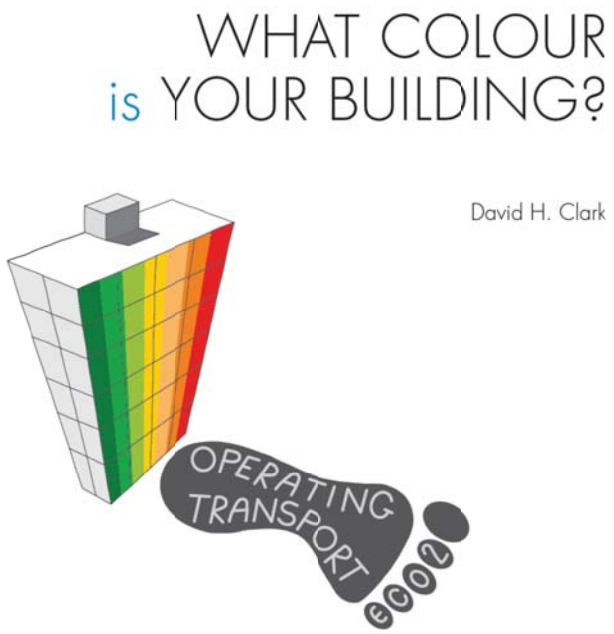
Information paper – 24

Photovoltaic panel types and efficiencies

Prepared by:
David Clark

A paper referenced in the book:



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This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

Photovoltaic panel types and efficiencies

This information paper provides a brief overview of the types of photovoltaic panels and their efficiencies.

1. HOW DO THEY WORK?

A solar cell consists of one or two layers of a semi conducting material, usually silicon – refer to Figure 1. Incoming solar energy charges the electrons which move through the cell into a wire creating a direct electrical current. Cells are connected together to form photovoltaic panels. The cells are typically embedded in transparent ethyl-vinyl-acetate, then fitted within an aluminium or stainless steel frame with transparent glass on the front side.

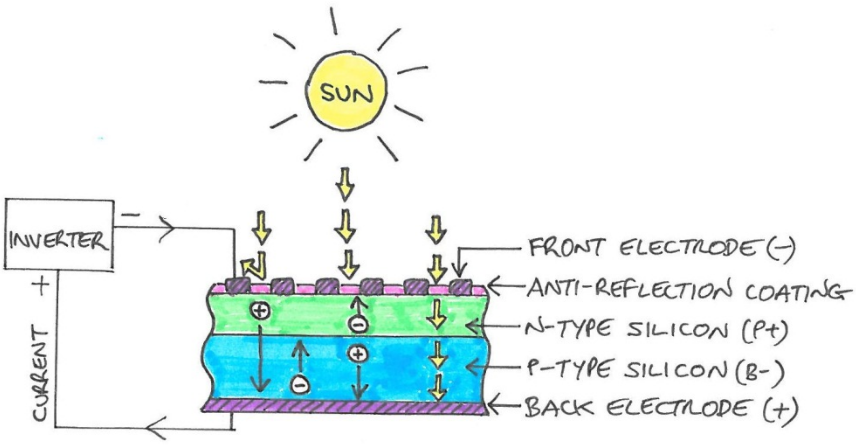

Fig 1 How a solar cell works

Research continues to improve the efficiency of solar cells in laboratories, but currently the most efficient panels are hybrid panels with efficiencies up to 20%.

2. TYPES OF PHOTOVOLTAIC PANELS

The four main types of photovoltaic panels are:

- **Thin film** - sometimes called amorphous silicon, this is the cheapest and least efficient type of PV. It is made by depositing a thin film of silicon onto a material such as glass or plastic. Large areas of panel are required but it works well in high temperatures. Also found in small devices such as solar powered calculators. Their flexibility allow for a wider variety of applications compared to rigid glass-based systems.
  (Typical module efficiency = 3 to 6%)
- **Polycrystalline** – comprises a number of smaller silicon crystals usually cut to form a wafer. Generally dark blue in colour it is widely used in buildings.
  (Typical module efficiency = 10 to 13%)
- **Monocrystalline** – are made from single silicon crystals and consequently more efficient, but more expensive than polycrystalline cells.
  (Typical module efficiency = 13 to 16%)
- **Hybrid** – or HIT (heterojunction incorporating thin film) this incorporates a monocrystalline material overlaid with a thin film layer. This is the premium panel currently on the market in 2013.
  (Typical module efficiency up to 20%)

There are many new types of solar cells under research and development which may transform the photovoltaic industry in the future. Technologies being investigated include:

- **Quantum dot solar cells** – an emerging research field, these use quantum dots as the absorbing photovoltaic material instead of silicon. Quantum dots have band gaps that are tuneable across a wide range of energy levels by changing the dot size making them attractive for multi-junction solar cells, where a variety of different band gap materials are used to improve efficiency by harvesting select portions of the solar spectrum.
- **Polymer solar cells** – a type of flexible solar cell made with polymers, large molecules with repeating structural units. They are lightweight and potentially disposable and inexpensive to fabricate, however they currently offer only one third of the efficiency of hard materials (e.g. silicon) and not very durable (they suffer from photochemical degradation).
- **Dye-sensitized solar cell** – a thin film photoelectrochemical solar cell based on a semiconductor formed between a photo-sensitized anode and an electrolyte. These are simple to make using conventional roll-printing techniques and the majority of materials used are low cost. Research continues to eliminate some of the expensive components and to resolve chemical stability issues.

3. FACTORS AFFECTING EFFICIENCY

The efficiency of PV panels are typically 1 to 3% less than the efficiency of individual solar cells tested under laboratory conditions due to glass reflection, frame shadowing and higher temperatures.[1]

The efficiency of panels are typically measured at 25°C and reduces as panel temperature increases. A monocrystalline panel with a measured efficiency of 15% might reduce to 11% at 75°C. Providing good ventilation to the back of PV panels is therefore desirable. A PV module that has a higher temperature coefficient of performance will perform better in warmer weather so for hotter climates, thin film tends to perform better.

No PV cell works well in overcast conditions, however, some work better than others. Some thin film cells use multiple junctions to cover a wider range of the light spectrum, and therefore do not rely as much on direct radiation.

Thin film (which can be mono, poly, amorphous or non-silicon based semiconductors) generally have a lower efficiency and lower embedded energy than rigid panels, but have a greater degree of shade tolerance.

The performance of PV panels gradually degrades over time. A typical PV panel will deliver about 90% of its initial output after 12 years and about 85% after 25 years. This is an average of 91% over the 25 years – refer to Figure 2.

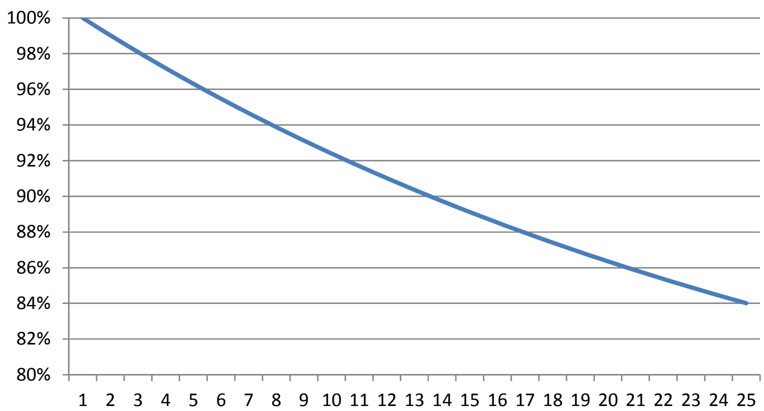

Fig 2 **PV panel output degradation over time**

Table 1 shows typical values used to calculate the system efficiency in Chapter 7 of the book.

Item	
PV panel efficiency	**15.5%**
Inverter losses	9%
Dirt derating	4%
Wiring losses	2%
Manufacturer's tolerance	3%
Temperature derating	5%
Efficiency loss over 25 years	9%
System losses	**28%**
Net system efficiency	**11%**

Table 1 **Photovoltaic panel system efficiency**

Notes

All websites were accessed on 15 June 2013 unless noted otherwise.

1. For further information on PV panels and efficiencies refer to:
   - www.solarserver.com/knowledge/basic-knowledge/photovoltaics.html
   - www.pvresources.com/en/module.php
   - Environmental Design: An Introduction for architects and engineers (3rd edition) – edited by Randall Thomas, Taylor & Francis, 2006.