Solar PV for Business

Best Practice Guide

About SEAI

SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with Government, homeowners, businesses and communities to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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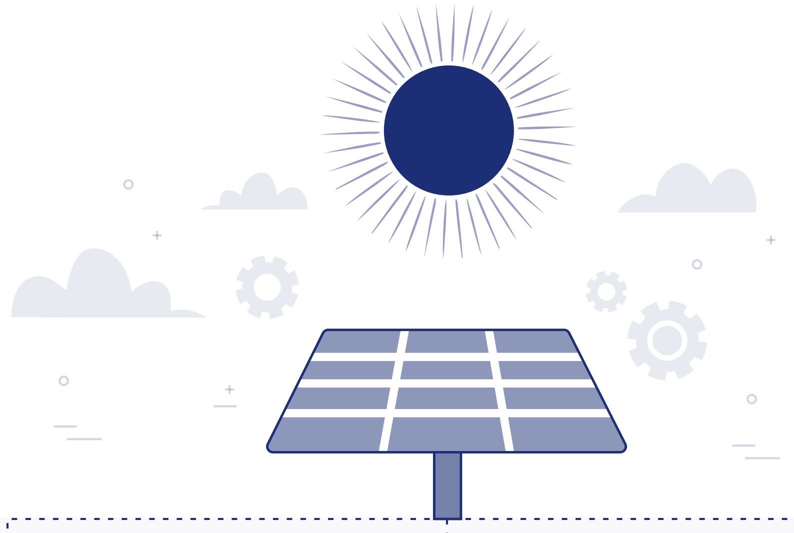
Glossary of Terms

Acronym	Definition
AC	alternating current
ACA	Accelerated Capital Allowance
CRU	Commission for Regulation of Utilities
DC	direct current
EGIP	embedded generation interface protection
EIAR	Environmental Impact Assessment Report
kWh	kilowatt hour
kWp	kilowatt peak
M&V	measurement and verification
NSAI	National Standards Authority of Ireland
PV	photovoltaic
PVGIS	Photovoltaic Geographical Information System
SEAI	Sustainable Energy Authority of Ireland
TAMS	Targeted Agriculture Modernisation Schemes
WEEE	Waste Electrical and Electronic Equipment

Introduction

The sun delivers more energy to the Earth in an hour than is used worldwide in a year. Solar photovoltaic (PV) technology generates renewable electricity from sunlight – a free and natural resource. Businesses can harness this clean energy by using solar PV technology and thoughtful building design.

This guide to solar PV for business has been developed by the Sustainable Energy Authority of Ireland (SEAI) to help your business understand solar PV technology and to support you to deliver a solar PV project. It explores the key areas of site suitability, as well as the technological and practical issues involved in a typical solar PV project.



Section 1

Understand solar PV technology and how it works

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- Mounting systems
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- Battery storage

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Understand how to deliver your solar PV project

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- Planning requirements
- Grid connection
- Commissioning & testing
- Operating & maintenance

1.1 The solar energy opportunity for Irish businesses

Does your organisation have a steady daytime electricity demand and available roof space? If so, installing solar PV could be a viable way for your business to produce green electricity and save money on your energy bills by reducing the amount of electricity you import from the grid.

Due to rapid market development, the cost of solar PV technology has reduced drastically in recent years. This, combined with the range of supports available for businesses, makes installation of a solar PV system a more economically viable option than ever before. In addition, solar PV offers businesses numerous opportunities and potential benefits. For example:

- It delivers a clean, renewable source of energy which can help your business to decarbonise its energy use and improve its environmental performance.
- It is a well-established, reliable and robust technology, and the market is well-developed.
- It is easy to install, operate and maintain.
- It provides a visible statement of your business's commitment to sustainability.

The economic and practical suitability of solar PV for your business depends on a number of factors, which this guide will explore in more detail. The critical questions to consider when assessing whether solar PV is the right solution for your business are outlined in Table 1 and further explored throughout this guide.

Table 1: Considerations for a solar PV project

Checklist	Electricity demand	YES	NO
	Is there steady demand during daylight hours?		
	What size PV array would be most suitable?		
	Will my business have high self-consumption/low spill to the grid?		
	Existing roof structure	**YES**	**NO**
	Is it in good condition?		
	Does the roof structure have a remaining lifespan of 25 years (or more)?		
	Can perforating the roof if be avoided?		
	What mounting system will be used?		
	Site location	**YES**	**NO**
	Is there shading from trees or other buildings/structures?		
	Is it susceptible to vandalism?		
	Orientation and inclination	**YES**	**NO**
	Are the orientation and inclination suitable?		
	Planning and grid connection	**YES**	**NO**
	What are the planning and grid connection requirements for the system?		
	Quality assurance and safety	**YES**	**NO**
	Will the system be installed by a competent contractor?		

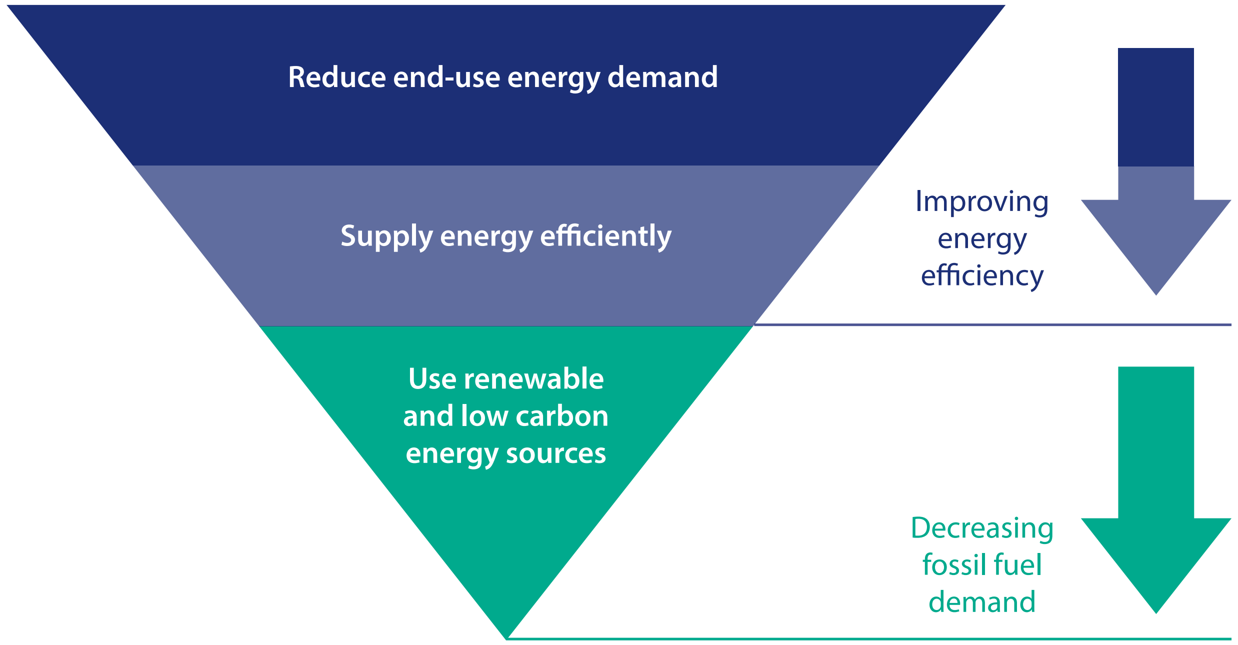
1.2 Solar PV and the energy retrofit hierarchy

Installing solar PV on your roof can significantly reduce the amount of electricity that you will need to purchase from the grid. However, before considering this option, it is best practice to first reduce the amount of electricity, and overall energy that your business uses.

Installing insulation and upgrading to energy-efficient heating systems, equipment and lighting will significantly reduce energy consumption in a building. Other potential energy-saving measures include improving the building fabric (for example, the roof, walls, floors, windows and doors), which may involve upgrading the insulation of the entire building, upgrading windows and doors where necessary, and improving overall airtightness.

Choosing to install solar PV before improving your building's overall energy efficiency puts you at risk of installing more solar PV than your business actually needs, thus increasing payback time. SEAI advocates an 'energy efficiency first' approach to upgrading buildings.

Figure 1: Energy Hierarchy



Top tip

Find out more about how your business can improve its energy performance, save money, and reduce its environmental impact on the SEAI website: **www.seai.ie/business-and-public-sector**

2 What is solar PV and how does it work?

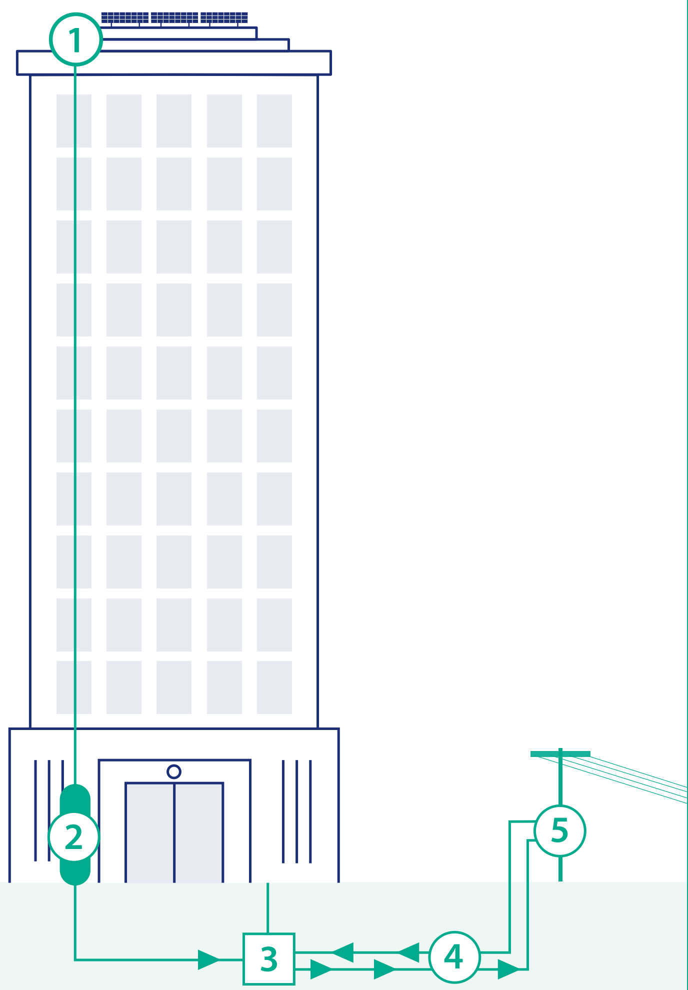
A solar PV system generates electricity from sunlight. It comprises four main components: PV modules (or panels), an inverter, mounting systems, and grid protection. A battery and a charge controller may also be added to the system, so that excess power from the solar PV system can be stored and used when it is required later. See Section 3.3.1 for more information about batteries.

Solar PV systems for businesses tend to be grid connected (sometimes called parallel connected) and are connected to the mains electricity grid through a distribution panel. An off-grid system is not connected to the electricity grid and is normally only used in remote areas, for communications or monitoring infrastructure, or for leisure activities such as caravanning and boating.

Typically, a grid-connected system will stop generating electricity in the case of a grid outage. If backup power is required, the PV system can be configured to operate with a battery system or diesel generator to provide a temporary backup electricity supply to a business.

All solar PV systems must comply with the National Rules for Electrical Installations (ET101/I.S. 10101 (as appropriate), published by the National Standards Authority of Ireland) and so it must be installed by an experienced and competent contractor.

Figure 2: How a solar PV system works



1. Solar PV modules convert sunlight to direct current (DC) power.
2. An inverter changes the solar DC power into alternating current (AC) power.
3. Your business uses electricity from the solar PV modules first, with additional demand supplied by the grid.
4. A meter measures your electricity production and consumption.
5. Excess power generated by the solar PV modules is fed into the electricity grid.

2.1 Solar PV modules

Solar PV modules comprise a series of PV cells connected in strings to form modules. Solar PV modules are generally differentiated by the semiconductor materials that their PV cells are made from – the materials that enable them to absorb light. Most solar PV modules are made of crystalline silicon, or thin film solar cells.

Crystalline silicon solar cells

Most installations use crystalline silicon solar cells. There are two main types of crystalline silicon modules, monocrystalline and polycrystalline.

- **Monocrystalline** silicon modules are more efficient, but they are also more expensive to manufacture than polycrystalline silicon modules because they are made from a higher quality of crystalline silicon. These modules can be identified by the homogenous colouring across the cells, and by their darker colour. To make cells for monocrystalline panels, silicon is formed into bars and cut into wafers.
- **Polycrystalline** silicon modules are less efficient, but they are cheaper to manufacture than monocrystalline silicon modules. Polycrystalline silicon modules can be identified by their blueish colour and an inconsistent pattern across the cell. To make cells for polycrystalline panels, fragments of silicon are melted together to form the wafers.

Thin film solar cells

Thin film solar cells are generally only used if there are specific weight, aesthetic or other design requirements. Common types of thin film solar cells include amorphous silicon, cadmium telluride, copper indium gallium selenide, and dye-sensitised solar cells.

Figure 3.1: Monocrystalline solar modules

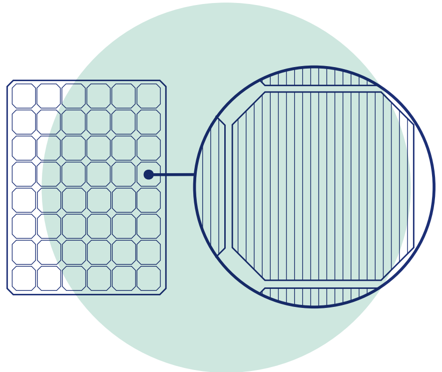


Figure 3.2: Polycrystalline solar modules

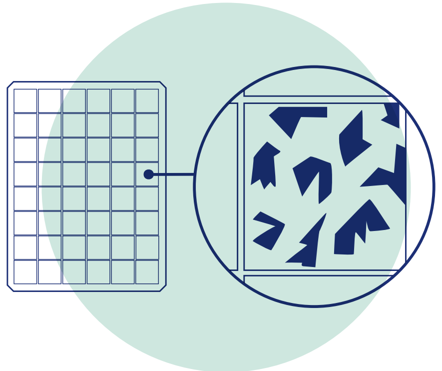
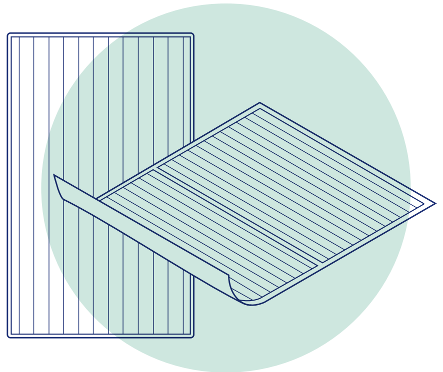


Figure 3.3: Thin film solar cells

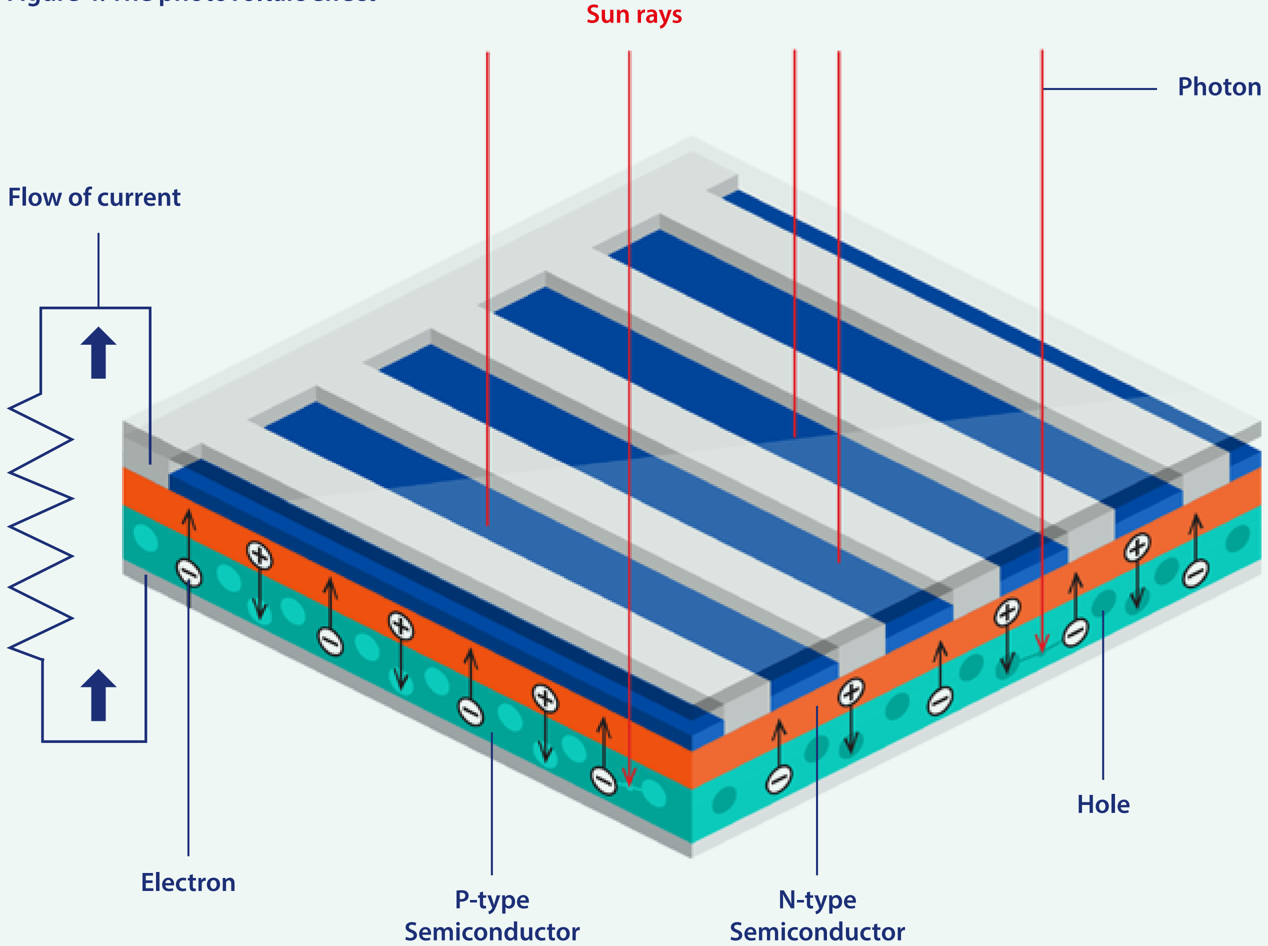


How do solar PV cells generate electricity?

When sunlight hits solar PV modules, the material emits electrons, and the modules use this process to convert sunlight into electricity. This is known as the photoelectric effect as described in more detail below:

1. PV cells contain at least two layers of different semiconducting materials.
2. One layer has a deficiency of electrons (P-layer) and the other has an abundance of electrons (N-layer).
3. When sunlight is absorbed by the N-layer, the electrons break free and can move freely in the semiconductor material.
4. This results in the creation of an electric field at the P-N junction, which in turn gives momentum and direction to the electrons, generating an electrical flow once connected to an external load.

Figure 4: The photovoltaic effect



2.2 Inverters

The national grid uses alternating current (AC) to deliver electricity to end users. The majority of appliances are powered with AC. In Ireland, this AC electricity is supplied at a voltage of 230 V or 400 V in most businesses, with a frequency of 50 Hz.

Solar PV modules generate electricity in the form of direct current (DC), which means that electricity flows in just one direction – similar to current supplied by a battery. By contrast, AC reverses the direction of the current periodically.

An inverter is used to convert the electricity generated by solar PV cells from DC to AC. There are three main types of inverters:

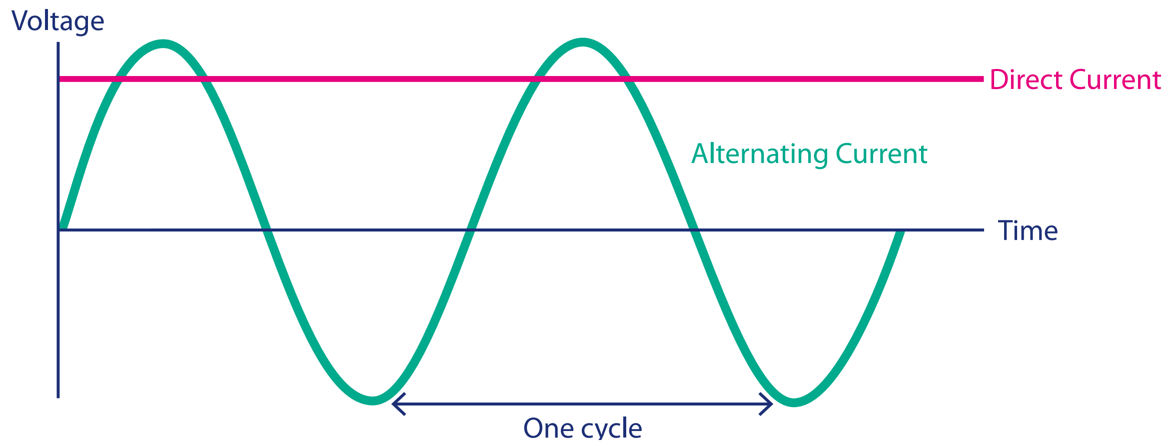
- String inverters;
- Micro-inverters; and
- Power optimisers.

If all modules in a string are receiving the same level of sunlight, the difference in conversion efficiency between string inverters and micro-inverters or power optimisers will be marginal. However, if a string of modules has one poorly performing module (either from shading or through a fault), this will limit the performance of all the other modules in the string. The next section of the document describes how these three inverters works and their relative advantages and disadvantages.

Top tip

AC is used because it can easily be changed to and from high voltages for transmission using a transformer. Higher voltages result in lower currents and therefore reduce losses in power lines. This allows electricity to be sent long distances.

Figure 5: Alternating and direct current



2.2.1 String inverters

The key advantage of string inverters is that they have conversion efficiencies of 95% or higher; this is one of the reasons why they are the most commonly used type of inverter. The disadvantage of string inverters is that they do not allow for individual module maintenance or individual module power optimisation, and therefore they are generally less tolerant of shading.

Two important considerations when installing string inverters are:

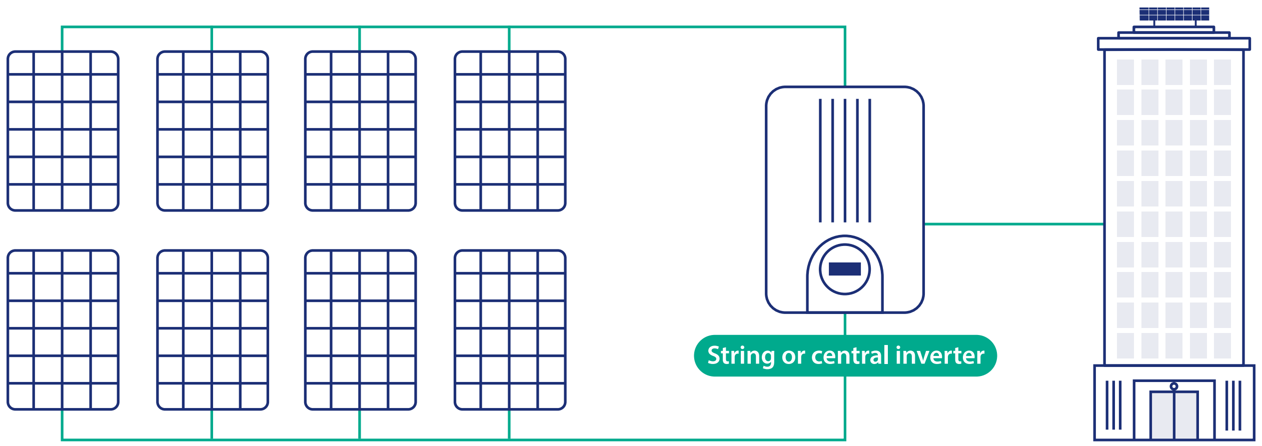
- they must be protected from potential damage; and
- they must be positioned in a cool, well-ventilated location. Neither a dusty environment nor a location with poor airflow are suitable for this technology.

Maximum power point tracking (MPPT) is an important feature of string inverters. This system is used to ensure that the strings of modules generate as much power as possible for the amount of radiant energy from the sun falling on their surface. Any strings that receive dissimilar levels of light as a result of differing orientation or differing levels of shading should be connected to separate strings with separate MPPTs, if possible.

How does a string inverter work?

- Solar modules on the roof are connected in series into one or more strings.
- The DC power generated in each string is fed via DC cables into the inverter, which is typically installed inside the building.
- the DC power is inverted into AC power of 230 V or 400 V and 50 Hz.
- The AC side of the inverter is then connected into a distribution board, where the power is subsequently drawn off by electrical loads in the building.
- Where local electricity generation is greater than that required by the building, the electricity is exported to the grid.

Figure 6: Illustration of a central or string inverter



2.2.2 Micro-inverters

Micro-inverters are positioned on a roof next to the solar modules, and they are usually fixed to a mounting system. The main advantages of micro-inverters are:

- Their efficiency, particularly where there is shading;
- Unlike string inverters, there is no need to position the inverter inside the building; and
- Overall, the system's configuration eliminates the risk of single points of failure.

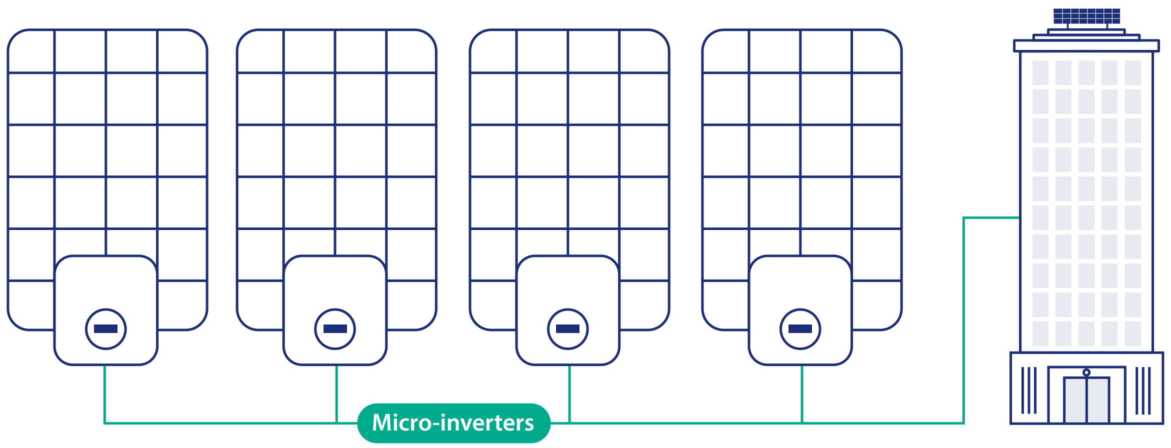
The disadvantage is that their location may create access challenges, and the selection and matching of PV modules and inverters is more sensitive. Micro-inverters are commonly used in systems where there are modules of varying orientations, tilts, and shading levels. Micro-inverters prevent shaded or lower performing modules from adversely affecting the performance of other modules. Another advantage of a micro-inverter system is that the performance (in terms of electrical output of the module) and overall health of each PV module can be tracked and monitored in real time, thus providing more accurate fault detection on a module-by-module basis.

Figure 7: Micro-inverters installed under each individual PV module

How does a micro-inverter work?

- A micro-inverter converts the DC power generated by a single solar module (or sometimes by two modules), rather than several modules on a string, to AC.
- Converting the power at each individual module optimises the production of energy, which may achieve a better overall conversion efficiency, particularly where there is shading.
- Each micro-inverter has maximum power point tracking, which ensures that the maximum efficiency for each module is achieved. The AC power then travels from the roof to a junction box, and then into a distribution board.
- Using a micro-inverter enables each module to achieve its highest output, thus leading to a higher overall efficiency for the system.

Figure 8: Illustration of a micro-inverter



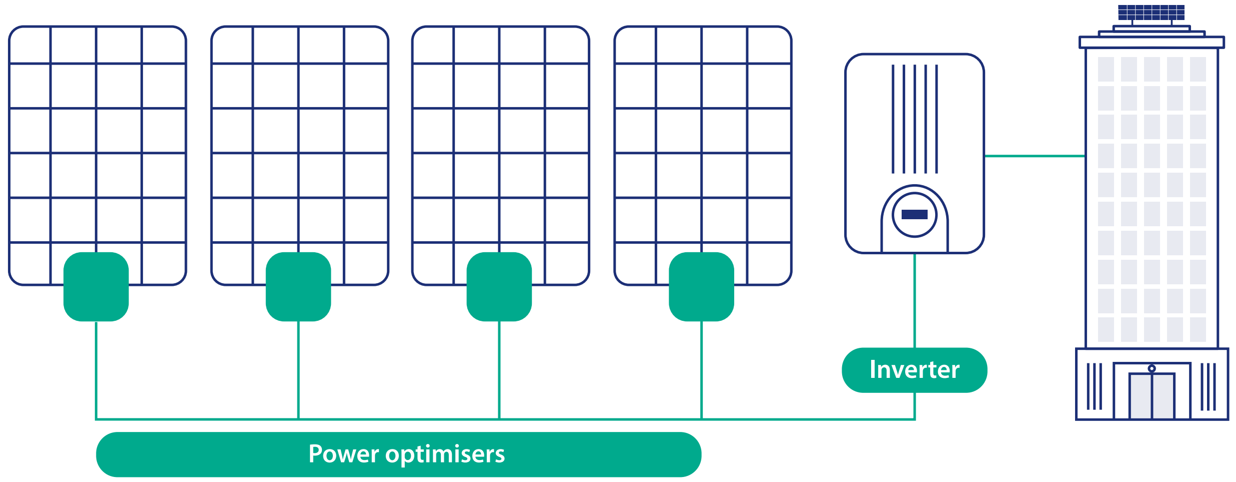
2.2.3 Power optimisers

Power optimisers can be considered as micro-inverters which optimise the DC voltage at each module. While the disadvantages are similar to micro-inverters, the key advantages of power optimisers are:

- They maximise each module in terms of power output;
- They can make the PV system more shade tolerant;
- They reduce DC circuit voltage on the roof and through the building (typically from several hundred volts for string inverters to less than 50 V for power optimisers); and
- They can control the DC voltage in the main cables to zero for safety.

Power optimisers are DC-to-DC converters which use maximum power point tracking to optimise the power output of individual modules. They are usually attached to the back of, or close to, the module. The DC output from a string of modules and optimisers is then converted to AC by a central inverter.

Figure 9: Illustration of a power optimiser



2.3 Mounting systems

One of the key considerations for a commercial-scale solar PV system is deciding where it will be located and what mounting system is appropriate for this purpose. For example, you may be planning to install the solar PV array on a rooftop, or at ground level, or you may be planning to integrate it into your building. This section explores the different common mounting systems available for different applications and building types, and the factors influencing system design.

Each of these solutions varies in terms of the advantages and disadvantages which may or may not suit a potential PV installation site. These solutions must be assessed according to the characteristics of the particular site in order to ensure that the PV designer chooses the optimal solution.

In choosing which mounting method to use on a specific type of roof, you will need to consider several factors, including cost, such as:

- the construction type and inclination of the roof;
- uplift resistance due to wind loads;
- waterproofing/weathertightness and how this can be maintained;
- the effect of the additional weight of the mounting system on the roof; and
- the PV system's electricity production.

It is essential to carry out a thorough evaluation of the roof condition and potential structural loading of the rooftop PV system. Repairing a roof or building structure that has been damaged by an inadequately installed PV system can be very costly. Therefore, you must ensure that a competent, qualified, and suitably experienced professional undertakes the design and installation of your rooftop PV system.

Figure 10: 300 kW installation at Kingspan Insulation

2.3.1 Roof-mounted PV systems

Rooftop or roof-mounted PV systems are becoming increasingly popular and visible in Ireland. Rooftop PV systems on non-residential buildings – including offices, factories, warehouses and agricultural buildings, amongst others – can vary significantly in size, with electrical capacity ranging from less than 10 kW to multiple megawatts (one megawatt is equal to one thousand kilowatts).

There are several advantages to installing a roof-mounted PV system:

- Roof space can be used, thus avoiding both wasting scarce urban land resources and the need to prepare land for civil works in advance of a PV installation;
- Connection costs are lower due to the proximity of the building's existing electrical plant rooms;
- The risk of shading may be lower due to the greater PV module mounting height; and
- Solar PV can create a visible statement of sustainability for the business.

When installing a PV array on a roof, there are two main categories of mounting systems to choose from. The type of mounting system chosen will depend on whether the building has a flat roof or a pitched roof. A ballasted fixing system is most commonly used if the roof is flat, and a structural fixing system should be used if it is pitched. With ballasted fixing, gravity holds the PV array in position. With structural fixing, the PV array is mechanically connected to the roof structure or surface.

Flat roofs

Flat roof solar installations (including low pitch roofs with inclination less than 10°) are installed on frames which are normally mounted under gravity on the roof surface. The frame system allows the mounting of the solar modules at the inclination and orientation desired, and provides enough mass (normally with concrete slabs, aggregate or other ballast) to ensure the PV array is secure on the flat roof surface.

The extra weight that the ballast places on the roof structure is the main disadvantage of this mounting system. The structural implications on the building, and the deformation impact on the roof surface and substrate should be carefully considered.

In addition, the tilt angle of the PV array is usually limited to a maximum of 20° but is typically lower than this. A higher tilt increases wind loading, which in turn increases the weight needed to ballast the system. This can result in higher costs, as well as a higher overall structural load on the roof. Conversely, a lower tilt angle decreases wind loading and ballast requirements, but also decreases energy yield and self-cleaning effect of the modules.

In rare cases flat roof installations with a mechanical fixing to the building are also considered and extreme care must be taken to ensure an appropriate weathertight solution that is appropriate for the age and design of the roof.

Figure 11: Rooftop solar PV on a leisure centre building

Pitched roofs

A pitched roof is defined in this guide as having a slope steeper than 10°. Types of pitched roof vary widely, as do the types of materials used to make these roofs. Additionally, the different materials used have different shapes and strengths. As a result, there are a wide variety of pitched roof mounting configurations and products.

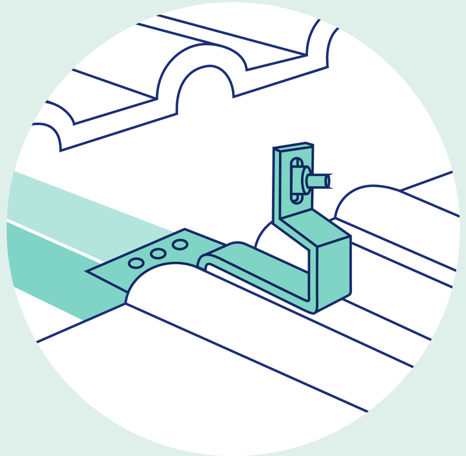
Four different pitched roof systems are described on the next page.

1 Tiled/slated pitched roofs

Pitched roofs found on domestic and small- to medium-scale commercial buildings are generally made of slates, roof tiles or plain tiles. Roof hooks are a very commonly used mounting solution for these roof types.

The installation of roof hooks is relatively simple and the proposed PV system array and the existing roof structure (both vertical and horizontal will determine where the roof hooks should be positioned, and how many connection points are required. Once the roof hooks are in place, mounting brackets should be attached to the roof hooks to form a frame on which the PV modules can be installed. Timber reinforcement may be required for rafters in timber truss roofs.

Figure 12: Roof Hook Mounting System

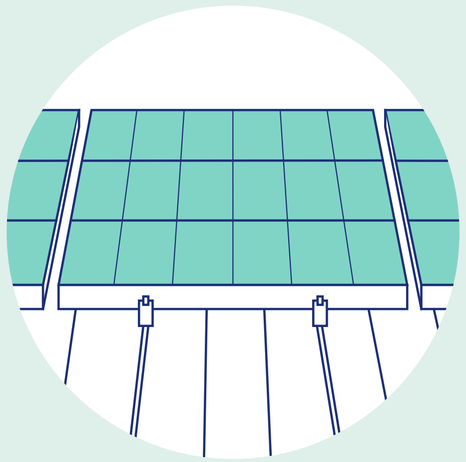


2 Standing seam roofs

Standing seam metal-cladded roofing (often featuring seamed zinc cladding) is a popular choice of material on public buildings. Unlike trapezoidal metal roofing, seamed metal roofing has relatively thin seams.

Standing seam clamps are the most common PV mounting system for seamed metal roofs. These systems do not require perforation of the roof structure (including roof seams); however, care must be taken to avoid bi-metallic reactions in zinc and copper standing seam roofs.

Figure 13: PV mounted on metal standing seam roof



Top Tip

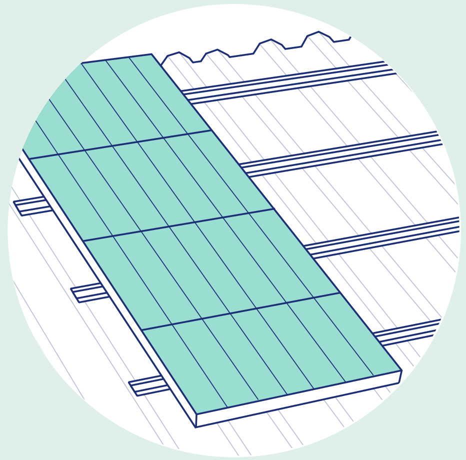
The National Standards Authority of Ireland (NSAI) has produced a code of practice for the installation of solar thermal systems **(SR 50-2:2012)**. This standard is commonly used to inform the requirements for solar PV systems. The NSAI will also publish a standard recommendation for the design, installation, commissioning and maintenance of solar PV panels in new and existing dwellings (SR 55 202X). Always ensure that your installer is compliant with the building regulations, NSAI Codes of Practice and NSAI Agrément Certificates.

3 Composite and trapezoidal roofs

There are many relatively simple PV mounting options available for installing PV systems on composite and trapezoidal roofs. These include:

- **Basic metal railing**
  Metal rails are screwed or riveted onto the roof corrugations at the crown of the roof. Once attached to the roof, the frame of each PV module is attached using end, mid- and cross-adapter clamps.
- **Longitudinal sheet metal railing**
  Metal rails are screwed into the surface of the roof sheeting, and the PV modules are connected to the metal mounting rails using clamps.
- **Horizontal mounting brackets**
  Metal rails are placed on the sections in between corrugations and screwed into the surface of the roof sheeting, as shown in Figure 13. Horizontal brackets are then screwed onto each metal rail while the PV modules are connected to the horizontal brackets using clamps.

Figure 14: Horizontal mounting brackets



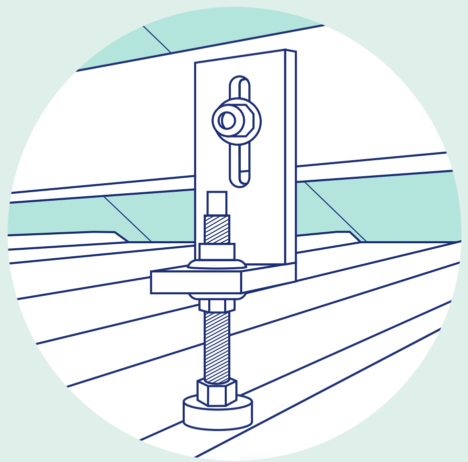
4 PV mounting system using solar fasteners/hanger bolts

Solar fasteners are used in situations where perforation of the roof structure (also known as through-fixing) is required. They are most commonly used in agricultural buildings, and open spaces.

Where through fixing is identified as a suitable technique for mounting the PV system, it is fixed to the roof structure using a bracket and hanger bolt – often referred to as a solar fastener. The bolt is screwed through the roof surface and into the purlins. The PV mounting systems is attached using vertical mounting brackets and horizontal mounting rails. Each PV module is then clamped to the brackets.

A typical solar fastener system has two horizontal mounting rails and at least two connections at the top and bottom of the PV module.

Figure 15: Through-fixing using hanger bolt



2.3.2 Ground-mounted PV

A ground-mounted PV system may be a viable option for businesses, especially in cases where roof space is limited and suitable land is available. There are many different types of ground-mounted systems for PV installations. These vary depending on the surface and subsurface of the site, the amount of space available or required, and the optimum PV module mounting height and tilt angle. Some common ground-mounted methods include:

- Concrete piers cast in situ;
- Driven piles;
- Pre-cast concrete ballasts;
- Earth screws; and
- Bolted steel baseplates.

Some preliminary work must be carried out before proceeding with the installation of a ground-mounted system including:

- A site survey considering the available space, cable routes, access, security and construction logistics.
- A geotechnical survey of the proposed PV site to inform what foundation to use for the PV mounting system.

Some preliminary work must be carried out before proceeding with the installation of a ground-mounted system including:

- A site survey considering the available space, cable routes, access, security and construction logistics.
- A geotechnical survey of the proposed PV site to inform what foundation to use for the PV mounting system.

If the proposed site has been identified on an Ordnance Survey Map as being located in a flood risk zone, then a stage 1 flood risk assessment must be carried out. If the assessment finds that there is a probability of flooding, measures must be taken to mitigate the risk of operational disruption or damage to the PV system. For example, key electrical plant components – such as substations, inverters, etc. – should be elevated off the ground. In addition, PV modules may be installed at a greater mounting height. If the flood risk is severe enough, the proposed location of the PV system may need to be changed.

Figure 16: Ground-mounted PV on an Irish farm

It is important to determine what effect the installation of solar PV modules will have on a site and its surroundings. Preparation of an Environmental Impact Assessment Report (formerly an Environmental Impact Statement) is not a mandatory requirement for planning permission, but the planning authority will assess each application and decide if an EIAR is required.

In most solar arrays, the solar modules are mounted with a fixed orientation and tilt. However, some arrays have trackers which shift the orientation and tilt of the modules so that they track the sun's path throughout the day. While this increases the power output of the modules, it also increases the overall cost of the installation. Furthermore, because this type of installation has more moving parts than a standard fixed installation, additional maintenance costs may be incurred. Figure 16 shows a solar car park as an example of a ground-mounted system that has a fixed orientation and tilt. Solar car parking facilities require a proportionally greater amount of structural components than conventional ground mounted solar PV, to provide the clearance, stability and robustness required.

2.3.3 Building-integrated PV systems

Building-integrated PV systems are PV arrays that form part of the building envelope; they replace or sometimes cover sections of conventional building components, such as façades and roofs.

Building-integrated PV systems can form either a non-ventilated façade of a new building, or a ventilated façade of an existing building. In both cases, the PV system is mounted on the façade, thus giving the building a new look while maintaining its existing structure.

Building-integrated PV systems can be installed on a roof, façade or overhang. They can also be installed in a brise-soleil, which blocks direct sunlight into a building while simultaneously using that sunlight to generate electricity. Finally, they can be installed as integrated glass, in glass PV skylights, or in PV tiles or slates, which can be used as substitute roofing materials. Building-integrated PV systems can be used in buildings where there is little roof space.

They can be aesthetically striking, allowing businesses to visibly showcase their commitment to sustainability. However, they tend to be more expensive than traditional roof-mounted solar PVs. They also tend to present different installation challenges; in addition, they generally have a lower power output due to their suboptimal tilt angle and cooling compared with roof- or ground-mounted PV systems. For these reasons, building-integrated PV systems are seldom used where alternatives are available.

While not technically building integrated, a PV system can also be overlaid on an existing wall surface. This is a relatively simple installation which will reduce energy yield due to the vertical installation.

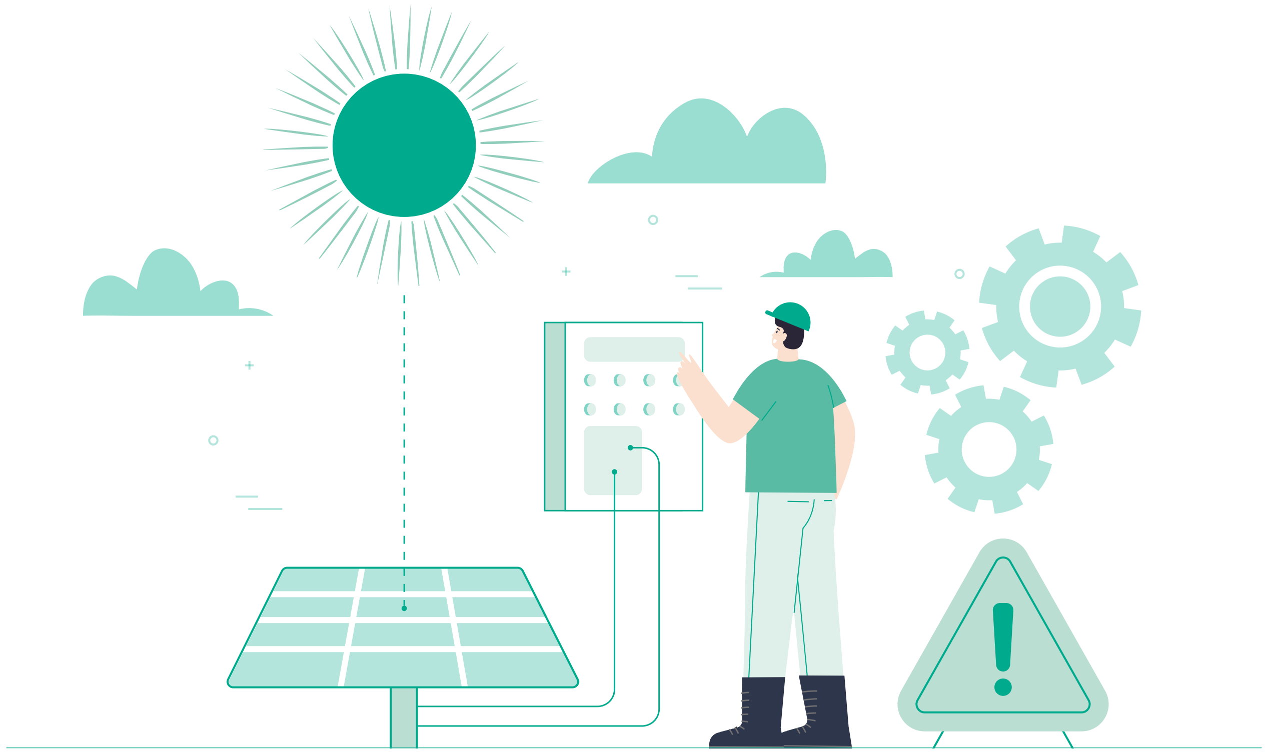
Figure 17: Solar PV Façade

2.4 Grid protection

Grid protection is an extremely important component of any grid-connected PV system. It protects your PV system from grid issues and it protects the grid from issues with your PV system. When there is a power cut, ESB Networks technicians working on power lines need to know that those lines are not being made live by a distributed generator, and a PV system without appropriate protection may be back-feeding power out of a building onto the grid during a power cut. Embedded generation interface protection (EGIP) is used to manage these issues.

EGIP monitors the status of the electricity grid. If an adverse event occurs, it automatically manages this, and in many cases it disconnects the building's solar PV system from the grid. EGIP is often integrated into an inverter for smaller-scale PV systems. For larger systems, you may require a separate protection relay and two disconnection points which trip and cut power from the PV system if adverse conditions occur.

When you make a connection application to ESB Networks, the company will tell you what level of EGIP is required for your PV system. For more information on EGIP in the context of generation navigate to Section 4.4 of the document.



3 Optimising your business' solar PV design

This section describes the factors which determine the performance of a PV system and the suitability of the technology to meet your business's electricity needs. Such factors include electricity demand (that is, your business current electricity requirements) and electricity production (the factors influencing the performance of the proposed PV system, and how to calculate this performance).

3.1 Electricity demand: designing for self-consumption

With the introduction of export payments, Irish businesses will have easier access to sell excess power from solar PV to the grid. However, it will always be more economical to use the electricity you generate yourself than to sell it to the grid.

If you install a PV system that is too big for your electricity needs, it may not be cost-effective. Therefore, when deciding whether solar PV is suitable for your business, it is essential that you understand your business's electricity demand and how and when this electricity is used, both now and into the future.

You should first work with your solar PV contractor or designer to assess how much electricity you use. This can be estimated based on your bills, or ideally based on metered data.

Secondly, you should consider when you use electricity; for example, a business that uses electricity during daylight hours will generate more cost savings than one that operates outside daylight hours. Thirdly, you should assess how much of the solar PV-generated electricity, from a range of solar PV system sizes, will be used on site. A robust calculation of this 'self consumption' figure will be vital for you to consider the practical and economic installation of solar PV for your energy demand.

Top tip

A simple, cost-effective way to understand your business's electricity consumption is to take meter readings at 10:00 and 14:00 for several days in order to determine how much electricity you are using between these hours on a typical day.

Your business' electricity demand, as well as site-specific data such as shading, orientation and irradiance, will help inform decision-making around what size of PV system you should install.

Generally, large industrial energy users have a meter that logs electricity consumption on a 15-minute basis. If you are a large energy user, you can request this data from the Meter Registration System Operator through ESB Networks and then analyse it to see how much electricity you are consuming during the peak solar PV hours of 10:00 to 14:00.

If you are a small energy user, then you can use a power logger to monitor electricity consumption over a few weeks, and thus determine your electricity usage profile.

If your business has available roof space and significant electricity demand, and you have minimised electrical consumption by implementing energy efficiency measures, you should consider installing a roof-mounted PV system to offset some of your remaining electricity demand.

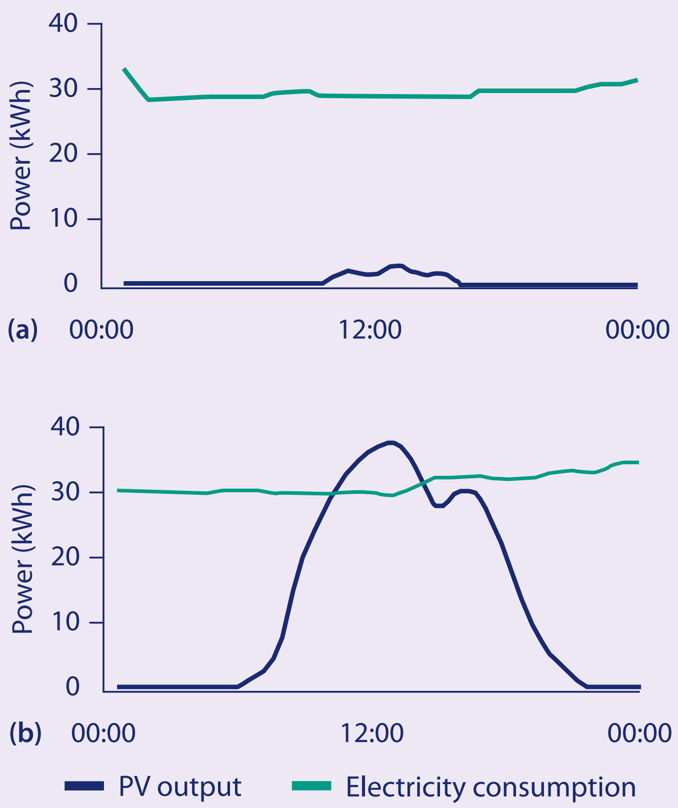
Example – Nenagh Civic Offices, County Tipperary

Figure 18 shows two typical daily electricity demand profiles for Nenagh Civic Offices in County Tipperary. One of these profiles is for 1st January and the other is for 1st June.

As can be seen in profile **(a)**, the roof-mounted PV system installed on top of the building generated less than 3% of the building's electricity requirement on 1st January (a typical winter's day).

By contrast, as can be seen in profile **(b)**, on 1 June (a typical summer's day), the roof-mounted PV system generated 100% of the building's electricity requirement during the peak hours of the day, between 10:00 and 14:00.

Figure 18: Daily electricity demand versus PV generation at Nenagh Civic Office



3.2 Energy production: calculating solar PV yield

In order to size and specify the design of your PV system, you will need to understand the potential solar PV yield. The performance and production capacity of a PV system can be assessed using three key parameters: specific yield, capacity utilisation factor and performance ratio.

3.2.1 Specific yield

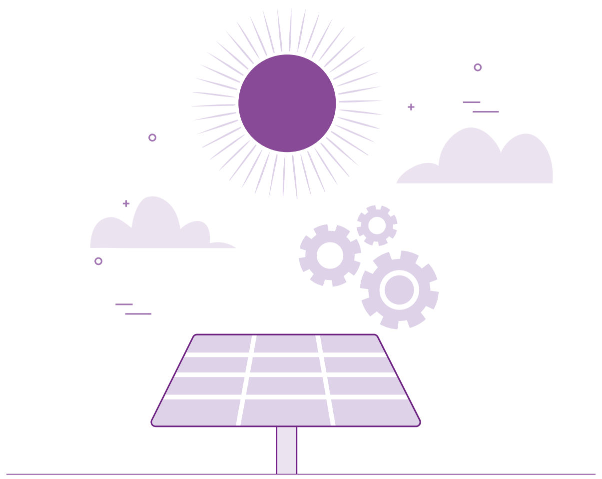
The specific or final yield is a significant indicator for evaluating the performance of a PV system. It is defined as the ratio of the final annual energy output (in kWh) of the PV system to that of its actual size or nominal capacity in kWp (kilowatt peak). This ratio can be used to compare the productivity of differently sized systems.

$$\text{Specific yield} = \frac{\text{Final Annual Energy Output (kWh)}}{\text{Nominal Capacity (kWp)}}$$

For example, if a 5 kWp system is generating 4,350 kWh of electricity in a year, it will have a specific yield of:

$$\text{Specific yield} = \frac{4{,}350 \text{ kWh}}{5 \text{ kWp}}$$

$$\text{Specific yield} = 870\text{kWh/kWp}$$



3.2.2 Capacity utilisation factor

Capacity utilisation factor is a performance metric that can be used to analyse the performance of all renewable energy generators. It is defined as the percentage of the full output that the system is generating over the course of a year. If, for example, a 100 kW system was at full output for an entire year, it would generate 876,000 kWh of electricity (there are 8,760 hours in a year); therefore, its capacity utilisation factor would be 100. For optimum solar PV systems in Ireland, a capacity utilisation factor of between 8% and 9.5% is a reasonable target to aim for.

$$\text{Capacity utillisation factor} = \frac{\text{Actual generation}}{\text{Annual generation at maximum capacity}}$$

Continuing the example described previously, the system capacity is 5 kWp, so if it were operating at full output for the entire year, it would generate 43,800 kWh of electricity (annual generation at maximum capacity). In reality, this particular system generated 4,350 kWh of electricity (actual generation), so the capacity utilisation factor is 9.9%.

$$\text{Capacity utillisation factor} = \frac{4{,}350 \text{ kWh}}{5 \text{ kWp} \times 8{,}760 \text{ hours}}$$

$$\text{Capacity utillisation factor} = \frac{4{,}350 \text{ kWh}}{43{,}800 \text{ kWh}} = 9.9\%$$

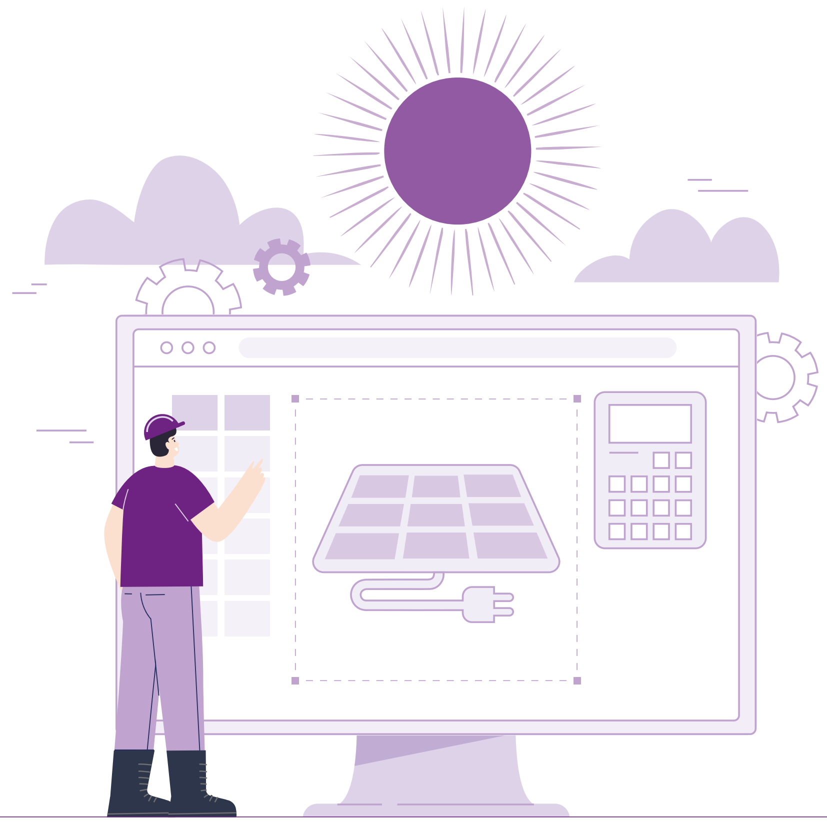
3.2.3 Performance ratio

The performance ratio is the relationship between the actual and the theoretical energy output of a PV system, and is expressed as a percentage. This accounts for losses in the system, such as thermal loss due to heating of the PV panels and resistive losses in the DC and AC cables. The closer this value is to one, the more efficient the PV system is. This value is useful for comparing PV systems and for indicating possible system faults.

For larger systems, it is common for contractors to guarantee the performance ratio, which will then be tested regularly over the first year of operation in order to ensure that the system is operating as designed. The guaranteed performance ratio will generally be lower than the design performance ratio, in order to allow for minor variations in design assumptions.

Top tip

It is essential that you carry out an evaluation of the performance of your PV system using appropriate software and making appropriate assumptions. There are a number of software platforms available which can be used to calculate the performance of a particular PV system; one example is Photovoltaic Geographical Information System (PVGIS), which was developed by the European Commission's Joint Research Council. Most solar PV contractors use modelling software to calculate the electrical output of their planned array. The software uses weather data, as well as details of the proposed system, to calculate the amount of energy the system can produce on an annual basis. Commonly used PV modelling software packages include PVGIS, PV*SOL, PVSyst and Sunny Design.



3.3 Maximising self-consumption: storage and load shifting

As discussed in Section 3.1, you will always find it more economically advantageous to consume PV electricity in the building where it is generated than to export it to the grid.

For example, if the market price paid for exported electricity was €0.05/kWh and the typical day rate for business electricity was approximately €0.15c/kWh, then this would make on-site consumption of your PV-generated electricity three times more economical than exporting it to the grid.

For financial reasons, you should always avoid 'spilling' any excess electricity to the grid. You can achieve this in three ways: by ensuring that the PV system is sized to match on-site electricity demand; by using battery storage; and by implementing an electrical load-shifting programme.

3.3.1 Battery storage

The price of storage batteries is falling rapidly, making it more cost-effective for businesses to install these with their solar PV systems.

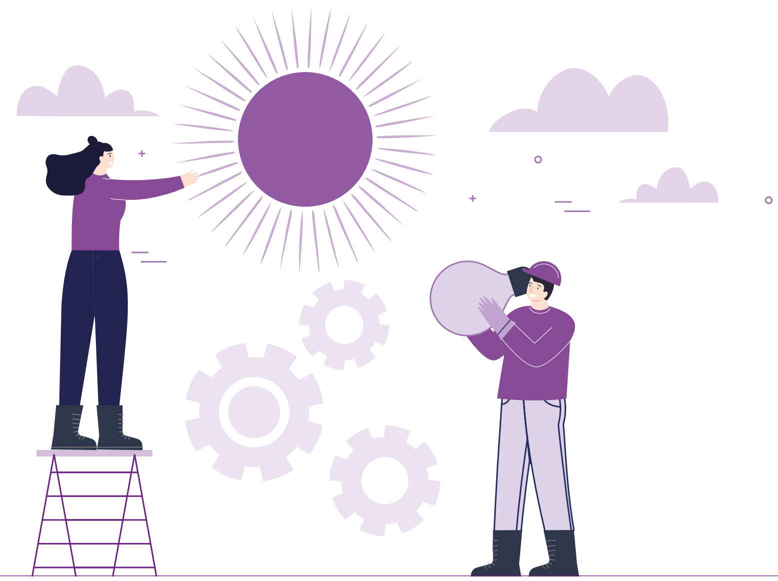
A battery storage system can increase self-consumption of solar PV and provide other services to your business, such as backup power. In addition, it can help reduce your demand from the grid and potentially reduce the peak demand charges in your electricity bills.

In a simple configuration a battery can be installed, with a monitor on a building's electricity meter, and whenever solar PV electricity is about to be exported to the electricity grid, it will instead be diverted to the battery for later use.

Storage batteries are often provided with their own inverter. This is because these batteries typically discharge DC power, which needs to be inverted to AC before it can be used in the building. In some cases, a DC-coupled battery can share the inverter with the PV system.

Charge controllers may also be installed; these control the rate of charge in the battery, ensuring that it does not charge or discharge too fast, and that it does not overcharge or undercharge. Without a charge controller these factors would stress the battery and shorten its lifespan.

Even with the falling prices, batteries for increasing self-consumption alone are unlikely to make economic sense. However, other revenue streams are emerging, such as grid system services and demand response, and these may make the business case for storage batteries more attractive in certain circumstances.

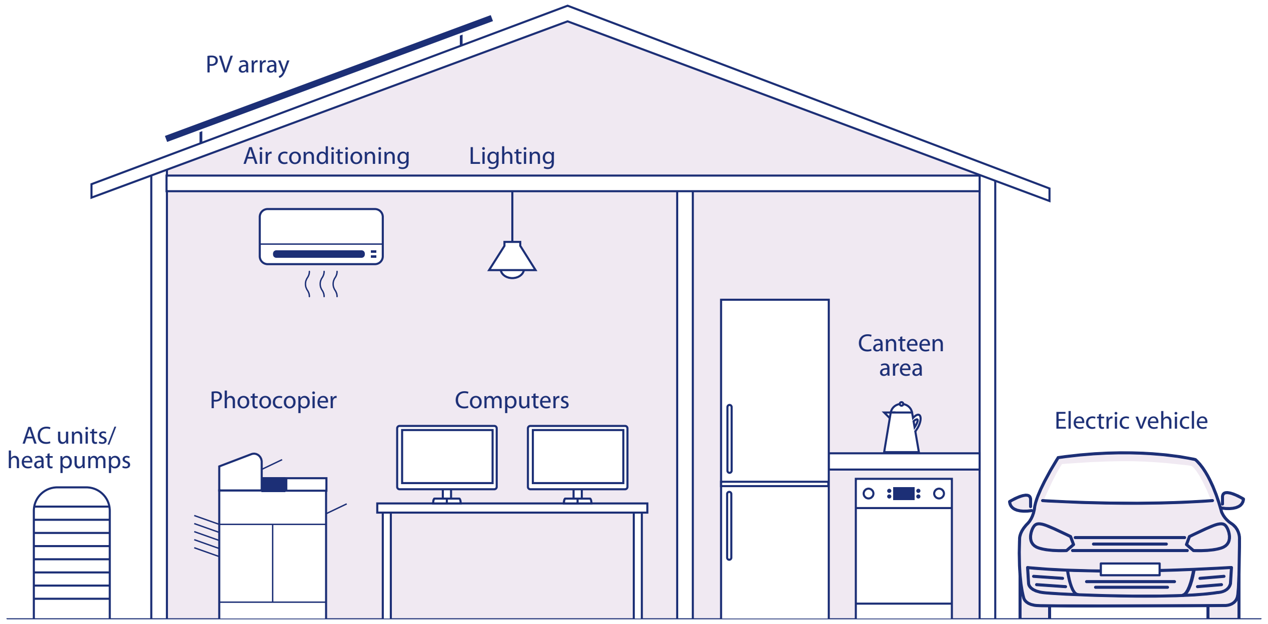


3.3.2 Load shifting

Load shifting is another way to optimise electricity generated by your solar PV system and reduce your electricity bills. This involves shifting the demand in electricity to when the PV output is high. By using your electrical plant and appliances when the PV system output is high, you can reduce the amount of electricity bought from the grid.

Examples of plant and appliances and plant which could be suitable for load shifting may include pumps, compressors, refrigeration, water heaters, and electric cars.

Figure 19: All-electric building maximising PV electricity use



3.4 Site suitability

A number of factors need to be considered when assessing the suitability of PV for your business. These relate to the performance of the system itself, your building's suitability to accommodate the structural and wind loading, and the location of the distribution board.

3.4.1 Solar PV system performance

Performance of the PV system is primarily a function of shading, irradiance and orientation. Together, these factors will influence the energy production of your business' PV system.

Shading

Shading is an important factor to consider when assessing the performance of a solar PV system. If a site is shaded, this will limit the number of hours of power production possible and reduce power output. Ideally, you should position your PV system in an unshaded location. Nearby trees, buildings, and obstructions on a roof (such as chimneys, parapet walls or an air handling plant), can cause shading and reduce the productivity of the solar PV system.

If your site is likely to experience some shading, it is essential to carry out an analysis of the potential impact. This should be undertaken as part of an assessment of the specific yield, capacity utilisation factor, and performance ratio.

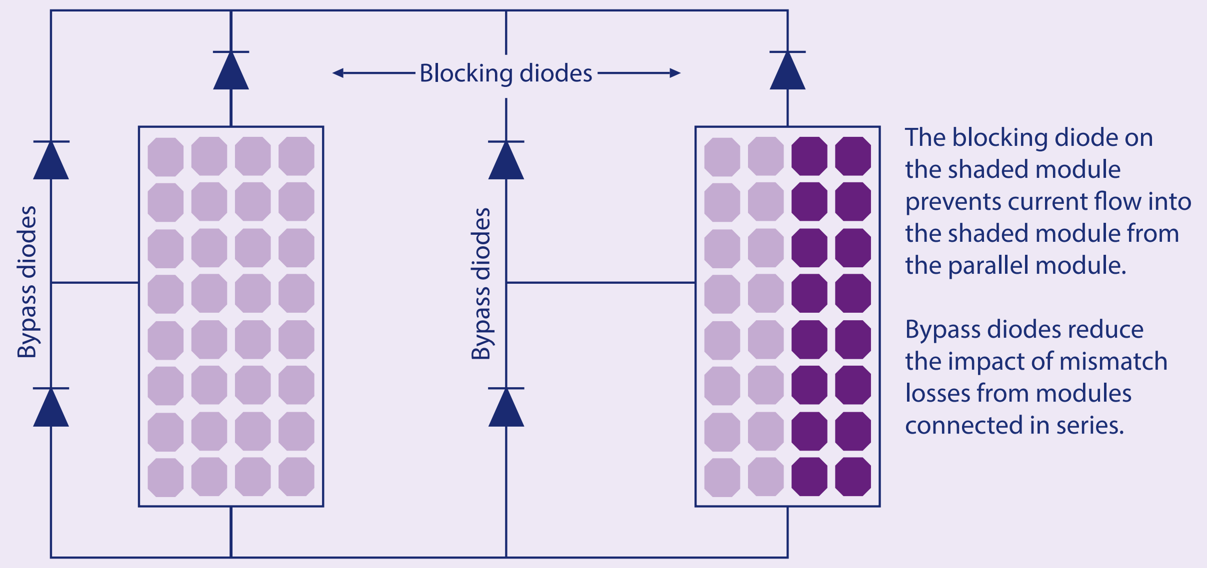
It is important to remember that shadows will be longest when the sun is low in the sky, and therefore your solar PV system output will be low at certain times of the year.

If shading is unavoidable, it is important to group modules with similar shading issues into the same strings. This will prevent shaded, underperforming modules from dragging down the output of unshaded modules. The following technologies can help to mitigate the impact of shading:

- Optimiser or micro-inverter configurations can make the system more shade tolerant.
- Bypass diodes at each module are often integrated into the modules themselves, thus allowing the current to bypass shaded diodes and preventing those diodes from dragging down the current of connected unshaded modules.

Blocking diodes ensure that the current does not flow back into shaded, bypassed modules.

Figure 20: Bypass and blocking diodes



Irradiance

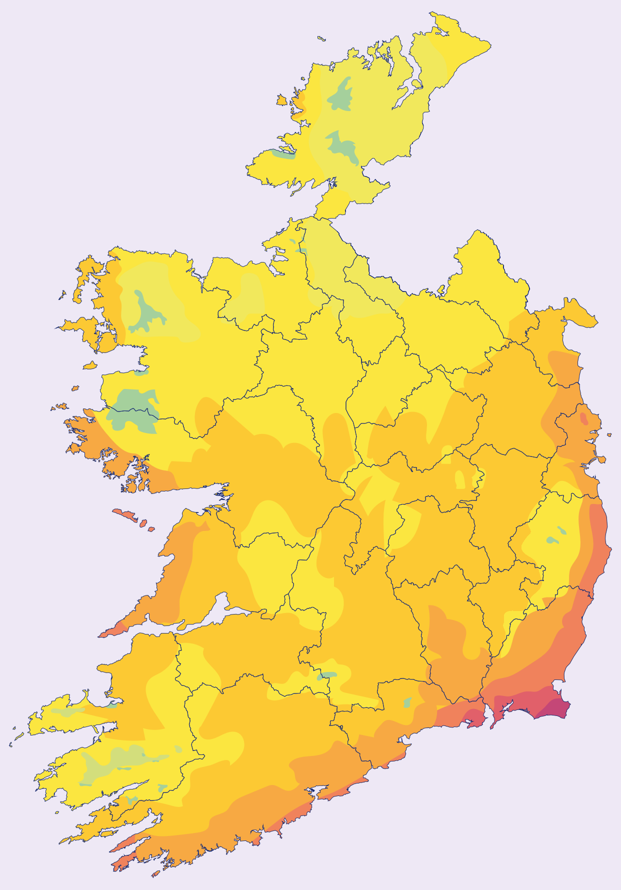
Irradiance is the measure of the amount of radiant energy from the sun falling on a surface. It is measured in watts per square metre (W/m2). Regions with higher irradiance will have more productive solar PV systems.

The southern coast of Ireland receives the highest level of solar irradiance, approximately 900 – 1,300 kWh/m2 per year. Figure 23 shows the varying levels of solar irradiation received in different parts of Ireland. While coastal areas in general receive more solar irradiation than inland areas, the difference in annual energy production between the best southerly locations and the worst northerly locations in Ireland is only about 10%.

Irradiance in a given area varies only slightly from year to year. However, it is important to account for the variation in irradiance when comparing actual generation figures with initial projections. While most solar PV design programmes have integrated local irradiance data, there are options if this is not available:

- Install a pyranometer. This will measure the site-specific irradiance, but this can be expensive.
- Install a reference cell. While this is a lower-cost option, a separate reference cell must be installed for each orientation and inclination of the PV system.

Figure 21: Map of solar irradiation



Orientation and Tilt

The direction and orientation of the solar PV towards the sun are critical to maximising yield. Ideally solar PV modules should be positioned and angled so they are directly facing sunlight at a time where there is a good balance between resource availability and electricity demand. In Ireland the largest solar gain will be achieved by orientating solar PV panels towards the south at a tilt angle of 35–40 degrees (the typical pitch of a traditional rooftop).

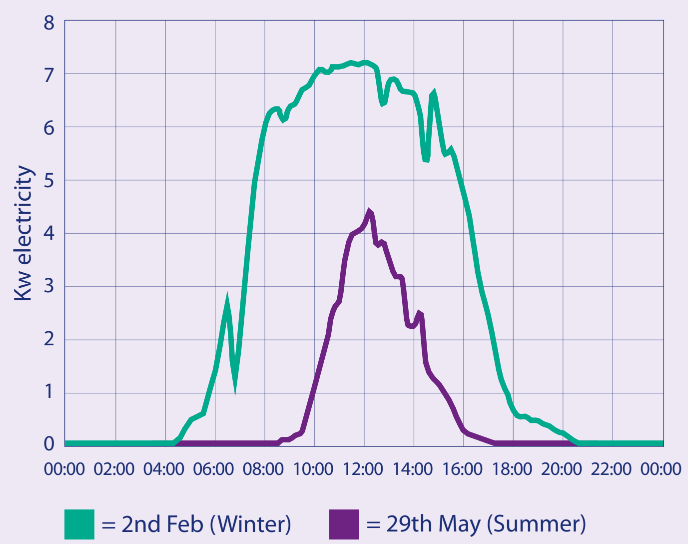
Figure 22: Solar PV output at varying orientations and tilts

Inclination / Orientation	North			North West			West			South West			South			South East			East			North East			North
	-180°	-165°	-150°	-135°	-120°	-105°	-90°	-75°	-60°	-45°	-30°	-15°	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
90°	25	27	32	37	40	44	50	57	60	66	70	70	70	70	70	66	60	57	50	44	40	37	32	27	25
80°	28	29	34	38	45	50	56	61	68	73	78	79	78	79	78	73	68	61	56	50	45	38	34	29	28
70°	32	34	37	42	48	55	66	69	75	80	85	87	87	87	85	80	75	69	66	55	48	42	37	34	32
60°	37	38	41	48	54	62	69	75	80	85	91	92	93	92	91	85	80	75	69	62	54	48	41	38	37
50°	42	45	48	52	59	68	72	78	85	91	95	96	97	96	95	91	85	78	72	68	59	52	48	49	42
45°	46	49	52	56	62	70	74	80	87	92	95	97	98	97	95	92	87	80	74	70	62	56	52	49	46
40°	50	52	55	60	65	73	76	82	88	93	96	98	99	98	96	93	88	82	76	73	65	60	55	52	50
35°	55	57	59	65	67	75	79	85	90	94	97	99	100	99	97	94	90	85	79	75	67	65	59	57	55
30°	60	60	61	67	70	78	80	85	91	94	96	98	98	98	96	94	91	85	80	78	70	67	61	60	60
20°	70	70	71	73	75	72	84	86	91	92	95	96	96	96	95	92	91	86	84	72	75	73	71	70	70
10°	78	78	79	80	82	85	85	88	90	91	92	92	93	92	92	91	90	88	85	85	82	80	79	78	78
0°	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

As the sun is not in a fixed position, and moves throughout the day, it is important to match the position of your solar PV modules with your electricity demand. For example, if your business' highest requirement for electricity is in the morning and afternoon, it may be beneficial to select and orientation which faces south-easterly direction. Figure 25 below demonstrates the output of a 22 panel array orientated towards the South East at a tilt angle of 45 degrees.

As described in Section 2.3.2., some solar PV systems can track the sun over the course of the day by shifting the orientation and tilt of the modules. While this increases the power output of the modules, it also increases the overall cost of the installation.

Figure 23: Seasonal Solar Array Output



Top tip

You can calculate the optimal orientation and tilt of your solar PV system with online tools such as the European Commission's PVGIS programme developed by the Joint Research centre. This free tool has many functions that are useful in designing your solar PV system. Try it out on the EU Science Hub website: **https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html**

3.4.2 Building condition & assessment

The strength and age of a roof is a primary consideration when planning to install a roof-mounted solar PV array. Some roofs will simply be too old or too weak to support the extra weight of a PV system. In certain circumstances, a roof may be strengthened, but the cost of the works may be prohibitively expensive. It is important to get professional advice from a suitably qualified engineer when assessing a roof's suitability for installation of a solar PV array.

Structural loading and condition assessment

A typical PV module measuring 1.6 m2 weighs about 20 kg. The mounting system and required ballast will also add to this weight. Before proceeding with the installation of a roof-mounted PV system, it is recommended that a qualified structural engineer must carry out a structural assessment of the roof and building structure impacted by the additional load.

Assessing the structural integrity of the roof and the building structure involves reviewing the initial structural design drawings for the roof. If these structural design drawings are not available, the structural engineer must carry out a detailed visual inspection to determine the construction materials used in both the building structure and the roof. In addition, they must assess the dimensions and the degradation of each construction material used.

Following a review of the structural design drawings or a visual inspection of the site, the engineer must calculate the structural load of the proposed PV array in compliance with the calculation methods and standards specified in the Eurocodes and the Building Regulations.

If the roof is relatively old, or if its remaining lifespan is less than the lifespan of the PV system, an inspection must be carried out by a roofing expert. This expert should inspect the roof for any damage or degradation and should provide a statement about its suitability for the proposed solar PV installation. Some remedial work on the roof may be required prior to the installation.

In addition, you should consult with your insurance company in advance of any investment to ensure that you meet all of its requirements in relation to a structural loading and condition assessment.

Wind loading assessment

A wind loading assessment must be considered and carried out when designing the proposed solar PV system. For the purposes of the assessment, the roof is divided into three sections: the interior zone, where lower wind loads occur;

- the perimeter zone; and
- the corner zones, which experience the strongest wind loads.

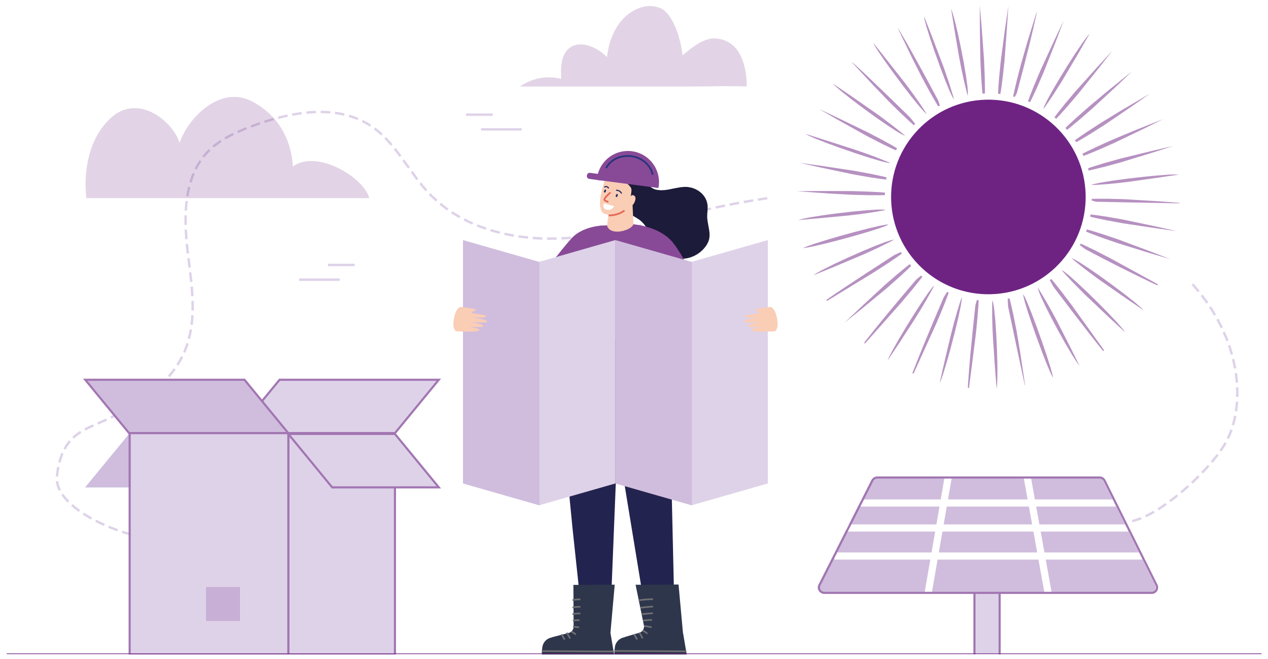
Eurocode 1 provides site-specific wind loadings to be used in wind load calculations. The PV system contractor must keep documentary evidence of their calculations and assessment of the structural and wind risks of the mounting system used. You should consult with your insurance company in advance of carrying out a wind load assessment in order to ensure that you meet all of its requirements in relation to this assessment.

3.4.3 Location of distribution board

Electricity used within a building needs to be converted from DC to AC power using an inverter, which should then be connected into the electricity supply through a distribution board.

Generally, a building will have one distribution board where electrical protection devices are located. The contractor will need to run cabling from the inverter to this distribution board. It is important to plan how the cable will be routed, as chasing, openings and containment may be required. The distribution board may also need to be upgraded in order to comply with regulations.

Larger buildings will often have sub-distribution boards located around the premises. These sub-distribution boards are commonly closer to the inverter and easier to connect into than the main distribution board. In this case, it is important to consider the capacity of the cable connecting the main distribution board to the sub-distribution boards. If the planned solar PV array is 50 kWp, then the cable connecting to the distribution board will need to be sized so that it can safely carry the system's full 50 kWp output.



4 Delivering your solar PV project

4.1 General specifications

When planning a solar PV installation, it is essential to have a written specification detailing the technical aspects of the proposed system. In order to ensure that you get the system you require, you may need to commission an engineer to develop this specification.

The main considerations for a solar PV specification are:

- General system requirements (size (kWp) or available area);
- Scope of work;
- Site layout, access hours, and welfare;
- Surveys, structural and wind loading assessment;
- Planning and grid connection requirements;
- Civil works;
- Electrical works;
- Mounting systems;
- Technical specifications of modules, inverters, and AC and DC systems;
- Metering and monitoring systems; and
- Documentation and training requirements.

Most PV modules and inverters come with a warranty. It is important that you specify what length of warranty you require; longer warranties may increase cost and also may limit the range of inverters available.

Many manufacturers will also offer a performance guarantee. Module efficiency will degrade gradually over time; however, many module manufacturers will guarantee an output of 80% of the initial output at 25 years. In addition, they may offer a ten-year product warranty. Inverter manufacturers will generally offer a five or ten-year warranty.

Considerations for electrical safety and distribution board modifications

In certain circumstances, for example in older buildings, you may need to modify the distribution board. You should make your contractor responsible for upgrades or modifications to the distribution board, for safety devices (fuses, earth leakage units, isolators) and to ensure compliance with Safe Electric standards. Information on these standards can be found at: **www.safeelectric.ie**. You can also search the register on the Safe Electric website to verify that the electrician carrying out work on your site is certified.

In addition, you should make your contractor responsible for compliance with all ESB Network requirements, including the grid connection application and embedded generation interface protection.

4.2 Financial feasibility

The cost of PV modules has decreased significantly in recent years. This has resulted in an increased uptake of PV and policy support in countries that experience low solar irradiation, such as Ireland.

As the size of an installation increases, the price per kW of electricity generated generally decreases. Based on 2021 estimates, the open market installation price is generally around €1,000 per kWp (ex-VAT) for installations of around 20 kW. Large installations will costs less than this. Additional factors that may increase the installation cost include:

- Ease of access to the roof;
- Flat roof mounting system cost;
- The age of the distribution board in the building; and
- The addition of micro-inverters or sophisticated metering.

Worked example – typical solar PV cost and payback

- A well-designed, correctly sized, south-facing system, inclined close to 35°, would be expected to generate 900 kWh/kWp.
- Assuming a day rate electricity cost of €0.14/kWh, this will save the user €126 per year per kW installed.
- For medium to large systems, this results in a payback period of approximately 8 years.

SEAI has grants and supports available for businesses which support energy efficiency and renewable technologies, including solar PV. Availing of such grants and supports could further reduce the length of the payback period.

4.2.1 Simple payback

The simple payback period is the length of time required to recover the cost of the investment. The shorter the payback period, the more attractive the investment.

$$\text{Simple payback} = \frac{\text{Cost of the investment}}{\text{Annual savings}}$$

In order to calculate the potential financial savings, it is important to use the correct cost of electricity. In analysing the cost of electricity, you should first investigate whether you are on the cheapest available plan. For example, are you using more expensive day rate electricity when you could be availing of cheaper night rate electricity?

Larger businesses may want to use more sophisticated metrics for analysing the economic feasibility of a solar PV project, such as discounted payback, internal rate of return, or net present value. These approaches are discussed in further detail in SEAI's Energy Audit Handbook, which is available on the SEAI website: **www.seai.ie/energy-audit-handbook**

It is important to note that annual savings are calculated from the electricity that is drawn down from the PV system, not from the electricity that is generated by the system. Some electricity may be spilled to the grid during times when the electricity supplied by the PV system exceeds your business's electricity demand. In order to ensure that your solar PV system is economical, it is important that on-site electricity use aligns with the amount of electricity generated by the system.

4.2.2 Alternative routes to project delivery – energy contracting

There are several energy performance-related payment models which support financing of energy technologies. The advantages of a pay-for-performance contract is that it removes your risk of a loss. Savings are guaranteed, and if they are not delivered, the energy services company (ESCO) will make up the shortfall.

Energy performance contracting

Energy performance contracting (EPC) is a contractual arrangement between the beneficiary of the energy efficiency upgrade and the provider. Savings are agreed from the outset and they are monitored throughout the contract.

If you are using this route to deliver your project you will enter into an energy performance contract with the energy services company, which provides a guarantee that the projected energy and cost savings will be delivered over the lifetime of the contract, usually 5–15 years. The energy services company offers a third-party loan which, if required, enables you to reduce your capital spend and use the cost savings from the installed PV system to repay the loan. If the actual savings are less than those initially projected, the energy services company has to pay the shortfall.

Local energy supply contract

A local energy supply contract is an agreement whereby an energy services company installs a solar PV system on your property free of charge, operates and maintains the system, and supplies electricity to you. You then pay the energy services company for the quantity of electricity supplied over the term of the contract.

Energy performance guarantee

This is where a contractor undertakes energy efficiency works, such as the installation of a PV system, and guarantees the energy savings for an agreed amount of money. If the savings fall short of expectations, the contractor loses a part of their fee.

Energy performance guarantee in practice

The Defence Forces has installed several solar PV systems using a standard works contract with a retention clause based on performance. This enabled the Defence Forces to ensure that each system was performing correctly before the contractor was fully paid and that the projected yields submitted at tender stage were achieved.

4.2.3 Project and financial supports

SEAI support	SEAI administers a number of grant schemes that support solar PV systems. These schemes are available for houses, businesses and farms, as well as for community halls and sports clubs. For more detailed information on SEAI project and financial supports, visit **www.seai.ie/businessgrants**
Export Payment	The government are currently developing a microgeneration (<50kW) support scheme and small scale generation scheme (50kW - 200kW) which will support the deployment of rooftop and ground mounted solar PV projects. A wholesale electricity price based export payment (Clean Export Guarantee) will be available to all solar PV installations from 2022.
Targeted agricultural modernisation scheme	The Department of Agriculture, Food and the Marine's Targeted Agriculture Modernisation Schemes (TAMS) offer financial support for PV installations to certain farming sectors. For more detailed information on TAMS grants, visit **www.agriculture.gov.ie**
Accelerated Capital Allowance	The Accelerated Capital Allowance is a tax incentive scheme that promotes investment in energy-efficient products and equipment that are listed on a register called Triple E. More information on the Accelerated Capital Allowances scheme and the Triple E register can be found on the SEAI website: **www.seai.ie/aca** The traditional approach to the treatment of plant and machinery capital allowances enables wear and tear to be counted as a deduction for tax purposes. By contrast, the ACA scheme allows a company to write down the cost of Triple E-listed equipment in the year of purchase, rather than over the eight-year period that is standard for plant and machinery capital allowances. This provides an incentive for companies and sole traders to choose a qualifying energy-efficient option when purchasing equipment such as a PV system.

4.3 Planning requirements

Under the Planning and Development Regulations, the installation of PV modules is exempt from planning permission subject to certain conditions.

The following exemptions relate to the maximum amount of PV modules that can be installed on different types of buildings, typically allowing 7–8 kWp on a commercial building and 2 kWp on a domestic building. These planning requirements are currently under review.

If the property is a protected structure, or if it is located in an environmentally sensitive area, such as an Architectural Conservation Area, a Special Area of Conservation (SAC) or a Special Protection Area (SPA), further conditions may apply. Before proceeding with a PV installation, make sure to contact your local planning department to check whether any planning restrictions apply to your business's premises.

Table 2: Planning requirements for solar PV modules

Building type	Planning requirements
Industrial	The total aperture area of any wall-mounted panel or free-standing solar array shall not exceed 50m².
Commercial	The total aperture area of any such panel, taken together with any other such panel previously placed on or within the said curtilage, shall not exceed 50m² or 50% of the total roof area, whichever is the lesser.
Domestic	The maximum amount of PV modules that can be installed on a domestic property is the lesser of 12m² and 50% of the roof area.

4.3.1 Planning application

For larger projects not classed as an exempted development under the Planning and Development Regulations, you will be required to submit a planning application to your local authority. The main items required are listed below, but a comprehensive list is set out in the Planning and Development Act:

- Planning application form;
- Drawings (plans/elevations, etc.);
- Ordinance Survey of Ireland location maps;
- Newspaper advertisement;
- Site notice; and
- Appropriate fee.

For larger projects, the following additional items may be required by the local authority planning office or by statutory consultees:

- Environmental Impact Assessment Report;
- Appropriate Assessment screening report;
- Natura Impact Statement;
- Flood risk assessment report;
- Glint and glare report;
- Outline Traffic Management Plan; and
- Outline Construction Environmental Management Plan.

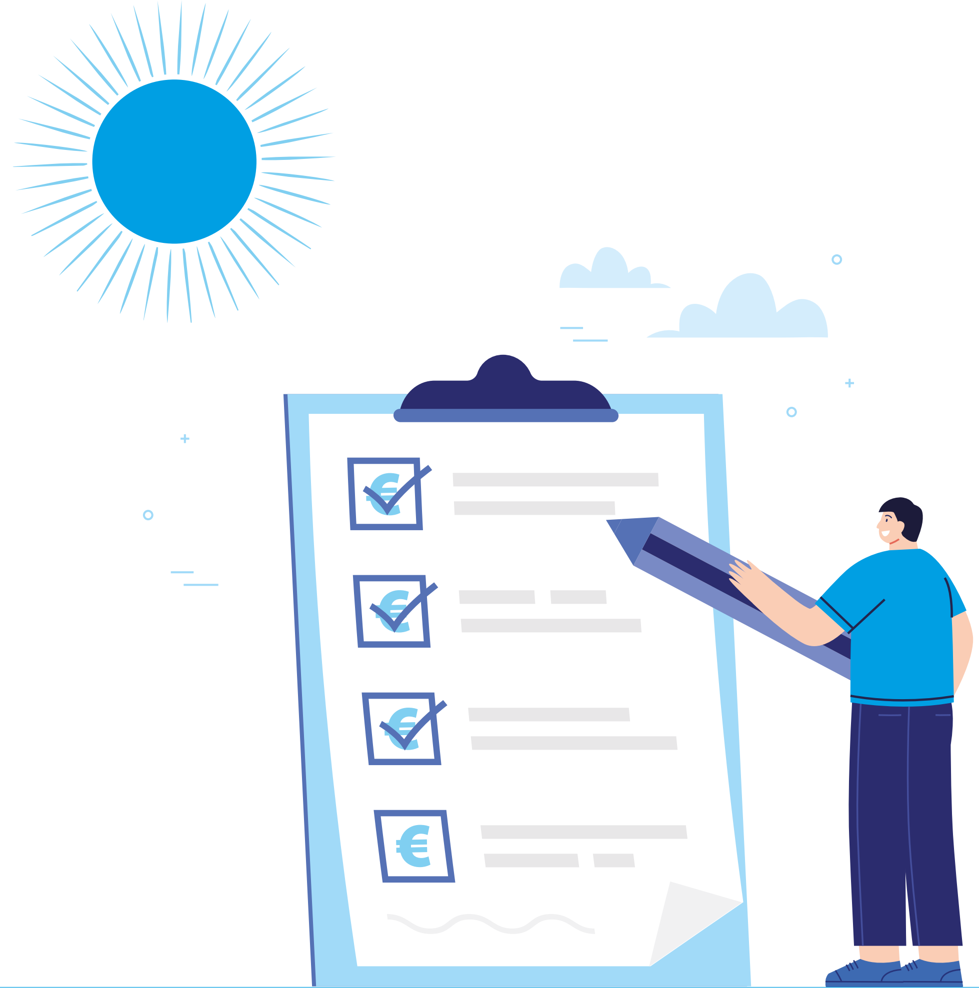
Always check your local authority's planning requirements before commencing a solar PV project.

Glint and glare

In certain circumstances, glint and glare from solar PV installations may create undesirable visual effects for nearby dwellings, motorists, airports and railways. PV modules are treated with an anti-reflective coating in order to reduce the amount of reflected light, glint and glare from solar PV installations. It is typically a very minor issue but may be raised during the planning process.

Your local authority may require a glint and glare report as part of a planning application for large installations, or for installations located in an area where the planning officer has identified a visual impact risk.

Online tools are available to assess the potential glare from a solar PV installation. These tools use interactive maps to help assess the site for the likelihood and severity of glare effects on sensitive receptors, such as nearby roads, railway lines, homes or airports.



4.4. Grid connection and embedded generation interface protection

4.4.1 Types of connection

Most solar PV systems are connected in parallel with the grid. This allows simultaneously supply of electricity to the building from both the PV system and the grid (depending on the current demand of the building and current generation from the PV system). It also allows excess electricity to be exported to the grid where the building has been granted export capacity.

You can choose from several different connection options depending on the size of your generator and your requirement to export electricity to the grid. Unless your system is completely off-grid, you will need to make an application to ESB Networks in one of a number of categories. ESB Networks offers several application categories, with increasing requirements for larger PV systems.
These connection options are described on pages 42 – 44.

1

Microgeneration (maximum export capacity <6 kW – 11 kW)

Microgenerators operate in parallel with ESB Networks' low-voltage system and are rated (AC rating) up to and including:

- 6 kW at 230 volts for a single-phase connection; and
- 11 kW at 230/400 volts for a three-phase connection.

Almost all smaller commercial PV systems and domestic installations fall within the 6–11 kW categories outlined above. For these categories, there is currently no application fee, but an NC6 form must be completed and submitted to ESB Networks. This is a straightforward application form, which your contractor can help you complete. You may need some additional information about your PV system to accompany the application.

The installation of a microgeneration system involves an 'inform and fit' process, whereby you must inform ESB Networks of your intention to proceed. ESB Networks then has 20 days to reject this proposal. If you do not receive a reply within 20 days, you are permitted to go ahead with the installation. As of the time of publication of this guide, you are currently not obliged to install a meter, however, with export payment in development it may be prudent to consider this at the same time as your application.

If the grid supply to your building fails, you will not be able to use electricity from your microgenerator, as this will automatically be disconnected for safety reasons. You can arrange for a manual changeover in order to use the PV system and battery storage as a backup energy supply to the building. This work must comply with the National Rules for Electrical Installations (ET101:2008/I.S. 10101). In addition, you must obtain Safe Electric certification for each microgenerator installation.

2 Minigeneration (maximum export capacity 6kW – 50kW)

Minigenerators operate in parallel with ESB Networks' low-voltage system and are rated (AC rating) up to and including:

- 6 – 17 kW for a single-phase connection; and
- 11 – 50 kW for a three-phase connection.

Larger commercial PV systems fall within the 6–50 kW categories outlined above. For these categories, there is currently no application fee, but an NC7 form must be completed and submitted to ESB Networks. This is a straightforward application form, which your contractor can help you complete. You may need some additional information about your PV system to accompany the application.

The installation of a minigeneration system involves an application process, whereby you must apply to ESB Networks, who will assess you application and provide a letter of offer. There may be associated upgrade costs in the letter of offer.

If the grid supply to your building fails, you will not be able to use electricity from your minigenerator, as this will automatically be disconnected for safety reasons. You can arrange for a manual changeover in order to use the PV system and battery storage as a backup energy supply to the building. This work must comply with the National Rules for Electrical Installations (ET101:2008/I.S. 10101). In addition, you must obtain Safe Electric certification for each minigenerator installation.

3 Embedded generation (zero export capacity)

An embedded generator is a generator that operates in parallel with the distribution system but does not require or have the capacity to export to the grid. A business that operates a PV array solely in order to reduce electricity imported from the grid, and not to export electricity to the grid, is a common example of embedded generation with zero export capacity. To apply for an embedded generation connection, you must submit an NC5 or NC5a form and other specified documentation to ESB Networks for evaluation:

- An NC5 form is used when the applicant has identified the specific generator manufacturer details prior to submitting the application. In such instances, ESB Networks will evaluate the NC5 form based on the data set out in the application.
- An NC5a form is used when the specific generator manufacturer details are not known at the time of application. In such instances, ESB Networks will complete its evaluation using assumed data, and you will be required to submit specific data one year prior to energisation.

When completing the NC5 or NC5a form for a zero export capacity embedded generator, you should record the maximum export connection for embedded generation as zero. ESB Networks generally reviews this type of application within 30 days and, if approved, it will send you a new connection agreement to reflect the addition of the parallel generator. As of 2020, ESB Networks does not charge for a zero export embedded generator connection.

Although in many cases there will be no constraint on exporting power from an embedded generator, under this type of ESB Networks connection agreement, you will have no facility for metering or selling your electricity (either upon installation or in the future) and if you were to export power, you would technically be in breach of your connection agreement.

4 Embedded exporting generation with 11 kW – 500 kW maximum export capacity (non-batch process)

In line with the Commission for Regulation of Utilities' (CRU's) Enduring Connection Policy, for connection with a maximum export capacity of 11 kW to 500 kW of electricity, you must apply for a connection under the non-batch process. In certain circumstances, you may need to obtain planning permission before making an application for such a connection.

ESB Networks evaluates non-batch applications in the order in which they are received. It takes a minimum of 90 days to assess such an application.

If your project is linked to a batch process application (>500 kW maximum export capacity) which is already under assessment by ESB Networks, the application process will be put on hold until ESB Networks has accepted or rejected the batch process application, or the timeframe for implementing the batch process project has lapsed.

In order to make an application for a connection under the non-batch process, you must submit an NC5 or NC5a form and other specified documentation to ESB Networks. The Commission for Regulation of Utilities (CRU) has capped the number of non-batch applications at 30 per year. If, ESB Networks confirms that all application criteria have been met, it will send you a quotation and a letter offering to connect you to the grid.

5 Embedded exporting generation with more than 500 kW maximum export capacity (batch process)

Applications for projects greater than 500 kW are processed in a batch in line with the CRU Enduring Connection Policy. You will need to obtain planning permission before applying for a grid connection.

In order to make an application for a connection under the batch process, you must submit an NC5 or NC5a form and other specified documentation to ESB Networks. The system operator divides applications into subgroups based on their grid connection location. Members of a subgroup will share the cost of connecting to the grid.

4.4.2 Embedded generation interface protection

All solar PV systems operating in parallel to the grid will require embedded generation interface protection (EGIP). EGIP monitors the status of the electricity grid, and if an adverse event occurs, it automatically manages this - in many cases it disconnects the building's solar PV system from the grid. When you make a connection application to ESB Networks, the company will tell you what level of EGIP is required for your PV system.

All installed microgenerators and minigenerators must comply with European Standard EN 50549 using the specific Irish protection settings. EN 50549 sets out the parameters for:

- Over-voltage;
- Under-voltage;
- Over-frequency;
- Under-frequency; and
- Loss of mains.

In the case of smaller PV systems and microgenerators/minigenerators, EGIP normally features as part of the inverter. For non-microgeneration/minigeneration connections, the EGIP requirements are normally met with a separate protection relay providing the required protection functions, and disconnection through circuit breakers or contactors.

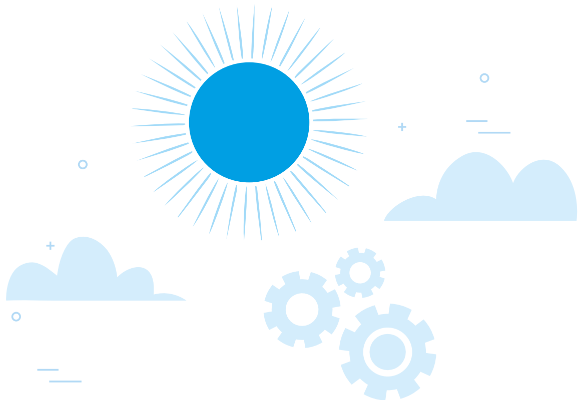
The level of protection required will depend on a number of factors, including the rating of the generator (PV system), the connection voltage of the site, and the rating of the transformer feeding the site. You will find details on this in the ESB Networks document Conditions Governing Connection to the Distribution System.

The following is a list of protection requirements that may be required for a non-microgeneration embedded generator connections:

- Over-voltage;
- Under-voltage;
- Over-frequency;
- Under-frequency;
- Loss of mains;
- Rate of change of frequency;
- Earth fault (requiring significant medium voltage intervention);
- Reverse overcurrent (requiring disconnection of the site in certain exporting situations);
- Impedance protection; and
- Differential protection

You should engage with ESB Networks both before and following the application process in order to ensure that the required EGIP is installed and specified. By taking this approach, you can avoid incurring significant post-installation costs to ensure that the PV system complies with ESB Networks regulations.

Once the PV system has been commissioned, ESB Networks will make a site visit and will witness a test the EGIP to ensure that it is operating correctly. Note that the cost of the EGIP testing for ESB Networks to witness is borne by the generator owner (i.e. the business).



4.5 Commissioning and testing

Commissioning must be undertaken according to the manufacturer's requirements and the requirements of the entire system so as to ensure that it is operating as designed. Installation and electrical certification must only be carried out by a Safe Electric registered electrical contractor.

The inspection and testing of the PV system must be carried out in accordance with ET101:2008/I.S.10101 requirements, Safe Electric requirements, and EN 62446 Grid Connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection.

You should ensure that your electrician provides a Type 3 Safe Electric form on completion of a new installation, or on completion of alterations to an existing installation. The Type 3 form certifies that the installation complies with current electrical regulations.

Checklist	Make sure you receive the following documentation:	YES	YES
	Datasheets for solar PV modules, inverters, and the battery energy storage system;		
	Warranties for solar PV modules, inverters, and the mounting system;		
	Operation and maintenance manuals for business owners;		
	Basic start up, shut down, safety, operation, and maintenance instructions; and		
	Estimation of system performance calculated using common estimator tools and databases such as PVSyst, PV*SOL, PVGIS, or equivalent, considering the actual location, orientation, pitch, and over-shading conditions of the PV modules.		

Health and safety

Solar PV system installation falls under the provisions of the Safety, Health and Welfare at Work Act 2005 and the Safety, Health and Welfare at Work (Construction) Regulations 2013. Accordingly, designers should ensure, as far as is reasonably practicable, that the solar modules are designed to be safe and are capable of being safely installed and maintained.

Similarly, the contractor installing the solar modules and the person maintaining the modules should ensure that they are carrying out these tasks safely. All solar PV installations should be commissioned and signed off on by a Safe Electric registered electrician.

4.6 Metering and performance measurement

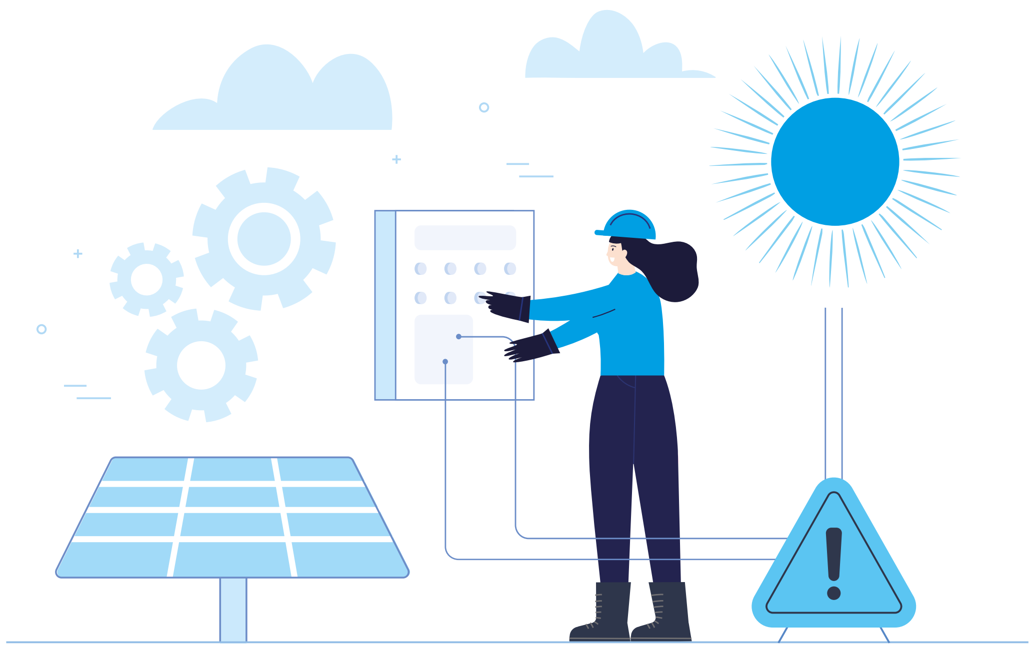
The measurement and verification (M&V) of a solar PV system is critical. In addition to checking that the PV system is meeting its projected electricity generation targets, M&V can highlight potential problems with the system so that these can be rectified.

Most inverters come with a built-in meter that logs energy generation. However, if you require more detailed measurements, you can install a separate metering and logging system. With this system, an online portal can be used to log the energy generation on an hourly, half-hourly, or quarter-hourly basis. You can use the portal to access this data remotely, and to verify that the PV system is operational. It can be very beneficial to display this information on a monitor in your lobby or staff room.

For larger installations, you may wish to have a built-in performance guarantee. The data from the energy generation meter is used to verify whether or not the system is meeting the design requirements. Depending on the contractual arrangement in place, you may wish to withhold payment pending the results of the M&V exercise.

Top Tip

Some SEAI grant schemes require measurement and verification in order to prove that the system is installed and working as designed. M&V is good practice in any design project, whether it is simple or completed in accordance with the International Performance Measurement and Verification Protocol (IPMVP)



4.7 Operation and maintenance

The typical lifespan of a PV module is 20–25 years (possibly longer), and the lifespan of an inverter is usually 10–15 years. As PV systems generally do not have any moving parts, the amount of maintenance required is minimal. Most of the energy loss that occurs is due to minor faults and lack of monitoring.

PV modules in Ireland with a tilt greater than 10° will generally self-clean in the rain. Unless the modules are located in a particularly dirty environment or at a roadside, rain will generally keep them dust free.

Table 3 lists a number of recommendations for maintenance works and checks to be carried out on PV systems. It is important to note that only suitably qualified electricians should carry out the electrical works listed.

In addition to the recommended maintenance works described in Table 3, you will need to do the following:

- Ensure that the contractor installs the inverter in a well-ventilated area, so that it does not overheat.
- Check generation from the PV system regularly (either by using remote monitoring systems or by checking the inverter in person). Ideally, you should carry out these checks once a month.
- Set up automatic alarms for faults, using text messaging or email alerts. If the PV system has an online portal logging feature and is monitoring energy generation from the inverter, you can set up an email alert to notify you when the system is not operating correctly.
- Visually inspect PV system components for evidence of dirt build-up, damage and intrusive objects (such as nests or weeds) resulting in shading. Dust or dirt build-up should be cleaned off so that the modules can most effectively convert solar energy into electricity.
- Check electricity generation readings (in kWh) from the monitoring system against projected values to determine whether the system is working correctly.
- Evaluate monthly electricity generation against the initial design performance ratio in order to verify that the PV system is operating as designed.

End of life of solar PV modules

Recycling solar PV modules is a legal obligation under the Waste Electrical and Electronic Equipment (WEEE) Directive, transposed into Irish law through the European Union (Waste Electrical and Electronic Equipment) Regulations (S.I. 149 of 2014).

This legislation aims to divert electrical and electronic waste from landfill and promote improved design of these products so that they can be more easily recycled. When your solar PV system reaches the end of its useful life and can no longer be repaired, you need to ensure that you dispose of it responsibly by returning it to a registered WEEE producer.

Under the WEEE Directive, retailers of solar PV systems are required to:

- Register as producers of WEEE with the Producer Register Limited;
- Provide free take-back for customers buying new PV modules;
- Ensure that waste electrical products are stored and transported to an approved facility; and
- Ensure that consumers of electrical equipment are aware of the take-back options available to them.

Table 3: Checklist of recommended maintenance works for PV systems

Checklist	Component	Inspection	Action	Done
	PV modules	Inspect for dust/residue on external surface of modules	Wipe clean using only water (likely required every 2–3 years)	
		Inspect for any physical damage and indentations on modules	Replace modules if damaged	
	Cabling	Inspect the condition of cable for damage, for example wear and tear	Replace cable if damaged	
		Inspect all cable terminations for damage, burn marks, hot spots and loose connections	Replace cable if damaged or tighten loose connections	
	PV inverter	Inspect for loose cable connections	Tighten loose connections	
		Inspect ventilation system condition	Clear all dust and dirt in ventilation system	
		Inspect inverter functionality	Replace inverter if functionality fails	
		Inspect for abnormal operating temperature, for example overheating	Recommend replacement if required	
	Junction boxes	Check cable terminals for loose connections and for wear and tear	Replace if required or tighten all loose connections	
		Check for warning notices	Replace warning notice if required	
		Inspect for physical damage	Replace if required	
	Earthing of solar PV system	Inspect earthing cable conditions	Replace if required	
		Inspect the physical earthing connection	Tighten if required	
		Inspect the continuity of the bonding to lightning earth	Troubleshoot or replace if required	
	Means of isolation	Inspect functionality	Recommend replacement	
	Bonding of the exposed metallic structure to lightning earth	Check bonding cable connections	Replace if required	
		Check physical bonding connection	Tighten loose connections	
		Check continuity of the bonding to lightning earth	Troubleshoot and replace if required	

Adapted from the handbook for solar PV systems – Energy Market Authority (2011)

References and further reading

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Notes

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