a Photovoltaic System?

A photovoltaic (PV) cell is a device that converts sunlight into electrical energy. The PV cell has one or two layers of a semi-conducting material so when light shines on the cell it creates an electric field across the layers causing electricity to flow. The greater the intensity of sunlight the greater the flow of electricity.

Although PVs can still generate some electricity on a cloudy day they will only generate electricity whilst there is daylight, so the energy must either be consumed as it is being generated, stored in batteries, or exported to the National Grid.

The main components that go to make a PV installation are:

- PV panel
  This is the part you normally see on the roof of a building. It takes the sun's rays and converts that energy into electrical energy. When several panels are connected together that is known as an **array**.
- Inverter
  This converts the energy from the PV panel from direct current (DC) into useable alternating current (AC). Inverters can be central, string or micro. Micro inverters convert electricity from one panel, string inverters convert electricity from multiple panels. Central inverters are used for much larger arrays.
- Isolator
  This is needed to be able to switch the power off from the PV array when carrying out maintenance or in an emergency.
- Electrical distribution system
  The cabling, distribution board etc. which are needed to get the electricity generated to where we want to use it.
- Batteries
  These can be used to store the electricity generated for use later when it is needed.

Figure 1
A typical PV system.

The maximum power generated under ideal conditions in full sun by a PV panel is expressed in kilowatt-peak (kWp). The kWp value will vary according to time of day, month, year and location.

A typical domestic installation would be around 1.5–4.0 kWp, generating enough electricity to provide almost half of the average family's annual requirement, covering a roof area of between 10 m^2 and 25 m^2. On a church or a school, an array could be anywhere between 4 kWp and 50 kWp, and larger arrays such as King's Cross station (an area of 2,300m^2) would be 240kWp.

The kWp value is when there are perfect conditions and the sun is shining on the PV array at full strength and at an optimum angle.

In order to know how much a system will generate you need to know what the 'estimated annual output' would be. The estimated annual output is given in kilowatt-hours per year (kWh/yr).

A roof-mounted PV array in the south of England on a south-facing, inclined plane, unshaded, can generate on average 750 kWh and 1,100 kWh per year for every kWp installed. The Microgeneration Certification Scheme provide 'Irradiance Datasets' to help with estimating the annual output for different areas of the country, using the incline and the orientation of the array from the south.

2 System Options

This section lists some of the most common types of photovoltaic systems, giving an overview of the issues that should be taken into account when planning your system. There are many options for installing a PV array:

- Fixed over the roof covering
- Integrated into the roof covering
- Ballasted or fixed on a flat roof
- Free-standing ground-mounted, set away from the building

In addition to the array, there are also options for the way the electrical energy generated is used or stored:

- Stand-alone
  Uses battery storage, usually in remote locations where all the energy is used locally.
- Grid-connected
  Either with or without battery storage, to maximise self-consumption and reduce export to the grid.

2.1 Over the roof covering

A PV array can be fixed over the existing roof covering, so it sits above the tiles or slates. Roof anchors are fixed to the rafters supporting a mounting rail for the PV panel to sit in and clamps used to hold the panels in place. The type of roof anchor will depend on the existing roof covering, and the height and spacing of the roof battens and should not impose loads on the roof that compromise the roofs primary function – keeping the weather out.

The supporting frame that the PV panel sits on is available in an anodised black or silver finish and should be selected in order to blend in better. A black finish for the rail and panel is the least visually obtrusive. Cut ends can be painted black or capped off.

The colour of the PV panel, reflectance, and finish should be chosen to complement the colour of the existing roof covering. PV panels tend to be of a dark blue or black colour although there are different finishes and tones available. Careful selection and design of the colour, contrast, framing, size and symmetry of PV panels can reduce the visual impact. The Campaign to Protect Rural England has produced design guidance in relation to solar PV on buildings encouraging an approach that is sympathetic to the visual appearance of the building and the local area from which it can be seen.

Tiled roofs

On roofs with thick tiles, the roof anchors are usually fixed to the rafters by lifting (and then replacing) the existing tiles and notching the underside of the tile above the anchor so that gaps are not opened up in the tiles.

Slate roofs

On slate roofs, the roof anchors again fix to the rafter below, but a proprietary clamp or lead flashing component is required to weather-proof the penetration through the slates. Slates should not be drilled through under any circumstances.

Figures 2 and 3

Roof-mounted PV arrays with low-profile supporting frameworks fitted over roof tiles (**2**) and slates (**3**). Panels arranged symmetrically and evenly spaced between chimneys and eaves tend to look better.

Lead roofs

Lead sheet, with its high coefficient of linear expansion, undergoes considerable expansion and contraction as the temperature changes, so joints in lead roofs are designed to allow the material to shift. Custom-built clamps to fix around the rolls are not ideal as the clamps do not allow the lead to expand and contract naturally with changes in temperature.

The Lead Sheet Association (LSA) advises using a simple raised timber block system, capped with lead sheet to allow for supporting and fixing typical hand rail systems and other mechanical equipment to roof structures. This approach could also be adopted to fix solar panels to lead roofs without interfering with the thermal movement of the lead sheet.

Figures 4 and 5

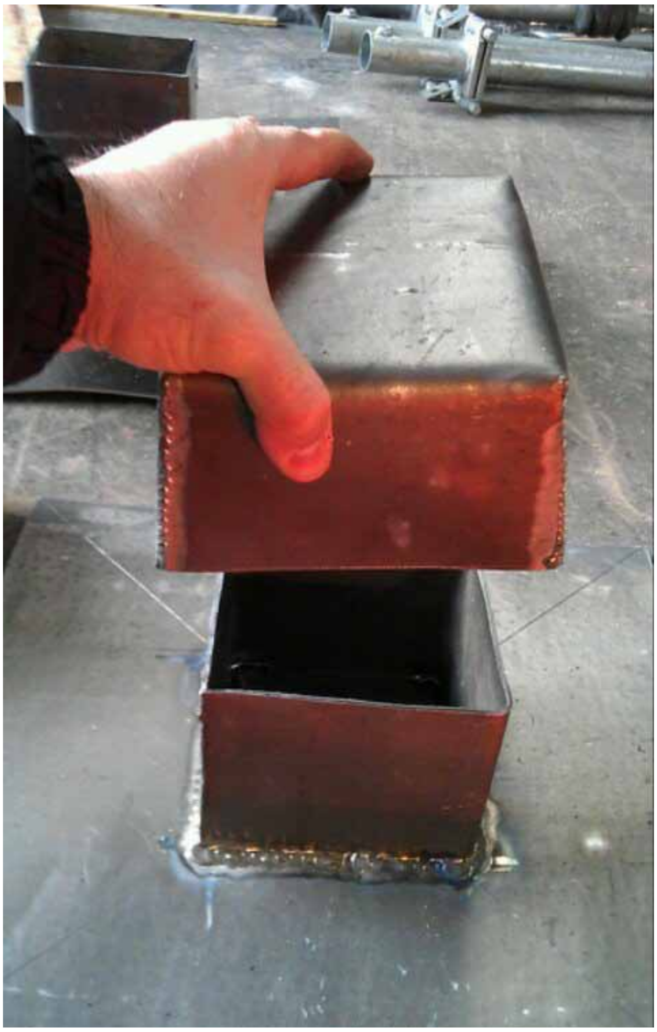
Lead capping pieces with allowance for thermal movement supporting the PV arrays brackets and rails.

As a rule of thumb, lead sheet is only fixed at the top third of the sheet to allow contraction and expansion of the two-thirds below, therefore any fixings such as support blocks should be added in this top third. Underlay, if fitted, should be retained. The support blocks should be positioned to accommodate for drainage on either side of the support, and away from any cross joints in the leadwork, like steps or laps.

Advice will be needed as to the fixings required for the blocks, to secure them to the substrate and provide stability and resistance to wind pressure.

Cabling to and from the PV array to the inverters will need to pass through the roof covering several times. For thick tiles it is common practice to notch the back of the tile, sleeve the cable to protect against rubbing, and pass under the tile. For thinner tiles and slates a lead flashing or proprietary cable gland product can be used.

Before designing the installation it would be advisable to consult an experienced lead contractor because the positioning of fixings and cabling is critical to the longevity of the lead.



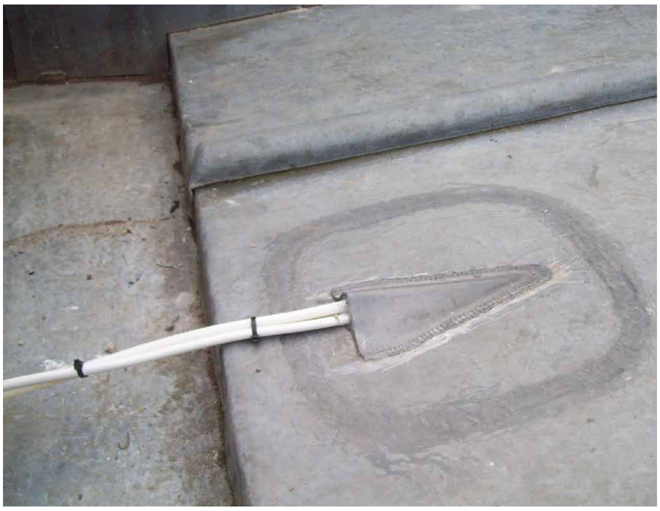


Figure 6
Lead capping piece with allowance for thermal movement where support rails/brackets can be fixed through the capping into the block. A watertight seal should be formed between the brackets and fixing penetrating through the lead capping.

Figure 7
Electrical cabling going through the lead roof with a purpose made lead weather proof covering to prevent the ingress of rain.

2.2 Roof-integrated

It is also possible to integrate solar PVs into the roof covering, replacing tiles or slates with PV panels. These roof-integrated PV panels are the same size as normal PV panels. The PV panels are integrated with the roof tiles or slates with flashing much like a dormer window in a roof.

The tile format systems are compatible only with certain types of roof tiles and slates so it is necessary to check with the manufacturer for the type of covering of the roof unless the whole covering is being replaced.

PVs can also be integrated into glazing. They can be used on the roof glass of conservatories or atria where there is still a good incline to the sun.

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Figure 8
A solar PV array integrated into the slate roof. The original slate tiles have been removed and replaced with PV panels which generate electricity and act as the roof covering. This does create a very low profile PV array, but the original tiles have been removed which if the roof covering is of high significance would not be advisable.

Figure 9
A domestic building with the existing roof covering replaced by PV slate tiles.

Figure 10
A large solar PV installation integrated into glass roofing over the platforms and concourses at King's Cross Station, London.

2.3 Flat roofs

When installed on a flat roof, the PV panels are normally fixed to a frame that tilts them up towards the sun. The frame can be held in place with ballast or, if the roof cannot take the extra weight, fixed with screws through to the roof structure. Where the roof covering must be penetrated it is important to ensure that it is sealed against the weather.

Felt roof coverings tend to have a life of only 10 to 15 years before the felt must be replaced, whereas other roof coverings last much longer. As a PV array has a useful life of over 25 years (according to the Solar Trade Association), it may be sensible to plan the installation at the same time as re-covering of the roof, or the PV array may need to be removed at a later date to re-cover the roof.

Where a tilted PV panel might have an undesirable visual impact, panels can be mounted at low pitch angles (as low as ten degrees) or even flat. This will allow the array to be hidden from ground-level view behind a parapet wall. The output will reduce slightly by not having the panels at the optimum tilted angle.

It is important to note that panels are to some extent self-cleaned by rainfall when they are tilted. If laid flat, they will require regular cleaning to ensure the output of the panel is not compromised by soil and moss buildup on the panel.

Another method of fixing on a flat roof and not penetrating the roof covering is to brace across the roof if there is a parapet wall. A lightweight framework can be fixed to the parapet walls to support the panels.

In all cases a structural engineer should be consulted in the design process in order to ensure the roof can take the additional weight of the PV array.

Figure 11
A small roof PV array mounted on a frame at a low-pitched angle. The visual impact of the array is minimised as it is hidden from view by the stone walls.

Figure 12
A large roof PV array mounted on a frame at a low-pitched angle. The visual impact of the array is minimised as it is hidden from view by the roof line.

2.4 Ground-mounted

If it is not desirable to have arrays fixed to the roof, or if the roof is not suitable, an alternative is to locate them on the ground or on an outbuilding. The panels and inverters can be mounted to a frame and fixed to the ground. It is important to ensure that they are not in the shade as shading can have a huge effect on the performance of a PV array.

From the PV array a cable must run back to the building's electrical distribution board. The cable size is determined by the load it must carry as well as its length: the further the array is from the building, the larger (and more expensive) the required cable. It is necessary to bury the cable to a sufficient depth to avoid damage by any reasonable disturbance of the ground, such as from general gardening or agricultural activities.

Before excavating, both for foundations and for cabling, it is important to assess the possibility of buried archaeology on the site. If the building or grounds are listed or scheduled, the statutory description may cover this aspect of the site. Where the archaeology prevents a cable being buried at a reasonable depth, an alternative route should be found. Where this is not possible, the cable duct should be protected from mechanical damage.

The access point of the cable into the building should be properly sealed to prevent water ingress and fire spread, and to keep pests out.

Figure 13
The visual impact of ground-mounted PV arrays can be minimised by using screening, such as hazel or willow enclosures.

3 Planning the Installation

The design and installation of a PV system needs to be carefully considered so that its efficiency can be maximised whilst avoiding damage both to the significance of the building, its fabric and setting.

3.1 Consents

When looking to install solar panels on a property, the need for permission and/or consents will need to be considered before work is carried out.

Planning permission

Generally, planning permission is required for works which are 'development' and broadly is given either after a formal application is made, or if it is considered to be 'permitted development' and can be carried out subject to compliance with any conditions or limitations set out.

Solar PV and other forms of renewable energy can fall within the scope of permitted development – see part 14 of Schedule 2 of Town and Country Planning (General Permitted Development) (England) Order 2015. If the proposals do not fall within the permitted development (perhaps because it is larger than what is permitted, or there are implications for the historic environment (listed buildings, conservation areas, scheduled monuments etc) or the ability to rely on permitted development has been removed) then an application for planning permission will be required.

It is worth looking on the planning section of the websites for the local authority where the property is located, as they may well have policies regarding renewables and development in their Local Plan, Supplementary Planning Documents and Conservation Area Appraisals/Management Plans. These could also identify Conservation Areas that are subject to Article 4 directions that include controls over the installation of PV. This is where the local planning authority may have removed certain permitted development rights in order to preserve the character and appearance of the Conservation Area.

You can find out more about planning permission and permitted development rights by visiting the UK Planning Portal's website.

Listed building consent

Listed building consent is required for the change to a listed building in any manner which would affect its character as a building of special architectural or historic interest. The requirement applies to all types of works, and to all parts of buildings covered by the listing protection (possibly including attached and curtilage buildings or other structures).

An application for listed building consent is made to, and determined by, the local planning authority. This is separate to any need for planning permission. The local planning authority must consult Historic England and the National Amenity Societies on certain listed building consent applications.

If listed building consent is granted, conditions may be attached to the consent, such as: how much the solar panels project above the roof, how quickly they need to be removed at the end of their useful life, and the colour of the framework.

Places of worship

If you intend to install a PV system to a listed place of worship, you may need to get permission from the relevant denominational advisory committee or listed building consent. If your denomination is one of those covered by the Ecclesiastical Exemption, you will need consent from the advisory committee. The Ecclesiastical Exemption does not remove the need for planning permission. If your denomination is not exempt, you will need listed building consent and planning permission as set out above.

Our website contains more information on listed places of worship and consents.

For listed places of worship, we also recommend that you:

- seek advice well in advance of any application to undertake works and before making any financial or contractual arrangements
- always consult with your local authority and denominational advisory body regarding statutory requirements
- develop an energy strategy for the place of worship and associated land and structures before making any decision on the installation of equipment

Scheduled monument consent

If the site where the solar panels are to be installed is a Scheduled Monument, any work will require scheduled monument consent from the Secretary of State, not the local planning authority. Historic England manages the process of scheduled monument consent on behalf of the Secretary of State. The protected site of a monument may also include any adjoining land essential for its support and preservation.

Building regulations and other consents

When installing a PV system, you also need to consider if it will harm a nearby protected habitat or designated landscape area. Your planning authority may not grant you planning permission if the work will damage a protected site or area. Natural England provides advice about these protected sites.

For all types of buildings, solar panel installations on roofs will need consent under Building Regulations.

3.2 Impact on building fabric and landscape

A PV system consists of the array outside of the building and the electrical equipment and cabling inside the building. The impact of the installation (and potential later removal) of the system should be considered for all component parts.

Reversibility

Great care must be taken when planning the installation to think about the 'reversibility' and the 'physical impact' an installation can have on a building. A PV array and its associated equipment can have a life exceeding 25 years, so a building could have more than one system installed over its life. Damage to the building fabric can be minimised by carefully planning how the array is installed, maintained, and removed at the end of its useful life.

Replacement tiles and slates

However careful the installer, during the installation it is possible for tiles and slates to get broken so it is advisable to have replacements available. For roofs with stone or old handmade tiles, replacements can be expensive and very difficult to find. It is therefore advisable to investigate what type of roof covering you have and how to get replacements before undertaking any work and whether installing panels on the roof is the right solution.

Significance

The location of the panels and managing their visual impact is an important part of the design. All parts of the system that are visible should be considered carefully. It is generally not considered sympathetic to a building's appearance to have a solar panel or other equipment fixed to its main elevations; that is, the face or faces seen from the direction from which it is most commonly viewed. Buildings with main elevations aligned in the direction of optimal solar radiation may present special installation problems with regards to visual impact.

Historic England's Historic Environment Good Practice Advice in Planning Note 2 provides further advice on assessing the significance of heritage assets.

When assessing applications for PV installations fixed directly to the building or within the setting of heritage assets like historic buildings, the significance of the asset will need to be properly assessed. This assessment may well conclude that the roof covering; its appearance, perhaps a decorative array of tiles, or intrinsic historic fabric (for example ancient local stone tiles) is of high significance and therefore the impact of the PV is harmful. The understanding of significance of the roof is often critical.

Setting

When assessing the impact of PVs, including ground mounted arrays, the impact is often measured against inter-visibility and views of the asset where they would be visually prominent. Further guidance can be found in Historic England's The Setting of Heritage Assets.

A way to mitigate this could be with natural screening, such as hazel or willow enclosures that limit the impact on the setting.

Places of worship with large south-facing roof slopes present opportunities to generate energy through solar electric panels or solar 'slates'. Such roofs are often highly visible and therefore contribute to the character of the building in its setting. Minimising visual impact is desirable but often difficult and will depend upon the form of the roof and the situation of the building.

Where a building has a shallow-pitched roof which is largely hidden from view by parapets, or internal roof slopes which cannot be seen from ground level, solar electric panels may be accommodated more easily. It may be harder for other buildings to find a suitable location which does not harm the building or its setting; possible solutions may be a ground-mounted solar collector or placing equipment on another building.

'Solar slates' are designed to have a similar appearance to natural slates, but the difference is usually still detectable to the naked eye and thus has a visual impact. The life-expectancy of solar slates is much shorter than a natural slate roof so the cost of more frequent roof repairs should be taken into account. Solar slates may be acceptable where the roofing material is not part of the building's historic integrity and the existing slates are in need of replacement.

The impact of some ground-mounted PV arrays can be reduced by screening. For example in a rural location, hazel or willow panels may be appropriate screening for a small-scale installation.

Harm

The National Planning Policy Framework sets out how the local planning authority, in making a decision, looks at balancing the harm of a PV scheme against the sustainability benefits of the proposal. Significance can be harmed or lost through alteration or destruction of the heritage asset or development within its setting.

When considering the impact of a proposed development on the significance of a designated heritage asset, great weight is given to the asset's conservation. The more important the asset, the greater the weight should be.

Even when carefully designed and managed, the installation, maintenance and eventual de-commissioning of solar electric panels or solar slates is likely to cause some damage to the historic fabric of the building. To mitigate this harm, it is therefore critical that the means of fixing and the operation of the panels or slates are planned and agreed in advance, whilst also ensuring that their location does not impede rainwater disposal or hinder maintenance work such as clearing gutters.

Geographical location, orientation and tilt

Where you are in the UK will have an effect on the amount of solar radiation that will be received from the sun. Solar radiation may be direct sunlight or diffuse after it's been scattered by the atmosphere. The further north you travel the lower the value due to the increased latitude.

An array should ideally be mounted on a southeast- to southwest-facing roof, with sunlight during the main part of the day. However, many arrays on flat roofs are installed facing on an east-west axis in order to provide a smoother generation profile throughout the day which may better match the building consumption profile. Arrays can still be on the east and west faces but the annual yield would be lower. In general, north faces should be avoided.

The optimum tilt angle for a PV panel in the UK is 30° incline from the horizontal to capture the maximum sunlight. As the angle varies from the optimum the efficiency of the panel reduces. Most pitched roofs have angles of between 20° and 50°. Many flat roof mounting systems tilt the modules at 10° as this reduces the amount of ballast required.

The Microgeneration Certification Scheme (MCS) provide 'Irradiance Datasets' to help with estimating the annual output for different areas of the country, using the incline and the orientation of the array from the south.

Shading

If not properly accounted for in the design, shading can have a huge effect on the performance of a PV array. If arrays are configured in 'strings' and one part of the string is in shade the rest of the string will also have its power production reduced. Using micro-inverters or solar optimisers, that optimise the production of individual solar panels, can stop shading on one panel affecting the performance of others.

3.3 Roof Loading

With roof-mounted installations it is necessary to check that the roof is able to support the wind, snow and static load.

The roof structure will need to be checked by a competent person to ensure it can withstand the additional load and ensure it complies with *Building Regulations Approved Document A: Structure*. In some circumstances, it may be that strengthening work or replacement of roofing members would be required.

3.4 Wildlife

Bats and birds use buildings for resting, breeding, and nesting. All bats and their roosts, and all wild bird species, their eggs and nests, are protected by law. If bats or birds using the building might be disturbed by any proposed work you should seek advice from Natural England for advice about wildlife licences.

Bats can roost under very small spaces in roof coverings or inside roof spaces. Work such as installing a PV system could disturb bats even if they are inside the roof and you will need expert advice about when and how to carry out work. Subsequent maintenance will also need to avoid times when a roost is being used. The Bat Conservation Trust Helpline (supported by Natural England) provides advice for homeowners.

PV system installation work must be carefully timed not to disturb birds during their nesting seasons from about the end of February to August.

3.5 Finding an installer

Installers can be found through the Microgeneration Certification Scheme (MCS). The Solar Trade Association provides a list of members who comply with their code of practice. However, neither of the schemes identify installers that have worked in historic buildings so when choosing an installer, it is important to ask questions about how they are going to do the installation:

- It should be possible to view examples of the installer's previous work, which will give you a good indication of whether they are the right company to match to your particular needs.

- Ask if they have worked on historic buildings in the past and whether they understand conservation issues and working in a sympathetic manner to avoid damage.

- Obtain a written quote for the project. Assume that if it is not specifically mentioned it is not being provided. Be sure you know exactly what is and what is not included to make it a fully operational system and to work optimally, particularly with the interface to any existing systems.

- Get as much detail as possible; where cables are going to run, and how they will be fixed. Be sure you receive relevant drawings for instance of the array, where the inverters will be and what type, method of fixings, loadings if the array is on the roof.

- If a building is fitted with a lightning protection system the engineer should check as to whether the array frame should be connected to the system.

3.6 Fire risk assessment

Research has shown that fires originating from PV systems are rare and can be mitigated through good system design and installation. It is recommended that a PV fire risk assessment is completed for all PV installations on historic buildings. The assessment should be completed during the initial survey or early design phases of a PV project to identify the following;

- **Potential fire hazards** – sources of ignition, combustible materials
- **People and property at risk** – occupiers, visitors, contractors, neighbours, type of building, building use, building contents
- **Existing fire safety measures** – provision and protection of escape routes, emergency lighting and signage, fire detection and warning systems, portable fire fighting equipment, staff training, provisions for disabled people, fire brigade access
- **Appropriate mitigation measures** – supporting firefighter and rescue service operations, specification of automatic shutdown devices and other fire mitigation solutions, independent quality assessment of installation workmanship, preventative maintenance

In the event of a fire, firefighters will require information on the type of system and appropriate signage.

4 Electricity Distribution and Storage Systems

The design of the PV electrical system will depend to a great extent on the building's present system. Is there a mains electricity supply to the building or is it independent of the National Grid? It will also depend on how the generated power from the PV array is to be used. Will it be fed back into the National Grid, or cater for a specific load? Will the energy be stored for use at other times?

Where equipment is to be fixed to the building wall, the number of fixing points should be minimised by the use of a fire-resistant board or aluminium frame system.

4.1 Grid-connected system

Most PV systems are grid-connected and are linked to a main or a local distribution board. The system operates in parallel with the normal mains supply so that when the PV is not generating enough energy, mains electricity is used. If more electricity is generated by the PV than is needed, the excess can be either exported to the National Grid or stored in a battery for later use or diverted to another form of energy storage such as a hot water cylinder.

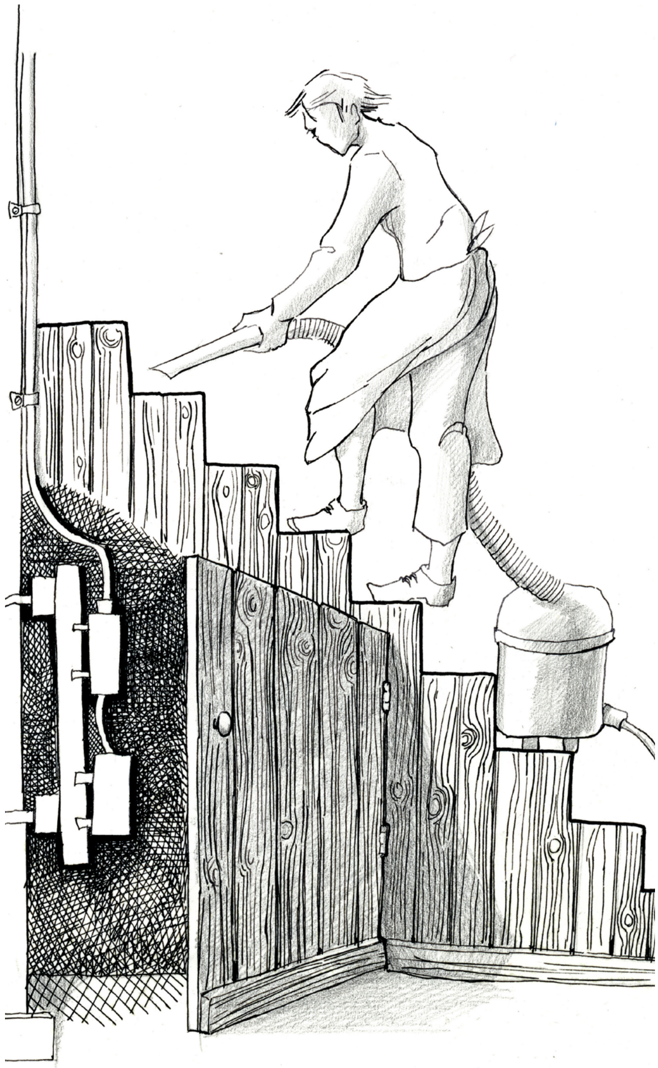


Figure 14
The fire-resistant board or framework is fixed to the wall with all the equipment then fixed to the board to limit the amount of fixing holes to the historic fabric. When the equipment needs replacing the old equipment can be removed and the new equipment fixed.

Where a system is to synchronise with the electricity supply it is necessary to liaise with the Distribution Network Operator (DNO). Systems need to comply with the Engineering Recommendations G59 or G83 depending upon the size; the documents can be viewed on the Electrical Networks Association website. For systems larger than 3.68 kWp per phase, an application must be submitted to the DNO for permission to connect the system, and a connection offer received prior to installation.

A solar installation will usually come with an electricity meter that measures the energy production and enables the Feed-in Tariff to be claimed. For systems larger than 30 kWps, the exported electricity must also be metered.

Figure 15
The grid-connected PV system consists of the solar panels, a means of isolating the PV panels and one or several inverters, usually located near the panels. The incoming power supply is the same as any regular supply and has a fused cut-out, metering and a means of isolation. In addition to the normal Import meter which measures electricity consumed an export meter may be required to measure the electricity generated.

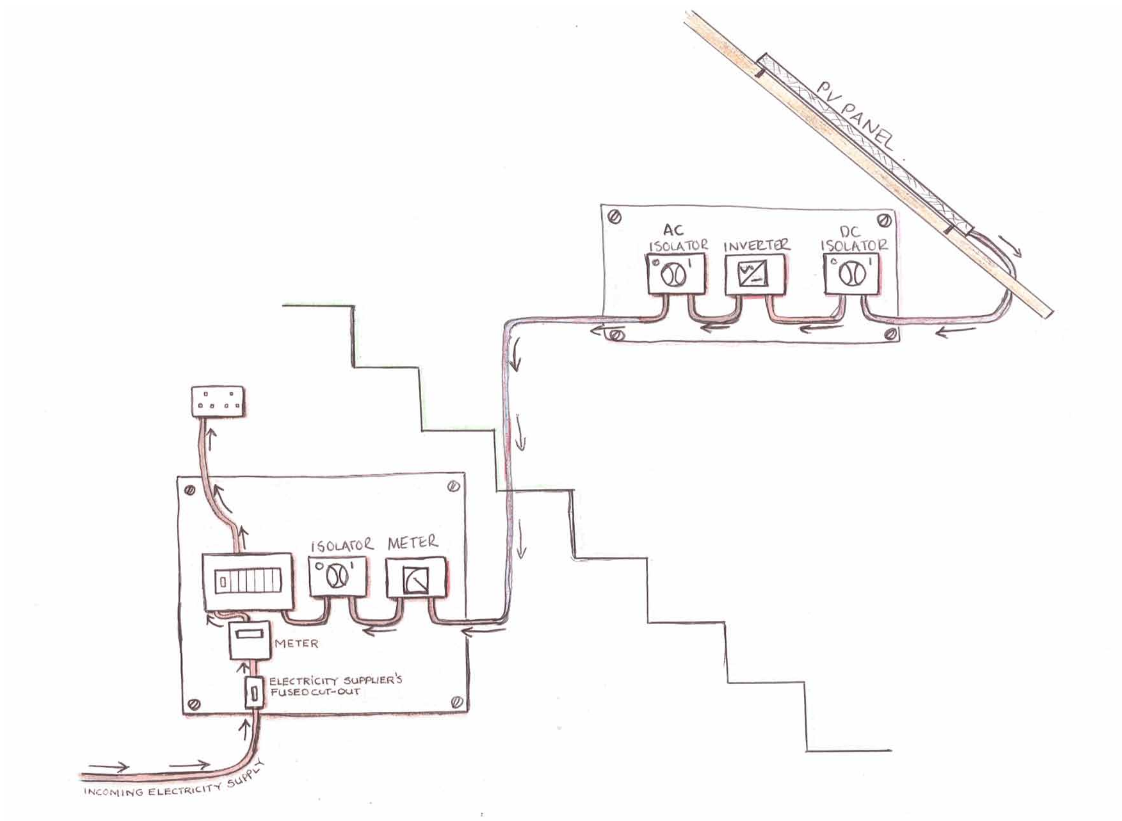
4.2 Off-grid system

Where a building or monument has no mains electricity, PV with batteries can be used to supply electricity to lighting and other low power devices. It may be a diesel generator is also used to supply electricity and this could be supplemented or even replaced with PV.

In this case the PV is connected to a battery via a charge controller and an inverter is connected to either a dedicated load or a distribution board.

For off-grid PV systems, batteries provide a vital function in storing energy during sunny periods for when there is no sunlight. The number and size of the batteries depend on how long they would be expected to continue supplying electricity without the PV. This is known as the 'autonomy' or how long the batteries need to operate. The batteries should be of a 'deep-cycle' type, which can be discharged deeply without damage.

The location of the batteries must be secure, and in the case of lead acid batteries, well ventilated, as batteries give off a hydrogen gas in their operation. Batteries should be kept cool as warmer temperatures reduce battery life.



5 Maintenance and Working Life

PV systems, like all electrical equipment, require regular maintenance to ensure continued and safe operation. The installer should provide a maintenance schedule as part of their handover documentation. This should detail how often equipment would need routine maintenance and how the equipment would be accessed. Maintenance regimes will vary depending on the size, type and location of the system.

It is important to remember that because the working life of a PV is around 25 years, and an inverter will typically need replacing between 10 and 15 years, a building in time could require a replacement or upgraded system. Damage to the building's fabric can be minimised with careful planning: the installation and decommissioning at the end of its useful life.

Batteries have a life of around 6–10 years, depending on the type of battery, the way they have been used and maintained, and also the environmental conditions they have been kept in.

All the components of a PV system are covered under the Waste Electrical and Electronic Equipment Directive (WEEE Directive) and must be recycled at the end of their life.

As a guide, an expected outline minimum maintenance regime every six months would be:

- Visually inspecting the mechanical fixing for all components
- Checking the AC and DC wiring and connections for signs of arcing, corrosion, damage and degradation and confirming the correct operation of isolation devices
- Checking current/voltage at inverter input or at string level
- Checking meter readings

On some roofs to access the system safely it may be necessary to provide a fall protection system such as ‘man safe’ running lines which need to be regularly maintained and inspected.

6 Glossary

Alternating current (AC) Electric current in which the direction of flow is reversed at frequent intervals of 50 or 60 cycles per second, or 50 or 60 hertz (Hz).

Array Any number of photovoltaic modules connected together to provide a single electrical output.

Charge controller An electronic device which regulates the voltage applied to the battery system from the PV array. Essential for ensuring that batteries obtain maximum state of charge and longest life.

Conduit/trunking Enclosed, mechanically protected channels or pipes, either galvanised, painted or enamelled.

Deep cycle battery A battery with large plates that can withstand many discharges to a low state-of-charge.

Deep discharge Discharging a battery to 20% or less of its full charge capacity.

Direct current (DC) Electric current in which electrons flow in one direction only. Opposite of alternating current.

Electrical distribution system Cabling, distribution board and such like, needed to get the electricity generated to where we want to use it.

Grid-connected system A solar electric or photovoltaic (PV) system in which the PV array acts like a central generating plant, supplying power to the grid.

Inverter An inverter converts the energy from the PV panel from direct current (DC) into useable alternating current (AC).

Isolator A device that can switch off the power from the PV array when carrying out maintenance or in an emergency.

Kilowatt (kW) 1000 watts.

Kilowatt-hour (kWh) One thousand watts over a period of 1 hour. The kWh is a unit of energy.

Kilowatt-peak (kWp) The 'rated' amount of power a solar panel will produce in optimum conditions.

Lead acid battery A general category that includes batteries with plates made of pure lead, lead-antimony, or lead-calcium immersed in an acid electrolyte.

Load Anything in an electrical circuit that, when the circuit is turned on, draws power from that circuit.

Microgeneration Certification Scheme (MCS)
A scheme to accredit installers and designers of heat pump systems to prove they are competent.

Network operator Operator of the power grid.

Orientation Placement with respect to the cardinal directions, north (N), south (S), east (E), and west (W).

Tilt Angle The angle at which a photovoltaic array is set to face the sun relative to a horizontal position.

7 Where to Get Advice

7.1 Historic England publications

This guidance is one of a series of documents on the principles, risks, materials and methods for generating energy from heat pumps, micro-hydroelectric power, and small-scale solar thermal energy.

This series forms part of a comprehensive suite of guidance on renewable energy available at: historicengland.org.uk/advice/planning/infrastructure/renewable-energy/

Historic England publishes a range of guidance on energy efficiency measures available at: historicengland.org.uk/energyefficiency

Historic England's advice notes on the planning system and topics such as conservation areas, settings and views, and curtilage are available at: historicengland.org.uk/advice/planning/planning-system/

7.2 Other sources of advice

Campaign to Protect Rural England (CPRE)

The CPRE campaign to protect, promote and enhance the towns and countryside of England and publish a range of documents that encourage energy efficiency.
https://www.cpre.org.uk/

They have published two documents on good practice in solar panel design, *Solar Design Tips* and *Ensuring Place Responsive Design for Solar Photovoltaics on Buildings*

Historic Environment Scotland

This is the lead public body established to investigate, care for and promote Scotland's historic environment. Information about Historic Environment Scotland's work into thermal performance of traditional construction is available from:
www.historicenvironment.scot/advice-and-support

The Institute of Historic Building Conservation

The IHBC is the UK's professional body for historic environment conservation specialists, and offers a wide range of online and other resources.
ihbc.org.uk

Microgeneration Certification Scheme

Microgeneration Certification Scheme (MCS) is a nationally recognised quality assurance scheme, supported by the Department for Business, Energy & Industrial Strategy. MCS certifies microgeneration technologies used to produce electricity and heat from renewable sources.
www.microgenerationcertification.org

Society for the Protection of Ancient Buildings (SPAB)
The SPAB is a building conservation charity. Information about the SPAB's research into the thermal performance of walls of traditional construction and the effects of added insulation is available from:
www.spab.org.uk/advice/research/findings

Sustainable Traditional Buildings Alliance (STBA)
STBA is a collaboration of organisations, including Historic England, that act as a forum for sustaining and improving traditional buildings.
stbauk.org

Guidance publications are available from the STBA's website including:

Responsible Retrofit of Traditional Buildings (2012)

Planning Responsible Retrofit of Traditional Buildings (2015)

Also available is the STBA Guidance Wheel. This is an interactive retrofit guidance tool that helps users to see how different energy efficiency measures might interact in a particular building and what risks they could pose to character and significance, building fabric and occupant health.
responsible-retrofit.org/wheel

7.3 Further reading

CIBSE 2002 *KS15 Capturing Solar Energy. CIBSE Knowledge Series.* London: Chartered Institution of Building Services Engineers
www.cibse.org/publications

HM Government, Building Regulations 2000 (2010 editions with later amendments 2011/2012/2013/2016) Published 2016
Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings
Approved Document L2B: Conservation of Fuel and Power in Existing Buildings other than Dwellings
www.gov.uk/government/publications

7.4 Contact Historic England

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8 Acknowledgements

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