Introduction

The sun is the source of most renewable energy. For many years researchers have been striving to develop methods of turning sunlight into electricity with high efficiency at low cost. In 1833 Charles Fritts constructed the first true photovoltaic (PV) cell capable of generating solar electricity using slithers of selenium but his device had an efficiency of less than one percent. Modern PV equipment has much higher efficiencies and can generate electricity in overcast conditions.

PV panels or tiles can be built into the fabric of a building, or bolted on afterwards. A variety of products are available, with differing performance and weight, the latter being important when retrofitting large areas of PV to roofs.

PV is expensive compared to other renewable energy technologies, but offers the advantage of generating electricity simply and silently. PV is not used for commercial power generation in the UK as very large areas would be needed to generate significant amounts of energy. However it is well suited to building integrated power generation and can make a significant contribution to the electricity needs of a wide range of different buildings, especially when combined with high efficiency lights and appliances.

Figure 1.
Framed PV modules

Figure 2.
A PV roofing system

South West Resource

Many PV systems provide power to isolated equipment and are therefore off-grid. This makes it difficult to estimate total power production. The International Energy Agency states that PV produced 17 GWh in 1990 and that this increased to 361 GWh in 2002, thus achieving 29% annual growth. This makes it the fastest growing sustainable energy technology. Germany alone produces 188 GWh/year from PV.

The UK has a relatively low exploitable solar resource compared with other countries, with an average annual solar insolation figure of 40kWh/m^{2}day compared to 65 kWh/m^{2}day in Madrid. However, the South West receives the highest levels of solar radiation in the UK - up to 1300kWh/m^2 on a solar collector inclined at 30° facing due South, compared to only 900 kWh/m^2 in Scotland.
The REvision 2010 report estimates that 1000 PV installations could be installed in the region by 2010 with a total capacity of 2 MW.

Technology

PV systems are usually modular, allowing almost any area of roof to be used. PV modules can be mounted in frames then fixed to a roof, facade or a pole (**Figure 1**), or integrated into the building fabric in the form of roofing tiles or other elements (**Figure 2**). Integrated systems tend to be more costly and have lower efficiencies but have less visual impact. A third option is to use very thin, flexible sheets of PV material bonded to the roof or integrated into glazing (**Figure 3**). **See case study 10 for examples of PV systems from the region.**

Figure 3.
PV can be incorporated into glazing to provide shading and electricity.

PV modules must be properly angled and orientated for the best performance. A reasonable compromise is to use an angle of 30-40° to the horizontal, facing between southeast and southwest. North facing facades are best avoided.

Most PV cells are made from silicon, which is an insulator. Adding a small amount of another substance such as boron or arsenic, produces a material with either an excess or a deficiency of electrons. Light shining on a junction of the two materials produces a small electric current. There are three main types of silicon based PV:

- **Mono-crystalline** - expensive, but with good cell efficiency
- **Polycrystalline** - cheaper to manufacture but lower cell efficiency
- **Amorphous** - cheapest to produce, but with the lowest efficiency, however can be made into light weight flexible sheets which can be bonded onto roofs

A number of non-silicon based PV systems are now being developed.
An individual PV cell only produces a very small amount of electricity, so cells are usually grouped into modules to provide a higher voltage. The modules are then linked together to provide a useful amount of power. Because PV cells produce direct current (dc) an inverter is used to convert this to alternating current (ac) at 240 volts for use in the home or export to the grid. The capacity of a PV system is usually given in terms of the peak power in kW the device could produce, and is termed kWpeak or kWp. The relative performance of the types of cells is illustrated in the table below.

Type	Efficiency (%)	Area required to mount 1 kWpeak (m^2)
Mono-crystalline	13-17	8
Poly-crystalline	8-12	10
Amorphous	4-8	20

Table 1 Efficiency of different PV technologies Source London RE tool kit

Issues

Common issues about PV installations are:

- **Vandalism**. In some areas it might be necessary to consider the potential for vandalism of the fragile modules.
- **Visual Impact**. If a system of inclined panels is mounted on a flat roof of a tall building it may not be visible. Framed systems on tiled roofs will be visible because of their blue colour and reflections from glass covers and aluminium frame. Integrated systems which follow the tiling line are far less visible. Some individuals, schools and businesses may decide to design systems so as to make a visual statement.
- **Ecological Impact**. There are some concerns over the chemicals and manufacturing techniques used in the production of the cells.
- **Energy and Cost Payback**. A PV system should pay back the energy used in its manufacture within around three years. However, currently PV systems usually never payback the capital cost without major subsidy.

Maintenance

PV modules have very few maintenance requirements, although there have been problems with inverters. Rain usually keeps the cells clean. PV modules are expected to last 18-40 years although most systems have yet to see a life time of use so this is difficult to judge.

Planning Permission

Depending on the technology type the householder wishes to install and the age and location of the house, it may be that planning permission will be required, especially if it is a listed building or in a conservation area. It is best to talk to the local planning department before starting the project as there may be local issues to overcome. Providing them with details of the technology, its scale and location will ease the planning application process.

Connecting to the Grid

PV systems can be connected to the grid via an electronic control unit and the consumer unit (fuse box) in a house. Top-up electricity is imported from the grid and surplus electricity is exported. An export meter (costing around £150) is required to sell surplus electricity to a purchasing company for around 2.5p per kWh. In addition, Renewable Obligation Certificates or ROCs can be claimed and sold via a third party. Some electricity suppliers now have tariffs for customers with renewable electricity systems and will trade ROCs on the customers behalf and provide a credit for each unit of electricity generated.

Small PV arrays can also be used to charge batteries, although normally only in off-grid properties using a diesel generator. Batteries can typically store two to three days worth of electricity.

Finance

As with any micro-renewable energy project, the first stage is to estimate the demand for energy and then try to minimise demand through conservation and energy efficiency measures. The PV system can be sized to meet the reduced maximum demand of the building, or some proportion of it. It is common to export any excess PV electricity via a grid connection and import electricity when the PV system is not providing enough electricity.

Example Calculation

A typical new, gas-heated four bed roomed terraced house uses approximately 2,500kWh/year for lights and appliances. Assume half this demand will be met from PV. In the UK 1 kWpeak of installed PV will generate around 750 kWh/year and each kWpeak will require 10 m^2 of space if poly-crystalline modules are used. Thus the house would require a system of size 1.7 kWpeak (calculated as (2500/750) x ½), which would take up 1.7 x 10 =17 m^2 of roof. PV costs are about £7,000/kWpeak installed for a non-integrated system . Thus the system would cost around £11,900 to provide about half the electricity required by the house. Costs would be higher for integrated PV modules.

Note: the average annual electricity use per year in the UK is around 4,400 kWh (including older homes and homes heated by electricity), illustrating the importance of addressing energy efficiency before investing in PV.

Sizing Tools

A very simple but approximate sizing tool for schools is available for free download from The Centre for Energy and the Environment (www.ex.ac.uk/cee/re). For homes and other buildings there is a much more complicated but more accurate free sizing tool from RETSCREEN at www.retscreen.net/ang/t_software.php .

Costs and Grants

Various grant schemes are available for home owners, farmers and other businesses. Under the DTI's Low Carbon Buildings Programme grants of £3,000/kWp installed are available:

- households: to a maximum of £15,000 subject to an overall 50% limit of the installed cost (excluding VAT)
- larger buildings: to a maximum of 40-50% of total costs (excluding VAT).

For more details see Grants section.

More Information

Regen SW maintains a list of installers on its web site: www.regensw.co.uk/directory

See the case studies section for examples.
Various EST guides are available at (www.est.co.uk/myhome/publications/):
For more information see the British Photovoltaic Association's web site: www.greenenergy.org.uk/pvuk2/about/index.html

For information on connecting to and exporting to the grid see: www.quietrevolution.co.uk/downloads.htm

Companion Guide to PPS 22: The technical annexes Also has information on PV available at www.odpm.gov.uk/planning