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PHOTOVOLTAIC SYSTEMS

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Section 1. Is This for Me?

Since 2010 the installed capacity for PV Systems has grown from almost nothing to well over 13 GW in 2020. About 2.7 GW of this capacity comes from smaller (sub 4 kW) residential installations, installed on almost 1 million roofs.

There are over 17,000 PV systems in the Southwest, so it is likely that you already have a residential PV system. If you don't and are considering getting a small PV system, then this guide should help you make a more informed decision. It may also be useful for those who want to learn more about their existing system.

There is the usual quick guide if you don't have the time or inclination to delve into some of the details. You may already be familiar with many aspects of PV system choices, installation and operation. If not, or you want to find out a bit more about certain aspects, the technical details sections cover most of what you need to know to make an informed decision.

There are of course many guides and calculators you can use, we have referenced some of these. The aim here is to give you enough understanding to be able to apply the general information as accurately as possible to your circumstances.

We have focused on those technical aspects which have the biggest bearing on whether and what configuration PV system is 'best' for you. Many of these aspects will apply to larger systems, but these have additional considerations especially in a commercial context. You can contact us if you want more information on these.

Section 2. Concepts Related to PV Systems

Photo Voltaic (**PV**) systems generate electrical energy from the sun. You can use this energy on-site instead of buying it from the electricity grid, thereby saving on greenhouse gas (**GHG**) emissions and money spend on buying the electricity. How much you save will depend on many factors all of which you can calculate.

A few rules of thumb to consider, please see definitions in the TECs Energy Assessment Pack (**E-Pack**) for a full explanation of the units used here:

- The annual energy generated for a perfectly situated system in Teignbridge, when new is ~950 kWh for every 1 kWpk installed. Use this as a realistic starting point for your emissions and cost pay-back calculations. So, a 3.5 kWpk installation could generate 3,325 kWh p.a.

- PV systems produce ~80% of their energy output between April and September, so they are not useful to operate space heating system like Heat Pumps during the colder parts of the year.

- The average price per installed 1 kWpk is ~£1,200, this includes everything. This can vary significantly depending on many factors, not least the accessibility or type of roof you have.

- Most of the price you pay is for the labour associated with the installation rather than the PV system components.

Section 3. A Quick Answer

Almost anyone with a suitable roof should consider getting a solar PV system.

This is because it will almost always help reduce your GHG emissions. The way energy prices are going, a PV system is also likely to reduce your bills in the long-term.

There will be large variations in both emissions and financial pay-back. That is the time it takes the PV system to offset its embodied emissions and installation price. The following is a list of things to consider when making your decision. It is in order of significance with some explanatory notes, for a full explanation, please refer to the technical section of this guide.

1. **Permissions>** Rooftop systems generally come under permitted development, but worth checking on your Local Planning Authority's website. Connection to the electricity grid will also need to be checked, but this is done by your installer.

2. **Emission Saving>** You should make sure that there will be enough of a reduction in GHG emissions for the cost and effort. Too often you'll be given only the operating emissions savings. Even these will be over optimistic and based on incorrect consumption data or outdated/incomplete electricity grid Carbon Intensity.

3. **Financial Saving> The** initial outlay will depend on several factors to do with the system configuration/features and ease of installation. You need to know the time it takes to pay-back this initial capital expenditure which in turn depends on a realistic system performance and electricity consumption. Don't rely on the installer's generic calculations, even if these are regulated.

4. **Suitable Roof>** This aspect is well regulated with commercial apps, such as PVSol or ones provided by PV system manufacturers. These calculate likely system performance. The more South facing the better as is a roof slope of 30-40^{O}. Many systems, but not all, are much more tolerant of orientation and partial shading. Your roof material, loading and ease of access will be considered and priced by the installer.

5. **System Size>** Size matters! You don't want to over or under size the system. Most installers will size the system to fill the available roof area. This can sometimes be beneficial, but often not. The size should be based on your objectives and consumption patterns.

6. **Components>** Normally a PV system comprises the PV panels a grid-tied inverter, their fixings and the electrical wiring/switch/fuse/meter. You may want to consider adding a battery system. This is useful if your objective is to reduce your emissions. Please refer to the TECs guide on Residential Battery Systems.

7. **Manufacturer and Compatibility>** There are a confusing array of manufacturers and models for each of the system components. Most installers will have their 'preferred' tried and tested components to install which helps with their costs and ultimately the price you pay. If you have special requirements or want to integrate your PV system with other existing/future storage/smart electrical systems, your choice of installer/manufacturer may become more limited.

8. **Installer>** They should have appropriate professional registration although these are not onerous and only guarantee a minimal level of competence. Always research installers on the web, ask neighbours and friends and get at least 3 quotations. We'd suggest you go for local installers who have a good track record and survived the turmoil of the past 10 years. Sole traders can be as good as larger firms.

9. **Insurance and Warranties>** Selecting larger/local, well established installers and manufacturers is often the best warranty. The cost of replacing components has dropped significantly, so that the majority of cost for a repair/replacement will be the labour. Getting insurance backed warranties for labour costs makes sense. PV is a well-established technology where little goes wrong, but there are some caveats to this worth checking out.

10. **Operation and Maintenance>** You should get an app or display to monitor your system. It will help you learn how you use electricity and hopefully be more careful with not wasting it. A regular (monthly) check will help you monitor the performance and take early action to correct any issues.
    Cleaning is mostly not necessary, unless your panels are at a shallow angle, so the rain doesn't wash the dirt off as well. Dust, smoke, bird mess and tree resin are the main sources of reducing the amount of light that gets through to the silicon which converts this to electricity. So you may need to have the panels cleaned occasionally if you notice the performance dropping significantly enough.

If you'd like to understand more, please read on.

Section 4. The Technical Explanations, Calculations and Options

The following sections expand on the previous headings. The purpose here is to provide more detailed information, sometimes technically complex, to help you assess a new or existing PV system.

You may find some of the information provided in the TECs E-Pack and other TECs documents for members useful in understanding the concepts explained here, but please contact TECs for any clarification.

Pay-back calculation mentioned here, whether in terms of GHG emissions or financial, can be found in the appropriate section of the detailed E-Pack notes available to TECs members.

4.1 Permissions

It's worth making initial enquiries with limitation set by your local planning authority. You can find these on Teignbridge District Council website for advice and contact them if you have specific questions.

Normally connecting a residential size PV system (<4 kWpk) to the electricity grid is not a problem. You can connect larger systems, but these require explicit Western Power Distribution's approval which would be negotiated/obtained by the installer.

4.2 Reducing Emissions

Apart from savings on electricity bills, the main purpose of having a PV system is to reduce your emissions. After reducing Energy consumption, generating and using low-emissions electricity or heat, is the next most effective way to lowering your Carbon Footprint.

Measuring how much GHG emissions you are likely to avoid with a PV system is not as simple as it may first appear. Installers, using the government approved MCS calculations, will readily quote you an annual weight of avoided emissions. Although a standardised methodology, it may not represent actual values in practice. There are a number of reasons for this:

- The theoretical maximum generated electricity is assumed over the expected life (~20 years). In practice many systems perform less well than this and reduce year on year due to loss of performance and accumulated dirt. These may not be significant, but worth considering in your calculations.
  In the worst cases, you can assume that your system will generate 10-20% less Energy than claimed over its expected life.
- The emissions claimed are based on electricity generated, rather than electricity consumed on-site by you. It is only the electricity you consume from the system and therefore do not import from the grid that should be used to calculate the reduction in GHG emissions. What you export is calculated by the government towards the level of emissions of the grid (the annual Carbon Intensity). If you also claim this, there would be double accounting of avoided emissions.
  You can estimate the % of PV generation you are likely to consume on-site. Either the installer should do this for you or you can use information provided in the TECs E-Pack and Residential Battery Systems which involves analysing smart metering data. For most situations, on-site consumption is as low as ~20%. This one of the reasons you should consider a battery system to increase avoided emissions.
- The calculations are based on an average grid Carbon Intensity. This is published annually by the government and has tended to reduce year on year as the grid decarbonises. That means the amount of avoided emissions is reducing year on year. However, the annual Carbon Intensity

published does not include emissions generated outside the UK, so extracting the fossil fuels (mainly natural gas) and transporting it.
It is difficult to predict the ongoing reduction in Carbon Intensity for electricity as we decarbonise. More renewables would further decrease this, but more demand for electricity may slow or even reverse this. The E-Pack apps use the latest published data on Carbon Intensity year on year, including emissions from imported fuels. You can use these to get an idea of trends and of course accurately calculate you actual historic avoided emissions.

- The emissions associated with manufacturing and shipping the PV system components, the embodied emissions, are not normally considered. There are significant variations in these depending on:
    - The Carbon Intensity of the manufacturing process, especially the manufacture of the Silicon material which requires high temperatures.
    - Monocrystalline silicon is more energy intensive to manufacture than polycrystalline wafers. This is because of the higher levels of waste when selecting wafers with the highest structural purity.
    - Shipping emissions will have their contribution and are related to transport miles. This is normally less of a factor than the Silicon wafer production emissions.

  It is sometimes possible to find out what low-emission claims are made for PV system components, but this is quite difficult to establish and verify. Some studies have suggested a range of ~25 -100 g CO2e per kWh generated over the expected life of the system (~20 years). This is a relatively high level of embodied emissions compared to all other renewable technologies. It is low compared to current UK grid electricity which is ~250 g CO2e per kWh which itself has come down from ~600 g Co2e per kWh about 8 years ago.

  In most cases for today's systems, residential PV systems will have a GHG emission pay-back period of 2-5 years. It is therefore worth making the effort to select system components with the lowest possible embodied emissions and ensure a design that maximises on-site electricity consumption and so as to minimise overall emissions.

4.3 Financial Saving

You will want to know the likely initial outlay and any ongoing costs/charges as well as the time it takes to recover these from the savings on your electricity bill, the financial pay-back time. You may also want to calculate the financial cost of the emissions avoided, in £/tonne of GHG. This can help you decide whether PV panels are the most cost-effective way of reducing your emissions.

To calculate these, you will need the same Energy data as those used to calculate GHG emissions avoided. The energy generated by the PV system and the energy consumed by you will be needed. If you have access to a smart meter, you can analyse the consumption data and the patterns for your normal consumption. The PV generation data can be determined using PV system planning tools, normally provided by the installer.

Instead of using Carbon Intensity though, you need the unit price for the electricity you buy. You would also need to make assumptions about future prices for grid electricity, typically these have increased by 0.05 – 1.5 % above inflation.

Since the end of the Feed-in-Tariff (**FiT**) incentive scheme, retail electricity operators are obliged to offer a Smart Export Guarantee (**SEG**). FiT rates were very generous, initially ~45p/kWh generated, while SEG will always be below the wholesale price for electricity ~5p/kWh.

Nevertheless, most PV systems will pay-back the capital invested within 7-13 years, well within the expected life of the system which is at least 20 years and often 30 years or more.

4.4 Suitable Roof

Most PV systems will be roof mounted because they are normally considered to be permitted development so do not require planning permission, see section on permissions. Roofs also tend to be unused surfaces, so mounting PV panels will not take away or interfere with otherwise useful areas.

Systems can also be ground mounted, these have several advantages but may interfere with the land use they occupy. Because they are considered to be a 'change of use', they will require planning consent.

The following are things to consider and find out about in relation to roof mounted PV systems, many will also apply to ground mounted systems:

- The optimal orientation is south facing with an angle of inclination of 30-40^{O}. There is quite a lot of tolerance on this as the performance only reduces gradually. Flat roofs work too, but they tend to be more challenging and require planning consent. You can use calculators to work out the drop-off in electrical energy output or ask the installer to provide this.
- PV panels are not heavy at ~20 kg, but having 10-20 of these on the roof can add up. Depending on the orientation and prevailing wind as well as the space underneath, additional loads will add to the structural loads on the roof. Installers normally perform a structural survey using qualified assessors, but check that is the case and the installation is guaranteed for damage caused to the roof structure and PV system.
- The roof material and its age can have an impact on the installation costs. Slate roofs tend to be the most difficult and prone to leaks, although more modern fixings have overcome many of the associated problems.
  You should consider the state of your roof and whether it is likely to need repair or replacement within the expected life of the PV system. It is possible to temporarily remove part or all of the PV panels, but you need to consider the additional costs. It is likely that these will not be significant in comparison to a roof repair.
- Shading used to have a significant impact on the overall performance of a PV system. Even partial shading of one panel could reduce the output of all panels in a series-connected 'string' of panels. More modern systems can now reduce this impact significantly. The installer should be able to advise you on this and what impact any shading may have.
  Installers use modelling software packages to calculate system performance for all aspects, but these have to be correctly entered. Make sure your installer is using a suitable modelling package and has correctly entered all the parameters.
- It is likely that you will need scaffolding for the installation. The higher the roof, the more costly the scaffolding, so make sure you know the price in advance. Roof access will also have an impact on ongoing maintenance, see later section on this.

4.5 System Size

The size of a PV system is given in kWhpk. The pk stands for peak Power the PV panels generate under ideal conditions. That is perfect orientation towards the sun and cloudless, clear skies. These conditions are quite rare, so your system will only occasionally reach its peak Power output.

This is not a something to be overly concerned about as it is the total expected Energy per year or day (seasonally adjusted) that is important. It is the Energy produced that avoids GHG emissions and costs by not importing grid electricity.

Normally installers will oversize the peak output of the PV panels for reason above. They avoid exceeding WPD's limit of a nominal 3.68 kW per phase (16 Amps at 230 Volts) being exported by restricting the output from the inverter, see system components. Typically, installers will suggest maximising the number of panels to fit the available roof space.

It is true that a few additional panels should not increase the overall cost significantly. They would also result in additional Energy generation, even when the inverter limits the output to below peak. However, there comes a point when the system is generating significant excess Energy which cannot be used on-site. Why have a PV system if 80% or more of what is generated is exported to the grid?

This over generation can be compensated with an appropriately sized residential battery system. A good option in terms of emission avoidance, provided it is correctly sized, which it often isn't. A battery system will also increase capital costs to make pay-back periods within their expected life very challenging.

4.6 Components

PV systems are now very well established and optimised technologies. Mass production has allowed a significant improvement in quality, functionality as well as lowering costs and GHG emissions. The main components of a PV system are:

- PV panels which come in different peak Power output, efficiency, colour/shading, quality of materials and assembly. Here are some things to be aware of:
    - Peak power and panel efficiency are not as important a feature as is sometimes made out. This can vary significantly, but the important factor is the relation between available roof area and required annual energy output. Paying extra for high efficiency panels, with the likely increase in embodied emissions, should only be considered where there is limited roof area to mount these.
    - Blue panels tend to be more efficient for the same area than black ones. Black is sometimes required by planners to lessen their visual impact, but these tend to show up the contrasting silver tracks that criss-cross many black panels. A darker, matching frame colour goes some way to reducing the visual impact and tend not to add cost. Chose a quality manufacturer where the frame colouring does not peal or fade.
    - The most important feature of the PV panels is quality of materials and manufacture. See section on Warranties.
- Most systems will be connected to the electricity grid, so will have a grid-tied inverter licenced for operation in the UK. These have become commodity items like PV panels, prices have come down and longevity has improved, largely removing the need to get long-term insurance cover. They have also become more efficient in converting the electrical output of the PV panels to supply your house and grid with compatible 'mains' electricity.
  Inverters come with many sophisticated features to control, monitor and report on the PV system. It is worthwhile considering what feature may be useful for your circumstances and degree of engagement in understanding how you consume electrical energy.
- Roof fixings can be important on difficult roofs such as slate tiles. Ensure that you have the best possible fixing and more importantly a labour/installation warranty, even the best fixings can be poorly installed.

Other ancillary components include wiring connectors and a generation meter. These tend to be quite standard. These separate PV generation meters were required for the FiT scheme. They may not be necessary for you to get a record of your system's performance as the inverter can provide this information, albeit not for official metering purposes. So if you want to get paid for exporting electricity to the grid, you will need to have a smart meter installed.

- Battery systems are a common adjunct to PV systems, there are some overall cost advantages, including lower VAT, if you install both a PV and battery system.
  Other additional components include switches to allow continued operation of your PV system when the grid fails, usually this would include a battery. Please refer to the Residential Battery System paper which describes many of these components.

4.7 Manufacturer and Compatibility

Although there are a very large number of manufacturers for the various system components, there are only a small number of larger, well established ones. Although products from the list of manufacturers below are readily available in the UK, your chosen installer may not offer you the choice. This is because installers tend to specialise in installing certain kit to keep costs down. It is worth asking if you have certain preference for low embodied emissions or specific features.

In general, those manufacturers that provide clear and comprehensive data on their products, including embodied emissions, are likely to at least be aware of the need to decarbonise. Price will often persuade us to opt for a particular make/model, it is best to focus on quality, longevity and features as these systems need to last several decades.

Many will already have an existing PV system, so may be considering adding more panels or a battery. You may also be considering smart controllers to manage how/when you use your electricity. If this is the case, make sure that the different makes and models are compatible and can interoperate as required and are future-proof with published interfaces. Be wary of installers who suggest ripping out the old system to put in a new, make sure you understand why and ask if others can keep the older components.

Here is a list of the most common manufacturers used in the UK, this is not a complete list nor is it a recommendation to use them. You should do your own research as things do change:

<list + brief comment and reference>

4.8 Installer

As for PV system components, the plethora of installers that existed during the heydays of the FiT subsidies has been drastically reduced. Most of those who have survived the turmoil of changes in government policies and other market forces deserve to be there because they probably provide a good service.

It is possible to categorise installers into three types:

- Local, sole trader, usually someone with an electrical background. They tend to hire local labour especially for the mounting of PV panels on the roof. They are a good option as they can be quite flexible, provided they have been around for a while with a good track record and reputation.
- Regional specialists in renewables or even just PV/battery systems. Ideal for more complicated configuration/design to ensure that the system matches your requirements.

- Large national installers can offer very competitive prices. If you simply want a PV system and are more concerned about the price, they may be the better option, but you will get a standard installation.

It is normally best to go for a local installer as you have a higher degree of comeback if things go wrong. They have a local reputation to protect and you can more easily find out about them and their installations. Using local installers is also good to maintain the skills and support the economy in your area.

Like with any outlay of the likely magnitude, you should shop around, get recommendations and most importantly ask at least 3 installers to quote. Here is a list of some local installers, again this is not complete and is most definitely not a recommendation:

<list and links>

4.9 Insurance and Warranties

In general, use an established manufacturer and installer as described in the sections above. All should provide a performance or installation warranty. These warranties are only valid while the company exists and needs to protect its reputation. Some offer an independent insurance backed warranty which adds a degree of confidence.

Read the warranties carefully as they may have significant exclusion clauses. Some warranties will only provide fixed financial compensation if a fault develops, especially after several years. This may cover the material and labour costs, but often only covers material replacement.

Getting additional insurance is an option, but only consider this if you have unusually high risk such as theft. You may also need to inform your building insurance of the existence of panels, this may have implication on your cover and the premium you pay.

4.10 Operation and Maintenance

It is likely that your panels will require cleaning during their expected life, some annually, but most only every few years. You can monitor the annual output to check this as it should not vary by more than 2-4% year on year. Panels on higher or inaccessible roofs more can become costly to clean.

The flatter the panel the less effective rain is in cleaning the dust and other dirt that will inevitably settle on the them. The biggest problem though, comes from excessive dirt from birds, especially those roosting at the top edge of panels. You can fit bird-spikes as a deterrent, but make sure they are sufficiently angled so as not to shade the panels.

Normally no other maintenance is required, so don't fall for the sales pitch that your system is due for its "annual check-up". It does help to monitor the performance of your PV system monthly and contact the installer if you think there is a problem.

The E-Pack provides you with facilities to monitor the performance of your system so you can accurately calculate the actual emissions and cost pay-back. You can also look at comparative performance data to assess your system against others in the Southwest.