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Solar Photovoltaics (PV)

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Summary

- Panel yields depend on location, orientation, pitch and shading.
- Yield varies throughout the day and throughout the year.
- Return on investment is best where grid electricity is offset.
- The higher summer yield is a good match for summer cooling loads.

Introduction

Energy from the sun lands on earth at approximately 10,000 times the rate of the worlds energy needs. However, it is a very diffuse energy source and requires capturing, concentrating and converting to a useable form. Solar photovoltaic panels capture a proportion of the sun**light** falling on their surface and convert it to electricity for use in homes and businesses.

PV panels

PV cells are made from two types of silicon in a sandwich and when sunlight falls on them a voltage difference is produced across them. When a circuit is connected across the cell a current will flow. A number of cells connected in a module and usually held in a frame and encapsulated in glass forms a solar panel. Solar panels are generally rectangular in shape and range from 1.0 to 2.0 metres in length and between 0.8 and 1.0 metres wide.

Figure 1: A typical PV panel would be 1.6 m long x 1.0 m wide x 35 mm and be rated at 0.25 – 0.45 kWp

Panels are rated in terms of their maximum (or peak) output in Wp or kWp. The “p” suffix indicates that this is the peak output that could be expected usually when there is a radiation intensity of 1000 W/m^2. Or in other words on a very sunny day in Scotland with the panel facing directly at the sun.

Panels are generally mounted in arrays on buildings or on the ground. Arrays on domestic house roofs range from 2 kWp to 10 kWp. A 50 kWp array is a common installation on a farm shed and ground mounted arrays can be as large as tens of megawatts.

Efficiency

Solar panels have been developed with efficiencies as high as 40%. That is to say that they can convert 40% of the sunlight falling on them to electricity. These panels are however still fairly expensive to make and typically commercially available panels will have efficiencies of around 16%. Efficiency of PV panels is only really an issue where space limitations exist. Where space is available the cost of an array in terms of £/kWp is a more useful measure.

Siting

For a fixed array there are a number of criteria regarding its location that will affect its output;

- Geographical location
- Orientation from due south
- Slope from horizontal at which it is mounted
- Shading at any time of the day or time of the year

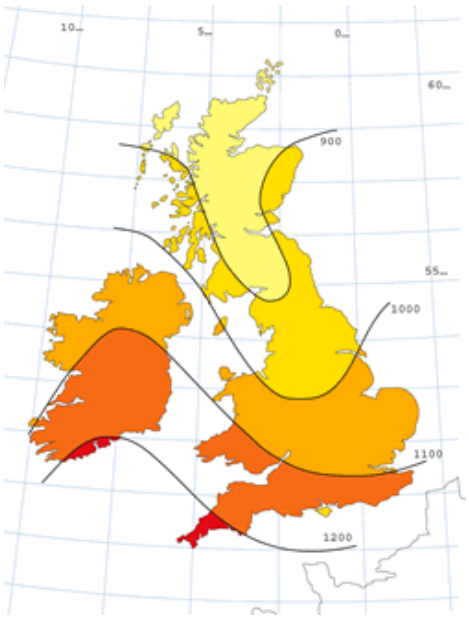

Figure 2: Annual solar irradiation across the UK

Data is readily available of average irradiation figures across the country. Where panels are to be mounted on roofs, suitable south facing roofs should be chosen and any reduction in output due to sub-optimal orientation can be calculated if the orientation of the building is known (can be measured from aerial photography if necessary). For an existing roof, the pitch will be fixed but for ground mounted installations or new buildings the optimum roof pitch for the location can be calculated. The further north the lower the sun in the sky and therefore the steeper the optimal pitch. A number of online calculators are available which will estimate the yield from a proposed array given the criteria above.
e.g. https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html

Static or tracking

For ground mounted arrays the option exists to mount panels on tracking devices that move to follow the path of the sun in both horizontal and vertical planes. These devices offer an increased yield for the same installed capacity of system but add a level of complexity and cost to the installation and increase maintenance requirements. Where space is restricted they may offer a better return on investment than static panels.

Yield patterns

Yield from a PV array will vary hugely throughout the day and also throughout the year and therefore where it is hoped to make savings by offsetting the use of grid electricity a comparison between the demand profile of the site and the estimated yield pattern of the array is necessary. Typical yield patterns from Scottish PV arrays are shown in figures 3 & 4.

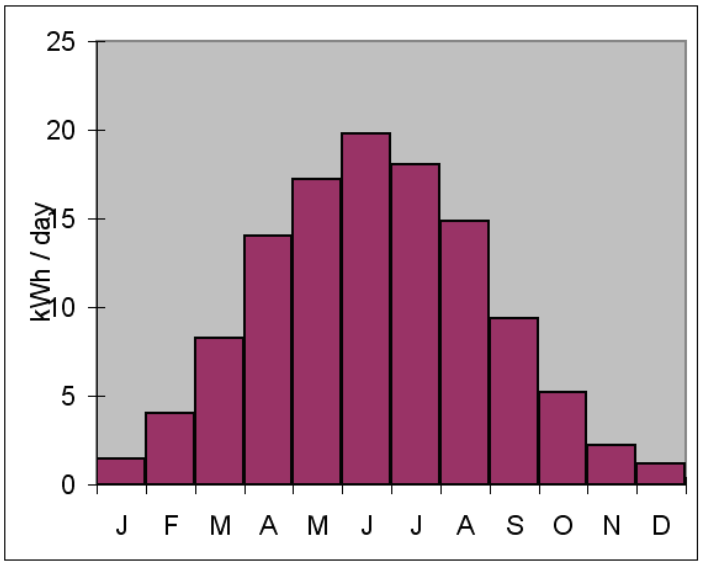

Figure 3: Month by month yield from one 4 kWp PV array in southern Scotland

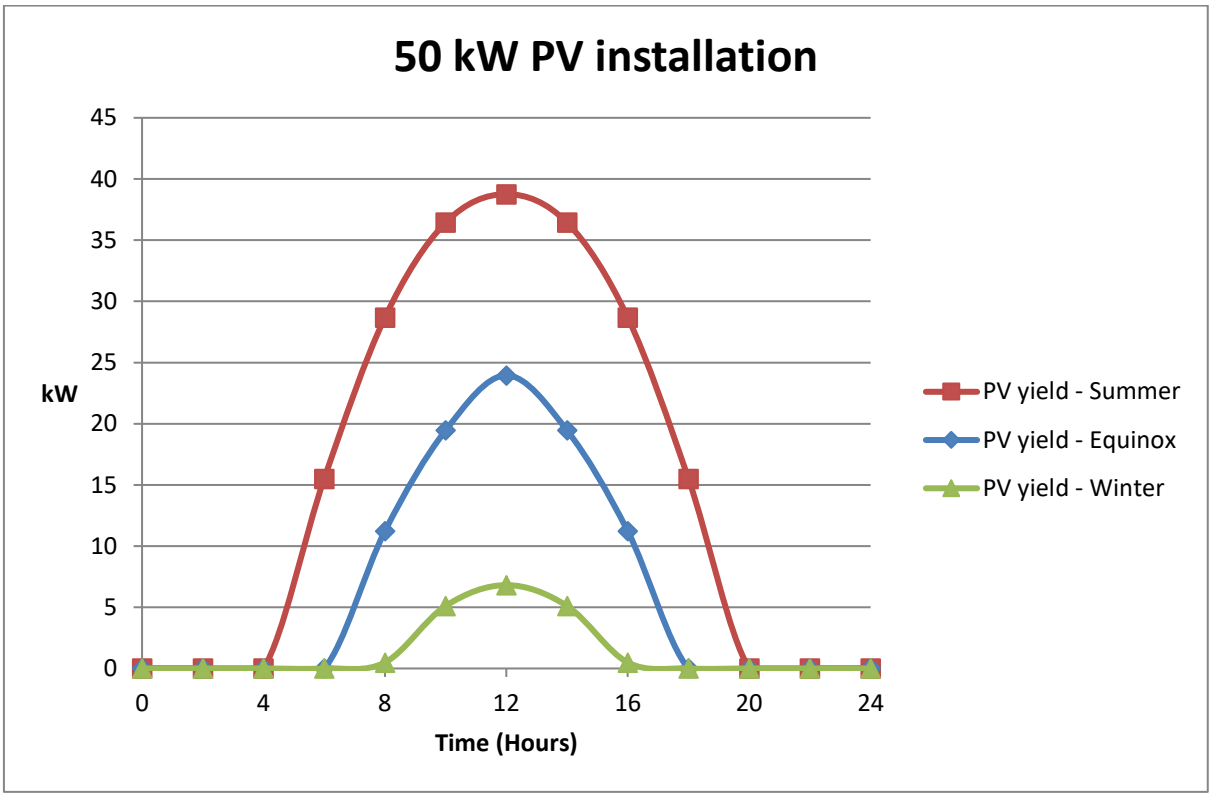

Figure 4: Average diurnal yield from a 50 kWp PV array in south west Scotland

Inverters

An inverter is required to convert the DC power produced by the panels to AC power for use on-site or for export to the grid. Grid connected systems also require that the AC current is synchronised with the grid and this task is normally taken care of within the inverter. Inverters can fail on occasion during the lifetime of the panels and consideration should be given to possible replacement costs when costing a project. Micro-inverters are a newer development for PV systems and include a small inverter for each individual panel. These are slightly more expensive but have a number of advantages;

- If an inverter fails the rest of the system will keep operating
- More efficient operation
- Individual panel yield can often be measured providing forewarning of panel failure
- Greater safety due to the lower currents involved in connecting cables

Roof mounting

Where panels are to be fixed to a building it is necessary to confirm the structural suitability of the building to support the extra load and any additional wind loads caused by the panels. Insurance companies should be consulted to confirm that the presence of panels will not affect the validity of any building insurance. Special fixings are available for different roofing materials and an installer

should be chosen with knowledge of the particular roofing type and fixings that will maintain the weather tightness of the roof used. The efficacy of insulated roofs should not be compromised by the use of inappropriate fixings. The safety of installers and any necessary future maintenance personnel should be given suitable consideration at the outset.

Planning permission

For small installations on houses or agricultural buildings planning permission may not be required, as these are usually classed as a permitted development. It is however wise to confirm this with your local planning department in advance as there are numerous situations such as within conversation areas, on listed buildings and on flatted properties where planning may be required. For larger field scale installations planning approval will be necessary and issues that will need to be addressed include; visual impact, wildlife habitats, protected species, construction access etc.

Grid Connection

Small installations with a maximum system output of 3.68 kW per phase or less can be connected to your existing wiring by an approved installer provided that the district network operator (DNO) is informed within 28 days. This could include 4 kW of PV panels and an inverter running at 92% efficiency. For larger systems permission must be obtained before a connection is made. Connecting systems of up to 50 kWp can be fairly straight forward where a 3 phase supply is available although any requirement to upgrade existing transformers should be checked in advance of committing to purchase of a system. As installation size increases potential connection problems will become greater. Many areas of Scotland also have constrained networks already operating at their design capacity and access to the network may require extensive upgrading to the local distribution network or the national transmission network. This can not only add huge costs to a potential project it can also result in substantial time delays (often of several years) before a new generator can be connected. Liaison with the local network operator at an early stage is advised. In order to be completely sure that a connection will be available when required it is necessary to have received an offer of connection including a connection date and have paid a deposit to secure the grid capacity.

Local Demand

Where a local demand exists for energy the income gained from a PV installation can often be enhanced by offsetting purchased electricity. Careful examination of the demand profile of the site with the estimated yield profile of the scheme will allow the financial benefits to be assessed. The yield pattern from a PV installation is well suited to summer cooling demands such as intensive

livestock buildings or cold stores for fruit for example. Smart controllers are available that will switch on local loads when panel output is high. Examples of the type of load where this could be appropriate is water heating where the water can be stored within a thermal store until required or ice building within refrigeration plant. Battery technologies or the generation of hydrogen are also developing areas that can help to make the most use of your renewable generation.

Revenue and funding

With the removal of incentive schemes such as the Feed-in-Tariff (FIT), the main drivers for small-medium farm scale renewables are to provide security against volatile energy markets, offsetting grid bought power and providing green opportunities from becoming more energy self-sufficient. Inflated energy prices can also help significantly lower the payback periods for farm renewables.

Income from a PV installation can be derived from the following sources;

- Sale of exported energy – either from a power purchase agreement (PPA) or from export tariffs such as Smart Export Guarantee (SEG).
- Savings on imported energy – energy used on site to offset imported energy will normally provide a greater saving than the export rate available.

For more info on SEG and other government schemes see:
https://www.ofgem.gov.uk/environmental-and-social-schemes

Land owners hosting large scale solar farms often lease the land to developers. Land rental income from this type of arrangement can be compared with income available from more traditional uses. Any costs associated with returning the land to agricultural use at the end of the project should be considered. In addition advice should be sought on the effect on an existing business of removing land from agricultural production which could have an effect on a number of issues including area payments and tax liabilities including inheritance tax. Developers typically are looking for large areas of non-prime agricultural land, with sites of around 100 acres for ground mounted systems and may offer payments of around £1000/acre, depending on the scheme.

Banks and financial institutions may offer favourable rates for loans on renewable and green projects. Further support may be available through schemes such as Business Energy Scotland, who offer a SME Loan and other cashback options, or Home Energy Scotland also offer similar smaller scale support if doing work to a residential property.

More info on Business Energy Scotland can be found here: https://businessenergyscotland.org/smeloan/ and more info on Home Energy Scotland can be found here: www.homeenergyscotland.org/funding/grants-loans/

Budget costs

The cost of PV panels has fallen in recent years and panels have become more efficient. Costs will vary depending on multiple factors including location, the size and type of scheme but typically installed price could be around £1000 - £1200/kW (based on quotes from 2022).

Business rates

Business rates in Scotland were reviewed in 2023, for the first time since 2017. Rateable value is not purely based on the size of the installation, as a number of other factors are taken into account. Once the basic parameters of a potential scheme are established it should be possible to estimate the likely rateable value. Solar developments could be eligible for relief which can result in a reduction in rates paid. The exact rates and reliefs can be subject to changes in government policy and legislation. To obtain accurate and up-to-date information on business rates for solar schemes in Scotland, it is recommended to contact the local assessor's office or consult with a qualified professional.

For more info on Renewable Energy Generation Relief see: https://www.mygov.scot/non-domestic-rates-relief/renewable-energy-generation-relief

Carbon Savings

The carbon saving attributable to any renewable energy generator will depend on the generation portfolio of the grid electricity that is offset. The electricity grid is becoming greener all the time as more renewables contribute to our electricity demand, but fossil fuels are still a major source. In 2022 the mean CO_2 intensity of the UK electricity grid was 182gCO_2/kWh. A 50 kWp PV array supplying an annual yield of 44,000 kWh annually would therefore have resulted in CO_2 savings of 8 tonnes of CO_2 in 2022.

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From more information visit: https://energysavingtrust.org.uk/advice/solar-panels/