2008

Small scale solar electric (photovoltaics) energy and traditional buildings

ENGLISH HERITAGE

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PLANNING AND HISTORIC BUILDING LEGISLATION

THE INSTALLATION OF A RENEWABLE TECHNOLOGY IMPLIES IN MOST CASES THE FIXING OF EQUIPMENT TO THE HISTORIC FABRIC OF A BUILDING. ENGLISH HERITAGE SEEKS TO ENSURE THAT ANY WORKS TO A HISTORIC BUILDING DO NOT UNNECESSARILY DISTURB OR DESTROY HISTORIC FABRIC.

In deciding how best to incorporate a renewable technology, the principle of minimum intervention and reversibility should be adopted whenever and wherever possible.

Installing a solar electric system will probably need planning permission. The local planning authority can grant permission under the Town and Country Planning Act 1990, and they will be looking for any issues about visual impact or proximity to land boundaries.

Installing a solar electric system on a Listed Building or a building in a Conservation Area will also need permission from the local planning authority under the Planning (Listed Buildings and Conservation Areas) Act 1990. Planning Policy Guidance PPG 15 'Planning and the Historic Environment' can help you with this: see **www.planningportal.gov.uk**. Work of any kind to a Scheduled Monument requires consent from English Heritage under the Ancient Monuments and Archaeological Areas Act 1979.

Your application will need to show clearly what you intend to do, with detailed drawings and photographs. It is useful to draw the panel on a photo of the site or building in order to help the planning officer visualise it in its proposed setting and determine its visual impact.

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Front cover image courtesy of Solar Century

INTRODUCTION

English Heritage is the UK government's adviser on the historic environment. Central to our role is the advice we give to local planning authorities and government departments on development proposals affecting listed and traditional buildings, conservation sites and areas, terrestrial and underwater archaeological sites, designed landscapes and historical aspects of the landscape as a whole. For our policy statements on climate change and energy, refer to English Heritage's Historic Environment, Local Management website, **www.helm.org.uk**.

The Department of Trade and Industry reports that domestic energy consumption has increased by 32 per cent since 1970 and by 19 per cent since 1990. Energy efficiency improvements, such as increased levels of insulation and the introduction of more efficient electrical appliances, have meant that domestic energy consumption has not increased at a greater rate. This rise has been attributed to the increased use of electrical appliances in our homes. Carbon dioxide is a by-product of the burning of fossil fuels to supply energy, and emissions have spiralled upwards as our demand for energy has increased.

The UK government, wishing to reduce the country's dependence on fossil-fuel stores and to cut carbon dioxide emissions, has made a commitment to find 10 per cent% of our energy from renewable sources by 2010, rising to 20 per cent% by 2025. Renewable energy may come from sources such as wood that are self-regenerating, or those such as the sun that are effectively infinite. The technologies associated with these sources are sometimes referred to as 'low-carbon', in that they emit much lower levels of carbon dioxide and related compounds into the atmosphere than do fossil-fuel technologies.

For more information on the UK government's position on climate change, contact the UK Climate Impacts Programme (*see* Useful contacts).

This guide is one of a series on small-scale renewable energy options. Separate guides look at generation, solar energy, bio-fuels, heat pumps and combined heat and power, explaining how each system works and what you need to consider if you wish to install it in or on a historic building. All the guides look at small-scale generation, or 'Microgeneration' as it is known. Microgeneration is defined by Government as 'The production of heat and/or electricity on a small-scale from a low carbon source'.

Cutting demand for energy is as important as finding alternative means of generating it. Before deciding whether to install a renewable energy technology in a building, all available energy-saving measures— including low-energy light bulbs, heating controls and improved insulation — should already have been taken. An English Heritage guidance document, *Energy Conservation in Traditional Buildings*, looks at methods of improving insulation and introduces other methods for saving energy.

PLANNING A SOLAR ELECTRIC SYSTEM

THERE ARE A NUMBER OF FACTORS TO CONSIDER BEFORE INSTALLING A PHOTOVOLTAIC SYSTEM ON A PROPERTY.

Have other energy saving measures been taken? Is planning permission or listed building consent needed and would it be forthcoming? Is a photovoltaic system the most suitable renewable technology for the occupants? Can this technology be installed easily on this property? The non-profit, government-funded and private-funded Energy Saving Trust (see Useful contacts) has fact sheets on a variety of small-scale renewable technologies.

A photovoltaic (PV) cell is a device that converts sunlight into electrical energy. The PV cell consists of one or two layers of a semi-conducting material, usually silicon. When light shines on the cell it creates an electric field across the layers causing electricity to flow. The greater the intensity of the light, the greater the flow of electricity. PVs will only produce electricity whilst there is daylight. So the energy must either be consumed as it is being generated, or stored for later use or exported to the National Grid.

The maximum power generated under ideal conditions in full sun by a PV cell is expressed as kilowatt peak (kWp) by manufactures. The kWp will vary according to time of day, month, year and location. It is more useful to find out from the installer what the estimated annual yield would be. This would give an average estimate for the year of how much electricity the array would generate, and is given in kilowatt-hours per year (kWh/yr). Thus, using the household electricity bill, also measured in kWh, the savings can be calculated.

The Solar Trade Association (see Useful contacts) has produced a map for the United Kingdom (Fig 1) of the average amount of solar energy falling on a south-facing 30° incline from the horizontal. A 30° incline is considered the optimum for maximising total solar radiation in the UK.

In the UK a PV array required to provide electricity for a typical home varies depending on a number of issues: how much power you need, the type of PV cell used, roof space available and the budget. The average UK household electricity usage is around 4,000 kWh/annum. The Energy Savings Trust says that a typical domestic installation is around 1.5-2.5 kWp. This could generate enough electricity to provide almost half of the average family's annual requirement, covering a roof area of between 10 and 40 m^2 (assuming gas is used for heating requirements and there are no energy-efficiency savings).

The annual yield of a domestic PV array in the UK on a south-facing, inclined plane, unshaded can be expected to generate on average 750 kWh per kWp installed per year. So for a 2-kWp installation you can expect to generate 1,500 kWh of electricity.

There are three types of PV cells to choose from: monocrystalline, polycrystalline and amorphous silicon (thin film).

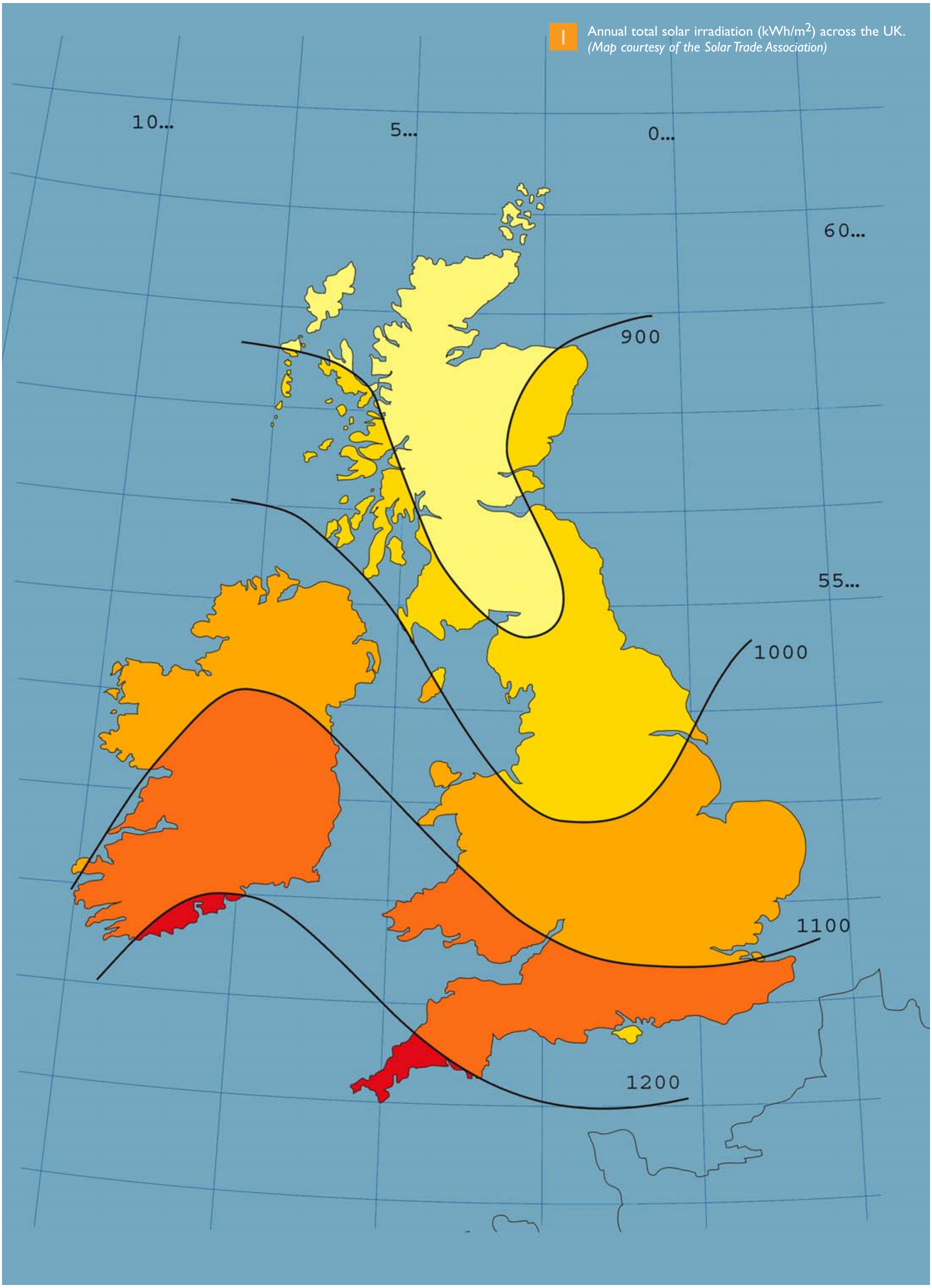
Monocrystalline silicon is made using thin wafers of a single crystal of silicon all arranged in orderly patterns. Polycrystalline or multicrystalline are similar to monocrystalline but are made from less refined silicon. Amorphous silicon cells or thin film are made up of silicon atoms in a thin layer deposited on a wide range of substrates, such as glass or metals. Monocrystalline are the most efficient at converting the sun's energy into useable electrical energy. They also have the longer life span but will be more expensive than the other types. See table 1.

To help understand what the efficiencies could mean in terms of affecting the size of the array the British Photovoltaic Association (see Useful contacts) give the following general guidelines. An area of around 8 m^2 would be required to mount an array with a rated power output of 1kW if monocrystalline modules were used. If polycrystalline modules were used, an area of around 10 m^2 would be required; and if amorphous modules were used, an area of about 20 m- would be required.

Efficiency (%)	Module type	Durability (yrs)
12-15%	Monocrystalline	25-30
10-13%	Polycrystalline	20-25
3-6%	Amorphous	15-20

Table 1. Typical conversion efficiencies of silicon-based PV modules. *(Table courtesy of the Energy Savings Trust 'Energy efficiency best practice in housing renewable energy sources for homes in rural environments').*

1 Annual total solar irradiation (kWh/m^2) across the UK.
(Map courtesy of the Solar Trade Association)



ORIENTATION

The array should be mounted on a southeast- to southwest-facing roof, receiving direct sunlight during the main part of the day, to generate a significant annual yield of energy.

It is generally not considered sympathetic to a building s appearance to have a solar panel or other equipment fixed to any of its main elevations, i.e. the face or faces seen from the principle viewpoint, towards which it is mainly viewed. Thus buildings with main elevations aligned in the direction of optimal solar radiation may present special installation problems with regards to visual impact.

Arrays can still be effective on the east and west faces but the annual yield would be lower and north faces should be avoided. Where a collector cannot be mounted on a building in an optimal direction for solar irradiation, it may be possible to mount it away from the building. In such cases it is advisable to speak to your local authority conservation or planning officer.

SHADING

It is important that no trees or other structures – or parts of the same building such as chimneys or dormer windows – should cast shadows on the array, as this would reduce its energy output. Shading can have a huge effect on the performance of a PV array. The arrays are configured in 'strings'. If one part of the string is in shade the rest of the string will not work, so will not produce electricity.

WILDLIFE

Bat and birds use buildings for roosting and nesting. Bats can roost under very small spaces in roof coverings or inside roof spaces. When planning an installation you would need to assess whether they are nesting or roosting in or on the roof, as all bats and some birds are legally protected. If they are using the building you will need to install equipment when they are not present. Subsequent maintenance will also need to avoid times when it a roost is being used, as bats tend to re-occupy the same site every year.

Natural England should always be consulted at an early stage when planning an installation with known wildlife interest or in areas known to be used by protected wildlife. The Royal Society for the Protection of Birds (RSPB) and The Bat Conservation Trust have guidance on their website (see Useful contacts).

INSTALLATION OPTIONS

ONCE THE ENVIRONMENTAL AND AESTHETIC CONSIDERATIONS HAVE BEEN CONSIDERED, THE NEXT STAGE IS TO PLAN THE INSTALLATION.

There are many options for installing a solar PV system:, fixing the array over the roof finish, tiles integrated into the roof finish, building integrated photovoltaics (BIPV) or installation away from the building. Photovoltaics can also be fitted as an array to a conservatory or glass and provide shading.

When planning the installation it is important to think about the reversibility and the physical impact an installation can have on a building. This is to say that a PV array and its associated equipment can have a life of 25 years, so a building could have many installations over its life. By carefully planning the installation and how it can be removed at the end of its useful life damage to the building fabric can be limited.

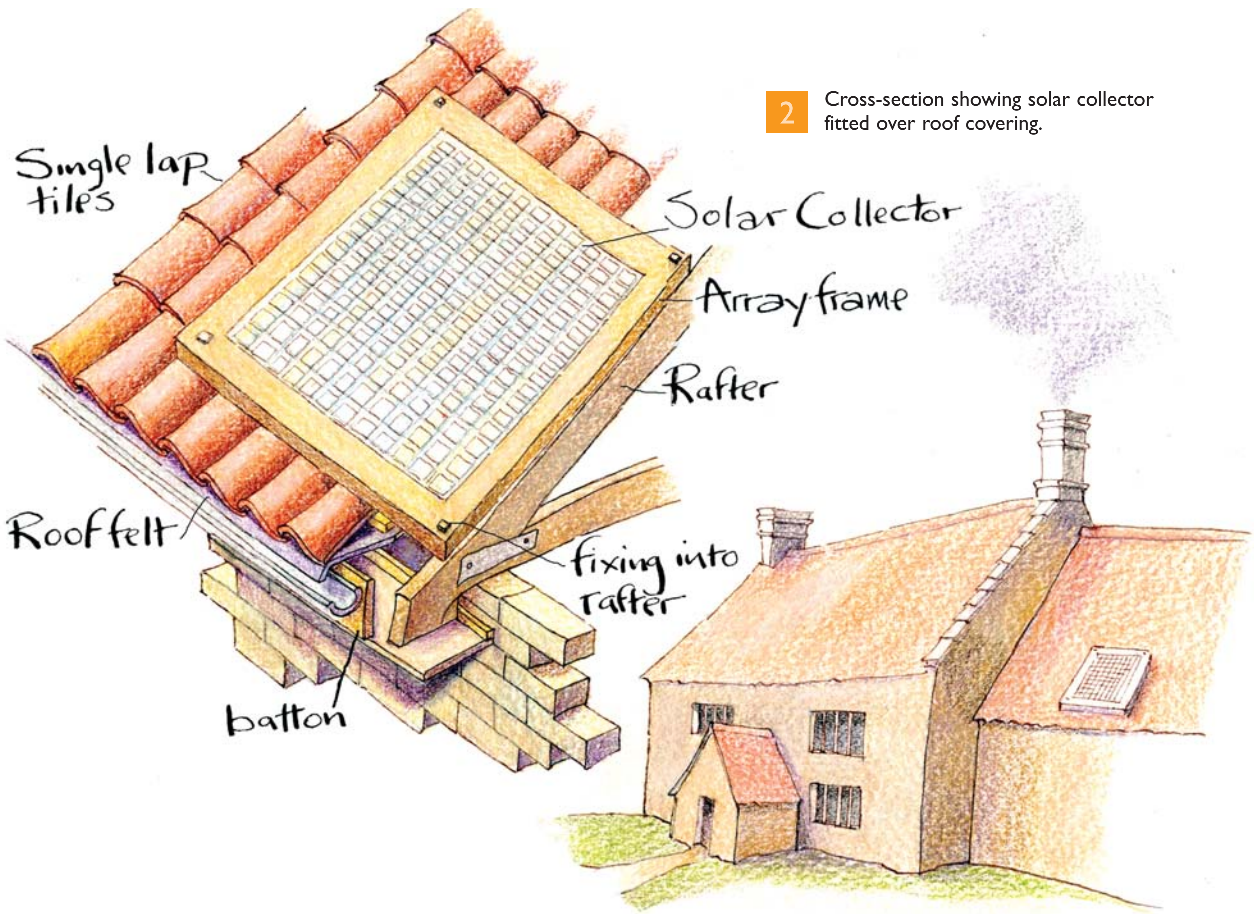
PV ARRAY

The PV array can be fixed over the roof covering, so it sits above the tiles or slates, or it can be integrated into the roof covering so it sits flush. With thatch roofs, where the material is organic, the thickness of the thatch decreases over time so we would not recommend fixing the collectors to thatch roofs.

The optimum angle for mounting the array is 30°, and as the angle varies from the optimum the efficiency of the collector reduces. Most pitched roofs have angles of between 30° and 50°. The angle of the roof or 'pitch' is determined by the exposure of the site and local weather conditions. The pitch of tile and slate roofs depend on the size and overlap of the individual tiles or slates.

With all the following installation options, where the PV array is going to be mounted on the roof it is necessary for a structural survey to be carried out. The PV array and fixing framework will be attached to the roof rafters, which will need to be capable of supporting them. It is advisable to speak to the installer and find the weight of the array and the weight of the supporting framework so an assessment can be made.

During the installation it is normal for tiles and slates to get broken, however careful the installer, so it is advisable to have replacements available.



2 Cross-section showing solar collector fitted over roof covering.

PV array fitted over roof covering

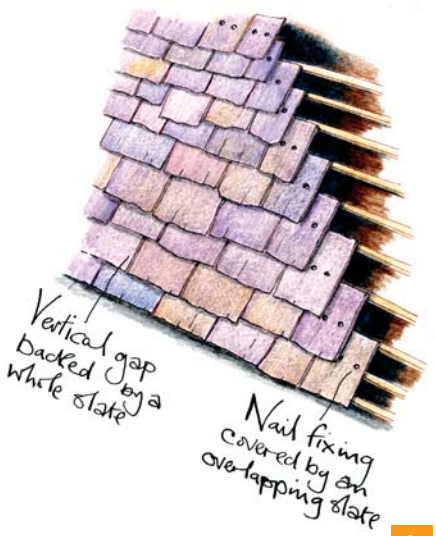
In this type of mounting the array is fixed to the roof structure by drilling through the roof covering (tile or slate, and roof felt) directly into the rafters (Fig 2).

For roofs with stone or old handmade tiles, replacements can be expensive and difficult to find and drilling through them will render them unusable. It is therefore advisable to investigate what type of roof covering you have and how to get replacements before undertaking any work.

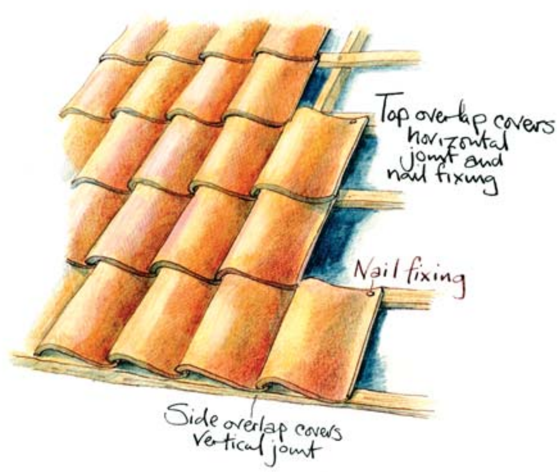
Careful planning is required, both in the locating the rafters and in drilling through the roof covering. To locate the rafters it is best to chalk a line up the roof rather than remove tiles. If the rafters don't coincide with where the frame needs to be, existing noggins can be used, or noggins can be attached to the rafters.

Slates or tiles are laid in a variety of ways. Plain tiles and slates are normally double-lapped, profiled tiles single-lapped (Fig 3). It is important to know the difference, because with double-lapped tiles you will be drilling through several tiles at once.

The holes must also be made into the loft space for cabling to and from the PV array to the inverters. These holes should be weather-sealed with roofing sealant and with lead flashing on a non-profiled tiled roof.



3 Single-lapped and double-lapped roof coverings.



Roof-integrated PV array

To integrate an array into the roof finish, PV tiles are used that replace individual ordinary roofing tiles or slates, or several, with larger single PV tiles (Fig 4). In some installations part of the original roof covering is replaced with PV tiles or the whole covering is replaced, depending on the energy need.

They PV tiles are anchored onto the roofing battens and are screwed in place (Fig 5). The tiles overlay like single-lap roof tiles and are connected electrically together with the cabling taken back to the electrical inverter.

Many of these systems will only be compatible with certain makes 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 (Fig 6). They can be used on the roof glass of conservatories where there is still a good inline to the sun.

5

PV roof tile being drilled to timber roof batten. *(Photograph courtesy of Solar Century)*

4

Top left: Close up of PV slate installation. Top right: Individual PV slate. Bottom: Roof covered with PV slates. *(Top left and bottom: Photographs courtesy of Sunslates Limited. Top right: Photograph courtesy of Solar Century.)*

6

PVs integrated into glass *(Photograph courtesy of Solar Century)*

7

PV installation on a flat roof at Crichton Castle, which is now in the care of Historic Scotland *(Photograph courtesy of Historic Scotland)*

PV arrays on flat roofs

On a flat roof a frame can be constructed to hold the collector at the optimum 30° angle (Fig 7). The frame can be held in place with ballast or more permanently fixed with screws through the roof structure. Where the roof covering must be penetrated it is important to ensure that it is sealed against the weather.

Where a tilted PV array might have an undesirable visual impact it may be mounted horizontally, allowing the array to be hidden from ground-level view behind a parapet wall.

Flat roof coverings tend to have a life of 10 to 15 years before the felt must be replaced. As a PV array has a useful life of around 25 years (according to the British Photovoltaic Association), it is sensible to plan its installation at the same time as re-covering of the roof.

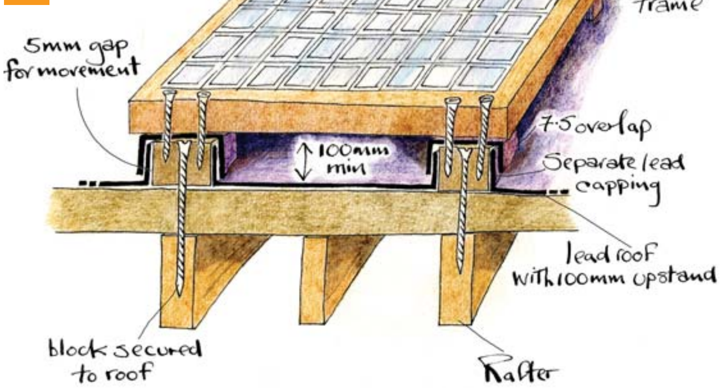
This is not an issue with lead roofs, which can last well over 100 years and require little maintenance. Lead sheet, with its high coefficient of linear expansion, undergoes considerable expansion and contraction as the temperature changes, so joints in lead roofs are designed to allow the material to shift. 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 should come within this top third.

Rolled lead sheet works in partnership with most building materials. However, additional precautions may be required when using some types of materials, as they will most probably have different coefficients of expansion and contraction.

Before designing the installation it would be advisable to consult an experienced lead contractor because of the positioning of fixings and cabling that go through the roof is critical to the longevity of the lead. (Fig 8) shows a detail of a fixing through lead sheet into the roof rafter.

Anyone contemplating putting PV panels on a lead roof should refer to the Lead Sheet Association (see Useful contacts) manual for guidance (ref: Rolled Lead Sheet – The Complete Manual. A guide to good practice in the specification and use of rolled lead sheet to BSEN 12588:1999. Lead Sheet Association 2003) on detailing.

8 Fixing through lead sheet



PV arrays: free-standing away from building

If it not desirable to have arrays fixed to the roof, or if the roof is not suitable, an alternative is to locate them off the building on the ground or on an outbuilding (Fig 9). From the PV array a cable must run back to the building's electrical fuse 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 usually necessary to bury it, to a depth of no less than 0.5 m to avoid damage from general gardening.

9

Ground-mounted PV array. *(Photographs courtesy of Wind and Sun Ltd.)*

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 it could be buried more deeply. Where this is not possible, the cable duct should be encased in concrete.

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

ELECTRICAL SYSTEM

Equipment should be located to permit easy access for maintenance and repair. All parts of the installation should be indicated on a working drawing. Where equipment is to be fixed to building walls, the number of fixing points should be minimised by the use of a wooden pattress or frame system (fig 10).

The PV system is made up of the roof top array and the electrical distribution system and equipment. The electricity generated by the PV cell is direct current (dc). An inverter is needed to convert this to alternating current (ac) so that it can be used for electrical appliances or fed back to the grid. Other essential elements of the system are an isolation switch, allowing the panel to be disconnected for safe maintenance or repair and a meter to measure the energy generated (fig 11).

ELECTRICAL SYSTEM

There are three options for connecting a PV to the electrical system: direct, off-grid and grid.

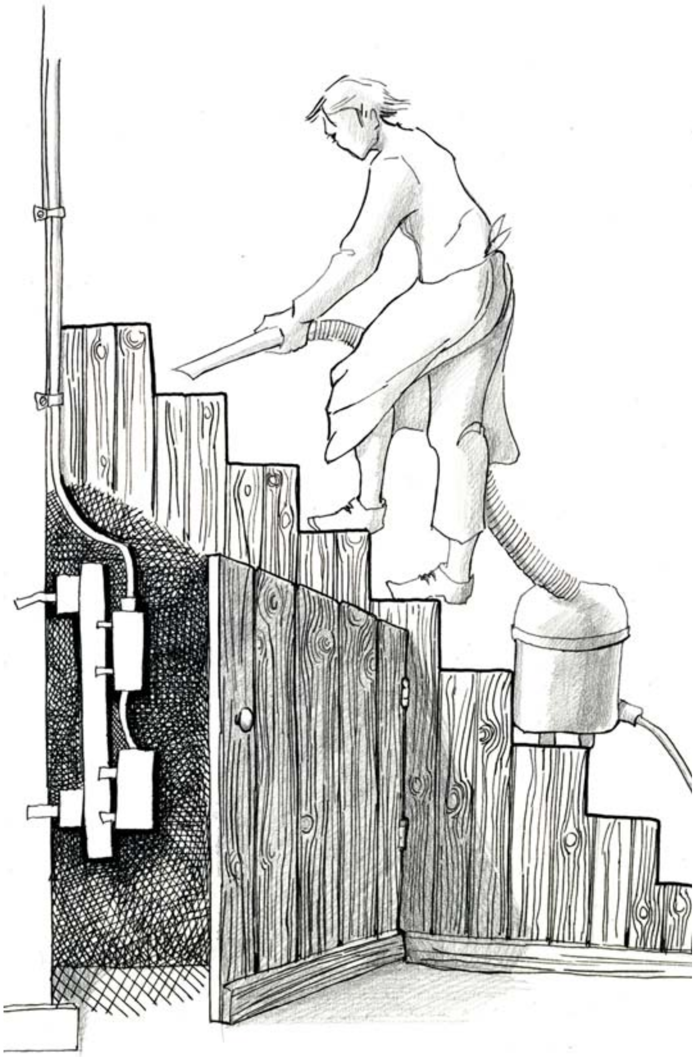
Direct connection

In a direct connection, the PV is connected directly to the load it is supplying. An example of this is with modern street lighting (Fig 12), where the panels are fixed to the street lighting column and only supply the individual street light.

Off-grid connection

Where no mains electricity is available, a PV can be used to replace or supplement the existing local electricity supply (a diesel generator, for example). The PV is connected via the controller and inverter to the fuse board or dedicated load.

10 Electrical equipment mounted on a pattress



11

An installation, showing the inverter, isolator. *(Photograph courtesy of Solar Century.)*

If there is no generator or other electricity supply, batteries can be used to store energy as it is generated by the PV, for use later when it is needed. (Fig 13).

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 storage space must be well ventilated, as batteries give off a gas in their operation, and preferably cool: warmer temperatures reduce battery life.

Grid connection

A PV can also be used to supplement mains electricity, offering the security of a continuous electrical supply. In this case there are two inputs to the fuse board, one from the PV and one from the mains (Fig 14). 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 exported to the national grid.

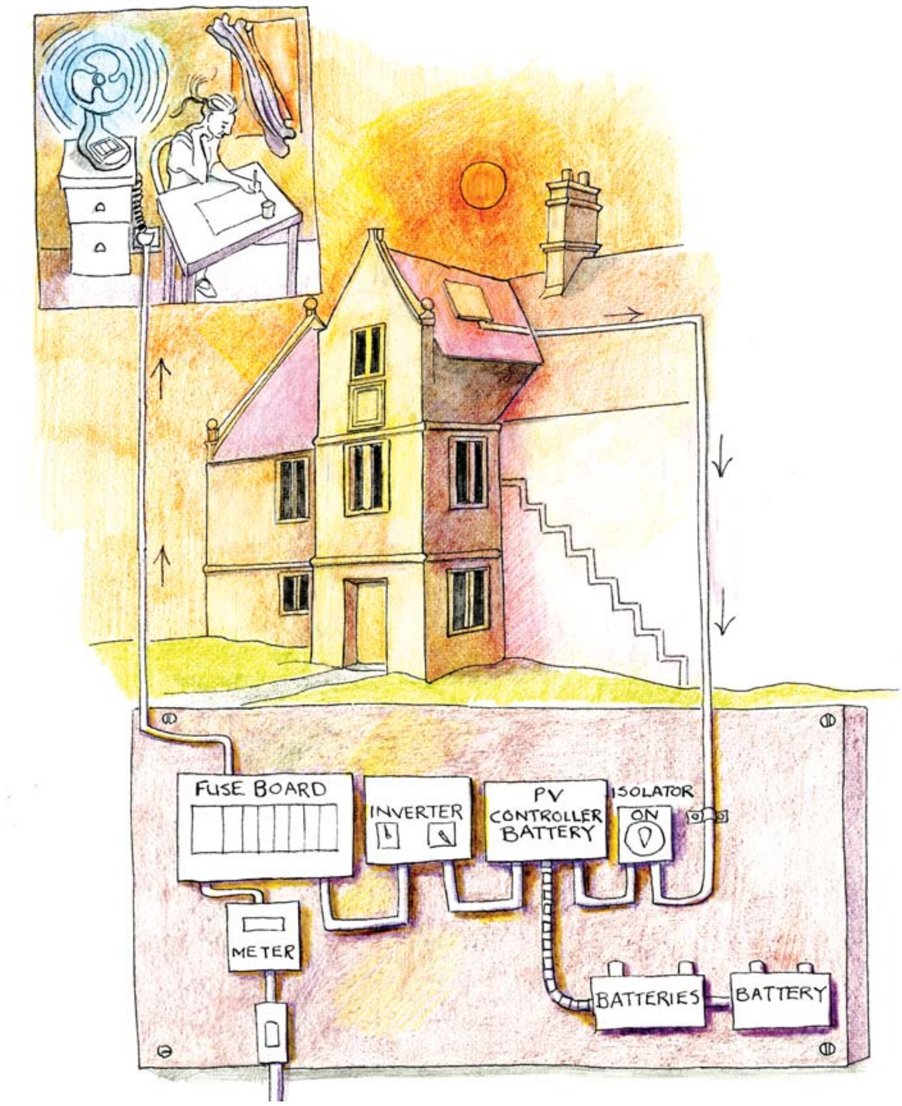
12

A street light with PV mounted on the column. *(Photograph courtesy of Roger Smart.)*

13

Deep-cycle battery installation. *(Photograph courtesy of Wind and Sun Limited.)*

Two meters are required, one to measure the amount of imported electricity and the other to measure the generated electricity by the PV system to be exported. This is done because the value of the units for exported units is lower than that of those imported. In addition, the electricity supplier levies a charge for the metering facility.



14 Electrical connection options.

MAINTENANCE AND WORKING LIFE

All renewable installations require maintenance to ensure they remain reliable and efficient. When maintenance is carried out there is the potential for damage to be caused to the fabric of the building. When planning the installation it is important to talk to the installer about how often equipment would need routine maintenance and how the equipment would be accessed. Regular inspection of cables and equipment conditions will also be necessary.

As mentioned earlier it is important to remember that, because the maximum working life of a PV is around 20 years and that of many of its electrical parts far less, a building could have more than one installation. Damage to the building's fabric can be minimised with careful planning not only of the installation but also of the PV's removal at the end of its useful life. Batteries have a life of around 6-10 years, depending on the type of battery and on environmental conditions. Once the batteries have come to the end of their useful life they must be disposed of carefully.

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GRANTS

Grants for the installation of PV's are available to householders, community organisations and schools from the Low Carbon Buildings Programme (*see* Useful contacts) which is managed by the non-profit, government and the private sector funded Energy Saving Trust. For the average domestic system, costs can be around £4,000-£9,000 per kWp installed, with most domestic systems usually between 1.5 and 2 kWp. The Low Carbon Buildings Programme grant is for a maximum of £2,000 per kW of installed capacity, subject to an overall maximum of £2,500 or 50% of the relevant eligible costs, whichever is the lower and are payable on completion of the installation.

Recipients of these grants must use programme-accredited installers and materials. The programme's list of accredited installers is a useful resource even if you are not applying for a grant.

USEFUL CONTACTS

RENEWABLE ENERGY AND CLIMATE CHANGE

Historic Environment, Local Management (HELM)
English Heritage
1 Waterhouse Square
138-142 Holborn
London EC1N 2ST
Tel: 020 7973 3000
www.helm.org.uk

UK Climate Impacts Programme (UKCIP)
Oxford University Centre for the Environment
Dyson Perrins Building
South Parks Road
Oxford OX1 3QY
Tel: 01865 285717
www.ukcip.org.uk

ENERGY CONSERVATION

Energy Saving Trust
21 Dartmouth Street
London SW1H 9BP
Tel: 020 7222 0101
www.energysavingtrust.org.uk

SOLAR POWER

British Photovoltaic Association
Renewable Energy Association,
17 Waterloo Place,
London SW1Y 4AR
Tel: 020 7747 1830
www.greenenergy.org.uk

Centre for Alternative Technology
Machynlleth
Powys SY20 9AZ
Tel: 01654 705950
www.cat.org.uk

PVS AND WILDLIFE

The Royal Society for the Protection of Birds
The Lodge
Sandy
Bedfordshire SG19 2DL
Tel: 01767 680551
www.rspb.org.uk

Bat Conservation Trust
Unit 2, 15 Cloisters House
8 Battersea Park Road
London SW8 4BG
Tel: 020 7627 2629
www.bats.org.uk

Natural England
Northminster House
Peterborough PE1 1UA
Tel: 0845 600 3078
www.naturalengland.org.uk

PLANNING GUIDANCE

Department for Communities and Local Government
Eland House
Bressenden Place
London SW1E 5DU
Tel: 020 7944 4400
www.communities.gov.uk

English Heritage
1 Waterhouse Square
138-142 Holborn
London EC1N 2ST
Tel: 020 7973 3000
www.english-heritage.org.uk

RENEWABLE ENERGY GRANTS

Low Carbon Buildings Programme
Department for Business Enterprise and Regulatory Reform
Tel: 0800 915 0990
www.lowcarbonbuildings.org.uk

Department for Business Enterprise and Regulatory Reform
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000
www.berr.gov.uk

LEAD ROOFS

Lead Sheet Association
Hawkwell Business Centre
Maidstone Road
Pembury, Tunbridge Wells
Kent TN2 4AH
Tel: 01892 822773
www.leadsheetassociation.org.uk

HISTORIC PROPERTIES WITH RENEWABLE-ENERGY INSTALLATIONS

Historic Scotland
Longmore House
Salisbury Place
Edinburgh EH9 1SH
Tel: 0131 668 8600
www.historic-scotland.gov.uk

The National Trust
PO Box 39
Warrington WA5 7WD
Tel: 0870 458 4000
www.nationaltrust.org.uk

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Building services
Engineering and Safety Team
English Heritage
1 Waterhouse Square
138-142 Holborn
London EC1N 2ST

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