bre

www.bre.co.uk/nsc

BRE National Solar Centre

Solar PV on commercial buildings

A guide for owners and developers

ANIRON RENEWABLES

BERWIN LEIGHTON PAISNER

REA RENEWABLE ENERGY ASSOCIATION

BRE NATIONAL SOLAR CENTRE

Authors: Kiran Arora, Sesh Diu, Jonathan Roper,
with contributions from Lauren Cook, Peregrine Fraser and
Jonny Williams

Editors: Gaynor Hartnell, Renewable Energy Association and
Chris Coonick, BRE National Solar Centre

This document should be cited as:
BRE (2016) Solar PV on commercial buildings: a guide for owners and developers, (K. Arora, S. Diu, J. Roper and G. Hartnell)

BRE National Solar Centre would like to thank the following colleagues for their significant contributions to the development of this guidance:
Kiran Arora
Christine Coonick
Sesh Diu
Peregrine Fraser
John Macdonald-Brown
Jordan Mawbey
Ray Noble
Stuart Pocock
Jonathon Roper
Jonny Williams

Thanks also to those companies and individuals who provided case studies and to the NSC Founding Partners.

The production of this publication was sponsored by Aniron, BLP and the Renewable Energy Association.

Front cover image: Plymouth Life Centre,
courtesy of Cleanearth Energy Ltd.

Contents

1. Introduction

There is an estimated 250,000 hectares of south facing commercial roof space in the UK.[1] If utilised this could provide approximately 50% of the UK's electricity demand.[2] This document provides guidance on the key issues associated with installing solar photovoltaics (PV) on commercial rooftops, in order to stimulate further deployment. The term "commercial" in the context of rooftops or buildings is used to cover all non-domestic premises.

To date commercial roofs account for around 50,000 of the UK's 870,000 solar PV systems and 1.2GW of the 4.1GW of installed under the Feed In Tariff (FIT).[3] Most of the UK's capacity comprises ground-mounted and domestic installations. This is in marked contrast to many other European countries. For example in Germany more than half of solar PV deployment is on commercial roofs.

Installing solar PV on commercial roofs can make sound economic sense; it reduces carbon emissions, offsets the need to purchase peak time electricity from the grid, puts unused rooftop space to good use, and helps to insulate companies from future electricity price fluctuations. It could also benefit from income from the Feed-in Tariff.

There are a variety of different scenarios depending on whether the building is leased or owned, and whether the proposed installation will be owned by a third party or the landlord. There are two over-arching business models for this sector; self-financing, where the owners or occupiers invest in the installation; or the Power Purchase Agreement (PPA) route, where a third party finances the installation and the building occupier buys the output. This guide covers both approaches, and is published alongside a downloadable financial model.

A typical project will involve a contractual agreement between the electricity consumer (likely to be the occupier of the building); the property owner (i.e. the landlord if the building is leased) and finally the solar PV asset owner (in the case of PPA projects). It is these legal complications that account for the relatively low rate of commercial rooftop installations to date. In addition, there is the challenge of making a robust long-term business case as the sector moves into a post-subsidy environment.

Despite the challenges, with the right knowledge and the right project partners, commercial solar is a viable way of electricity reducing bills and saving carbon.

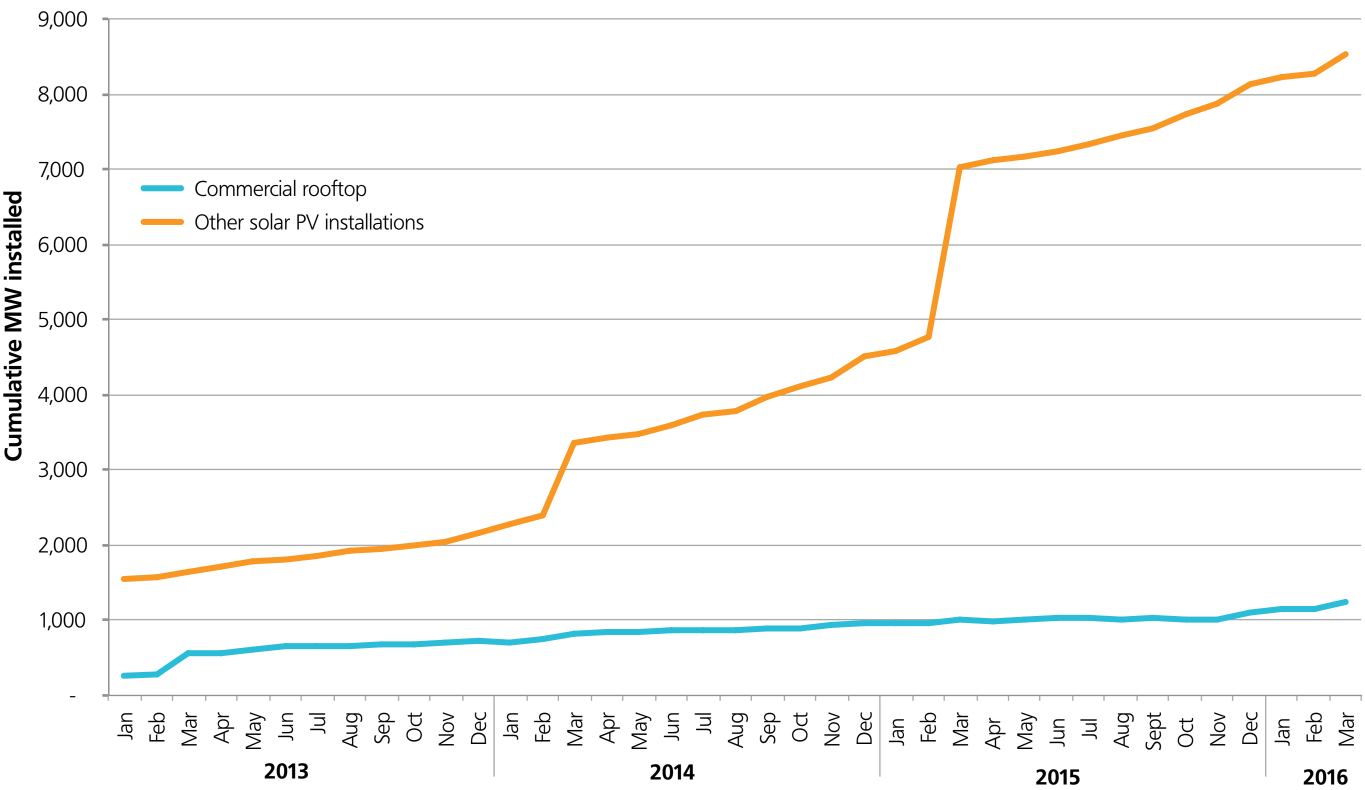


Figure 1 **Solar PV deployment to date**

1 DECC, UK Solar PV Strategy, Part 1, April 2014
2 This assumes PV is installed on 50% of the 250,000 ha south facing roof surface. BRE calculations, available upon request.
3 Feed-in Tariff Installation Report 31 March 2016. https://www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme/feed-tariff-reports-and-statistics/installation-reports Based on systems >10kW installed capacity claiming FIT

2. Solar PV installations on commercial roofs – an overview

Types of PV system

90% of PV installations on commercial rooftops use either mono or poly crystalline cells. Monocrystalline PV cells are made from high-purity silicon, giving an even colouring and uniform look to the panels. They are slightly more expensive to manufacture than polycrystalline cells, but have higher efficiencies (15-20%). Polycrystalline cells are made from raw silicon, which is cast in square moulds and cut into wafers, giving the panels a distinctive look with the squares visible on the panel surface. Their efficiency is slightly lower (at around 14-17%) as is their cost.

Panel choice should be a measure of the available roof space and electrical capacity sought. There is relatively little difference between standard mono and polycrystalline cells. However some monocrystalline cell manufacturers have achieved efficiencies of up to 23%, making their panels a good option where a higher output is sought, but space is constrained. There is an additional price premium for these panels.

A general rule of thumb, around 6000-8000m^2 of sloping roof space is required per megawatt of capacity installed (MWp). A flat rooftop will accommodate less capacity, as spacing must be left in between each row of panels to avoid self-shading. On flat roofs, panels are fitted on mounting systems, usually at a slope of around 15 degrees. However, if the roof has an existing slope of around 5 degrees then panels can be mounted directly onto the roof. Slope selection is a compromise between promoting greater yield and better water run-off, and reducing wind loading.

Orientation (or aspect) is another key factor. This may be dictated by the existing slope of the roof. However, if the roof is flat there will be a choice to be made between having panels facing due south, which will give the best overall yield; or oriented east - west, which will extend the duration of the solar generation curve but reduce the overall yield.

Both flat rooftops and pitched ones (slate, pan tile, plain tile, trapezoidal profile metal sheet, Kalzip-profiled metal sheet or fibre cement) are suitable for solar PV.

PV can also be incorporated within the fabric of the building (i.e. the roof or the walls of the building can comprise PV panels). This is known as Building Integrated PV (BIPV).

For each type of rooftop and their respective sub-categories, there are approved mounting solutions and means of not invalidating any roof warranty.

Energy usage and expected yield

The consumption profile of the building(s) on-site is key to the financial viability of the project. For existing buildings with operational businesses, solar installation companies should be provided with the monthly electricity bills and, if the site is half hourly metered, raw half hourly data for a period covering at least the last 12 months. Half hourly data is the most useful, and with this developers are able to map the electricity consumption profile against the proposed PV yield across a year. Generally speaking the higher the self-consumption percentage, the better the financial outlook. This is because the avoided cost of purchasing electricity is greater per kWh than the potential earnings from selling it on.

Solar developers should use data that is trusted by investors to predict the likely output per annum. This typically takes the form of software tools such as PVsyst and PV*SOL, which are used by solar designers and engineers to analyse PV system sizing and yield potential. The yield is typically calculated by considering the following:

- the efficiencies of core components (panel, inverters, cabling)
- the orientation and inclination of the PV array(s)
- the shading to the PV system (both horizon shading and building-specific shading, such as ventilation pipes, other buildings etc.)
- the solar irradiance potential

Polycrystalline and monocrystaline panels, image courtesy of BRE National Solar Centre

PV mounting system on flat roof, image courtesy of BRE National Solar Centre

Solar Irradiance

The solar irradiation potential of a site has a large impact and it varies across the country as shown in Figure 2, global horizontal solar irradiance[4].

There are a range of data sources and tools for estimating the solar irradiance[5] in a specific location and according to the orientation and the slope of the panels. Larger schemes should use more robust sources, whereas systems below 50 kW must use the UK's MCS standard measurement methods[6].

Annual Variation of PV Yield

The output of a PV system varies throughout each day depending on the path of the sun, the temperature and cloud cover. Figure 3 shows a typical weekly and annual production for a PV system. There can also be an annual variation in solar irradiance, typically in the range of + / - 5% annually, with the maximum year-on-year variation in mean annual irradiation across all Meteorological Office sites being approximately +/- 15%[7].

Figure 2 **Global horizontal solar irradiance. image courtesy of Solar GIS**

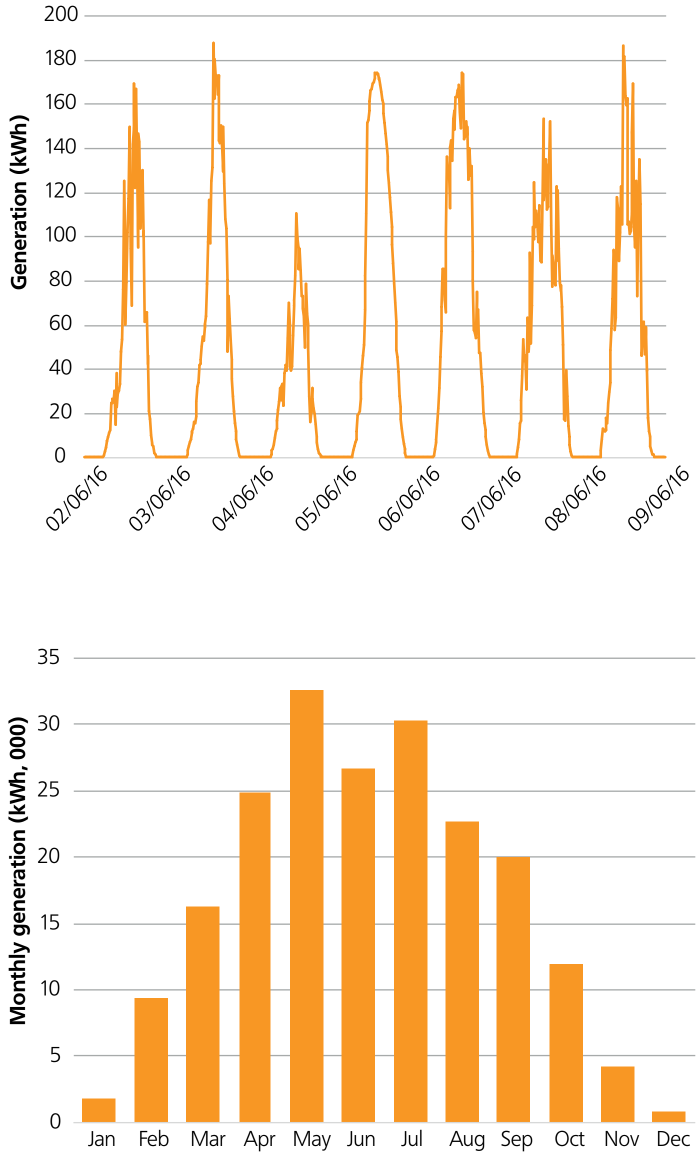


Figure 3 **Typical weekly and annual solar generation graphs, source SolarEdge**

4 The total amount of shortwave radiation received from above a surface horizontal to the ground.

5 e.g. Meteonorm; SolarGIS and data from the Meteorological Office.

6 Irradiance datasets can be downloaded from http://www.microgenerationcertification.org/mcs-standards/installer-standards?id=17. There are a total of 24 zones and the estimation method is described in the MSC Guide to the Installation of Photovoltaic Systems, which can be downloaded from http://www.microgenerationcertification.org/images/PV%20Book%20ELECTRONIC.pdf

7 Personal communication, Jamie Taylor, Sheffield Solar, University of Sheffield.

Shading Analysis

Since shading has a detrimental effect on yield, accurate measurement of the following is critical:

– horizon / distant shading (which occurs due to the sun being obscured by hills or distant buildings. This translates to the number of hours that a proposed site can obtain direct beam irradiation from the sun)

– near shading from site level shading objects such as vents and other buildings

Tools are available for measuring both types of shading, giving measurements which can be entered into simulation and design software to calculate the expected yield. Whilst nothing can be done to avoid horizon shading, careful planning and siting of a PV system should be undertaken to minimise near shading as much as possible.

Performance and monitoring

PV panels generally come with 10 year product warranty and 25 year performance guarantee. With no moving parts, their life expectancy is in excess of 25 years. Manufacturers commonly offer a performance guarantee of 90% of power for up to 10 years and 80% for up to 25 years; however most now offer linear performance guarantees, which continually decrease by a fixed % over the life of the panels.

The performance of a solar PV system should be monitored over time. This can be automated via monitoring software linked to the inverter and/or the generation meter. Trend analysis can be used to look for changes in performance which cannot be accounted for by normal changes in light levels. Larger systems can use reference cells and pyranometers to monitor light levels and the output can be used to give an indication of performance independent of light levels. A reduction in performance can relate to various factors such as system damage, new shading, and soiling of panels. For more information see BRE publication *Performance of photovoltaic systems on non-domestic roofs*[8].

Energy management systems

Modern solar PV systems can deliver live data which can enable building management systems to maximise the use of the self-produced electricity. Data loggers can track how much electricity is being taken from the grid and how much PV generation is consumed on-site. An example of a day and week view is shown in Figure 4 below.

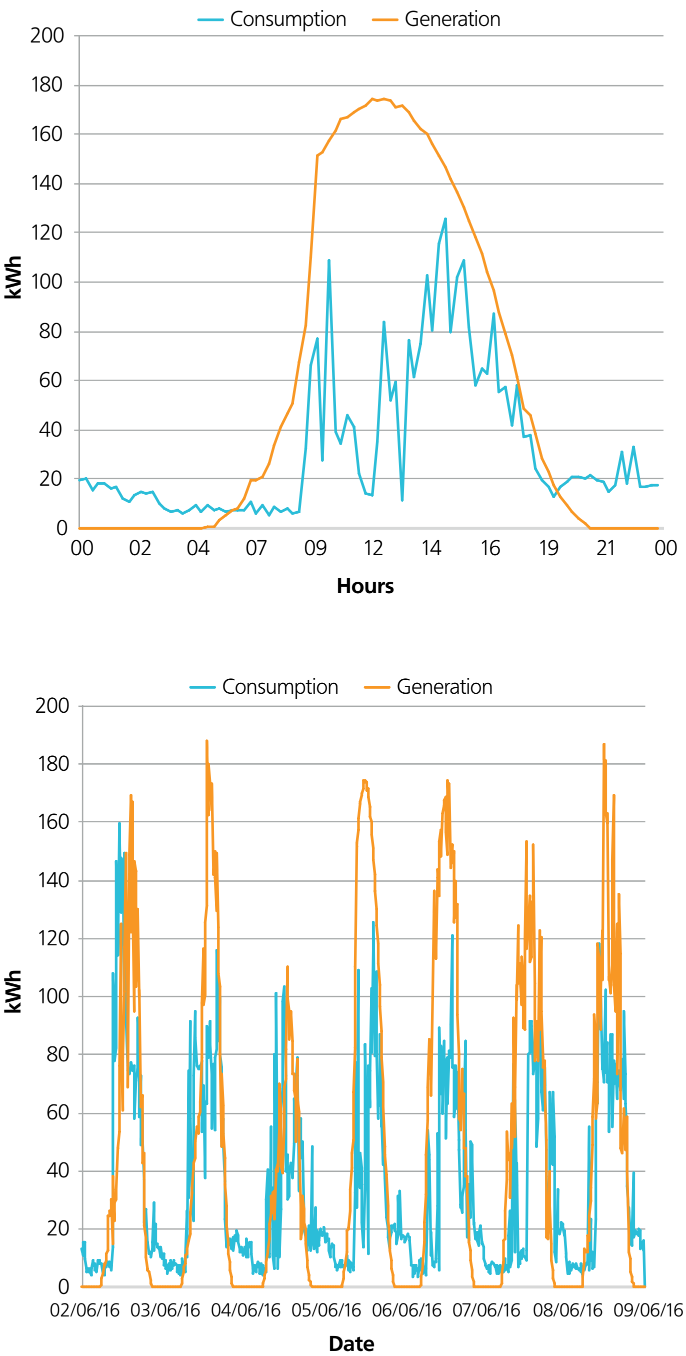


Figure 4 **An example of a daily and weekly generation and consumption graph, source SolarEdge**

8 BRE (Pester and Crick), "Performance of photovoltaic systems on non-domestic roofs", FB60. October 2013.

3. Financing options

There are three main stakeholders in a solar PV project;

– the electricity consumer (i.e. tenant /owner-occupier)

– the property owner (i.e. the landlord /owner-occupier)

– the PV installation owner (i.e. the tenant / landlord / owner-occupier; or in the case of a PPA business model, a third party)

If the property owner or tenant is considering investing in a solar PV installation themselves, then the remainder of this chapter, along with section 4 - *Making the business case* will be of prime importance. It is less common, though certainly not unheard of, for tenants to invest in PV. The text on self-investment refers to building owners, but is equally applicable tenants.

If neither the electricity consumer nor property owner is able or willing to invest the required capital, then a PPA business model could be an attractive option, in which case go to section 5 of this guide.

Self-financing

In situations where the property owner and solar PV asset owner are the same entity, the self-financing option allows them to benefit from all of the income streams offered by solar PV. This will typically offer the highest Internal Rate of Return (IRR), the quickest payback period and the largest return on investment. This is because there is no interest being paid on capital raised to finance the solar PV system and more of the income can be counted as profit generated. The potential IRR from the PV installation can be compared to that from other investments the company might be considering.

Naturally, not all entities will have sufficient surplus capital to adopt this model and as the capital invested in developing the solar PV system cannot be used for other purposes there is an opportunity cost to be considered. If internal capital is not available or considered best value, then there are a number of external sources of finance that may be considered.

Corporate loan/project financing

A corporate loan or a project finance structure may be a preferred option for a number of occupiers. Companies with strong credit ratings may be able to secure favourable terms without granting security over the installed assets, whereas companies with weaker credit ratings should expect to grant security in favour of the lenders as a condition of receiving finance. Under these structures, the company will retain all of the benefits from the solar PV installation provided they do not default on the loan but will get a slightly lower return on investment because of the interest paid to the lender.

Generally loans will charge interest rates of between 3 and 10 % depending on the credit rating of the company and the risks associated with any underlying project. Repayment terms are generally in the region of 1-7 years, although this can sometimes be much longer for asset finance. Traditional sources of loans would be the high street banks, however more favourable interest rates may be offered from specialist project finance lenders or through green investment schemes. Project finance lenders tend only to be interested in larger schemes or portfolios of smaller schemes with a large enough aggregate size. There are also a number of well-established providers of asset finance. Typically, the occupier retains all of the income streams and uses them to make the repayments according to the negotiated formula. The customer would also be responsible for the operation and maintenance but can use a third party. Terms of 5-7 years are most common, but certain organisations or transactions sizes may achieve longer terms.

Debenture model

A debenture is simply a debt instrument and is typically not secured by any assets. There are a number of platforms which allow developers to raise money for a project through selling debentures to a selected pool of investors or by crowdfunding through an online portal. Because debentures are not secured, they are typically viewed as being higher risk than a traditional loan and therefore as requiring a higher rate of return to justify the investment. A number of types of debenture are available; variable return (where the returns are linked to energy generation); fixed return (which pay back a fixed amount for the lifetime of the investment); income growth (where a regular income is given at a set interest rate) and finally inflation-linked.

Mercury Mall photo courtesy of Syzygy Renewables Limited

4. Making the business case

Introduction

If a building owner is not looking to go down the PPA route (described in section 5) but looking to fund the capital expenditure directly, it is important that there is a robust business case to justify the installation. In some circumstances solar PV can also offer less tangible benefits, such as attracting good press, improving public relations and opening up access to supply chains for businesses that have mandatory sustainable supply chain criteria. These are difficult to monetise but are increasingly important to businesses. PV installers should be able to show the business owners how a solar PV installation will aid their organisation in numerous ways. Whatever the initial reasons for deciding to install solar panels and the business model chosen to do so, a simple and compelling argument is being able to rely on a regular supply of electricity for 25(+) years at a reliable price[9]. This will directly influence the balance sheet and budgeting for the coming years for a proportion of the investor's energy costs.

Solar PV can offer an investment with a simple payback of between 6 and 12 years. The payback period depends on site electricity consumption and the retail price of electricity both now and anticipated in the future. As a general rule, the more electricity consumed on-site and the higher the price paid for grid electricity displaced, the shorter the payback period. The downloadable financial model[10] published alongside this guide should help establish the IIR, net present value and Levelised Cost of Electricity (LCOE) for proposed projects. The green cells represent the input assumptions such as build cost, PV system size, annual yield, FIT rate (if available), energy price inflation and operations and maintenance costs. The model is free from copyright and was developed by EvoEnergy and Aniron.

The remainder of this section covers the costs and revenue streams for solar projects and how to determine the LCOE, and provides guidance for filling in the financial model.

Capital costs

Solar PV technology has seen cost reductions of nearly 70% in the past five years. This trend in cost reduction is likely to continue, with another projected 35% decrease in levelised costs by 2020[11]. Installers can provide details of the latest figures, and the default values in the financial model available will be updated from time to time.

Ongoing costs

PV systems require very little maintenance besides regular monitoring, cleaning and replacement of inverters[12]. For larger solar PV systems O&M can be outsourced. The solar O&M market is maturing over time as companies specialise and consolidate. Prices vary and will continue to do so as the market develops. Solar PV installations are subject to business rates; these vary by region so you will need to check these with your local authority.

Revenue streams

Avoided electricity purchase costs

This consideration is likely to have the most bearing on a solar PV project's potential profitability. As electricity purchase prices are significantly higher than the price paid by the export tariff (explained further below), consumers are incentivised to maximise "self-consumption" and displace electricity purchased from the grid. Industrial electricity users might purchase non-renewable electricity at 9p/kWh, whereas the export tariff would only earn them around half this amount. Businesses with half hourly metering can seek to offset electricity purchases from the grid at the most expensive times e.g. with the use of south-west or west facing roofs to reduce the requirement for peak rate electricity tariffs during late afternoon and early evening periods.

Feed-In Tariff (FIT)

Whilst the FIT has been an important driver in the past, it is becoming less so following changes made in early 2016. Due to the uncertainty of availability and its relatively low payment level, this guide does not elaborate on the mechanics of the FIT in detail, although an overview is provided in section 8. It is suggested that the business case should be capable of standing up without the benefit of the FIT generation tariff.

	A	B	C	D	E	F	G	H
1	Cash Flow Projections using a PPA							
2								
3	Assumptions			Savings				
4	RPI (FIT & Export rate)	1.40%		Savings after 5 years	£6,221.52			
5	Energy Inflation	3.50%		Savings after 10 years	£15,087.68			
6	Degradation of PV /yr	0.5%		Savings after 25 years	£62,915.99			
7	Average cost of electricity	£ 0.11600						
8	PPA base price	£ 0.08500						
9	System Size kW	50						
10	Annual output (kWh/kWp)	850						
11	Self consumption of PV	80%						
12								
13	Power Purchase Agreement							
14								
15		Investment	PV Yield (kWh)	PV Consumption (kWh)	Electricity Tariff	PPA Tariff	Energy Savings	Accrued Savings
16	Year 1	-	42,500	34,000	0.116	0.085	1,054	1,054
17	Year 2		42,288	33,830	0.120	0.086	1,146	2,200
18	Year 3		42,076	33,661	0.124	0.087	1,241	3,441
19	Year 4		41,866	33,493	0.129	0.089	1,339	4,780
20	Year 5		41,656	33,325	[illegible]	0.090	1,441	6,222
			41,448				1,547	7,768
			41,241					9,425

Figure 5 Extract of downloadable financial model

9 This cost is mostly embedded in the initial capital, although there will be some ongoing maintenance costs.

10 Download the model from www.bre.co.uk/nsc > Our Library > BRE Publications

11 UK solar beyond subsidy: the transition. KPMG, July 2015. http://www.r-e-a.net/resources/pdf/206/UK_Solar_Beyond_Subsidy_-_The_Transition.pdf

12 Current industry practice is to include the cost of a replacement inverter in the business case every (say) 10 years, depending on the make and warranty provided by the manufacturer.

Calculating the LCOE (Levelised Cost of electricity)

The electricity produced from a PV installation can be analysed to give an average cost over its lifespan. The LCOE can be determined over a period of 25 years (the traditional length of warranty for solar panels) or longer. If the calculation is over a 25 year period, a decommissioning and recycling cost for the equipment should be included. As shown in Figure 6, the LCOE improves over time. At 25 years, although panel warranties will have ended, systems will still be generating at more than 80% of their original power, sometimes more. Decommissioning at this point therefore might not be the most sensible course of action. If calculating the LCOE over a longer period, the lifetime system output will be higher and the anticipated O&M costs will need to cover the full extended life. Some adjustment will also be required to account for the anticipated reduction in efficiency over the longer term. Generally this scenario is overlooked as economic models require some certainty and rely on known generation outputs. The financial model accompanying this guide caters for determining the LCOE under both scenarios.

A solar PV system LCOE calculation takes into account the total costs of the system, subtracting any income from government incentives (e.g. FIT, tax incentives, Annual Investment Allowance etc.) and divides the net amount by the anticipated electricity production over the (25 years or more) time period. This will give a £/kWh cost of electricity which can be used to compare against other energy sources. The financial model will carry out the LCOE calculation, as well giving an Internal Rate of Return (IRR) and Net Present Value (NPV). For guidance on how to anticipate the system's production, see section 2.

Although initially expensive in terms of £/kWh, the cost comes down with time as the capital cost is divided by a greater amount of generation. In this theoretical case, the LCOE of the PV becomes lower than that of grid electricity after 9 years, and thereafter continues to fall.

The cost of grid electricity

Once the LCOE of the PV system has been calculated, it can then be compared with the levelised cost of purchasing electricity from the grid. The long operational lifetime of solar PV means that investment decisions will be significantly affected by expectations of future electricity costs and interest rates.

There are two starting points to estimating the LCOE of grid electricity; the current price paid for power or an average determined from historical electricity bills. An energy price inflation rate should then be applied, to give a forward projection over the relevant time period. This could be derived from the DUKES[13] published by the Office of National Statistics, or from a projection curve such as that in National Grid's Future Energy Scenarios[14]. Your installer or consultant should be able to assist you with these calculations.

A high-level comparison of LCOE of a PV system with that of grid electricity can show that the PV system is cheaper over the long term and is more predictable, which aids business planning.

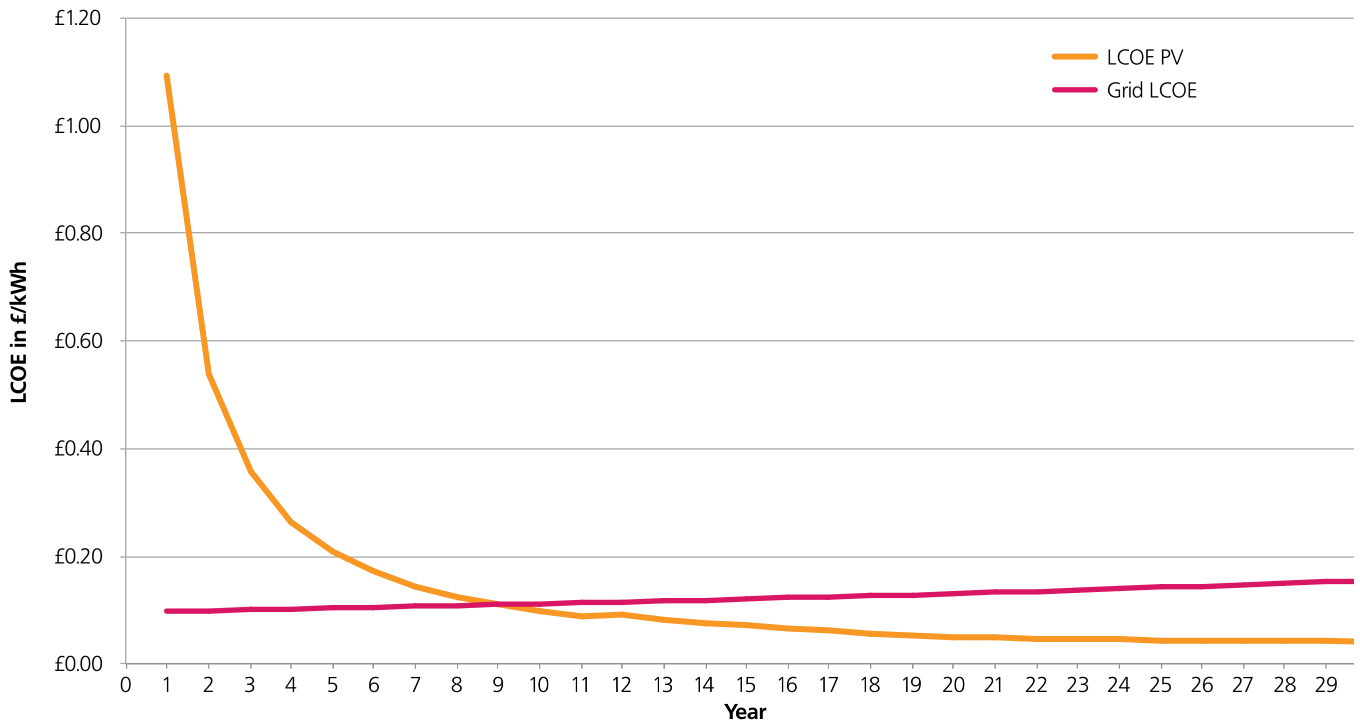


Figure 6 How cumulative LCOE changes over time, source EvoEnergy

13 DUKES (Digest of UK Energy Statistics) Gas and electricity prices in the non-domestic sector. https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector

14 E.g. see Figure 5, GB base load electricity prices, from Future Energy Scenarios 2015. The 2016 publication of the FES is due on 5th July 2016.

Detailed information on some elements of a commercial electricity bill

Electricity bills can either be aggregated, showing a single cost per unit (kWh) or disaggregated. The latter are more complex, and show the various components such as time of use fees, grid capacity charges, losses and the costs of governmental environmental policies. Some elements of a non-aggregated commercial energy bill are described below. Building owners are unlikely to want to delve into this level of detail, but it is provided here for the sake of completeness.

MPAN – Meter Point Administration Number. This is the address or site of the bill's reference. It contains various numbers which refer to elements of the supply's characteristics, including usage profile type, line loss factor, unique site identifier. The first two digits on the bottom line of the MPAN, are known as the Distributor ID and relate to the region in which the site is situated and dictates the timing of the DUoS charges.

Consumption Charges – you will find some or all of these on a commercial energy bill, all can be affected by PV, so it is advantageous to understand all of these and how they cost the commercial organisation.

BSUoS – Balancing Services Use of System charges. This covers the cost of day to day operation of the National Grid transmission system. It is levied on bills usually on a p/kWh rate.

DUoS Red/Amber/Green – Distribution Use of System Charges – These vary according to the part of the National Grid you are connected to. Each distribution network has a different charging profile, with certain times of the day and certain days when electricity consumption (and therefore distribution costs) peak (red) and when they are low (green), as shown in Figure 7. To estimate the correct amount of DUoS saving that a commercial organisation could make, half hourly generation data is required to be modelled and overlaid with current consumption data of the commercial organisation. There are various software tools on the market which utilise average historic weather data for the purpose of modelling solar panel systems. These can be used to create system output data. By means of simple subtraction, the overall building consumption in any half hour can be shown to be reduced by the modelled solar generation and therefore the DUoS energy saving. It is worth noting that DUoS times and rates are reviewed annually, so forward projections should be caveated.

Excess Reactive Power Charge – Sites with a power factor of less than 95% or 0.95 will be subject to this charge in p/KVArh. This is minimised or prevented, not by solar panel installation, but by modifying, fixing or updating any onsite equipment which causes this lag, typically transformers or large motors. If this is not possible, then adding in a transformer dedicated to this task, like a Power Factor Correction Unit, will reduce this cost.

Climate Change Levy – Some businesses will pay this charge which is a direct tax on the production of electricity from fossil fuels. This is passed on to large businesses unless the large business is a high energy user and has agreed a Climate Change Agreement (CCA). This CCA will reduce the percentage of electricity that the company pays the CCL on, in return for enacting other energy efficiency reductions.

Other charges, (e.g. Non-Firm Provision/Shape Charge/AAHEDC/ ELEXON Settlement Charge/RCRC Charge/Feed in Tariff Obligation/ Capital Market Settlement Levy – These and more are all charges that could be added to a bill. Usually, though, all are billed in p/kWh on the total consumption, sometimes distribution losses are taken into account for these charges, and sometimes not.

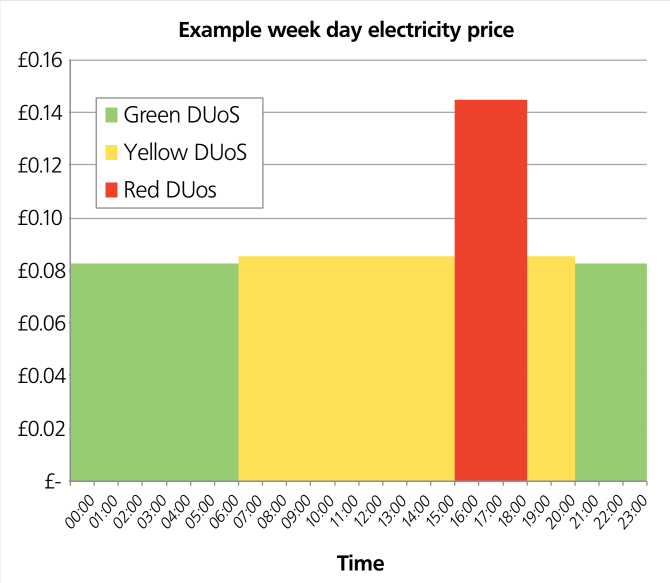


Figure 7 Impact of DUoS charging on typical cost of electricity (weekday), source EvoEnergy

5. Third party ownership / Power Purchase Agreements (PPAs)

An alternative to investing directly in a PV scheme is to enter into a PPA with a third party provider. PPAs enable the building occupier (be they tenants or owner-occupiers) to benefit from solar energy without any upfront capital or ongoing maintenance costs. In this case, the business case hinges on comparing the terms of a PPA with the anticipated costs of continuing to purchase power solely from a licenced electricity supplier.

Under a PPA, the third party installer will require the building occupier to purchase a certain proportion of the power generated by the PV installation, at a discounted rate (typically between 8 – 10p/kWh) and the third party benefits from the FIT generation tariff (if available), export sales and income under the PPA.

PPAs can be linked to RPI, to the grid price of electricity or fixed for the entire PPA term. PPA terms can be between 20 and 25 years. After the PPA term, ownership of the system can transfer to the building owner at zero cost, the PPA can be extended or the panels can be left in situ with the owner selling the power to the grid and paying rent to the building owner.

With a PPA the building owners and occupiers can expect the solar PV system to be very well-maintained, as the system owner needs the installation to generate reliably, or it has no income as a business.

PPAs are attractive because they provide organisations with the ability to forecast the cost of a percentage of their energy demand over the long term and reduce their dependency on retail electricity suppliers.

Landlords benefit from gaining green credentials from roof space that would otherwise be unutilised and from increasing the rentability of their properties in an economic environment that is becoming increasingly eco-conscious and doing so without an upfront cost. The improved Energy Performance Certificate (EPC) rating of the property and the opportunity of benefitting from reduced electricity bills often improve the marketability of a property[15].

The legal structure of PPAs normally consist of two distinct agreements:

- A lease agreement, specifically on the airspace above the roof with access allowed for the purposes of installation and maintenance to the PPA funder and roof maintenance access to the landlord
- A PPA agreement, detailing the commercial agreement on pricing and obligations on both parties

The most favourable type of building for PPA funding is normally owner-occupied. However, it is also perfectly possible for leased properties by granting an underlease and PPA or, as is now increasingly common, entering into a single agreement that combines the PPA terms with a licence to satisfy the landlord requirements of hosting a solar PV system.

PPA solar systems must be built to investment grade criteria, from initial design and planning through to implementation. This is because ultimately most PPA agreements are held by institutional investment houses which command guarantees on system performance and longevity. This provides building owners with further assurances about the technology on their property, over PPA term.

To be offered a PPA, there are qualification criteria that must be satisfied, namely:

- a sufficient amount of structurally-sound roof space to host a PV system
- a high electricity demand
- a good credit rating on the part of the host organisation
- an electricity connection able to accommodate the proposed size of the solar system
- an annual yield (i.e. kWh generated per kWp of PV installed) which exceeds a certain threshold

The aim of the PPA funder is to hit a baseline internal rate of return (IRR), and this is dependent on the variables above as well as the cost of building the system. The more favourable the variables, the better the PPA offer to the client (i.e. price per kWh) becomes.

Variations to the criteria above can occur, for example owners of multiple buildings which may be of a smaller scale could also qualify. Likewise if the credit rating of a client is deemed excellent then some of the other benchmark criteria can be relaxed.

Plymouth Life Centre, courtesy of Plymouth Energy Community

15 News article quoting Savills Energy. http://www.solarpowerportal.co.uk/news/savills_energy_still_plenty_to_be_done_for_commercial_solar_6546

6. Landlord/tenant leasing structures and terms

Where the electricity consumer, the property owner and the asset owner are all the same entity leasing terms will not be an issue. Where the property owner and the asset owner are separate entities there is likely to be a lease between these two parties. This means that whether it is the tenant or the landlord seeking to install solar PV on a roof, there are likely to be contractual ramifications to resolve before an installation can take place. Additional contractual agreements may be required if installing solar PV is not permitted within the terms of the existing contract. If a tenant or landlord wishes to install solar whilst in the process of negotiating a new lease, this should be written into the new lease and terms which accommodate the installation should be agreed upon.

Leasing considerations on existing leases

The 2007 Code for Leasing Business Premises (the "Code") provides an institutional framework within which a prospective tenant can reasonably expect a landlord to operate and promotes fairness in commercial leases[16]. Heads of terms ("HOTS") are a set of agreed principles between the landlord and the tenant and set out the intention of the parties before the drafting and negotiation of the lease. A key part of the Code is the 'Model HOTS', which is a template that can be completed online and downloaded. The Model HOTs are for general use to document the main terms of a commercial lease and therefore do not contain any specific reference to the installation of solar PV. It is therefore good practice to insert any key additional terms that would be required from the installation of solar PV into the HOTs to protect all of the stakeholders.

In a structure where the electricity consumer is the tenant and the property owner is the landlord, the following sections of a lease would need to be considered when installing solar PV on commercial roof space:

Lease duration

Business premises are often leased for a relatively short term. As the business case for a solar PV installation is generally made for 25 years, this can often be incompatible with length of the term in a lease. A forthcoming change to the FIT, allowing panels to be moved (see "Transferability of a solar PV system" section 10) will assist with this. As discussed elsewhere in this guide, it may be that the presence of a solar PV installation could encourage tenants to agree to a longer lease term or attract new tenants with the offer of generated electricity

Repair obligations

The repairing obligations of the solar PV installation may fall on the landlord or tenant, depending on which party owns the installation and what has been agreed between the parties within the lease.

Where a landlord installs a solar PV system, it will usually form part of the roof and the building that the landlord is obliged to maintain and repair (as the property owner). The costs of providing these services (amongst other services to the building) will be recovered from the tenant via a service charge, but the initial cost of installation and connecting the solar panel will usually be excluded from this charge.

Where the tenant installs a solar PV system, the tenant will usually be obliged to install this in a good and workmanlike manner, making good any damage caused to the roof and repair and maintain the installation in accordance with an agreed standard. Tenants will usually take premises in their current state and condition, but in some cases may limit their repair liability by reference to a photographic schedule of condition showing the state of the roof before the solar PV system is installed.

If a roof is due for repair or replacement this should be undertaken by the landlord as part of, or prior to, the solar PV system being installed. This should be agreed between the landlord and tenant as part of the project planning.

Alterations and Use

A set of permitted alterations are usually contained in the HOTs. If the tenant's right to install a solar PV system is not permitted, the parties would need to enter into a separate licence to alter, under which the landlord consents to the installation by the tenant. A tenant right to install solar PV as a permitted alteration would need to be specifically referred to in the lease. In any event, the tenant's right would be subject to the usual provisos e.g. to install in a good and workmanlike manner in a position approved by the landlord, make good any damage caused to the roof and the landlord's right to relocate the installation. These caveats will be agreed in the lease or licence, as appropriate.

If the lease is silent on permitted alterations or if the installation of solar PV does not fall within a 'permitted alteration' under the terms of the lease, the installation will be prohibited.

According to the Code, landlord's control over alterations and changes of use should not be more restrictive than is necessary to protect the value, at the time of the application, of the premises and any adjoining or neighbouring premises of the landlord. Arguably solar PV installations are now seen to add value to premises, but either way discussions should be held between the tenant and the landlord to agree specific terms.

Rights

Where the tenant is installing the solar PV, it will need specific rights in the lease to use the roof space (and parts of the building to access the roof space) in order to comply with its repair and reinstatement obligations detailed above.

Where the landlord is installing the solar PV, it may need to reserve rights over the tenant's premises (e.g. where these are needed to access the roof) in order to comply with its obligations to provide the services detailed above. This right may already be covered in the landlord's usual right to install, maintain and replace conducting media serving the building. This landlord right would be subject to the usual provisos (e.g. making good any damage caused to the tenant's premises, not causing any disruption to the tenant and potentially compensating the tenant for any disruption caused during the installation process).

The tenant's termination rights

The tenant should consider whether it would want to terminate the lease on the occurrence of specific events including:

- theft or loss of the solar panel equipment installed on the roof
- material breach by the landlord (where not remedied on notice by the tenant)
- termination of the associated power purchase agreement
- damage of equipment beyond economic repair
- interruption to the flow of light over a certain period (which reduces payments received by more than a certain percentage over a previous period).

16 http://www.leasingbusinesspremises.co.uk/

Insurance

Whether the obligation for insuring a building falls on the tenant or the landlord, the insurer will need to be notified and consideration should be given to the buildings sum insured. Generally insurers are not too concerned by the installation of solar PV on a roof space. Some of the potential issues however are as follows:

- some third parties will seek to retain ownership of the panels. In these circumstances, they may require their interest to be noted on the policy. If an interest is to be noted on an insurance policy it is important that it is made entirely clear what this means for both parties
- consideration also needs to be given to where the energy produced by the system is going, i.e. consumed on the premises by the building owner/tenant or for export onto the electricity distribution network. Insurers will need to be notified of this
- poorly-installed solar PV panels may add a fire risk to the building. By ensuring a solar PV system is installed to a high standard, fire risk can be mitigated. If a solar PV system is installed according to the Institution of Engineering and Technology Code of Practice for the installation of Grid Connected Solar Photovoltaic Systems (IET solar PV CoP) and, ideally, individually certified to the BRE solar certification scheme, or equivalent, then risks of this kind can be avoided. (The IET solar PV CoP and certification scheme are discussed below in Electrical Safety)
- fixings could affect roof coverings and be an additional source of water leakage. Again, if the system is installed according to the IET solar PV CoP and certified to the BRE solar scheme these risks can be avoided

All these considerations could lead insurers to consider charging additional premiums and/or imposing special terms by way of cover restrictions or exclusions, irrespective of any increase to the sum insured. However according to the British Insurance Brokers Association (BIBA) they have very few queries from members concerning PV installations, and on that basis there does not appear any real problem in obtaining affordable insurance for buildings with solar PV installations[17]. It is recommended that insurance cover be sourced through a BIBA member firm.

Leasing considerations on new leases

If a proposed solar PV installation is planned on a building where the lease has yet to be agreed then the HOTS should be written in such a way that PV can be installed without being in breach of the agreement. The key considerations for a lease compatible with installing solar PV are the same as those given for solar installations under an existing lease.

Mortgage considerations/Bank consent

From a practical perspective, property owners (i.e. landlords) considering leasing their roof space for a PV installation, or carrying out an installation on a mortgaged building, should be aware that most lenders' mortgage conditions will require the lender's consent to be obtained. It is good practice for the landlord in this situation to contact their lenders at the earliest opportunity (prior to entering into any arrangements regarding panels) to check their requirements. Proceeding without the lender's consent, where required, may be a breach of the mortgage terms and conditions and even if the lease can be registered, the lender may not be bound by it in the absence of their consent. See the document entitled Council of Mortgage Lenders CML/BSA guidance and minimum requirements regarding leases of roof space for fitting photovoltaic (solar) panels for a full process of obtaining the lender's consent for a solar PV installation[18].

In addition, if the landlord's building is mortgaged, its lender may require mortgagee protection provisions in the lease which would enable the lender to step into the landlord's shoes and cure the landlord's breach (so as to avoid termination of the lease by the tenant on the relevant grounds detailed above).

Decommissioning agreements

The tenant is typically responsible for removing any alterations or additions it makes to the premises (which could include the installation) before the lease ends. This is because these items are considered to belong to the tenant. However, the landlord may not want the tenant to remove the installation if it benefits the landlord's building (and adds to value as mentioned above) and the tenant may agree to this on the basis that the installation would be difficult to remove in any case. The reinstatement of the premises to be fit for occupation and use may also be linked to a formula to establish whether a baseline of FIT/other income may then be obtained.

If a solar PV system is intended to be left on a building beyond expiry of the lease and the tenant is not required to reinstate, arrangements should be made for its decommissioning. There will be a cost entailed, which is typically borne by the main benefactor. It may be necessary to put in place some form of security (such as a bond) to cover decommissioning costs.

Decommissioning will not necessarily take place after the 25 year warranty period has expired, and therefore a decommissioning agreement should avoid specifying a date.

Roof system warranties

Installing a PV system constitutes a material change to a roof space and if installed carelessly or improperly can cause leaks. Generally commercial roofs that are less than 15 years old will come with a collateral warranty from the manufacturer or installer; giving the party who appointed the contractor the right to require them to remedy any defects in workmanship (at no cost). However, installing solar PV could make that warranty void if not approached correctly. Some roof manufacturers will stipulate specific mounting technologies that will not make the warranty void. It is important to check the wording of the warranty (and particularly the exclusions section) to determine under which circumstances the warranty would be void and to contact the roof manufacturer to discuss their suggestions as to how to install whilst maintaining the warranty agreement. It is also important to have regular quality control audits during the installation phase to ensure installers are taking the necessary care not to compromise the roof.

The BRE National Solar Centre solar certification scheme effectively provides an independent external QA process to ensure that the installation meets all design requirements.

Building performance warranty

If the building is new (i.e. less than 10 years old), it may still have a building performance warranty in place. If so, the landlord will need to check the building contract with the main contractors to ensure that installing PV does not void the building's performance warranty.

Energy Performance Certificates (EPC)

Landlords are required to provide a full copy of the EPC to a potential tenant at the earliest opportunity and in any event before the lease is completed. Where the lease has already completed and the landlord subsequently installs a solar PV system, it must provide the new EPC to the tenant on completion of these works.

Equally, where the tenant is installing the solar PV system, it must provide the EPC to the landlord on completion of these works and at its own cost. EPCs are not required for all buildings (e.g. non-residential agricultural buildings with low energy demand are exempt).

17 Anecdotal correspondence with Steve White, Chief Executive of the British Insurance Brokers Association

18 Council of Mortgage Lenders – Building Societies Association - Guidance for solar photovoltaic panels on roofspace, 18 Mar 2015 https://www.cml.org.uk/policy/guidance/all/cml-bsa-guidance-and-minimum-requirements-regarding-leases-of/

7. Project processes and timescales

Feasibility

It can take between 2-4 weeks to determine the feasibility of a commercial rooftop solar PV project. This could comprise an initial desktop-based phase followed by a physical survey. The following information will be needed:

- the suitability of the building for solar PV, including details on orientation, shading and pitch of the roof space (which can be done in combination with satellite-based analysis). This is translated to a likely yield of a system based on historical satellite-based irradiance data
- the building structure
- the roof type
- the building's existing electrical infrastructure
- the building's connection to the electricity network
- an understanding of the electricity consumption profile of the building (via half hourly data or monthly billing)

It is worth speaking to an independent adviser when assessing the viability of a project. They will be able to help with the specification and advise on the structuring routes available (funding sources, PPA negotiation, lease structuring). If self-funding they can run a competitive tender to identify the most suitable contractor.

Development stages

This can take a little longer, at around 1-10 weeks, as responses could be required from the local planning department and Distribution Network Operator (DNO), before the project can be taken forward. The development stage includes the following:

- designing the system based on the available roof space, such that it adheres to the current planning regulations and best practice guidance
- taking legal advice on the contractual structure and issues that will need to be resolved before works can commence
- securing a grid connection agreement with the DNO once the likely output of the system is defined
- producing a design and access statement for the project if planning permission is required
- submitting a full planning application with all of the supporting material. Though for systems up to 1 MW a certificate of lawful development certificate is sought (see planning consents).

For systems that exceed 50 kW, once a grid connection agreement and successful planning application is in hand the system can be eligible for pre-accreditation for the FIT. This enables a system owner to lock in a FIT tariff for a period of six months from the date of submission of the application with Ofgem[19].

Installation, commissioning, connection & accreditation

It can take between 2-8 weeks to install and commission a solar PV project, depending on the size and complexity of the project. The following stages are entailed:

- arranging scaffolding on site
- installation of the solar PV technology
- connecting the system to the electricity network
- commissioning the system
- notification to the DNO of the installation as well as building control
- (if applicable) application for the FIT

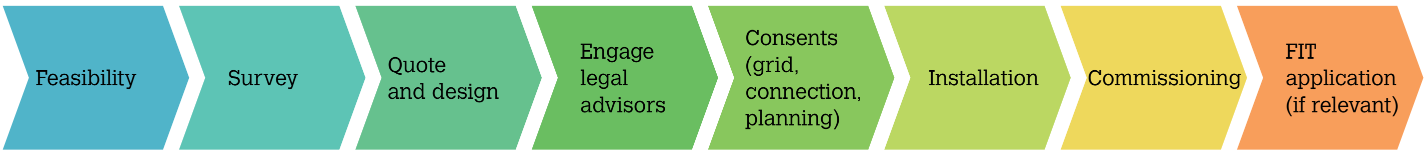


Figure 8 **Solar PV project process and timescales**

19 Note, pre-accredited systems are still subject to the deployment caps and the tariff that is pre-accredited will depend on the status of the caps at the time of pre-accrediting and could be different to the tariff in the current quarter if that cap for that quarter has been reached.

8. Consents

Planning consents

Permitted development

Permitted development rights are set out in The Town and Country Planning Act (General Permitted Development)(England) Order 2015[20], Schedule 2, Part 14, Class J.

Installations below 1 MWp on non-domestic premises are now considered permitted development, providing they adhere to the following design stipulations. They must not be:

- protruding more than 0.2 metres beyond the plane of the roof slope when measured from the perpendicular with the external surface of the roof slope
- higher than 1 metre above the highest part of a flat roof (excluding any chimney)
- installed within 1 metre of the external edge of that roof
- installed on a roof slope which fronts a highway if the building is in a protected area (i.e. conservation area, Area of Outstanding Natural Beauty, National Park, the Broads or a World Heritage Site)
- installed on a site designated as a scheduled monument
- installed on a listed building or on a building within the curtilage of a listed building

In addition the installations must be:

- sited, so far as practicably possible, so as to minimise its effect on the external appearance of the building and the amenity of the area
- removed as soon as reasonably practicable when no longer needed

In additional to the above points, BRE will be publishing a joint guide with Campaign to Protect Rural England (CPRE) in 2016 on responsible design for solar PV on buildings which provides a methodology for the assessment of landscape and visual impact.

Permitted developments must comply with a number of planning conditions. The developer of a rooftop solar PV system must apply to the local planning authority for a determination as to whether the prior approval of the authority will be required as to the design or external appearance of the solar PV, or the impact of glare on occupiers of neighbouring land. The application must be accompanied by the items listed below, and possibly further additional information:

- a written description of the proposed development
- a plan indicating the site and showing the proposed development
- the developer's contact details
- any fee required to be paid

The developer must have received written notice that prior approval is either not required or is granted, or 56 days must have elapsed with no notification having been received, before development can begin. Prior approval may be granted unconditionally or subject to conditions.

20 The Town and Country Planning (General Permitted Development) (England) Order 2015 (SI 2015 No. 596) http://www.legislation.gov.uk/uksi/2015/596/pdfs/uksi_20150596_en.pdf.

Lawful development certificate

If it is not a clear cut case as to whether a project falls under permitted development, a developer can apply for a certificate of lawfulness of proposed use or development (CLOPUD). This clarifies the permitted development status of a proposal or flags up any amendments required in order for it to qualify as permitted.

A CLOPUD is not the same as planning permission but enables people to ascertain whether specified questions or activities would be lawful under planning law. The applicant must describe the proposal in sufficient detail to enable the local planning authority to make a decision. The local planning authority has no discretion in dealing with an application, as it is making a determination of law based on the facts established by the applicant. This will also be useful to provide assurances should the property ever be sold. The application can be made using the Planning Portal's secure online application service and entails a fee.

Planning applications

If a project does not comply with any of the permitted development exceptions, limitations or conditions, then planning permission will be required. Roof-mounted solar PV is a relatively non-contentious technology with low opposition so well-designed, sensible projects are likely to be approved.

The Planning Policy Guidance sets the following minimum requirements for a planning application:

- the **standard application form** must be duly completed
- the **plans** must be submitted as supporting documents. Most planning applications require two plans[21]:
  1) **the location plan**, which shows the application site area and its surrounding context. A location plan should identify sufficient roads and/or buildings on land adjoining the application site to ensure that the exact location of the application site is clear. The application site should be edged in red. Location plans can be purchased online from one of the Planning Portal's accredited suppliers either as part of the application process, or separately, and then attached to the application
  2) **the site plan** (sometimes known as a block plan), which shows the proposed development in detail and can be purchased from one of the Portal's four accredited suppliers
- an **ownership certificate** must be completed, providing details about the ownership of the application site and confirming that the relevant notices have been served on the owners
- an **agricultural holdings certificate** is required, confirming whether or not any of the land to which the application relates is, or is part of, an agricultural holding. Agricultural tenants must be notified of the application prior to its submission to the local planning authority. This declaration is required whether or not the site includes an agricultural holding
- a **design and access statement** is required. This should outline the design principles and concepts that have been applied to the proposed development and how issues relating to access to the development have been dealt with (see below).
- the application must be accompanied by payment of the correct **application fee**

In addition to the above requirements, the local planning authority may have a local list which details any specific supporting information that is required to accompany a planning application.

21 Additional plans and drawings will be necessary in most cases to describe the proposed development.

This information summarises the page on Mandatory documents, National requirements on the Planning Portal Website[22] and the Making an application section of the Planning Practice Guidance[23].

Design and access statements

A design and access (DAS) statement is a short report accompanying and supporting a planning application. It provides a framework for applicants to explain how a proposed development is a suitable response to the site and its setting, and demonstrate that it can be adequately accessed by prospective users.

A DAS must explain the design principles and concepts applied to the proposed development; how the proposed development's context has influenced the design; the applicant's approach to access; how relevant Local Plan policies have been taken into account; any consultation undertaken in relation to access issues, and how this influenced the proposed development. The level of detail in a DAS should be proportionate to the complexity of the application, and for a commercial rooftop PV installation may only need to be a page long[24].

Regulations

Building regulations

Installation of solar panels is normally subject to the Building Regulations[25], which set out the legal requirements for specific aspects of building work and the notification procedures that must be followed when starting, carrying out, and completing building work.

Installation of solar panels may also be subject to other statutory requirements including the Construction (Design and Management) Regulations 2015 and the Party Wall Act etc., 1996.

The Building Regulations apply to "building work" as defined in Regulation 3 of the Building Regulations. The installation of solar panels on a roof space normally falls within either Regulation 3(1)(b) "the provision or extension of a controlled service or fitting in or in connection with a building" or Regulation 3(1)(c) "the material alteration of a building, or a controlled service or fitting…" because they typically increase the load on a building and require new electrical circuits to be installed.

Schedule 1 of the Building Regulations contain 14 sets of "requirements" (labelled A-P). To aid compliance, these are supplemented by detailed technical guidance called "Approved Documents" which explain how the Building Regulations requirements may be satisfied. The most relevant of these are listed below. There is no obligation to follow the guidance in the Approved Document provided that it can be demonstrated that compliance with the Building Regulations has been achieved.

- Approved Document A - Structure[26], which sets out the technical requirements for structural analysis of buildings. See sections below on "Solar PV system static loads" and "Wind uplift dynamic loads"
- Approved Document P - Electrical safety (Dwellings)[27] on the technical requirements for electrical work
- Approved Document B2 - Fire safety (Buildings other than Dwelling houses)[28] which cover the technical requirements for fire safety precautions

While the relevant local authority will ultimately be responsible for enforcing compliance with the Building Regulations, there is normally a choice of routes to apply for approval. Options for compliance normally include submitting an application for Building Regulation approval to the local authority building control department, applying for approval from a private sector approved inspector, or by way of self-certification under the Competent Person Scheme (CPS) by a qualified member of the installation team. Different local authorities will have different approaches so best practice is to check with the relevant local authority building control department as to what is the preferred compliance route.

Competent persons scheme (CPS)

The Competent Persons Scheme (CPS) allows individuals and enterprises to self-certify that their work complies with the Building Regulations. It therefore avoids the need to seek approval from the local authority or from an approved inspector.

Schedule 3 of the Building Regulations sets out the CPS self-certification measures which cover solar PV and solar thermal installations.

Solar PV system static loads

Solar PV systems typically result in an increase of loading of around 15% on a building[29], but it can vary significantly from roof to roof and technology to technology. Panels currently in production normally have an installed mass of approximately 10-20 kg/m^2. It is prudent to make a more accurate calculation based on the specific technology to avoid any risk of damage to the roof.

Part A of the Building Regulations requires that a building should be constructed so that the dead, imposed and wind loads are transmitted safely and without causing deflection or deformation.

Under Part A of the Building Regulations (Structural Stability), if the weight increase is significant (i.e. over 15%) then a structural survey is required to determine whether or not strengthening work is required. Any structural strengthening work must be inspected by a suitably qualified structural engineer or surveyor before the installation can continue[30].

22 http://www.planningportal.gov.uk/planning/applications/howtoapply/whattosubmit/nationaldocuments

23 http://planningguidance.communities.gov.uk/blog/guidance/making-an-application/

24 Design and Access Statements on the Planning Portal. http://www.planningportal.gov.uk/planning/applications/howtoapply/whattosubmit/designaccess

25 Building Regulations 2010 (SI 2010/2214) (as amended).

26 https://www.gov.uk/government/publications/structure-approved-document-a

27 https://www.gov.uk/government/publications/electrical-safety-approved-document-p

28 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/441669/BR_PDF_AD_B2_2013.pdf

29 *Guide to retrofitting solar panels - Technical guidance for building control surveyors, designers and installers*. Local Authority Building Control. See http://www.labc.co.uk/sites/default/files/labcpd0914_techg_solar_panels.pdf

30 The National Federation of Roofing Contractors Limited, Technical Bulletin 41 *Solar Installations on Roofs* (TB 41) June 2012. See http://www.nfrc.co.uk/publications-list

Wind uplift dynamic loads

Commercial roof PV installations will need to consider wind uplift force. To ensure the system is suitably well-attached the number of fixing points needs to be calculated to withstand the maximum feasible wind force.

The BRE Digest 489[31], sets out a comprehensive methodology for calculating the wind uplift force a solar PV system is likely to experience. The IET solar PV CoP suggests the use of the BRE Digest 489 to calculate wind uplift force. See Figure 9.

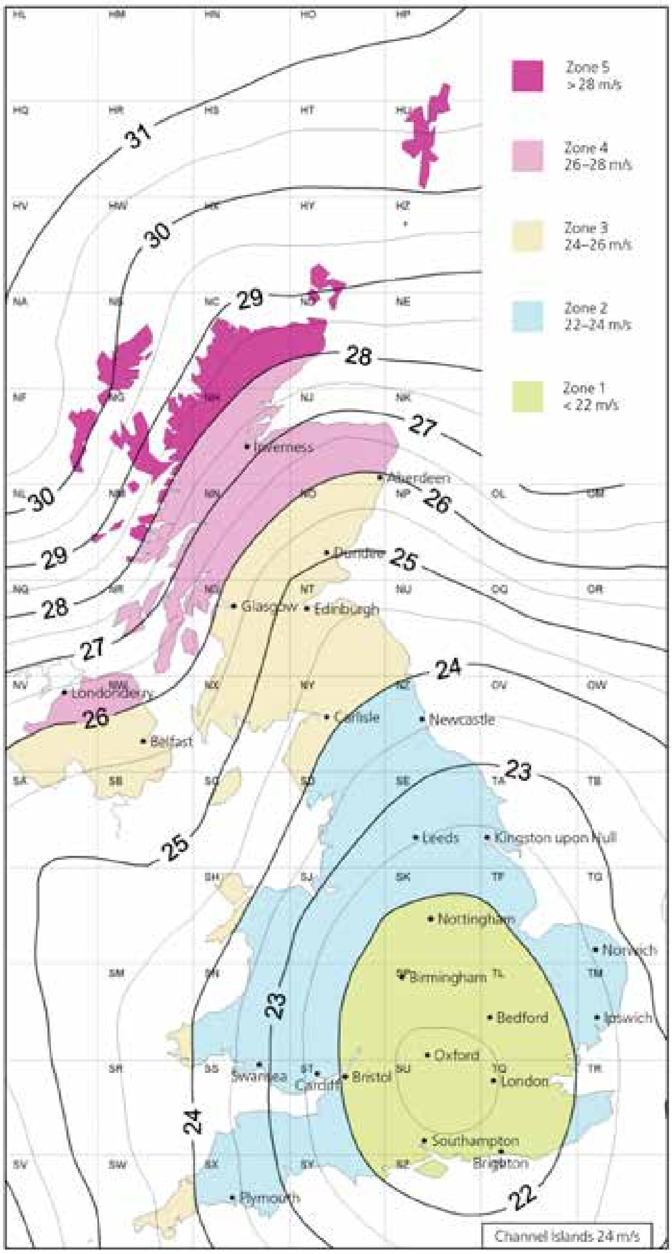


Figure 9 Map of UK wind speed zones for determining wind loading © IHS, reproduced with permission from BRE DG 489, 2014

31 *Wind loads on roof-mounted photovoltaic and solar thermal systems*, BRE, Paul Blackmore, May-2014.

Health and safety

The Health and Safety at Work Act (HSWA) 1974 is the principal piece of legislation covering work-related health and safety in the UK. The Health and Safety Executive (HSE), along with local authorities are responsible for enforcing the act. The act sets out general duties which employers have towards employees, members of the public or contractors with respect to premises, property or plant for which they are responsible. It also sets out duties which employees have to themselves and each other.

The Management of Health and Safety at Work Regulations 1999, more explicitly define what employees are required to do. A key part of this is conducting risk assessments on working practices and determining safety measures that will mitigate the risks identified.

There will also be other regulations which may apply, such as the Working at Height Regulations 2005, and installers and employers should ensure that they cover the additional issues which may come into play and take appropriate steps to properly discharge any duties which arise.

The HSWA states that employers should so far as reasonably practicable endeavour to avoid or reduce risk for their employees. Solar PV projects pose a number of significant risks to installation teams and other stakeholders and so substantial consideration should be given to the health and safety implications of any project. The Construction Design and Management regulations (see below) place health and safety duties on organisations for whom construction projects are carried out and their designers, contractors and workers.

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 Regulations[32] set out the process of reporting certain accidents or incidents in the workplace. These put duties on the Responsible Person (i.e. employers, the self-employed and people in control of work premises) to report certain serious workplace accidents, occupational diseases and specified dangerous occurrences (i.e. near misses).

Construction Design and Management (CDM) Regulations 2015

The Construction (Design and Management) Regulations 2015[33] apply to all construction work in the UK. There is no exclusion for small-scale projects. The CDM Regulations are designed to secure construction health and safety in four key respects:

- parties involved are required to evaluate, avoid and control risks;
- employers throughout the supply chain are required to appoint the right people for the right job at the right time;
- duty holders must ensure that everyone has the information, instruction, training and supervision they need to carry out their jobs in a way that secures health and safety; and
- cooperation and communication across construction projects are promoted to ensure that parties are able to coordinate their work[34].

A summary table of the duties of different stakeholders is provided on the HSE website[35].

Projects which last longer than 30 days and have more than 20 workers working simultaneously on site at any point or involve more than 500 person days of work are known as 'notifiable' and written notice must be given to the HSE as soon as possible before construction begins. Almost all of the requirements of the CDM 2015 Regulations apply regardless of whether a project is notifiable.

32 http://www.hse.gov.uk/riddor/

33 http://www.hse.gov.uk/construction/cdm/2015/index.htm

34 HSE. The Construction (Design and Management) Regulations 2015. http://www.hse.gov.uk/construction/cdm/2015/index.htm

35 Summary of duties under Construction (Design and Management) Regulations 2015 (CDM 2015) http://www.hse.gov.uk/construction/cdm/2015/summary.htm

Electrical safety

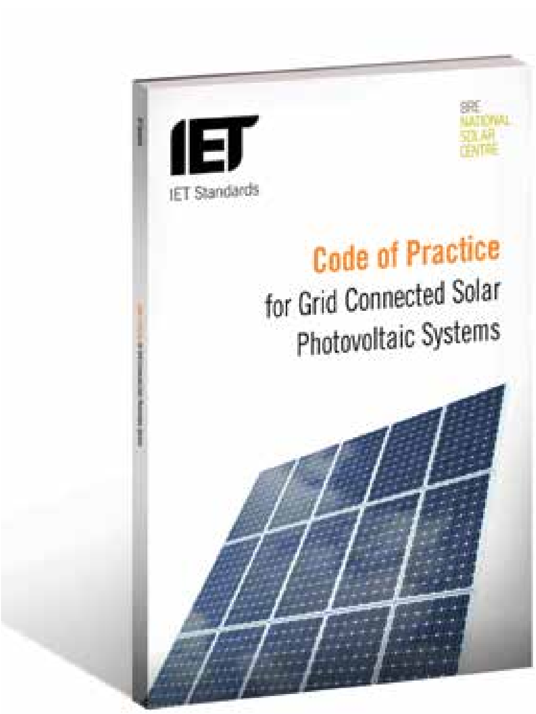
The Institute of Engineering Technology Code of Practice (IET solar PV COP)

BRE National Solar Centre and the Institute of Engineering and Technology (IET) have developed a Code of Practice for Grid Connected Solar PV Systems. This was developed to cover systems >50 kW and to address areas currently not covered by the Microgeneration Certification Scheme (MCS) technical standard, which was introduced for small scale renewable energy systems in the mid-2000s. The IET solar PV COP has a wider scope, incorporates the requirements of more recent technical innovation and incorporates the lessons learned from over 750,000 systems installed by MCS-certified installers.

The IET solar PV COP covers:

- all parts of a grid-connected solar PV system up to and including the connection to the AC mains
- LV and HV connections and components
- all scales of application, from small domestic systems to large scale PV farms
- building-mounted, building-integrated, ground-mounted, domestic and non-domestic systems, along with solar canopies
- the causes of fire and fire prevention measures
- grid-connected systems with battery storage

The implementation of the IET solar PV COP should increase PV systems' safety and performance, reliability, resilience, yields and performance ratios. Compliance will also lead to a reduced risk of DC arcing that has been seen to lead to fire. Whilst fires are not a common occurrence, in recent times there have been several widely-publicised fire incidents involving PV systems.



IET Solar PV COP document, source IET

IET solar PV COP training and certification

The BRE runs classroom training for installers on the requirements of the IET solar PV COP and online training courses for Energy and Facility Managers. These are run in partnership with the BRE Academy. More information can be found on the BRE website[36].

BRE Global have a certification scheme that demonstrates compliance with the IET solar PV COP at an installation level. The scheme comprises of a design stage review and a final site sign off review for completed installations. For single developments a full review will be required, for portfolios of similar multiple installations a statistical representation of sites will be reviewed. Note that other certification schemes, such as MCS, cover only products and installers, while this scheme addresses onsite installation quality.

Additionally, from 2017 one BREEAM credit will be available for new build projects that certify their solar installations against the requirements of the IET solar PV COP.

Solar inverter plant room, image courtesy of EvoEnergy

36 See BRE Academy - https://www.bre.co.uk/academy/

9. Grid connection

As discussed in section 7, a connection application must be made to the relevant Distribution Network Operator (DNO). Applications to connect a power generating source to the electricity distribution networks are covered by either ENA's Engineering Recommendation G83 or G59 procedure, depending on the size of the system[37]. Most commercial roofs will be required to follow G59. Single small[38] system installations follow G83, which is a "fit and inform" procedure, not requiring DNO permission in advance.

There is a simplified G59 procedure for projects where the capacity is less than .50kW (three-phase) or 17kW (single-phase) and the inverter equipment used has been type-tested. The procedures are described in the ENA Distributed Generation Connection Guide[39].

There are currently six DNOs servicing the UKs distribution network[40], a further eight licensed Independent Distribution Network Operators (IDNOs) operating smaller networks within the DNO areas, as shown in Figure 10. Many projects become financially unviable due to the cost of grid connection, and therefore connection applications should be made at an early stage. Some areas on the DNO network have little or no grid connection capacity remaining and connecting additional capacity causes problems with voltage rise, thermal capacity, fault levels, network harmonics and real time network information. To combat these issues, significant investment in the electricity network infrastructure is sometimes required.

It is good practice to have an initial meeting with a representative of the DNO to outline the proposed generation project, discuss the process and see which works will need to be carried out by the DNO (i.e. the non-Contestable work) and which could be carried out by an independent connections provider.

DNOs can provide an indicative connection design and a budget estimate for a charge. If this is acceptable, then the next stage is to submit a formal connection application, accept the Connection Offer from the DNO and then enter into a formal Connection Agreement. A Connection Offer is time-limited, and if it expires there is no guarantee that the same offer will be made again, particularly in areas of high demand. The DNO must provide the Connection Offer within 30 – 65 working days depending on the connection voltage, and how much of the work they are quoting for.

On occasion the DNOs quote very large sums for the connection of a PV system. This is because they are accounting for the full cost of upgrading the electricity network to which a proposed project might attach. Export management and storage options may avoid the need for, or reduce the costs of, reinforcement.

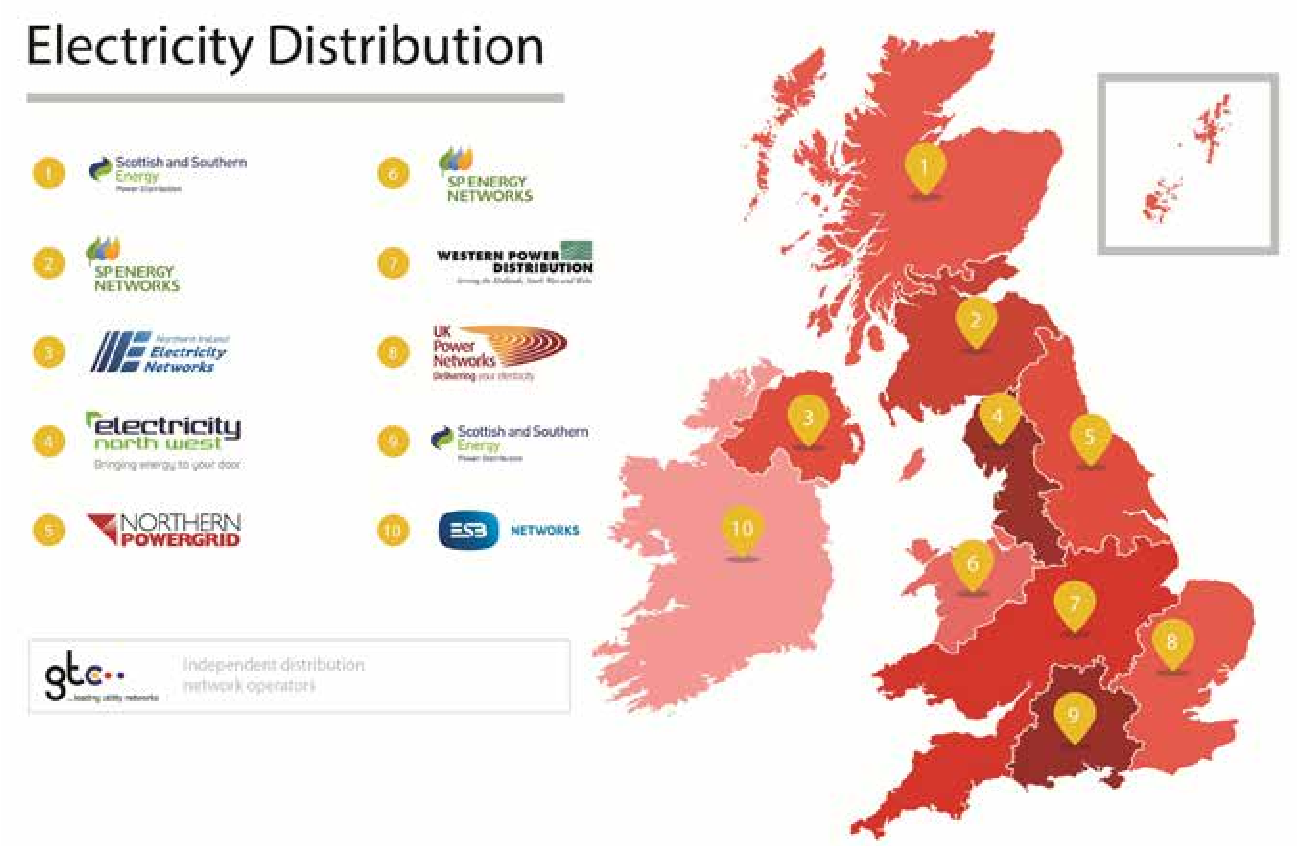


Figure 10 **Regional coverage of Distribution Network Operators, Courtesy of Energy Networks Association, http://www.energynetworks.org**

37 For more information go to http://www.energynetworks.org/electricity/engineering/distributed-generation/dg-connection-guides.html

38 defined as distributed generation of less than 16A per phase (i.e. 3.68kW for single phase connections and 11.04kW for three phase connections)

39 *Distributed Generation Connection Guide - A Guide for Connecting Generation to the Distribution Network that Falls Under G59/3*, Energy Networks Association, June 2014

40 For a map, see http://www2.nationalgrid.com/UK/Our-company/Electricity/Distribution-Network-Operator-Companies/

Export-management devices

Export management is where a device or export limiting inverter is designed such that it will never export more than a predefined level of power onto the network. This is increasingly seen as a way of installing a solar PV array where the grid connection offer given by the local DNO is too expensive to be absorbed within the cost of a solar PV system.

Some export-management technologies come in the form of an additional component which reduces the output to ensure it remains within export limits. Alternatively some more sophisticated inverters already have the functionality to limit their power output and can provide an export limitation service with the addition of an extra control system.

Where all or a significant amount of generation is likely to be consumed on-site, this kind of solution is increasingly viable. Where a significant amount of export is likely, then the system profitability and payback are likely to be adversely impacted.

The addition of export limiting technology can add to the cost and complexity of the solar PV system, but will rarely be significant in comparison to the electricity connection costs.

These technologies need to be signed off on a case by case basis by the local DNO and can cause additional cost and complexity to the commissioning process.

Energy storage

Energy storage is increasingly being seen as a good partner technology to solar PV. Solar generation can be stored for use later in the day, or in order to limit the power exported to the grid. Currently the most commonly used storage technologies are batteries and water heating.

Generation which is curtailed by export-limiting devices is essentially lost revenue, whereas with energy storage the excess generation is not wasted. Storage could therefore be a more cost-effective way of managing export to the electricity network.

Batteries

Battery storage systems had traditionally been considered too expensive to be commercially viable as a component of a solar PV system; however an increasing number of products on the market and significant component cost reductions mean that in the right scenario battery-based storage can be economically viable.

Many of the batteries currently on the market come with energy management software enabling them to perform other functions, such as the provision of ancillary services to the grid, demand side response and enhanced frequency response. These opportunities are not yet being fully exploited, but in the future these could provide additional revenue streams. For more information see BRE's solar storage guides for consumers[41] and installers.[42]

Storage as heat

There are a number of products on the market that divert energy that would otherwise be exported to the grid, to heat. The heat is either stored as hot water or in a heat battery, such as those using phase-change materials. These have seen a wide market penetration in the domestic solar PV market, but could be applicable to commercial and industrial applications with high hot water demands. This type of storage limits the usefulness of the stored energy but it can be a cheap method of storing excess solar energy.

10. The Feed-In Tariff

The Feed-In Tariff (FIT) and Export tariff

The UK's Feed in Tariff scheme commenced in April 2010, and has been modified on various occasions since. The government is clearly concerned with keeping the costs of the FIT Scheme (managed through the Levy Control Framework (LCF)) down and has stated that these will be no more than £75-100 million annually by 2018/19. In line with this objective, the government intends to close the generation tariff to new entrants from 2019, but not the export tariff.

It is possible to claim a generation tariff (i.e. a payment for each kWh of electricity generated) under the FIT scheme, provided the generator is eligible and the deployment cap has not been reached. Deployment caps were introduced in January 2016 and more information on progress towards meeting the caps, the latest tariff tables and information on applying can be found on the Ofgem website[43].

The export tariff was introduced as part of the FIT scheme, and pays for generation that is exported to the distribution grid. Unlike the generation tariff, the availability of the export tariff is not constrained by the capacity caps. At the time of writing, the export tariff is 4.91p/kWh, and it increases annually in line with the retail price index.

Systems under 30kW are assumed (or "deemed") to export half of their generation to the grid. Those over 30kW must have half hourly metering of exported generation. If export volumes are significant, it can make sense to enter into a PPA for the export, either with the licensed electricity supplier providing electricity to the site or another electricity supplier.

Transferability of a solar PV system

The inability to move PV panels and still remain eligible for the FIT had been seen as a significant barrier to PV deployment on commercial roof space. In Germany it is possible to transfer a solar PV system and it is thought this has contributed to the much higher commercial solar penetration in that market.

However, this is set to change and installations greater than 50kW will in future be able to move solar panels but remain eligible for the FIT scheme. More details can be found in the "Government response to the consultation on the transferability of building-mounted solar PV installations"[44], published on 20th March 2015.

11. Conclusion

There are huge opportunities for commercial solar in the UK. Companies are becoming more aware of their energy use and consumers are demanding stronger environmental credentials. Commercial solar has been slower to take off than other sectors, but as we see the FIT being reduced and new drivers come to the forefront it will become a much more obvious proposition for commercial energy users.

41 BRE and RECC (2016) Batteries and Solar Power: Guidance for domestic and small commercial consumers (available as a free download).

42 BRE (2016) Batteries with Solar Power: A technical guide to the use of Energy Storage with Grid-connected solar photovoltaic systems. Available from the BRE Bookshop www.brebookshop.com

43 https://www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme

44 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414930/transferability_government_response.pdf

12.Case studies

Muller Precision Engineering project, Cleobury Mortimer, Shropshire

An example of a PPA project benefitting the owner-occupier

180 kWp (Solarworld panels and SMA inverters)

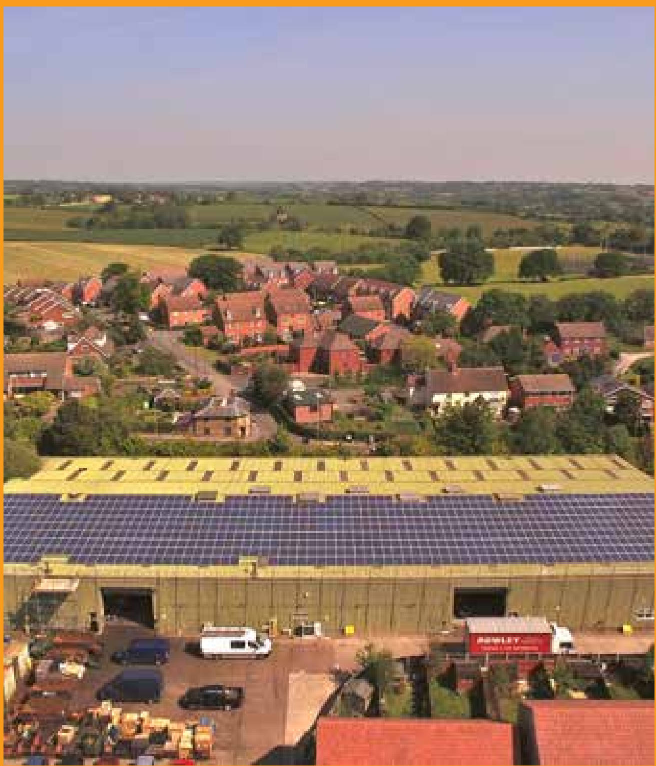


Photo courtesy of Aniron

Muller Precision Engineering is one of the largest privately owned sub-contract machinists in Europe. The site has an electricity demand of 500,000 kWhs per annum. The company chose to go down the PPA route to help offset its power demand, and entered into a (fully-funded power purchase) agreement with Palmetto.

The PV system generates around 163,260 kWhs per annum, 80% of which is consumed onsite. Muller benefits from a 26% reduction in its dependency from grid electricity for the 20 term of the agreement, after which the ownership of the system transfers to them at no cost.

Cambridge Regional College, Cambridge, Cambridgeshire

A PV project incorporating export limitation

202.95 kWp (Trina 275W panels and ABB inverters)

Photo courtesy of EvoEnergy

In 2015, EvoEnergy won Cambridge Regional College's Pro6 framework tender to install a multi-roof PV system to reduce the college's carbon emissions and significantly reduce its energy bills.

With the original design rejected by the DNO due to grid constraints, EvoEnergy redesigned the system, locating the panels on the 3 buildings with the highest power consumption. Three separate export limitation devices were also installed, to prevent any electricity being exported and thus satisfy the 'zero export' requirement imposed by the DNO.

The system now generates around 182,125 kWh annually, all of which is consumed on site, reducing the college's annual carbon emissions by over 74 tonnes CO_2 per year[1].

1 DECC's standard GHG conversion figures (2016) have been used for all CO_2 savings figures, i.e. 0.410kg CO_2/kWh or 0.112kgC/kWh. Source https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016

Lyreco, Telford, Shropshire

An example of a PPA project benefitting the owner-occupier

3.811 MWp (Trina 275W panels and ABB central inverters)

Photo courtesy of EvoEnergy

Lyreco is a global office and workplace solutions provider with a large distribution centre based in Telford. The site has an electricity demand of around 3.2 GWh per year. The 20 year PPA it has signed with Addison Energy Ltd – a company funded by Guinness Asset Management's EIS service – will result in it saving more than £53,000 per year in energy bills, as well as cutting annual carbon emissions by 1,700 tonnes. The whole site is now carbon neutral in terms of electricity usage.

EvoEnergy carried out the installation, incorporating specially-built step-down voltage regulators in order to integrate the system with the existing 11,000v on-site power supply. This solution allowed Lyreco to install a PV system much larger than initially planned. Two large central inverters were also installed, bringing ground-mount technology to a rooftop environment for the first time. The system was commissioned in January 2016.

M&S PLC East Midlands Distribution Centre

A PPA project between tenant and 3rd party owner / selling electricity directly to the tenant

6MWp (ET Solar 250W panels and Kaco Powador inverters)

Photo courtesy Amber infrastructure

This 6.1MWp, 24,272 panel array is installed on the 83,613m^2 roof of Marks and Spencer's East Midlands Distribution Centre.

The project was commissioned in March 2015 and generates over 5,000 MWh of electricity per year (enough to power 1,190 homes). This makes the fully-automated distribution centre close to self-sufficient in electricity during daylight hours - and is expected to lower M&S's carbon footprint by 41,000 tonnes over 20 years.

Amber Infrastructure financed, supplied, installed and maintains the PV array through a special purpose vehicle, EMDC Solar Limited. M&S purchases all of the electricity generated by the solar panels under a 20 year onsite PPA, and sells any excess to the grid under its own spill PPA.

Aldi Distribution Centre, Bolton, Greater Manchester

An east-west orientation, for improved profile-matching

2.1 MWp (Renesola 255W panels and Fronius inverters)

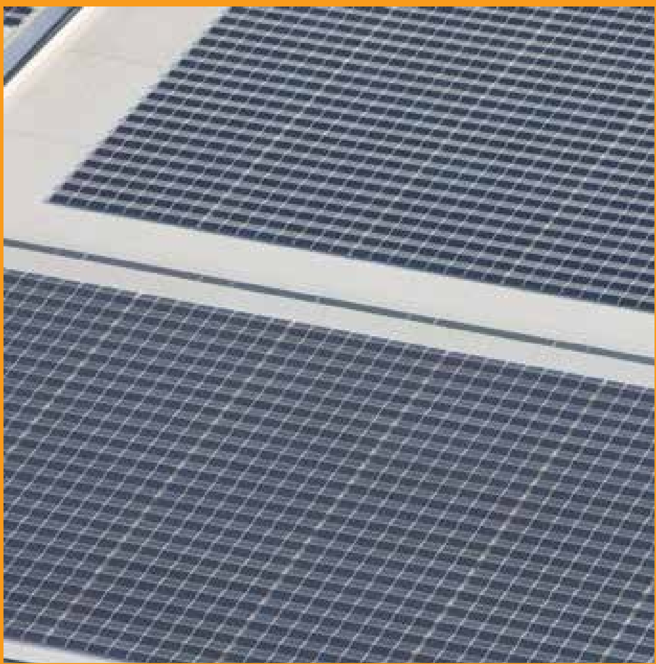


Photo courtesy of EvoEnergy

In 2015, the contractor, DSP Construction Management, turned to EvoEnergy to help them install a 2.1 MWp system on Aldi's new 51,000 m^2 regional distribution centre.

The PV system was purposely designed with an east/west split to spread the generation throughout the day. This design also allowed a bigger system size to be installed on the available roof space. 62 wall mounted inverters were also installed in a purpose-built room onsite, freeing up additional space on the roof.

The system generates over 1.7 GWh of electricity every year and reduces the Supermarket chain's annual carbon emissions by 190 tonnes.

PC Specialist, Wakefield, West Yorkshire

A project in which the owner-occupier invested directly

235.5 kWp (Risen 250W panels and SolarEdge optimisers/ inverters)

Photo courtesy of EvoEnergy

PC Specialist chose to invest directly in a PV installation to contribute towards achieving its goal of being carbon-neutral by 2020. With the company testing up to 500 personal computers at any one time, its annual electricity demand is around 285,000kWh. Its PV system provides around two-thirds of this (around 194MWh/year) and reduces carbon dioxide emissions by nearly 80 tonnes annually

The system was designed with SolarEdge technology to maximise generation. This separates panels within the string, to prevent those that become shaded at different times of the day from reducing the overall efficiency of the array. This improves output by up to 25% as well as making the system safer and easier to repair should anything go wrong. PC Specialist can also check the performance of each inverter and panel 24/7 via the free web portal. Operation and maintenance is carried out by EvoEnergy.

PEC Renewables, Plymouth Life Centre, Plymouth

Ensuring quality through compliance with the IET Solar PV Code of Practice

366 kWp (China Sunergy panels and SMA Tripower inverters)

Photo courtesy of Plymouth Energy Community and Cleanearth Energy Ltd.

Having previously developed 21 community PV projects across Plymouth, PEC Renewables looked for larger and more ambitious projects for their second share offer. The Plymouth Life Centre has a high on-site energy demand and is the largest of PEC Renewables' roof-mounted PV installations.

The east/west orientation of the array maximises the generation capacity of the available un-shaded roof space, whilst delivering a longer generation day to better match the energy demand of the leisure facility. The system is estimated to generate 377MWh and reduce carbon dioxide emissions by 155 tonnes.

As part of the IET solar PV CoP compliance process, BRE carried out a pre-installation design review, a quality assessment of the commissioned system and a thermographic survey of the solar PV panels, to check for manufacturing defects and hidden damage.

Eastheat Project, Edinburgh and surrounding towns

A rollout of heat battery storage and self-consumption devices with Solar PV

2.5 MWp of PV and 4.4 MWh of Sunamp heat batteries across 850 Housing Association properties

Photo courtesy of Sunamp

Scottish Government's Local Energy Challenge Fund co-funded this competitively-awarded Eastheat project, which ran from March 2015 to March 2016.

The Eastheat project assists Castle Rock Edinvar and East Lothian Housing Associations meet regulatory drivers and delivers tenants a benefit in terms of reduced fuel bills. Over 1000 tenants benefitted from the installation of 850 solar PV systems, of which 650 were fitted with Sunamp heat batteries. These store excess solar generation and release it as space heating and hot water when needed and should save £90 – £300 per year per home.

Solar installation on commercial unit a Heathrow Airport, courtesy of Syzygy Renewables Limited

Notes

BRE Trust
The BRE Trust uses profits made by BRE Group to fund new research and education programmes, that will help it meet its goal of 'building a better world'.

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

T +44 (0)1726 871830
E nsc@bre.co.uk
www.bre.co.uk/nsc