SOLAR POWER
– For PV

PV panels have become a common sight on roofs all over the country. For that, credit is due both to the Chinese, who make most of the world's PV cells, and to the former Coalition government, which introduced a Feed-In Tariff scheme that offered very generous rewards for producing PV electricity. Unfortunately, the FIT scheme no longer offers juicy fat carrots for new installations, only shrunken ones. (I'll be writing about the PV Feed-In Tariffs in a later issue.)

For a selfbuilder, there is also the stick to be considered, that stick being requirements in the Standard Assessment Procedure (SAP) of the building regulations. The 'Fabric First' approach to house design makes the stick irrelevant – no PV is required. But if insulation and airtightness are more modest, then PV is an obvious way to reduce both carbon emissions and primary energy consumption, and thereby satisfy the SAP requirements. (What will be the requirements for the 2016 edition of the Standard Assessment Procedure? See the Aside, below.) Of course, best of all is to go for the Fabric First approach and PV – they are not exclusive!

I wrote about PV electricity in the March 2008 issue, and the Feed-In Tariff scheme in July 2010. It's time to review the whole topic. There are now more options to consider, and deciding the optimum size and orientation for a PV system is more difficult.

Solar irradiance

Irradiance is the technical term for the intensity of radiation. (Units: W/m^2, with the radiation being perpendicular to the area.) In our context, irradiance is a measure of the solar power at any given moment at any given spot.

At any particular time and place, the solar irradiance is determined by:

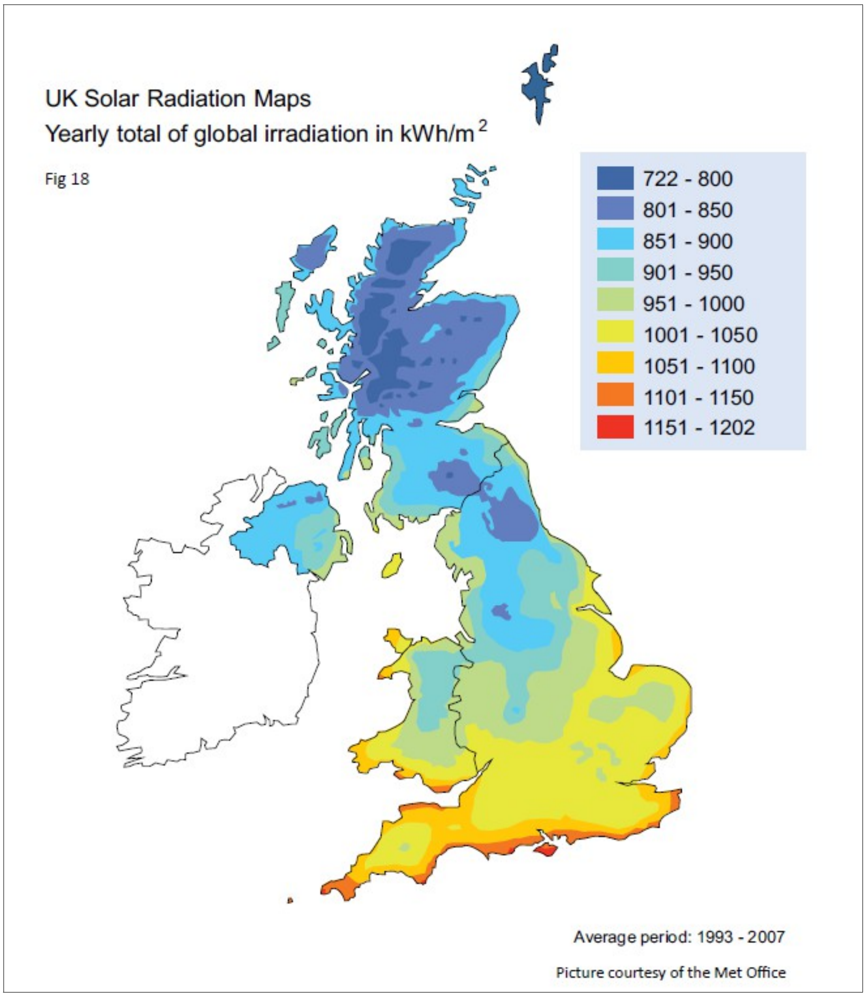
- *Length of the sunbeam's path through the earth's atmosphere.*
  This varies with the elevation of the sun in the sky, which, as we all know, varies with the time of day and season.
  In its passage through the atmosphere, some solar radiation gets absorbed, and some gets reflected away into space. The effect is quantified by considering the 'air mass' that the sunbeam passes through. When the sun is directly overhead at noon (in the tropics), the air mass has the value 1. In England/Wales, at noon midsummer the airmass is about 1.1 (elevation 62°). But at noon midwinter the airmass is about 4.0 (elevation 15°), and this results in the power of the sunbeam being approximately halved, compared to noon, midsummer.
  Above the atmosphere, the solar irradiation is about 1,370 W/m^2. At ground level in the UK, the irradiation is generally reduced to about 1,000 W/m^2 – with a clear sky, around noon, in the summertime. (Though on an exceptionally clear day, the irradiance can be higher, even, it is said, as high as 1,200 W/m^2.)

- *Cloud cover.*
  When the sun is obscured by cloud, the irradiance received at ground level has been reflected inside the clouds – and is much weaker.
  For a 'standard' overcast sky, light comes equally from all angles – including

northerly ones. (Approximately half the energy in the solar spectrum comes as light.)

- *Shading.*
  Trees, buildings, and the like can cause part of a PV panel to be in the shade for some of the time. Because of the way that PV panels work, shading causes a much greater reduction in the electrical output than would be expected by a simple consideration of the area shaded.
  Shading can be 'soft' – from trees, buildings, etc – or 'hard' – from leaves, etc, lying on a panel. Hard shading can cause a 'hot spot', and this can drastically reduce PV output. (In the past, hot spots even caused panels to catch fire, though that should not be possible with modern panels.)

The product of irradiance times duration gives the irradiation – or solar energy – over that duration. The map below shows the yearly solar irradiation for the UK.



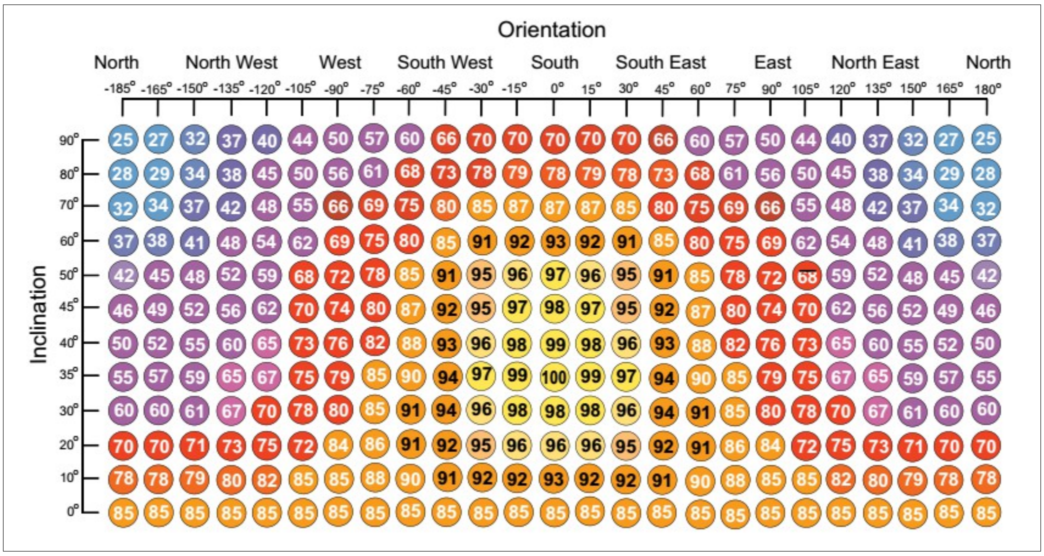
Yearly solar irradiation for UK

(Source: *Guide to the Installation of Photovoltaic Systems* – see Further Info.)

The yearly irradiation for the Shetlands in the north is two thirds that of the Isle of Wight in the south. Coastal areas are generally sunnier than inland.

Inclination and Orientation

When a PV system is to be installed, a common objective is to maximise the solar energy harvest over the course of a year. For this, the roof should face south. And it should have a pitch of 30° to 40° – which fortuitously most roofs do.



Relative variation of annual PV output with orientation and inclination (pitch)

(Source: *Guide to the Installation of Photovoltaic Systems*.)

As the diagram above shows, the optimum roof pitch is 35°, facing south. (Output: 100%.) But if the roof faces SE or SW, the reduction in output is only 6%; facing east or west the reduction is 21%. For flat roofs, the reduction is 15%. And a vertical, south facing wall receives 30% less than the maximum possible on a roof.

But is your intent to maximise your PV harvest over the course of a year? With the generous FIT generation tariff of the past, maximising the PV energy harvest was the simple and obvious objective. With today's greatly reduced generation tariff, that simple objective may no longer hold. Deciding the best size and orientation for an array is now a more complex matter, as we shall see in a later article.

Annual PV output

The government sponsored organisation known as the Microgeneration Certification Scheme (MCS) publish the Guide to the Installation of Photovoltaic Systems. (See Further Info.) The Guide gives a method for estimating annual PV output:

Annual PV output (kWh) = Array size (kWp) x Kk x SF

(Wp: peak watts – see later.)

The UK is divided into 21 regions (as used in SAP and based on postcodes), and 21 tables in the Guide give the value of Kk according to the inclination and orientation of the array. SF is a Shading Factor, which is 1 if the array is unshaded throughout the day, even in midwinter.

Let's consider a largish, 4kWp array with an area of about 26m^2. Assume it is facing south on a roof with a 35° pitch which is unshaded throughout the day. And let's consider it to be situated at two extremes of the country: either the Isle of Wight, off the south coast, or the Shetlands, the northern-most islands of Scotland.

From the tables in the Guide:

Kk = 1,021 kWh/kWp for the Isle of Wight,
and Kk = 712 kWh/kWp for the Shetlands.

If SF= 1,

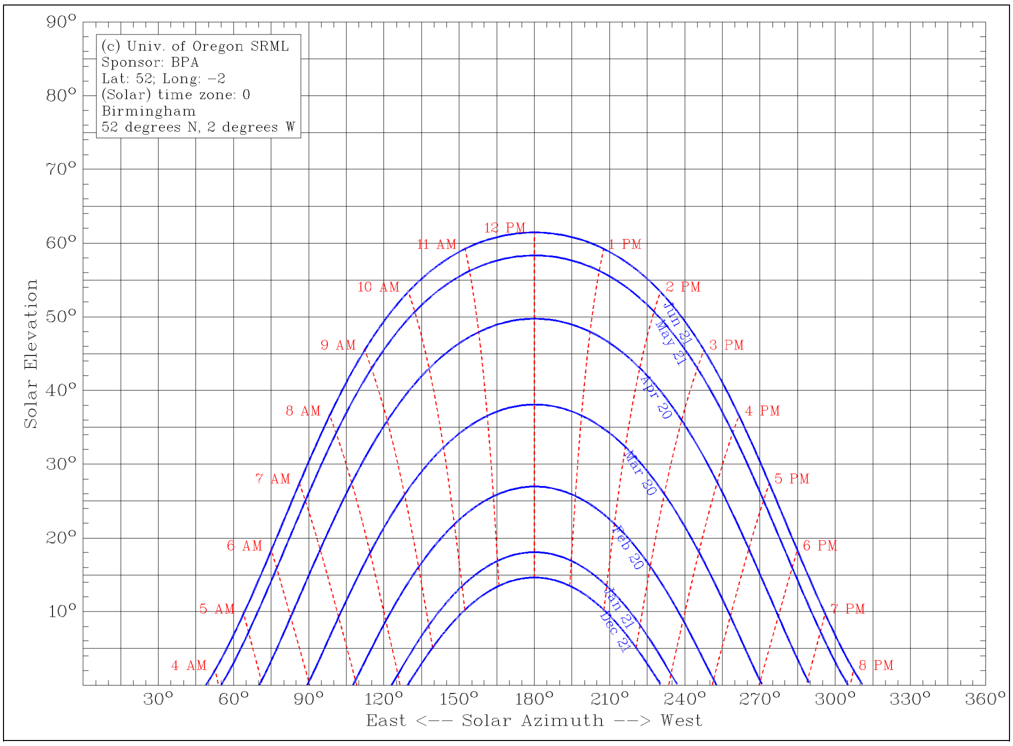
Expected annual PV output for the Isle of Wight = 4 x 1,021 x 1
= 4,084 kWh.

Expected annual PV output for the Shetlands = 4 x 712 x 1
= 2,848 kWh.

(For comparison, the average household usage of electricity is 3,800 kWh a year.)

Shading

In the above, the Shading Factor has been assumed to be 1. In fact, the calculation of the Shading Factor is complex. But some intuitive assessment of the degree of shading over the seasons can be derived by using a sun path diagram, such as the one below for Birmingham (Latitude: 52°N, Longitude: 2°W). At what different times of the day and season will obstructions be hiding the sun from the panels?



Sun path diagram for Birmingham (UK)

(Source: Oregon University – see Further Info.)

In Birmingham at noon midsummer, the sun has an elevation of 62°; but at noon midwinter, the elevation is only 15° – neighbouring trees or buildings might well shade the panels. And don't forget that a nearby sapling might grow into a tall tree!

Shading by a building's own chimney, vent pipe, satellite dish, etc, should be avoided if at all possible – this shading has a much greater impact on the Shading Factor than would be expected from its area of shadow.

If a PV survey shows that SF = 1, then you are very fortunate – or the surveyor has been lazy! If the Shading Factor is below 0.7, then fitting a PV system may not be worthwhile. (The MCS Guide gives a method for finding the Shading Factor using a sun path diagram.)

The hours of daylight in midsummer are about twice as long as in midwinter: 4am to 8pm (GMT) in summer, compared to 8am to 4pm in winter.

Measurements show that the average daily irradiance in December is about a quarter of that in June. In practice, PV output might be reduced by more than this because of increased shading in December. (Last month, we saw in my article about the 'Build Beside the Seaside' that the PV output for December was only a tenth of that for June. Though the PV panels face south, in midwinter the sun is above the trees on the brow of a hill for only a short time.)

The power and energy of PV

Many PV panels are rated at 250 Wp – under 'Standard Test Conditions' (STC) the panel will deliver 250 Watts. This is its so-called 'peak' output, though under extra bright irradiance its output might be higher.

STC is equivalent to:

- Bright sunlight with an irradiance of 1,000 W/m^2.
- A spectrum distribution equivalent to that of an air mass of 1.5.
  (The air mass is a measure of the length of the sun beam's path through the atmosphere, and is very much influenced by the inclination of the sun.)
- Cell temperature of 25°C. (PV output falls with an increase in cell temperature.)

So an array of 16 such panels under peak irradiance could deliver 4,000 Watts, ie, 4kWp. (4,000 = 16 x 250.)

In Southern England (where Kk = 1,000, very approximately), a 4kWp system mounted in a good position might deliver in total about 4,000 kWh of electrical energy a year. (4,000 = 4 x 1,000.)

See the Footnote for more about these two quantities, power and energy, which are often confused.

One last thought

Don't let the pitch, orientation and area of the PV roof determine your house design. Solar harvesting is only one factor amongst many. And as we will see in a later article, facing south is not necessarily the best option.

Next month: PV Systems.

FOOTNOTE: **Power and Energy**

Power:

There is a simple connection between electrical power, amps and volts:

Electrical power = amps x volts.

As an example of the use of this equation, let's find the maximum power that can be delivered through a 13-amp mains plug. The nominal mains voltage is 230 volts, so:

Maximum power = 13 x 230 watts
= 2,990 watts
≈ 3.0 kW.

The most power-hungry, domestic appliances are electric kettles, some of which are rated at 3kW – but not more.

Energy:

What a householder purchases from an electricity company is electrical energy, which is measured simplistically in 'units'. A unit is 1 kilowatt-hour (kWh), ie, a kilowatt of power being used for an hour.

In a future article we'll be looking at battery storage for PV energy. As a lead into that, let's consider how much energy is stored in the starter motor of a car. A typical 12-volt starter motor has a capacity of 80 amp-hours. In theory, it could deliver 80 amps for one hour. During that hour, the power output would be 80 x 12 watts, ie, 960 watts. So the energy stored by the battery is 0.96 kWh.

Food, too, at its most basic is an energy store. How much energy is there in a 500g packet of digestive biscuits? Printed on a packet is information such as '2,000 joules per 100g'. So the 500g packet gives 10,000 joules of energy. Out of curiosity, let's convert that to kWh.

A 'joule' is a name for 1 watt.second.

1 kWh = 1,000 watt.hours
= 1,000 x 60 x 60 watt.seconds
= 3,600,000 joules.

So the packet of biscuits gives 10,000 / 3,600,000 kWh of energy, ie, 0.0028 kWh.

Is that interesting, or not? – Perhaps not. But the point I am trying to get across is the nature of 'energy' in a technical sense.

ASIDE: **Whither SAP 2016?**

The last revision of the Standard Assessment Procedure was SAP 2012, which was a feeble tightening up of SAP in the UK's progress towards Zero Carbon by 2016. But last year, the Government abandoned that target. In prospect, though, was the EU Directive that by 2020 all new buildings were to be 'nearly zero energy'.

Now that the UK is leaving the EU, that directive will no longer apply, and no doubt it will be one of the pieces of 'red tape' that the new government will be pleased to be rid of.

Prior to Brexit, SAP 2016 would have had to be a substantial step towards 'nearly zero energy' in 2020. But if the 'nearly zero' target is abandoned by the new government, I suspect that the SAP 2016 revision will be another feeble tightening up of the energy and carbon standards. (The draft edition of SAP 2016 is overdue. Might it become SAP 2017 instead? BRE produce SAP. They must be in a quandary right now as to how to proceed.)

Anyway, I suspect that by 2021, the UK will be having the dirtiest house builders in Europe – with the honourable exception of selfbuilders, of course.

FURTHER INFO:

Guide to the Installation of Photovoltaic Systems
Published 2012 by MCS (Microgeneration Certification Scheme).
124 pages. Free download (for the technically inclined):
www.microgenerationcertification.org.

University of Oregon USA – Solar Radiation Monitoring Laboratory
Create a sun path diagram for anywhere in the world:
http://solardat.uoregon.edu/SunChartProgram.html.

National Solar Centre
The NSC is located at the Eden Project in Cornwall. It is a new offshoot of BRE.
https://www.bre.co.uk/nsc.

Words: 2271.