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DOMESTIC PHOTOVOLTAIC FIELD TRIALS

Good Practice Guide: Part I - Project Management and Installation Issues

CONTRACT NUMBER: S/P2/00409

URN NUMBER: 06/795

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PV DOMESTIC FIELD TRIAL
GOOD PRACTICE GUIDE
PART 1 – PROJECT MANAGEMENT AND INSTALLATION ISSUES

Contract number: S/P2/00409/00/00
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Contractor
BRE

The work described in this report was carried out under contract as part of the DTI New and Renewable Energy Programme, which is managed by Future Energy Solutions. The views and judgements expressed in this report are those of the contractor and do not necessarily reflect those of the DTI or Future Energy Solutions.

First Published 2006

Introduction to the Guide

Achieving good practice in the design, installation and operation of photovoltaic (PV) systems is key to instilling customer confidence and establishing the PV industry as a whole. This is especially important when introducing a new technology into the market, allowing suppliers, designers, installers and service companies to offer a good-quality service built on previous experience.

The Guide is aimed at local authorities, housing associations, developers, suppliers, utilities, consultants and end-users. It aims to provide an outline of what to look out for and how to structure the work on a PV building project. Although not a technical installation guide, it is also of interest to PV specialists.

Based on the Domestic Field Trials[1] (DFT), the Guide aims to comprehensively signpost the wide range of issues that need to be addressed when installing PV systems. It references other key publications and standard texts applicable to PV projects, and should therefore be treated as a supplement and used in conjunction with these other publications (see Section 10). It should also be noted that the Guide is predominantly aimed at clusters of domestic installations, i.e. by developers or housing associations, rather than at individual installations. However, many of the issues raised are relevant to single installations.

The Guide is in two parts. This document, Part 1, focuses on domestic building integration issues, covering project development through to operating and maintenance. More specific details on system component design, performance and operating costs will be covered in Part 2 (to be published early 2006). Please also note that this Guide is based on the PV systems used within the DFT. The market is changing rapidly and new and more advanced systems are becoming available, however most of the principles discussed here will still apply.

Background to the DFT Guide

This part of the Good Practice Guide covers the key issues in the installation of grid-connected PV systems in domestic settings. Considerable experience has been gained through feedback from developers, installers and end users involved in the programme. The box on the right gives some statistics showing the range of projects, which include a wide variety of properties: houses, flats, bungalows; and different types of PV systems: PV tiles, laminates, modules, that utilise various integration methods.

PV Domestic Field Trial Statistics

- Over 470 dwellings benefited
- Over 740 kWp of PV installed
- 28 sites
- 16 new-build, 11 retrofit, and one site including both types
- Two-thirds social housing or mixed developments
- Exemplar energy efficiency technology
- New-build located mostly on brownfield sites
- Total budget £4.7m excluding management costs
- Initiated in 2001, completed 2006

[1] The PV DFT (Photovoltaic Domestic Field Trial), funded by the New and Renewable Energy Programme of the DTI, comprised the installation of more than 470 PV systems (totalling over 750 kWp) in a wide range of domestic building across the UK.

Contents

1 PROJECT PLANNING

1.1 The project team

One of the key factors in the delivery of an effective project is the project team. In general a team consists of the client, main contractor, PV contractor, sub-contractors and residents. This will vary depending on the specifics of the project.

At the tender stage try to ensure that boundaries of contracts meet up neatly, and no work is left unaccounted for - some PV quotes exclude some of the 'other trades' work assumed to have been done as a preparatory contract.

Responsibilities need to be identified and allocated at the very start of the project. This will ensure that potential problems or delays are either avoided or handled swiftly, causing minimum disturbance to the overall project. Ideally a plan should be drawn up in conjunction with the conventional project plan, identifying potential problems at each stage. This could, for example, address whether the PV modules are insured and whose responsibility it is to arrange cover. Also assessing the potential of vandalism, how serious it is and whether it could lead to systems being damaged.

Involving all parties as early as possible at the development stage ensures that the potential for misunderstandings is minimised. Well-planned logistics are critical in minimising additional costs and ensuring that good working relationships are maintained. For example, late deliveries of PV equipment will result in additional costs, either due to delays caused to the programme of work or the need to keep people on site to receive goods late in the day. When the construction process is delayed, it may be necessary to reschedule the PV delivery and provide appropriate storage. Ideally this should be on-site, separate from other building material and secured in order to avoid potential damage and/or theft.

Maintaining good working relationships is especially important when technicians, i.e. roofers and/or electricians, are installing a technology that is unfamiliar to them. Their co-operation and goodwill is essential for a successful project. Unforeseen problems can always occur in a construction programme and if a good working relationship is maintained these can usually be resolved at little or no additional cost, for example using another contractor’s equipment to unload PV equipment even though they are not contracted to do so.

Ideally the same site manager will handle the installation from concept through to handover, and will be on-site throughout the whole process. If this is not the case, clear training and handover procedures should be in place. Co-ordination is also important when continuity of contract workers cannot be maintained. One DFT site had numerous changes of personnel with poor handover procedures, which led to considerable additional work for the PV contractor in training and detailing work.

For the PV installation (particularly for tiled roofs), the ideal is to employ a qualified roofer who is also an electrician, however this is a rare combination.

Good communication between roofers and electricians, including being on site at the same time during installation, helps to ensure the process goes well. It may be possible to train an electrician to carry out the mechanical installation of a roof-mounted system. For large commercial development projects, a good solution is for the main contractor to employ roofers and electricians within the project team for the mechanical and electrical works respectively. Both should be under the guidance of a PV engineer, usually provided by the company responsible for design and supply of the system. Alternatively, installation can be carried out by the PV supplier, who will have the appropriately skilled and trained workers. The approach taken will depend on a large number of factors, including the type of building programme, cost, and client preference.

In terms of training conventional building workers, experience indicates that it is better to train roofers to install integrated PV systems, rather than site electricians, as roofing skills take much longer to acquire. Generally, where roofers had been given proper training they found that installations went smoothly, further aided by having an electrician on site at the same time. If training is provided it is important to make sure that all relevant trades attend. Those providing the training should make sure they arrive on time, well prepared and have any tools required at hand.

The importance of maintaining good communication cannot be overemphasised, particularly where a new technology such as PV is being introduced into the construction process. Failure to provide high-quality installation work and comply with the agreed building schedule is often related to poor communication. It is good practice to ensure that contingency plans are in place to address known potential problems.

Newbiggin – an example of good coordination with one person in charge. The project finished ahead of schedule realising considerable savings

Summary

- Define responsibilities at the start of the contract.
- Ensure contractual arrangements are efficient and effective and all work for the project is included in the contracts overall.
- Have one organisation or person overseeing the whole project.
- Ensure good co-ordination between PV installers and other trades.
- Maintain continuity of contract workers or provide training on handover.
- Consider site/component security and insurance.
- Plan the logistics well.
- Set in place contingency plans that can be adopted should something go wrong.
- Disseminate information from PV companies to other groups within the build team, and beyond.

1.2 Local regulations and practices

It is important to make sure that the products being used are suitable for the project; for instance, European products may not fit in a British context. Local regulations and practices should also be checked and adhered to – for instance, Scottish roofing practice is different to English practice in a number of ways. Scottish Building Regulations, for example, require tiles to be nailed to the roof battens, due to the need for greater wind and infiltration resistance. Sarking (ply and felt) is used instead of battens above felt, which means that solar tile hooks have to be made to different dimensions.

Summary

- Check that the products are suitable for the context in which they are to be used.
- Check adherence to the relevant local regulations/practices.

1.3 Resident consultation

An integral part of any community project should be to involve the development's residents as early and as frequently as possible. Householders involved in PV initiatives through housing associations, cooperatives or new developments may be unaware of the processes involved and the frequency of access required during the installation process. Arranging access can be time consuming and lead to considerable delays and/or the need for repeat visits often adding costs. Project teams should give householders background information highlighting the benefits, as this will most likely result in positive support and good understanding on both sides. Even in cases where access to properties is not required, i.e. flats where equipment is located in communal areas, it is important to consult residents and make sure they are aware of the extent and duration of the work.

Residents will also need information on the operation of their system to ensure that they understand at least the basics of the operating principles. There have been cases where systems have been switched off when residents have gone on holiday and then not restarted on their return, also when coin or key-card operated meters have run out and the electricity switches off, systems have not been re-set.

Summary

- Consult with residents from an early stage to gain support for the installations.
- Adopt appropriate consultation process for residents.
- Make access requirements/site disruptions (e.g. scaffolding) clear to residents.
- Ensure that residents understand the basic operating principles in relation to their property, especially here key-card or coin operated meters are in use.

2 PV SYSTEM DESIGN

During the design process it should be verified by the supplier and installer that the system to be installed conforms to all of the necessary standards as well as to good practice. For the PV system this Good Practice Guide specifically recommends:

- PV Modules – type tested and certified to IEC 61215/IEC 61646 depending on material type; warranty guaranteeing power rating at STC to within 90 % of its original performance for 10 years and, preferably, 80% for 20 years
- inverter and protection: compliance with Engineering Recommendation G83 or G59, as appropriate; guarantee covering repair or replacement of malfunctioning inverters for two years
- electrical installation – confirmation that installation will conform to 16th Edition of the IEE Wiring Regulations (BS7671) and Engineering Recommendation G83/G59.
- cabling, junction boxes, isolation switches – direct current (DC) cabling to be sufficiently rated to maintain voltage drops of less than 3.0%; external cabling, conduits, junction boxes, cable entries, etc, to be UV and weather resistant; DC isolation switch to be located near the inverter, recommended double pole, load break; alternating current (AC) isolation of the inverter to be provided local to the consumer unit, consisting of a single phase fused switch securable in the off position; DC cabling to be double insulated
- AC power meter to be provided to give a visual display of the energy supplied by the PV for the resident
- energy appraisal including estimate of system yield or output to be provided.

These are issues that the PV designer/supplier will be aware of and should include in the recommended system specifications. In addition the approvals listed below must also be gained, if required:

- planning consent – in some cases, provided the installation is not of an unusual design, or involves a listed building, and is not in a designated area, PV is regarded as 'permitted development' and is thus deemed not to require a planning application; see PPS22
- Building Control Approval; Building Regulation Part P
- Distribution Network Operator (DNO) Connection Agreement (see Section 4).

3 INSTALLATION AND COMMISSIONING

The key document for the installation and commissioning of PV systems is the technical guide *Photovoltaics in Buildings: Guide to the installation of PV systems* (see Section 10), which covers the installation requirements from design through to commissioning, including the relevant standards, recommendations and good practice.

3.1 General issues relating to H&S

The PV system installer/supplier should provide risk assessments and method statements for the installation, these will help to avoid project delays and accidents. Serious accidents can lead to a Health and Safety Executive accident investigation which can cost companies huge amounts of staff time and money, court appearances, and loss of future business through damaged reputation and negative public relations. Issues to consider include precautions taken against shock during handling; working at height; handling heavy goods; breakage avoidance, during and after installation; as well as conventional issues when working with electricity and at height. More detailed information can be found in the reference publications listed in Section 10. H&S expenditure should be seen as a saving, allowing the installation to be safely completed on time and to budget, rather than as a cost.

Summary

- Risk assessments and method statements must be supplied by the PV contractor.
- Standard H&S procedures for building construction must be adhered to.

3.2 Building installation – general issues

The location of the balance-of-system (BOS) components, i.e. inverter, switches, etc, needs to be carefully considered to minimise any potential access problems. The location needs to allow straightforward access for installation and maintenance, but should be within the boundaries of the owner's property, be that the householder or Housing Association. In addition, inverters make a slight noise, which will affect their possible location. Within the DFT site redesign occurred on one tenanted project where each flat was going to have its own dedicated metering system installed. Instead a dedicated cupboard was built to house this equipment in the entrance hall, accessible to householders. In retrospect this redesign has saved money avoiding delays due to access problems. Finally, there can be long lead-times required for the supply of some PV modules so that initial schedules must ensure that delivery dates fit with the main build programme.

Summary

- Site BOS components in accessible areas if possible, but where they will not be a nuisance.
- Ensure that the PV supply and installation is correctly scheduled into the main build programme.

3.3 Building installation - site-specific issues

The following sections cover issues that relate to a specific type of site or installation method.

3.3.1 New-build systems

New-build installations are those included during the construction of new buildings. The PV array, either modules or tiles, may be integrated, i.e. forming part of the weather skin of the building, or mounted onto the conventional roof structure. On new-build sites, the PV installation can be taken into account from the earliest stages of the project and integrated fully into the design process. The same applies to associated good practice features, such as extra ventilation and user display for the residents, all of which can be integrated from the outset. Further information on why these best practice features are essential is provided in Sections 6 and 7 and in Part 2 of this guide (to be published early 2006).

Gaining access is not an issue until the properties become occupied, although there may be concerns about vandalism on unoccupied sites, not necessarily associated to the presence of PV systems. One DFT project fitted covering meshes to protect the PV panels during installation. Once the properties were occupied and 'ownership' of the house was defined, vandalism was not a problem.

Steelstown – protective meshes were kept over the PV panels during installation

Machyllneth (Dulas) – showing modules installed during construction of the building

The main concern with new-build sites is the likelihood of the programme of work falling behind schedule. This is in general unrelated to the inclusion of PV but adds extra complications and unanticipated costs. Good communication is the key to the ensuring that the whole team is aware of progress and can plan accordingly.

Summary

- Inclusion of the PV system in the conception/design process as early as possible will ease its progress and keeps costs lower.
- Always aim to complete the installation before the properties are occupied, access is a major issue and can cause substantial delays/add additional costs.
- Take steps to reduce the opportunity for vandalism.

3.3.2 Retrofit systems (roof integrated and roof mounted)

Retrofit refers to installations where the PV array, either modules or tiles, are fitted on to an existing roof. These may be integrated, but more usually they are simply mounted above or on the existing structure, i.e. in the case of flat roofs. It should be noted that removing a perfectly good roof in order to integrate a PV system is not considered good practice. Generally, a roof-integrated solution should only be considered if the roof structure, or part of it, is being replaced.

All retrofit installations should have a feasibility study or structural evaluation done at the outset of the project to assess the suitability of the site/building for PV. An important structural issue to assess is the load capacity of the current roof (see Section 8 – Field Trial Belfast). In addition the layout of any existing roof should be checked. Even if drawings are available, they may not be correct. Potential sources of shading should also be checked during a site visit and are vital for designing for optimum performance. This is discussed briefly in Section 7 and will be discussed further in Part 2 of this guide.

In the example on the right the structural engineer did not feel that the top of the roof was suitable for the PV panels as set out in the design. As a result, they were mounted further down the roof and consequently suffer from some shading.

Hunters Moon – retrofit modules on the roof

For older buildings the existing roof structure needs to be evaluated, i.e. tiles, etc. These may be difficult to replace should any damage occur during installation and special care should be applied, especially if they are found to be non-standard.

Summary

- Do not make assumptions about the strength of existing roofs. If there is any doubt or concern a detailed survey should be carried out by a structural engineer as part of the project feasibility work.
- Positioning of the array on the roof needs to take account of loading, particularly for older, refurbished properties.
- Roofing layout may have changed during construction; if there are any doubts regarding the layout of the roof structure, a system that offers maximum flexibility should be considered. Similarly in older buildings it should not be assumed that roofing timber is necessarily square, nor that it has retained its squareness over time.
- The availability of replacement roof tiles should be considered – damage may occur during installation.

3.3.3 Roof-integrated systems

Roof-integrated systems have PV modules (often laminates) or tiles as part of the roofing structure, meaning that they actually replace some of the roof covering. They can be integrated into new buildings or retrofitted into existing ones. When integrated into the roof, the operating temperature of the PV can get quite high, affecting performance (see Part 2 for details). To increase the ventilation of the system, some sites have used vent tiles, which significantly reduce the operating temperature. Counter battens can also be used to increase ventilation; if these are used, roofers must be reminded that the installation sequence is slightly different to that of normal batten installation.

An important issue for the roofer is that the integrated PV tiles have to be laid in rows, not diagonally as is done with typical roof tiles. With this kind of system, an electrician or suitably trained roofer has to be on site, as the continuity of each row has to be tested before the next row is fitted. In a typical string, the open circuit voltage can be in the region of 150-200 Vdc so suitable safety precautions must be taken. If roofers without electrical training are responsible for the DC connections, an advisable precaution is to keep the individual string voltage below 120 Vdc. This should be taken into account by the PV system designers, though roof strings can be joined in series strings rather than parallel to meet the voltage ranges required by the specified inverters.

Montague Road – showing continuity testing and finished integrated tiles

Summary

- Consider allowing increased ventilation of the PV panels/tiles, if feasible, and the effect that this will have on the installation process.
- Installation methods for PV tiles are different to conventional tiles and specific safety issues of working with DC electricity need to be considered for these systems.

3.3.4 Roof-mounted systems

Roof-mounted systems incorporate PV modules/laminates in a specific structure or mounting system but the final product is located above or on the roof covering. There are no specific issues for these types of system other than the general issues noted above.

Bradan Road – roof-mounted modules

3.3.5 Special/double glazed

In some cases, usually in non-conventional housing, custom-made glass/glass modules offer an alternative to the typical roof-mounted or tile system. They are often used for their visual impact on the site (see pictures on following page). The main drawback is that they are often very large modules, so breakages are expensive to replace. Extra care should therefore be taken when handling these modules during transportation, storage and installation. It is also very important that PV laminate deliveries to site should always be closely examined at the time of delivery, allowing damaged modules to be returned immediately. The inspection should include an examination for any scratches to the front face of the laminate as this will weaken it and may make it unsuitable for installation. If on-site storage is required, it would also be advisable to locate them in a separate container only accessible by specified personnel.

Clockwise from top left: BedZed – glass/glass modules installed vertically outside view, inside the sun space and Llanelli – FIS on the front façade of the building

Summary

- Confirm that the supplier/installer has taken special measures to mitigate against breakages, i.e. suitable protection of edges and surfaces of laminates, until installation.
- Confirm the warranty arrangement, i.e. module replacement at no extra cost should breakages occur at any of the installation stages.

3.4 Electrical installation

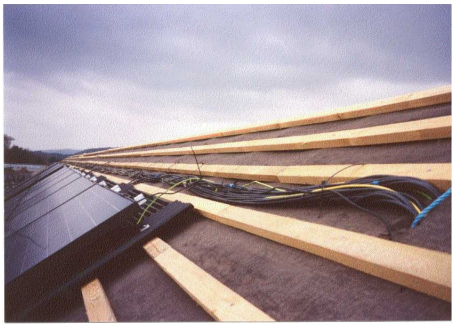
At the installation stage many of the pre-installation issues noted above obviously apply: the installation must comply with BS 7671 and Building Regulations, in addition to standards relating to other issues, e.g. earthing and lightning protection (see the publication listed in Section 10 for details). In terms of the general quality of the installation, good practice will include tidy finishing/clipping of wiring.

Grid-connected PV systems work in parallel with the grid supply and include DC electrical cabling, and therefore incur associated risks that are not typically found in most domestic properties. An important aspect of any PV installation is clear and concise labelling and this is a requirement under the relevant engineering recommendation. Labelling allows new residents to be informed and obtain contact details of company responsible in case of any subsequent maintenance requirements. Appropriate labelling includes: warning labels at power supply connection point, meter position, and AC isolation switch; system information displayed with circuit diagram, summary of protection settings and contact details.

Newcastle Great Park
– example of good labelling

Stroud
– example of good inverter labelling

Results from the DFT projects illustrate the importance of effective continuity checks for the PV modules at the installation stage whilst access, e.g. scaffolding, is still available. Occasionally problems can arise with electrical connections, or more rarely, with the modules themselves. If access is still available then it is obviously simpler to rectify such faults.



Machynlleth
– example of good roof cabling

Summary

- Installation must comply with all of the appropriate standards.
- Installers should always aim for the highest quality of general installation, e.g. wiring should be clipped and tidy.
- Electrical continuity of the PV modules/tiles should always be checked on installation.
- Appropriate labelling, according to the standards, must be put in place.

3.5 Commissioning

Responsibility for commissioning the system should be defined within the contract, although it will usually be completed by the installer/supplier. For good practice, commissioning procedures should be in place, there should be agreement on who will complete the test certificate for the Distribution Network Operator (DNO) and, for larger systems, on who is liaising with the DNO, including checking if they need to witness test the systems at the commissioning stage.

Summary

- The contract should define the responsibility for commissioning and ensure that commissioning procedures are in place.

4 GRID CONNECTION AND EXPORT

4.1 The electricity supply system and grid connection permissions

Connecting to the electricity network requires that the local Distribution Network Operator (DNO) should be informed (systems that fall under ER G83) or their approval gained for larger systems (usually written confirmation with the possible requirement for witness commissioning). Electricity suppliers, on the other hand, are responsible for the supply of electricity. Agreements for the sale of electricity from a PV system into the electricity network must therefore be made with an electricity supplier.

Licensed electricity suppliers are required by law (through the Renewables Obligation) to provide a specified proportion of electricity from renewable sources. Suppliers can meet their obligation through producing Renewables Obligation Certificates (ROCs) and/or by paying buy-out (see www.ofgem.gov.uk). ROCs are issued to accredited generators as evidence that a licensed electricity supplier has supplied green electricity to their customers.

4.2 Grid connection

Generally the PV supplier/installer will contact the local DNO with the relevant information. For all systems the DNO must be notified by the first day of connection, and full details provided within 30 days. For systems under 16A no approval is needed but the DNO must still be notified. A list of DNOs operating in the UK is available from PV-UK (www.pv-uk.org.uk) or Ofgem website (www.ofgem.gov.uk). The separate components of the PV system must also be approved for use (see Section 10).

4.3 Export tariffs and Renewables Obligation Certificates (ROCs)

As well as benefiting from 'free' electricity when the PV system is generating, there are two ways the system owner/user can benefit financially.

The first is to have a metering system in place that allows for the units exported to the grid to be recorded. This means when electricity generated by the PV system is not all being used within the property, the excess is exported to the grid and a contract set up with an electricity supplier to buy that electricity at an agreed price. There are a number of electricity suppliers currently offering premium rates for 'green' electricity. The current premium rates available are typically in the order of 7p/kWh, but this varies considerably due to frequent changes of offers and schemes. A list of 'green' electricity suppliers in the UK is available at www.greenelectricity.org and www.whichgreen.org. Most of these contracts will require appropriate metering and it should be noted that in

many cases new meters will need to be purchased, although some suppliers will cover these costs.

The second is to claim ROCs for all the electricity generated, either by applying directly to Ofgem or through a sell and buy-back contract with one of the electricity suppliers. A generating system accreditation questionnaire and a list of accredited meters can be downloaded from Ofgem's website: www.ofgem.gov.uk (the present consultation on the RO aims to simplify applications from small-scale generators (<=50kW)). Alternatively, some electricity companies offer a price for every unit of green electricity generated, typically about 4p/kWh, meaning they can then claim the ROCs and keep a premium for 'brokering' them. This avoids the need for householders to go through the paperwork; they simply receive a cheque for the relevant amount.

4.4 Metering system output

If a net metering agreement cannot be obtained then it is likely that some additional metering may be required. Depending on the agreement reached with the electricity supplier, this may take one of two forms: import/export metering or system output metering. If the agreement consists of the supplier buying back excess energy that has been fed back to the grid, an import/export metering system will be required (see picture below). This keeps separate records of the energy drawn from the grid, and the energy exported back. This may be done on a single meter with two registers, or by placing two conventional meters back to back. Often the import meter will already be present for billing purposes, and in this case the simplest solution will be to install a second meter to record exported energy.

If, on the other hand, the system owner wishes to claim ROCs, a meter will be required that records the total output of the PV system, irrespective of what the local load is. To do this, a meter must be installed between the system and its connection to the grid. Meters are now available that can be conveniently installed inside a consumer unit, providing a neat and cost-effective solution.

Newbiggin Hall – import and export meter

4.5 Overview

Overall it is important to ensure adequate and effective liaison with the DNO (if appropriate) and electricity supplier, as this can help alleviate potential problems. Interest in, and understanding of, small PV systems by electricity companies varies considerably. It does help to find a single contact within each organisation at the earliest stage possible and PV companies should be able to assist in finding the right ones (see Sections 4.1 and 4.2). The less people that need to be kept in the loop the easier it will be to establish a good working relationship which in turn will ensure smooth and effective progression of the installation(s). For community projects, it is vital to engage householders at an early stage in order to explain the benefits of signing up to a green tariff.

Summary

- Adequate and effective liaison with the DNO and electricity supplier is important.
- Ensure that the DNO is notified and the contractor responsible for doing so is defined at the start of the project.
- Residents, especially tenants, should be contacted at the start of the project. Information provided should advice on the benefits of PV in general and specifically on how to export electricity and obtain the associated financial benefits (mentioned above).

5 SYSTEM COSTS

PV system costs are made up of hardware (inverter/BOS components, modules) costs, module installation and electrical installation. Installation costs can vary significantly between different sites depending on the type of installation. During the DFT it was found that, as this was a relatively new skill for many installers, costs were higher at the beginning of the scheme and dropped as installers became more experienced.

New-build frame-mounted modules are generally the cheapest, followed by retrofit modules on frames, and finally new-build tile-integrated are the most expensive to install. This is likely to be because the additional costs such as scaffolding, preliminaries and H&S, have been covered in new-build projects as part of the overall build programme, rather than the installation of PV itself. A retrofit installation with no other works on site will have to bear all these costs under the PV installation, so may appear more expensive on the surface. It should also be noted that the cost differences between the different types of installation are very site-specific. Electrical installation costs are highest in new-build tile-integrated systems (probably because every row of tiles has to be checked for continuity) and lowest on new-build, framed modules. Other costs, such as monitoring, depend on the type of system employed. A simple consumer display unit will be less expensive than integrating a complex system monitoring data at 5-minute or 30-minute periods (also see Section4.4 for metering recommendations). Generally monitoring is more expensive to install on a retrofit project than a new build, as it is an add-on feature and is much cheaper to integrate it into the design process at the beginning.

All sites £/Watt peak (Wp) of installed PV system	**Module installation**	**Electrical installation**	**Inverter cost**	**Module cost**	**Total**
All sites					
Average	0.69	0.52	0.47	4.14	**5.82**
New-build modules on frame					
Average	0.37	0.21	0.33	3.77	**4.68**
New-build tile integrated					
Average	0.61	1.06	0.53	6.15	**8.36**
Retrofit modules on frame					
Average	1.16	0.49	0.59	3.09	**5.34**

Installation cost averages for all the sites in the DFT, excluding monitoring and management costs specific to the project

Overall, module and installation costs have decreased over the years. Significant savings can be realised when integrating PV frame-mounted systems into new-build properties, as the cost of site works, storage,

scaffolding, etc, can be shared with other construction work taking place at the same time. This is a prime example of an opportunity for cost reduction through good communication.

It should be noted that the figures in this section are based directly on results from the DFT and hence are based on real data for a limited number of projects. Not only will actual figures vary but also the relative costs of the different installation options may change over time.

6 OPERATION AND MAINTENANCE

PV systems are in general designed to operate for a significant length of time, typically 20-25 years. Everyday operation requires very little input from the householder however faults can occur and these are exacerbated if the user does not understand or at least check the system's operation. If this happens operation may be reduced or halted for a considerable time before the problem is detected, let alone corrected.

Common faults found during the DFT programme include:

- inverter problems – fuses and other minor problems, which were simply solved by contacting the installer whilst the systems were under warranty
- user mis-operation – systems turned off for various reasons, e.g. decorating, maintenance work on other electrical systems. It is important that users understand when they need to turn off the PV systems but that it is equally important to remember to switch them on again
- grid voltage variation causing MCBs to trip (this will be discussed further in Part 2)
- system display faults – although not strictly a system operation issue, faults in consumer displays do cause problems as the user cannot see if the PV system is operating correctly.

6.1 System maintenance

As mentioned above maintenance should be minimal, but there are a number of visual checks that should be performed at regular intervals on the PV system:

- electrical wiring – similar to all wiring in domestic properties
- PV arrays – to assess the level of dirt, bird fouling, etc, or actual damage (every few months)
- support structure, fixings, junction boxes, inverter, DC circuit breakers, AC switchgear (on an annual basis)
- meters and inverters to assess the level of output and possible equipment failures (monthly or more often if possible)
- shading of the array to identify any increasing problems (see Section 7 for more details).

6.2 Effective system operation

There are two important aspects to ensure good operation of the PV system. Firstly the user should be told how the system operates and carry out minimal checks and maintenance procedures (at certain intervals). Secondly, there should be a designated point of contact in

case of any faults with or damage to the equipment. This must be clearly documented and written in easily understandable language. As the lifetime of the system is likely to be significantly longer than the typical occupancy period of the property, it is vital that the information is in a format that can be easily passed on to new residents. Good practice would therefore suggest that the installer provides handover documents outlining general problems and how to solve them, including contact details for more serious concerns.

Providing simple and easily accessible information will encourage householders to get involved allowing them to deal with minor issues themselves, such as AC isolators left open or a tripped MCB. Checking the inverters at regular intervals will ensure that there have been no equipment failures. However, inverters are usually located in lofts, cupboards or other relatively inaccessible areas, so one of the simplest methods of encouraging householder involvement is to provide easy to understand and accessible system displays.

A minimum requirement is being able to see the energy generated since commissioning. In addition it is also useful to find out how much electricity is being generated at a given moment in time (together with how much is being exported) whereby the meter shows instantaneous readings. The choice of metering will depend on end user preference and type of refund option taken (see Section 4). Anything of concern not easily addressed by the householders themselves should be reported to the system installer or other designated contact mentioned in the handover documentation.

Examples of user displays:
Llanelli *Newcastle Great Park*

Summary

- Handover documentation should be provided that outlines visual checks that can be made, general problems and solutions including contact details for more serious concerns.
- An easy to understand and accessible system display, i.e. showing instantaneous power generation, should be part of the overall PV system.

7 MAXIMISING PERFORMANCE

A more detailed discussion of performance issues will be provided in Part 2 of the Guide. However, some general principles for maximising the system performance are provided here.

The orientation of the building needs to be considered in order to decide the tilt and general layout of the PV modules. Once this has been completed the system performance can be simulated and likely output calculated. There are two main causes for the underperformance of PV system on domestic properties: shading of the PV array and issues relating to inverter operation. Both of these aspects should be addressed at both the design and operation stages.

Because a PV array has a number of electrically connected modules, the losses resulting from shading of part of the array can often be significantly higher than the proportional area that is affected by the shading. Therefore it is particularly important to site the array where shading is minimised. Shading sources include both structures and vegetation (mainly trees) adjacent to the house and self-shading from other parts of the building on which the array is mounted. When looking for sources of shading, the change of position of the sun with day and season should be taken into account. Most shading occurs at low sun angles, so care should be taken for sun positions at the beginning and end of the day and for all day in the winter season. If assessing the situation during the winter then leaf cover needs to be taken into account.

Whilst shading should be minimised during the design process, shading can also increase during operation if care is not taken. The most common cause of increased shading is the growth of trees, which may not be a problem at the time of installation but can quickly become a significant shading source. This should be explained to the system users, so that action can be taken to keep any trees at an appropriate height. In some cases, additional shading from items such as satellite dishes and cabling has been introduced. Again, this can usually be prevented by education of the user.

There is a range of issues relating to inverter operation, to be addressed in detail in Part 2:

- correct matching of inverter to the array characteristics for maximum initial performance
- setting the inverter thresholds to allow prolonged operation at quite low light levels (this may require amendment of the default settings of the inverter)
- care when installing on sites where the grid voltage is high – this can lead to inverter drop out under certain conditions and/or failure to track the maximum power point of the array

- establishing a checking procedure for inverter operation during the first few months; most failures caused by faulty inverters will occur early in the operation, but it is easy for faults to be missed if the user is not aware of the checks that have to be made.

Summary

- Site the array to minimise the effects of shading. Shading sources include both structures and vegetation and self-shading from other parts of the building.
- Consider the potential for shading increase during operation, i.e. tree growth.
- The design should allow for ventilation of the modules where possible, as elevated temperatures reduce system efficiency.
- If the arrays are installed as part of a larger building programme, significant soiling of the panels can occur. The panels should be cleaned once all adjacent building work has been completed.
- The quality of the work in terms of the installation, wiring and associated building work will have a direct impact on the quality of performance of the system so good workmanship should be ensured.

8 CASE STUDIES

8.1 Newcastle Great Park

A retrofit PV module (left) and PV tiles (right)

Site summary

- Private development – Bryant/Taylor Woodrow & Persimmon
- New build, both roof mounted and roof integrated
- 12 properties, 17 kWp total rating
- Redland PV 700 tile system and BP Solar 'Sun in a box' modular system
- Installation - SunDog and Windsund
- DNO – Scottish & Southern Energy plc
- Commissioned June 2004

Newcastle Great Park is an example of a new-build, private development and consists of PV systems on twelve individual houses, ten using Redland PV tiles and two using BP Solar 'Sun in a box' systems. The team wanted to demonstrate retrofit and integrated systems side by side to allow new customers to make an informed choice about which type of PV system they prefer. In addition, the team were keen to compare the two systems during the construction process.

A number of valuable lessons were learned from this project. There were problems with the provision of meters and access to properties that significantly affected the project timescales. This situation highlights the effect that the specification of 'non-typical' equipment may have on traditional equipment suppliers. The project involved two housing developers with different processes. As a result, the sites were installed very differently (the importance of ensuring that the contractual arrangements are known and agreed is discussed in Section 1.1). In addition, a development project of this size often experiences a high staff turnover, which can make project-related communication difficult, especially when a relatively new technology such as PV is involved. It is therefore important that developers ensure that good handover procedures are in place and that any new site personnel are fully briefed on the project requirements and its relative importance to the overall development.

8.2 Corn Croft (Green Lane), Nottingham

Site summary

- Nottingham Community Housing Association
- New build, roof integrated
- 22 systems, 34 kWp total rating
- BP Solar 85Wp (BP585) mono-crystalline
- Installation – PV Systems
- DNO – East Midlands Electricity
- Commissioned April 2002

View of row of bungalows from within the cul-de-sac

Corn Croft (Green Lane) is a new-build social housing development. The 22 bungalows use a bright aluminium framing system sunk into the roof, ensuring the PV system is flush with the roof tiles. Parts of the development are located next to a busy road from which the south-facing PV modules are very visible. The street is lined with trees, resulting in some shading and hence reduced electricity production at low sun angles (i.e. early and late in the day). However, many systems on the site are unaffected. Ventilation is achieved by allowing an air gap between the modules and the roof when mounting the PV system. This will result in lower operating temperatures, and higher module efficiency. Overall system performance has been very good, with the total production of 51,690 kWh over two years for the whole site. This corresponds to an average annual yield of 752 kWh/kWp, which is in line with the UK predicted output.

There were minor on-site problems during installation, including the breakage of one PV laminate, storage, and co-ordination with roofers who expected the PV installer to respond with little notice. An important lesson learnt from this installation is to ensure that works are completed before properties are let. Here houses were occupied before commissioning and this caused delays due to access requirements. Also, that it was important to implement good communication and be clear about all the required contacts, i.e. PV installer, roofer, electrician and DNO. Simple ideas such as using walkie-talkies on this site improved direct communication. Building site delays and changes in specifications could be solved quickly, thus avoiding financial penalties.

Generally the installation went smoothly, largely due to the good relationship between the site trades people who stated that this project helped to dispel any previous reservations and misconceptions they might have held about PV.

8.3 Field Trials Belfast

Roof-mounted PV on three blocks of flats

Site summary

- Northern Ireland Housing Executive
- Retrofit, roof mounted
- 3 blocks, 30 flats, 51 kWp total rating
- BP585L Solar laminates
- Installation: BP Solar
- DNO: Northern Ireland Electricity
- Commissioned March 2003

This project involved the refurbishment of three blocks of flats and consists of 30 PV systems, each comprising 20 BP Solar 585 modules. The PV laminates are mounted on a steel channel matrix using BP Solar 'diamond' fastenings and held in place by roof hooks. High insulation and double glazing are among the energy efficiency features used at the site.

One of the main lessons learned from this project is to not assume the existing roof structure will be suitable for PV. In this case, the flat roof was initially thought to be strong enough but a structural survey revealed otherwise. The Housing Executive was forced to rethink the project. Two of the blocks (containing 24 flats) were to benefit from PV power, and the third block of six flats was to be used for control purposes. The roofs were at the end of their design life and it was concluded that re-roofing all three blocks would be the best option, offering the opportunity to mount the PV panels onto the sloping roofs. The decision was also taken to provide PV power to all 30 flats. Although this inevitably added project costs and time, it is a valuable lesson for all retrofit projects.

An ongoing issue with this site is vandalism of the PV panels. In general this should be considered where vandalism is a known problem and/or where the PV is visible and accessible from a nearby point.

8.4 Peterborough Homes, East Anglia

Site summary
- Nene Housing Society
- New build, roof integrated
- 14 properties, 25.8 kWp total rating
- United Solar 'Solar shingles'
- Installation – Solar Century (local roofing/electrical contractors)
- DNO – Eastern Electricity
- Commissioned March 2003

Solar shingles at Peterborough

This project formed part of the (then) largest new social housing development in Europe. PV shingles were integrated into nine houses and seven bungalows. The shingles are designed to easily interface with ordinary roofing shingles and can be nailed in place over plywood or similar decking. Visual integration is achieved by making sure the PV shingles are in balance/lined up to the position of the windows and front door. It is usually difficult to spot the difference between the solar and normal tiles when looking up at the roof from below.

The installation of this system was quite straightforward once installers got used to the procedure. Problems were encountered due to the chosen electricity supplier being bought out, resulting in not only having to find a new supplier but also delaying the installation of the export meters. Tenants were originally offered the possibility to sign up to the *Solarnet* net metering scheme, whereby they would be paid for any electricity exported. Initially tenants were wary of the scheme but eventually all except two signed up and are now receiving the same price for their exported electricity as they pay for imported electricity. The fact that two of the tenants are not benefiting shows how people are still wary of such schemes, and highlights the need for clear, accessible information on the subject.

9 CONCLUSIONS

It should be remembered that applying good practice at all times should be considered as a saving rather than a cost. As an example, within one site on the DFT it was found that careful consideration and application of good practice led to the installation being completed ahead of schedule enabling scaffolding to be removed and security ramped down early, providing cost savings and reduced disruption to residents.

PV has a number of benefits to the occupier of the building. A typical household-size installation of 2 kWp will, on average, cut electricity bills by up to 30%, allowing the use of 'free' electricity while the system is generating. This will save an estimated 645kg of carbon dioxide (CO_2) emissions each year. Its high visibility allows PV to raise awareness of renewable energy in general. The lessons learnt over the past few years demonstrate how much experience has been accumulated in this field, which will aid the industry as it continues to grow and improve.

10 FURTHER GUIDANCE

- BRE Digest X/05 Mechanical installation of roof-mounted photovoltaic systems – ww.BREconnect.com
- BRE Digest 489 Wind loads on roof-based photovoltaic systems - www.BREconnect.com
- British Standards website - www.bsi-global.co.uk
- Department of Trade and Industry (DTI): Photovoltaics in Buildings: Guide to the installation of PV systems, DTI/Pub URN 02/788,
- Distribution Network Operator (DNO) information:
    - PV UK website - www.pv-uk.org.uk,
    - Ofgem website - www.ofgem.gov.uk
- Domestic Field Trial (DFT) Website (for further detailed/technical information on the DFT); www.dti.gov.uk/renewables/renew_6.1h.htm
- Electricity Association (www.electricity.org.uk) -: Key Engineering Recommendations
- ER G83 - Engineering Recommendation G83/1: Recommendations for the connection of small-scale embedded generators (up to 16 a per phase) in parallel with public low-voltage distribution networks. Electricity Association, 2003.
- ER G59: Engineering Recommendation G59/1: Recommendations for the connection of embedded generating plant to the public electricity suppliers' distribution system. Electricity Association, 1991, Amendment No.2 1995
- The German Solar Energy Society, Ecofys, James & James 2005: Planning and Installing Photovoltaic Systems – A guide for installer, architects and engineers;
- Green electricity suppliers' information:
    - www.greenelectricity.org,
    - www.whichgreen.org
- Health & Safety Executive website (for all H&S and CDM [Construction (Design and Management) Regulations 1994] information.; www.hse.gov.uk
- IEE Wiring Regulations - requirements for electrical installations:, 16th Edition. BS 7671, 2001.
- Deo Prasad & Mark Snow; Earthscan 2005: Designing with Solar Power – A source book for building integrated photovoltaics (BIPV),
- ODPM – Planning Policy Statement 22 (PPS22) and Planning for Renewable Energy; A Companion Guide to PPS22 both available at /www.odpm.gov.uk

Disclaimer: This Good Practice Guide has been produced based on experience gained from the PV DFT as well as the wider PV market. However, it does not represent an extensive survey of present UK installations or an exhaustive

review of all installation issues. The authors therefore can accept no responsibility for issues not raised herein.

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