



Campaign to Protect
Rural England
Standing up for your countryside



ENSURING PLACE-RESPONSIVE DESIGN FOR SOLAR PHOTOVOLTAICS ON BUILDINGS

A good practice guide for designers, manufacturers and installers





www.cpre.org.uk
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FOREWORD

Shaun Spiers, Chief Executive, CPRE

The English countryside can make a significant contribution to reducing greenhouse gas emissions. We need to find cleaner sources of energy – but this should not be at the price of unacceptable harm to our countryside.

Solar PV on buildings offers a great opportunity but it should be installed in ways that do not harm the character of the local environment, whether in towns or villages.

This publication fills a gap. Most solar PV goes on non-listed buildings but there is little guidance on how to do it well. Solar PV can look inappropriate if not well sited or designed. Done well, it can be unobjectionable or even enhance a building's appearance. The aim of this guide is to ensure that solar PV is done well.

This guide sets out 10 principles, along with examples of what can be achieved. By illustrating the principles of good design and siting of solar PV, the guide shows the difference that a bit of thought and some relatively straightforward measures can make.

Incorporating the principles outlined here in the everyday practice of designing and installing solar PV would ensure more exemplary installations: less carbon, less ugliness, even, perhaps, more beauty – a pretty good outcome.

Now, over to the designers and installers.



Shaun Spiers

1. INTRODUCTION

Over recent years there has been a large increase in the installation of solar photovoltaic (PV) systems on buildings. While technical guidance on installing solar is available (in this publication, 'solar' refers exclusively to solar PV technologies), as well as some guidance on installing solar on heritage buildings, there is little overall guidance on the design of solar PV for conventional buildings, and with regard to landscape and visual impacts. This is the case both for the built and the natural environment.

This guide, the result of a partnership between the Campaign to Protect Rural England (CPRE) and BRE National Solar Centre (NSC), aims to fill this gap. By setting out principles on the place responsive design, including siting, of solar on buildings, it aims to promote better design and deployment of solar PV systems. These principles should be considered in addition to technical guidance on the safe, professional installation of solar PV.

What is place-responsive design?

Place-responsive design means considering a development's landscape and visual impacts in the context of buildings, the local area and the wider setting.

Landscape impacts are the direct and indirect effects on the landscape as a resource; they concern the landscape's character as well as its specific aesthetic qualities. Visual impacts relate to the effects on views and visual amenity as experienced by people.

In relation to solar PV on buildings, responsive design and siting encourages an approach that is sympathetic to the visual appearance of the building and the local area from which it can be seen. It is important that solar PV is in harmony with the building on or into which it is installed, as well as maintaining or enhancing the character of the wider area and landscape. (For more information see the Landscape Institute's 2013 third edition of its Guidelines for Landscape and Visual Impact Assessment.)

Good design respects function, not just form. Place-responsive design as applied in this document respects the need for solar PV systems to be cost effective and to generate electricity effectively.

This guide therefore:

- Examines available solar PV technologies and approaches to installing solar PV;
- Presents ten principles for place-responsive design, including siting;
- Identifies and addresses barriers to improved practice;
- Presents case studies of real projects that put the principles into practice;
- Reviews existing guidance, planning regulations and energy policy in relation to the visual impact and responsive design of solar PV systems (Annex).

An accompanying leaflet, Solar Design Tips, illustrates the principles listed in this guide in a simple and accessible form.

Why is a guide needed?

While the planning system promotes good design and there are many examples of good practice, there are also many cases where poorly designed or installed solar can be perceived to have a negative impact on the appearance of a building or the wider area. Solar on most domestic buildings has permitted development rights, as has solar PV of up to 1MW on non-domestic buildings.¹ This means that in most of these cases planning permission is not required. Although there are still conditions to be met (see Annex A), there is, therefore, some freedom in decision-making around installing solar. So, in cases of permitted development, where there is no scrutiny by the local planning authority, there might be little or no consideration of visual impact, particularly if the installation is rushed or not properly thought through.

Unfortunately, it is the poorly designed installations that tend to attract attention, rather than those that take account of, and enhance, the appearance of buildings. The potential impact is huge: more than 800,000 solar PV systems have been installed in the UK under the feed-in tariff (FiT) scheme since it was introduced in April 2010.²

The FiT scheme, which pays for electricity generated by solar, together with the prospect of long-term stable returns in a volatile electricity market, means that many people have been encouraged to install solar for financial reasons. In addition, recent survey findings suggest that solar PV could add to the value of UK homes,³ which may be another financial motivation for some. Responsively designed solar can be considered an asset as it can enhance the building's attractiveness and improve its energy performance, reducing bills and increasing the value of the property. In the USA, real market data on house sale values has shown a link between solar and higher house prices. However, despite strong calls from industry, this work has not yet been done comprehensively in the UK due to data protection issues.⁴

In early 2016, FiT tariffs were greatly reduced. While the installation of solar PV has slowed, it has not come to a standstill,⁵ because of the falling costs generally of installation. This makes it all the more important that concerns about its appearance and/or effects on the landscape are addressed. The cumulative impact – that is, the combined effect of several solar installations in a given area – should also be considered. A planned approach is needed.⁶ Good design costs little and a small effort can ensure schemes are as attractive as possible.

The place-responsive design principles presented here will both help to realise the benefits of solar energy and, at the same time, reduce the risk of a bad visual impact.

Intended audience and building types

This guide aims to influence those with the greatest potential to improve good practice: system designers, including architects, manufacturers and installers of solar equipment. Other audiences who might find it useful include local planning authorities in terms of policy making and development management; heritage and conservation organisations, and property agents.

The scope is new-build and retrofit solar PV installations on conventional buildings, whether domestic, industrial or commercial. It is not intended to cover other applications such as solar farms or novel applications such as on roads and noise barriers, though some of its principles may be relevant.

While primarily concerned with solar PV installations, many of the design principles discussed are applicable to other solar technologies, such as solar thermal and solar hybrid (PV-T) systems. (Solar thermal technologies harness solar energy to heat up water. PV-T systems combine the functionality of solar PV and solar thermal.) The emphasis is on adopting good practice with standard equipment that is commercially available today.

2. TECHNOLOGIES AND APPROACHES

The choice of solar cell technologies and approaches, whether integrated within buildings or applied to them, provide opportunities to consider design and siting. This section discusses the most commonly used technologies, as well as promising technologies, and approaches to installing solar PV systems.

2.1 Technology types

The most widely-used PV cell technologies are mono- and polycrystalline silicon, as well as thin film. Prices of these materials vary, as does their performance and maintenance as this depends on how they are applied. The following characteristics should be noted:

First generation technologies include mono and polycrystalline silicon. These materials generally produce a relatively high yield per square metre.

Approximately 90% of the world's installed solar PV to date uses mono or polycrystalline silicon technology. Crystalline silicon panels have traditionally been blue but are now available in a wider range of colours. The more unusual colours (that is, not blue or black) are less efficient, meaning they convert a smaller percentage of sunlight into usable electricity. Crystalline silicon panels typically vary in efficiency from 14%-22%, and cost rises with efficiency and quality. If cost is a consideration but space is not, then a larger, lower-efficiency system can be installed, generating the same electrical output as a smaller, more expensive version.

Monocrystalline glass-glass laminate panels that consist of octagonal solar cells allow some natural light through. This can improve the visual appearance when used as roofing, shading, cladding or as a vertical wall or facade.

Second generation technologies, such as 'thin film', have a lower cost per square metre than crystalline silicon panels but are typically less efficient; they range in efficiency from 12%-18%. Often a larger area is required for the same electrical output, although thin film has been shown to perform better in partially shaded locations, such as those commonly found in the built environment.

Thin film is typically black but is available in a wide range of finishes and different levels of transparency, which allows it to be built into glazing. Integrating solar PV into the building fabric, possibly replacing conventional building materials, is referred to as building integrated PV (BIPV). Second generation thin film technologies are commonly used in this way in the UK, especially in new installations. This can be done, for example, with BIPV glazing or by adding solar PV to an atrium.

Thin film can be rigid or flexible. Flexible panels are often chosen for architectural or lightweight applications in buildings such as canopies or shading, but tend to be more expensive.



Monocrystalline glass-glass panels.



Polycrystalline solar PV with aluminium frames.

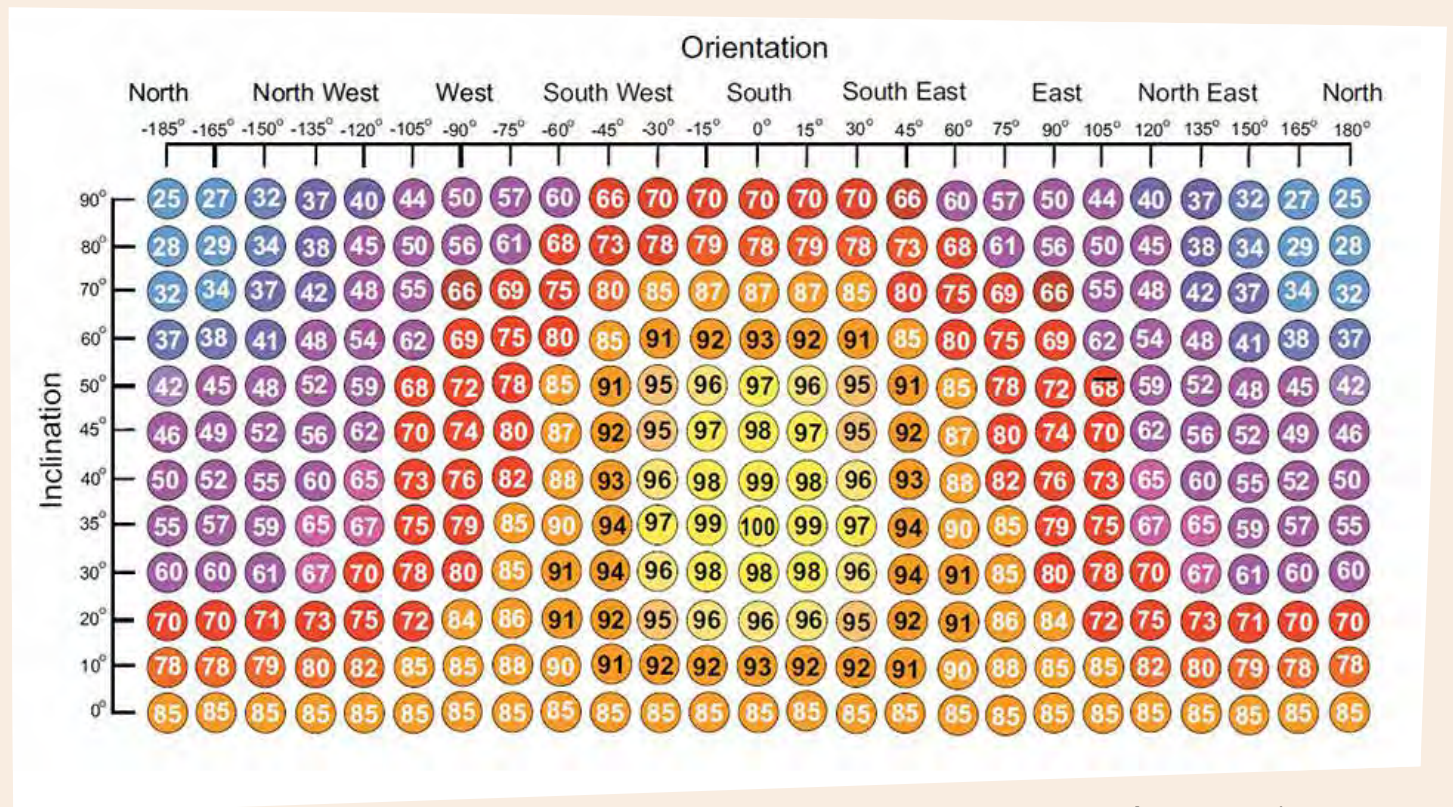


Transparent thin film solar PV.

Third generation relates to materials that can be printed onto a wider variety of building components and other materials, such as glazing and canopies. This has the potential to be very cheap to deploy, yet at present is not used commercially on buildings as their efficiency is lower and the performance will degrade over a relatively short period. Nevertheless, these materials have great potential and much academic and commercial research is focused on this area.

Note on system performance

As the main reason for installing solar is to generate power, good design also relates to how the system performs. Solar PV systems are given a rating in 'kilowatt peak' (kWp) – the rate at which the system generates energy at peak performance. They work most effectively when facing the sun for as many hours as possible. In the UK, systems facing south and angled at 30-35 degrees produce the most electricity. The diagram below shows the variations.



Variation in solar output with orientation to south and angle of inclination.⁷

The result is that most solar PV building installations are on roofs facing south. While some PV systems have been installed as facades or integrated glazing, if the system is not facing south and up, then electricity output tends to be reduced. Also, shading can significantly reduce performance and must, therefore, be avoided where possible.

Some systems are designed to match the usage patterns of the building's occupants. Systems that are split over east and west-facing roofs can supply power in the early morning and later evening. While their output is overall slightly lower than that of south-facing systems, the power is generated when residents are generally at home, rather than giving a peak in power in the middle of the day as do south-facing panels. This way, residents can themselves make better use of the power they generate, rather than exporting most of it to the grid.

2.2 Approaches

Solar PV can be installed in two ways:

- Building applied photovoltaics (BAPV), which is a retrofit added to the building after construction, and
- Building integrated photovoltaics (BIPV), where solar PV is integrated into the building and its components; the BIPV becomes a functional part of the building fabric.

Whatever the approach, it is important first to consider the condition of the roof or other surface; for example, whether the roof can cope with the weight. The installers' expertise must extend beyond simply knowing how to put panels on a roof.

Building applied photovoltaics

BAPV is the most commonly available solar installation and is generally considered the conventional, or standard, approach to rooftop solar PV systems. The image below shows BAPV applied to the roof of an industrial building.



BAPV on industrial roofs at the Olympus Business Park in Newton Abbot. Standard sets of solar panels with metal frames have been used on a low pitch industrial roof. As the setting is industrial, the potential for negative visual impact is low.

Building integrated photovoltaics

BIPV, which is part of the building, is recommended for new-builds; integrating the system when the roof is installed reduces the risk of damaging it. BIPV systems can also be retrofitted but this is usually more complex and expensive. The BIPV market is not as well developed as that for BAPV, although it is growing and much of it is made in the UK. Clients may not be aware of the range of BIPV products now available or the variety of ways in which it can be applied.

The options for using BIPV include roofs (for example, solar slates, shingles and in-roof solar systems), canopies, louvres or solar shading, facades and solar glazing, such as part of an atrium.

Roofs



Sunstation: a BIPV solar system that blends into the roof.

Canopies



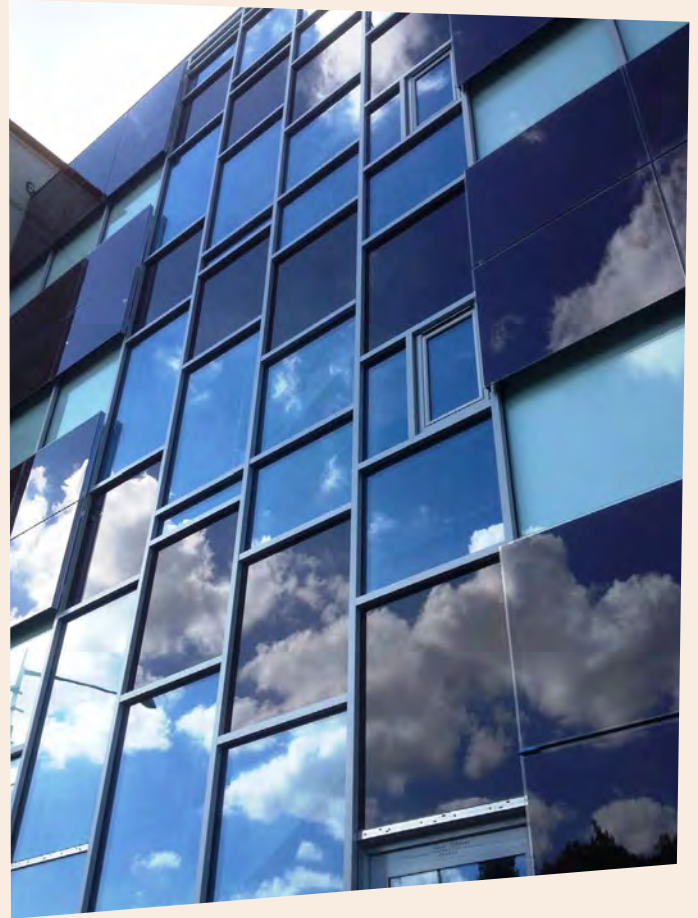
Clear solar glass, a second-generation technology, used as a canopy at a school building, Nantou, Taiwan.

Louvres/solar shading



Solar deployed as brise-soleil (a solar shade) on a building's south facade to reduce the risk of internal overheating.

Facades



Solar glazing



Both images show examples of solar glazing, with different levels of light transmittance. Solar glazing can now be designed into buildings as a form of BIPV.



External and internal view of the solar facade, a second-generation technology, at Future Business Centre, Cambridge.

3. PRINCIPLES TO BE CONSIDERED IN PLACE-RESPONSIVE DESIGN

This section describes and illustrates ten principles that should be considered in relation to place-responsive design and the siting of solar PV systems. The principles include the different technologies discussed earlier, address BAPV and BIPV approaches, and are informed by methods that are easy and practical to apply to a range of installations without incurring excessive cost. They are the result of discussions with solar PV professionals and building designers.

The principles are in three categories, discussed in more detail below. They are also addressed in the leaflet accompanying this guide.

Product

- Colour and contrast
- Framing
- Size

Application

- Symmetry in panel layout
- Coverage
- Complementing features
- Mounting system

Setting and wider context

- Roof positioning
- Neighbouring solar roofs
- Planning designations

3.1 Product

1. Colour and contrast

Panel colour, reflectance and finish can be chosen to complement the building or surroundings. In some cases, a contrast of panel colour and roof finish can work well, but generally a match of panel and roof colour works better. Most crystalline and thin film panels are dark blue or black but a variety of finishes and tones are available. The use of low-reflectivity PV can reduce glare which can be a nuisance to neighbouring properties. Distributors can often advise on product availability and suitability.



Colour matched 'in-roof solar' BIPV, where the colour of the solar panels has been matched to that of a modern terracotta roof tile on new build housing.



The Dyfi Eco Business Park shows BAPV with black anodised frames on a slate roof, where the panel colour is closely matched to the colour of the slate (see the case studies section).



BIPV installation demonstrating good colour match of panels and roofing material at the Commonwealth Games Athletes' Village, Glasgow (see the case studies section).



First-generation polycrystalline in the form of green-and-gold louvres are designed to provide shading and prevent summertime overheating at these flats at Kingsgate House in London. The colours were chosen to complement the tree-lined environment and blend in with the local streetscape (see the case studies section).

2. Framing

Frameless or black-framed panels can be used where frames would detract from the building. Untreated or natural finished metal panel frames can draw attention to the system unnecessarily. This does not have to be the case, as the images illustrate. Many manufacturers supply panels with painted or anodised frames.



Domestic BAPV installation with frameless panels.

3. Size

Giving thought to the size of the components and matching the system to other building components, such as windows or building stones, can complement the building and its surroundings. For example, solar tiles of similar size to the other roof tiles help blend the solar system into the overall appearance of the building.



The size of the panels of this brise-soleil matches the size of the tiles on the building's walls (see the case studies section).



C21e solar slate has been used to integrate the solar system with the existing appearance of St Paul's Church in Devon, a grade 1 listed building (see the case studies section).



Eight solar panels and two solar thermal panels have been installed on the roof of this building in Cornwall. The panels are identical in size and colour, enabling an effortless combination of different forms of power generation.

3.2 Application

4. Symmetry in panel layout

How the panels are arranged can have a significant effect on their appearance. If possible, avoid installing them one by one on a roof without considering how they will look in combination. Panels in a combined landscape and portrait format are less pleasing to the eye. If possible and practical, roof furniture such as aerials and flues should be moved to allow for a symmetrical installation.

A symmetrical installation is easier to achieve on rectangular roofs. For non-rectangular roofs, more attention to detail is often required.



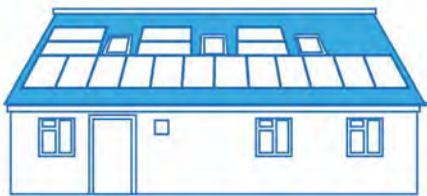
Non-symmetrically installed BAPV: panels are positioned in landscape and portrait format, panel edges are not always aligned and rails are protruding in an inconsistent manner.



BIPV system with high degree of symmetry, achieved through consideration of roof furniture and installing all elements in portrait format.

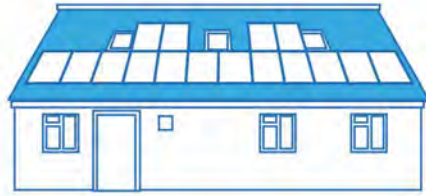
The symmetrical layout of panels can have a crucial effect on the appearance of an installed system. The illustrations below, produced by Viridian Solar, illustrate how different layouts have different levels of visual impact.

Poor



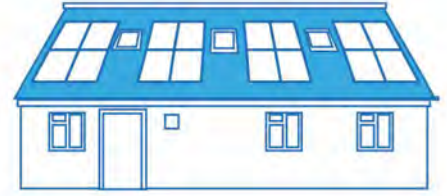
Poor: 18 panels in a mixture of landscape and portrait; little symmetry and panel edges not aligned between rows.

Better



Better: 16 panels with a single axis of symmetry; panels aligned between rows but not evenly spaced relative to roof lights.

Best



Best: 16 panels with two axes of symmetry; panels evenly spaced around roof lights, organised in broken blocks.

Poor



Poor: 13 panels, no symmetry, panels arranged around roof features, evenly spaced around windows but misalignment between rows.

Better



Better: 11 panels, no symmetry, neater arrangement with panels aligned between rows.

Best



Best: Eight panels, single rows of blocks with symmetry around dormer windows.

Poor



Poor: Seven panels, no symmetry, stepped edge and misalignment between rows, oddly placed single panel.

Better



Better: Six panels, no symmetry, stepped edge and misalignment between rows.

Best



Best: Six panels, rectangular blocks of portrait panels, trade off of shading in bottom left

5. Coverage

As well as how panels relate to one another, it is also important to consider how the installation as a whole relates to the roof or building. In terms of the visual impact of a rooftop, an ‘edge to edge’ installation covering the whole roof is often desirable. However, for non-domestic buildings, permitted development requires a one metre separation between panel edge and roof edge.

On non-symmetrical roofs, care should be taken not to overload the roof visually – if a well-finished edge is not possible it may be more aesthetically pleasing to install fewer panels.



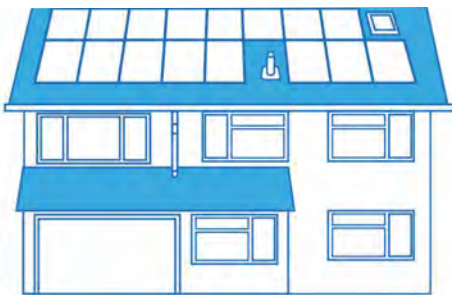
BIPV installation on building in rural Cornwall. The panels are installed to span from eaves to ridge.



The BAPV installation on Yorkshire Building Society in Bradford demonstrates careful design and implementation of a large solar PV system over a complex, non-symmetrical roof layout.

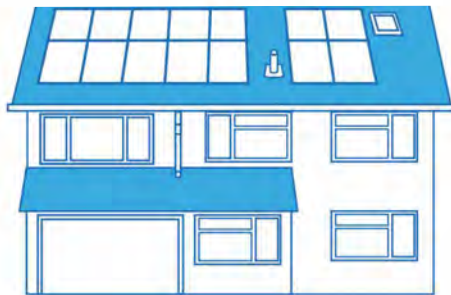
In terms of coverage and positioning, the illustrations below, by Viridian Solar, illustrates how (near) edge to edge installations can reduce the level of visual impact.

Poor



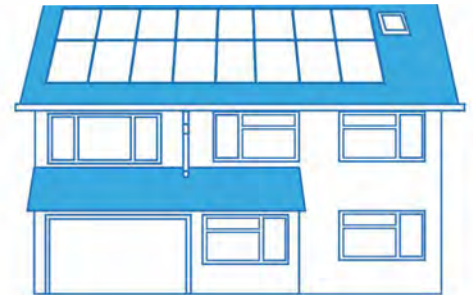
Poor: 16 panels, no symmetry, panels arranged around roof features

Better



Better: 14 panels, single axis of symmetry, neater arrangement

Best



Best: 16 panels, two axes of symmetry, vent pipe moved or replaced with a low-profile version below panels, near full-roof coverage.

6. Complementing features

Solar PV should be positioned in proportion to the building and its style, including in-roof features. With careful design and implementation, systems can be effectively combined with roofing elements such as in-roof windows. Giving thought to the principles of panel size and symmetry, discussed above, is critical to success.

Panels can also be installed in such a way as to closely mimic traditional roofing elements. For example, in the image below the local council's planners required the panels to be arranged as symmetrical 'broken blocks' to resemble roof lights or dormer windows.



An in-roof BIPV system, designed to complement the roof-light windows.



A 'broken block' approach to BIPV panel layout was used on this council-owned social housing refurbishment in Brandon Court, Cambridge.

7. Mounting system

For rooftops, both BIPV and BAPV require mounting systems. In-roof systems have the advantage over on-roof systems in that the mounting system is not visible. For BAPV then, attention should be paid to the profile of the mounting and its rails.

In the UK, planning regulations allow a gap of up to 200mm between the panels and the roof. This therefore affects how BAPV is installed. Gaps as large as 200mm can have a negative visual impact on the building and the local area if they are visible from the ground. A careful choice of roof hooks can lower the profile of the mounting system, reducing both the visual impact and the risk of wind loading. For example, direct rail mounting systems can be used for trapezoidal roof sheeting (see the full-roof installation in the rural poultry farm case study).

The visibility of the rails also affects the visual impact of the mounting system. While many BAPV mounting systems require a small length of rail to protrude, this can be kept to a minimum.



In contrast, the Victorian Terrace at BRE uses a different mounting system to give a low mounting profile.



BAPV installation with a larger than necessary mounting system profile due to a high roof hook.



Example of a mounting rail protruding more than necessary.

3.3 Setting and wider context

8. Roof positioning

For non-domestic buildings, it is sometimes possible to install solar PV in the valley of a roof or on roofs that are not visible from the ground or other buildings. In this case, the principles about choice of product and installation are less important. Nevertheless, responsive design and siting are still relevant in terms of choosing to place the system where it will have minimal visual impact. The picture below shows how responsive design principles have been applied, and have added to the appearance of the building, even in a location with minimal visual impact.



Symmetrical positioning of solar PV on roof valley, covering a roof in its totality.

9. Neighbouring solar roofs

Solar PV on adjacent houses of the same type may look out of place if there is no standardisation. Examples include neighbouring houses with panels of different sizes and colours, positioned differently in relation to the roofs and mounted onto, or integrated into, the roofs in various ways. These differences can have a negative impact on the street-scene as a whole.

Such cumulative impact can be reduced if property developers consider the appearance of the building in relation to other buildings in the vicinity and work with planners to ensure the same PV systems are used across the area. Applying the responsive design principles for product and application across the buildings would further improve overall appearance.

Even so, some cumulative impact is inevitable if the public is encouraged to use solar on their homes. Also, as technology develops it will be challenging, if not impossible, to have uniformity between new and older systems.



Demonstrating excellent standardisation of BIPV systems on adjacent homes.



High levels of standardised residential solar installations in Nottingham.



Although there is symmetry in how the panels are placed on the roofs of these adjacent buildings in Wales, there is contrast between the framed and frameless solar panels.

10. Planning designations

Designations detailed in Annex A show where the design and installation of solar PV require more consideration of the visual aspect of the building and the landscape. Examples include conservation areas or National Parks and Areas of Outstanding Natural Beauty (AONBs). Where development requires planning permission, many planning authorities' local plans, informed by the National Planning Policy Framework (NPPF), encourage sustainable development, requiring balanced judgements to be made. This is often reflected in design policies and a local plan's overall vision.

Useful background information on a specific area can be found in the profile documents for each of England's 159 National Character Areas. These can be used to assess landscape sensitivity, as well as the local capacity for solar PV development and can also support the Guidelines for Landscape and Visual Impact Assessment (GLVIA) process. They set out general objectives guiding the protection and enhancement of the landscape (in designated areas). The principles described above can be used to shape responsive design for solar PV in these areas. For example, neutral-coloured BAPV with dark frames is generally less obtrusive to the landscape, as is low-reflectivity rooftop BIPV of similar size to the tiles on the roof into which it is fitted.

The general rule of thumb for solar PV on buildings is that the more harmoniously the solar PV system matches the building, the better it fits into the designated area where the building is located.



Solar installation and domestic conversion on a listed barn in Chester, installed by The Greener Group.

4. ADDRESSING BARRIERS TO IMPROVED PRACTICE

There are, however, some obstacles to installing place-responsive solar. Four important barriers are discussed below.

4.1 Financial concerns

Cost is important to most clients but while a tight budget limits choice, there is still plenty of scope for installing attractive solar. Clients, designers and installers can play a role, particular the latter as many clients prefer to be led by expert advice.

Clients who are interested in BAPV can ask about symmetry, colour and contrast, mounting systems and roof objects when choosing a product; manufacturers are often able to follow the principles of place-responsive design with little additional cost. For example, they can use anodised or painted frames, which can be a cost-effective way of reducing the visual impact. Frameless BAPV panels and BIPV systems, however, can come with a higher price. Although BIPV is generally more expensive, innovation is driving down costs. Also, in some cases, such as roof replacements, BIPV can be cheaper than BAPV.

Clients should also consider revenue streams as well as capital costs. Solar PV can be an effective way of reducing electricity bills. For domestic properties, a well-designed solar PV installation can be an asset, and has the potential to increase the value of the property. Similarly, an increase in the property's Energy Performance Certificate (EPC) can mean a lower interest rate for some mortgages.⁸ For non-domestic properties, additional revenue streams can be generated; for example, a solar canopy over a car park could lead to electric vehicle charging and power purchase agreements. These initiatives can help to make a viable business case.⁹

4.2 Lack of understanding of the availability of products

Clients often lack knowledge of the products available or are bewildered by the different technologies and approaches, which can stand in the way of place-responsive design. Yet the advantage of a wide range of products and approaches is that informed clients should be able to find what they want.

Designers and manufacturers have a role to play in advising clients, as do guides such as this. The internet, trade association publications and trade shows can also provide information on what is available.

4.3 Consideration of new build and retrofit

Retrofitting solar can be difficult, mainly because of the difficulty in integrating old and new materials, both visually and technically.¹⁰ It is difficult to retrofit BIPV on non-rooftop areas, for example, as there are few suitable products. This does not mean that solar cannot be installed; BAPV and rooftop BIPV are often still possible but potential structural issues need to be considered.¹¹

New-build construction generally offers more opportunity for BIPV. Yet building designers are sometimes concerned about the perceived cost and performance and feel they do not know enough about the benefits.¹² Manufacturers, therefore, should provide more information, while designers should think about the clients' reasons for installing BIPV. The drivers might be a desire for sustainable buildings, low-cost electricity and high Building Research Establishment Environmental Assessment Method (BREEAM) ratings, and meeting renewable energy or carbon reduction targets such as those set by local authorities.

4.4 Subjective nature of the topic

A rural area may lose some of its character if rooftop solar PV is installed with little consideration for its impact on the landscape. Yet the importance of the character of the landscape is highly subjective. While most people agree about what is good and bad design, they rate the importance of visual impact differently.

Nevertheless, installing solar in a way that is in sympathy with the building and the wider environment could be considered good judgement. The overall improvement of the appearance of a building is good planning and has the potential to increase its value, both for domestic and non-domestic buildings.

5. GOOD PRACTICE CASE STUDIES

5.1 Domestic

Roof for outbuilding of historic country home



Principles of symmetry, full coverage and frameless panels have been applied to an in-roof BIPV system in what is a sensitive local context in Cambridgeshire, given the historic buildings. This project used large format (500Wp) roof integrated panels of the same size, all in the same position. They cover approximately 18 m², span the roof from eaves to ridge on the outbuilding as the furniture on the ridge of the roof doesn't prevent their use. The installation, therefore, has a clean, uncluttered look.

Client	Private
Capacity (kWp)	2.5
Estimated generation (kWh/year)	2,400
Building electricity load met by solar (%)	50% depending on usage
Contractor/developer	Viridian Solar and Huttie Ltd
Solar manufacturer	Clear Line

Louvres at modern apartment building



Principles of colour and contrast, symmetry and full coverage have been applied to the BIPV glass louvres (above) at Kingsgate House, Chelsea, London.

The building incorporates various low-energy design features including the glass louvres, which have been arranged in portrait format across the front of the building. The system uses three shades of green and gold PV cells to blend in with the local streetscape; the colours complement the tree-lined environment and the panels are designed to look like a living wall. Romag PowerGlaz coloured BIPV laminated cells were integrated into the Colt Shadowvoltaic systems. This use of BIPV shows how solar can be applied in modern architecture in a challenging urban environment.

Together the PV cells and the building's exhaust air heat pump account for a 20% renewable energy contribution, as required by the local authority.

Client	Colt
Capacity (kWp)	Not available
Estimated generation (kWh/year)	13,145
Building electricity load met by solar (%)	~20%
Contractor/developer	Not available
Solar manufacturer	Romag

Rooftop installations using in-roof features at an athletes' village



The installations demonstrate many of the principles in this guide, with attention to colour and contrast, symmetry and the cumulative impact of neighbouring solar installations. They also address coverage and making sure features complement each other by working with in-roof elements; in this case, windows.

The Glasgow Commonwealth Games Athletes' Village was delivered by City Legacy, a consortium of Glasgow-based companies in partnership with Glasgow City Council. The development had to contribute to carbon reduction through the use of renewables. Forster was selected to install integrated solar PV roofing and roof windows to 220 homes, partly based on the added value the contractors could provide in terms of roof finishes and roof lights. They used black trim 250Wp panels, and combined several panels to form 1, 1.25, 1.5 and 2.25 kWp systems. The panels are mounted by means of an in-roof system.

Client	City Legacy
Capacity (kWp)	442 (the total of a mix of 1, 1.25, 1.5 and 2.25kWp PV systems) for the 220 houses
Estimated generation (kWh/year)	Approximately 375,700
Building electricity load met by solar (%)	It is estimated that a 1.5kWp system would generate approximately 30% of a dwelling's electricity demand.
Contractor/developer	Forster Group
Solar manufacturer	Delsolar/Ubbink/Enphase Energy

Roofs on low-carbon homes at the BRE Innovation Park

Zero Bills Home



The BRE Innovation Park in Watford uses a range of innovative construction approaches and techniques. The most recent houses incorporate different types of BIPV in the roofs. The park currently has 10 domestic and non-domestic buildings, including the Zero Bills Home and the ÜserHuus.

Client	Zero Bills Home
Capacity (kWp)	7
Estimated generation (kWh/year)	6,650
Building electricity load met by solar (%)	~90%
Contractor/developer	ZedFactory
Solar manufacturer	Himin

ÜserHuus/Tigh Grian



This house uses volumetric construction, with the main structure assembled on site in one day. It represents an affordable, repeatable and sustainable approach to high-quality home construction.

The roof is a fully integrated, bespoke system: the roofing cassettes have a layer of integrated solar cells on top of the metal substrate. The system was manufactured and supplied by Nexpower, based in Taiwan. The solar PV functionality is provided by an amorphous cell technology, with a total capacity of 3.5kW across 49 functioning roof panels.

The terracotta colour selected for this property successfully blends a traditional appearance with modern technology. Tigh Grian is gaelic for “house of sun”.

Client	ÜserHuus
Capacity (kWp)	3.5
Estimated generation (kWh/year)	3,150
Building electricity load met by solar (%)	~50%
Contractor/developer	Userhuus/ Tigh Grian
Solar manufacturer	Nexpower

5.2 Non-domestic

Brise soleil and roof at Renishaw Innovation Centre



This installation in Gloucestershire combines performance with visual appeal; and incorporates the principles of framing; mounting system profile; symmetry between panels; coverage and positioning on the roof; size of components and minimal protruding of on-roof mounting rails. Also, the rooftop solar is barely visible from the ground, which conforms to the principle of the roof's positioning.

The installation is in two parts: the roof and the brise soleil. The rooftop system is at low pitch so that cannot be seen from the ground but care was taken to ensure that performance was not affected. Romag solar PV panels were chosen for the brise soleil as they could be made to size. This is important as special engineering and design considerations were taken into account to ensure the brise soleil generates maximum output while shading the building at a certain angle. The brise soleil allowed Renishaw to increase the size of their system, and therefore its overall annual output, which helps them meet their corporate social responsibility objectives.

Client	Renishaw
Capacity (kWp)	241 roof + 50 brise soleil
Estimated generation (kWh/year)	202,154
Building electricity load met by solar (%)	Not available
Contractor/developer	Solarsense
Solar manufacturer	Romag

Full-roof installation at rural poultry farm



This agricultural installation in Somerset demonstrates many of the principles in this guide. It shows consideration of colour and contrast: the panels complement the building and the frames complement the roof's colour. The panels are placed symmetrically to give a standardised appearance. The panels cover the whole roof (except where there is partial shading due to the feed silos) and are laid out in the same way on both buildings, conforming to the principle on neighbouring solar roofs. It also meets the principle about the roof's positioning, as installing solar PV on a low-pitched roof such as this reduces visual impact. In addition, the installation uses a direct rail mounting system, allowing the panels to be mounted with as low a profile as possible.

The system is east and west facing, allowing for generation throughout the day and offsetting the requirements of the poultry heaters. At present around 90% of all electricity generated is consumed on site, which means that the system will have paid for itself in under five years.

Client	Private
Capacity (kWp)	240
Estimated generation (kWh/year)	195,120
Building electricity load met by solar (%)	90%
Contractor/developer	Your Power, financed by Lombard Asset Finance
Solar manufacturer	Yingli

Symmetrical rooftop solar at rural businesses



Using an in-roof mounting system to ensure a low profile, two solar PV arrays of 174 m² each were installed on the south-facing roofs of two industrial units at the Dyfi Eco Park at Machynlleth, mid-Wales. The colour of the panels is closely matched to the colour of the slate. Taking into account the stringent planning requirements, Dulas installed the systems and finished them with black anodised profile frames. The panels are symmetrically aligned and placed on the roof as a block, almost covering the entire roof. The attention to colour, contrast, proportion and the surrounding rural landscape has led to an exemplary rooftop installation.

Client	Welsh Development Agency
Capacity (kWp)	13
Estimated generation (kWh/year)	11,700
Building electricity load met by solar (%)	80%
Contractor/developer	Dulas Ltd
Solar manufacturer	AstroPower

Solar slates at listed church



St Paul's Church in Devon is a Grade I listed building. When designing a solar system to integrate into the roof, it was vital to consider the character of the building and the potential landscape and visual impact. When the planners rejected standard solar PV panels, Solarcentury's C21e solar slate was suggested and subsequently installed. Hand in hand with the principle on considering designations, one of the most prominent principles listed in this guide that has been applied is that of colour and contrast. The colour of the slates is close to that of the roof, while their size and shape are closer to that of the original roofing than regular PV panels.

The tiles are also robust and generate the highest amount of energy in their class. They are 'the perfect solution', according to the Reverend Chamberlain: "They have allowed us to preserve the look of the church while generating renewable energy and lowering our carbon footprint."

Client	St Paul's Church, Newton Abbot
Capacity (kWp)	3.95
Estimated generation (kWh/year)	4,000
Building electricity load met by solar (%)	50%
Contractor/developer	Sungift Solar
Solar manufacturer	Solarcentury

ANNEX:

REVIEW OF EXISTING GUIDANCE, PLANNING REGULATIONS AND ENERGY POLICY



To set this guide in a wider context, this section reviews published guidance on design and siting for buildings, planning policy and regulations, and energy policy in relation to solar PV systems in the UK.

Guidance on solar PV design for buildings

Existing literature on the visual impact of solar PV systems provides little information that is relevant to conventional buildings. Most documents relate to specific protected areas¹³ and/or heritage buildings.¹⁴ The guidelines in these documents, therefore, focus on the restrictions imposed by the location and specific characteristics of buildings. While these principles are useful, non-heritage buildings offer more opportunities for responsive design.

Architectural literature addressing solar systems tends to focus on technical rather than aesthetic considerations.¹⁵ A BRE technical document states that well-designed systems can complement new construction and retrofit can be designed to reduce any visual impact.¹⁶ Additionally, the recent booklet from the Solar Trade Association, *Stunning Solar*, contains images that show particularly attractive solar installations.¹⁷ Several of these pictures are presented as case studies.

Perhaps one of the most relevant supplementary planning guidance documents to date is that from Cornwall Council. The county has a larger-than-average number of solar systems. This guidance stresses the importance of thinking about the effect of any solar installation on the character or appearance of the building, as well as considering any cumulative impacts on the overall appearance of a collection of buildings or roofs. It highlights the siting of solar installations and characteristics of the product, such as colour.¹⁸ Several of the principles set out in this document are illustrated in more detail in the section ‘Principles to be considered in place-responsive design’.

Guidance for managing development impacts on landscape and environment

The recognised methodology for assessing and mitigating the impact of development on the surrounding landscape and local environment is provided by the GLVIA.¹⁹ This methodology is normally used for large, stand-alone projects where there is a legal requirement for a full Environmental Impact Assessment, and a landscape and visual impact assessment as part of that.²⁰ However, the GLVIA methodology can also be voluntarily or informally drawn upon.

The GLVIA assessment process includes identifying landscape designations and heritage sites, and respecting the frameworks for the management of these sites. Relevant designations include:

Heritage

- UNESCO World Heritage Sites
- Historic England Listed Building status
- Registered Parks and Gardens
- Conservation Areas

Landscape

- National Parks and/or AONBs
- National Character Areas
- Locally designated areas within local plans

Also relevant are design codes, which capture the specific requirements of a place and encourage looking at the development in its entirety. Design codes are often used as part of planning application processes but can also be part of local plans, neighbourhood plans, or covenants, such as garden cities.

None of the designations necessarily exclude the development of solar PV, although planning permission is required for listed buildings. The section on case studies provides examples of how solar PV designers have approached designations and how responsive design has been applied.

Planning policies and regulations

The National Planning Policy Framework (NPPF) provides the regulatory backdrop to planning policy and decisions in England. The NPPF supports the transition to a low-carbon future through the use of renewable energy and stresses the importance of local policies in maximising its development.²¹ Supplementary government guidance stresses that rooftop solar development should be considerate of designated areas, and that the colour and appearance of solar panels should be considered.²²

In England, domestic solar PV has permitted development rights under Schedule 2 to the 2015 Town and Country Planning Order for England.²³ This means that planning permission is not required to install solar, except on listed buildings. However, there are conditions which must be met. Solar panels must not protrude more than 200mm from the roof or wall surface, and the solar should not be higher than the highest part of the roof (e.g. the roof ridge line). Also, in conservation areas or World Heritage Sites solar PV is not permitted if it is installed on a ‘wall or roof slope that would be visible from a highway’.²⁴ Permitted development rights do not apply when the council has removed them through an Article 4 direction.²⁵ Article 4 directions restrict the scope of development; for example, to preserve the character of an area.

In 2015, permitted development rights for solar PV on non-domestic buildings were extended up to 1MW, subject to approval of design and external appearance. Non-domestic solar PV up to 1MW is still subject to approval of its design and appearance,²⁶ and must 'so far as practicable, be sited so as to minimise its effect on the external appearance of the building and the amenity of the area'.²⁷ Permitted development requires that solar PV on pitched roofs must not protrude more than 200mm from the plane of the roof, solar PV must not be more than 1m above the highest part of a flat roof, and must not be installed within 1m of the edge of the roof. It must not be installed on a listed building or its grounds.²⁸ Solar PV installations over 1MW still require planning permission.

The permitted development status of many solar installations cuts costs and unnecessary regulation while respecting the rights of building owners to make their own decisions. However, it also means that there is a real need for good quality guidance. Informed by the GLVIA methodology, this document sets out how to address the permitted development requirements in a structured way.

The need for planning permission should not be seen as a barrier but as an opportunity to install solar that largely incorporates the principles of responsive design.

UK government energy policy

Beyond reducing available solar subsidies (see *Why is a guide needed?*), the current UK government has not issued any new policy or strategy for the solar PV industry. What strategic guidance is available was published by the coalition government of 2010-2015 and is not necessarily up to date. However, it is worth reviewing it briefly.

The UK Solar PV Strategy, Part 1 (2013),²⁹ refers to visual impact, with appropriately sited installations as one of four guiding principles. The focus, however, is mostly on ground mounted solar. The UK Solar PV Strategy, Part 2 (2014),³⁰ makes explicit reference to the visual impact of solar on rooftops and the need for guidance. The strategy states: 'Clusters of rooftop installations in residential areas can affect visual amenity. Industry will need to continue to innovate to improve the appearance of roof-mounted solar installations and to achieve best practice in design.'

Although industry plays a role in improving the appearance and design of solar PV, it must be recognised that there is a need for clients to initiate and support improved practice. The leaflet accompanying this guide is a practical contribution to meeting this need.





Endnotes

- ¹ The Town and Country Planning (General Permitted Development) (England) Order 2015
- ² Ofgem (2016) Feed-in Tariff Installation Report 31 March 2016. Available from www.ofgem.gov.uk
- ³ Barclays Mortgages reveals the top technology that can attract homebuyers: http://www.newsroom.barclays.com/r/3261/barclays_mortgages_reveals_the_top_technology_that_can
- ⁴ Solar Trade Association (2016) Solar Homes Sales Premium Scoping Study. Available from <http://www.solar-trade.org.uk/solar-homes-sales-premium-scoping-study/>
- ⁵ See <https://www.ofgem.gov.uk> and the FIT Deployment Cap reports. (For early March 2016, approximately 1,000 domestic roofs per week were installed.)
- ⁶ Architects' Journal (2012) The photovoltaic aesthetic, Andrew Mellor. Available from <http://www.architectsjournal.co.uk/opinion/the-photovoltaic-aesthetic/8629465.fullarticle>
- ⁷ Microgeneration Certification Scheme (2012) Guide to the installation of photovoltaic systems
- ⁸ BRE conducts study on green mortgage lending. Available from <https://www.bre.co.uk/news/BRE-conducts-study-on-green-mortgage-lending---1123.html>
- ⁹ BRE (2016) Solar car parks: a guide for developers and owners
- ¹⁰ BRE (2012) Building Integrated Photovoltaic Systems: Challenges and opportunities for manufacturers and specifiers
- ¹¹ For more information see: National Federation of Roofing Contractors (2012) Technical guidance: Fixing solar panels to timber rafters and battens (pitched roofs)
- ¹² BRE (2012) as above.
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- ¹⁵ For example: German Solar Energy Society (2013) Planning and installing photovoltaic systems. A guide for installers, architects and engineers, and National Federation of Roofing Contractors (2012) Technical bulletin: Solar installations on roofs
- ¹⁶ BRE (2011) IP 8/11 Photovoltaic Systems on Dwellings - Key factors for successful installations, Steve Pester and Andrew Thorne.
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- ¹⁸ Cornwall Council (2012) The development of domestic and medium scale solar PV arrays up to 50kW and solar thermal.
- ¹⁹ Landscape Institute (2013) Guidelines for Landscape and Visual Impact Assessment, third edition
- ²⁰ For more information: <http://planningguidance.communities.gov.uk/blog/guidance/environmental-impact-assessment/>
- ²¹ DCLG (2012) National Planning Policy Framework. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/60772/2116950.pdf
- ²² DCLG (2013) Planning practice guidance for renewable and low carbon energy. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225689/Planning_Practice_Guidance_for_Renewable_and_Low_Carbon_Energy.pdf
- ²³ The Town and Country Planning (General Permitted Development) (England) Order 2015
- ²⁴ The Town and Country Planning (General Permitted Development) (Amendment) (England) Order 2008, no 675. Part 40 Installation of domestic microgeneration equipment.
- ²⁵ The Town and Country Planning (General Permitted Development) (Amendment) (England) Order 2008, no 2362. Explanatory note.
- ²⁶ DCLG (2016) Reducing planning regulations to support housing, high streets and growth. Government response to consultation.
- ²⁷ The Town and Country Planning (General Permitted Development) (England) Order 2015 (SI 2015/596). Schedule 2, Part 14, Paragraphs J.3 and J.4
- ²⁸ The Town and Country Planning (General Permitted Development) (England) Order 2015 (SI 2015/596). Schedule 2, Part 14, Paragraphs J.3 and J.4
- ²⁹ DECC (2013) UK Solar PV Strategy, Part 1: Roadmap to a brighter future
- ³⁰ DECC (2014) UK Solar PV Strategy, Part 2: Delivering a brighter future

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