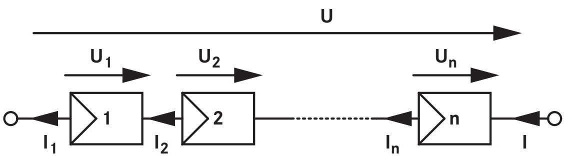
5 assembling crystalline solar modules

wiring

Individual solar cells produce relatively low levels of voltage and current. A 5-inch solar cell, for example, under standard conditions delivers

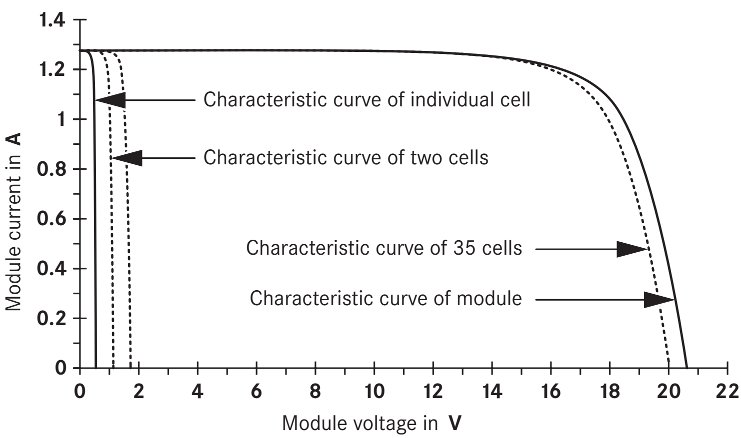
- **open-circuit voltage (U_{oc}) of 0.6 V**
- **short-circuit current (I_{sc}) of 7.8 A**

Since most consumers need considerably more voltage, solar cells are typically connected in series (with the minus contact of one cell connected to the plus contact of the next) to create what are known as 'strings.'



Series connection

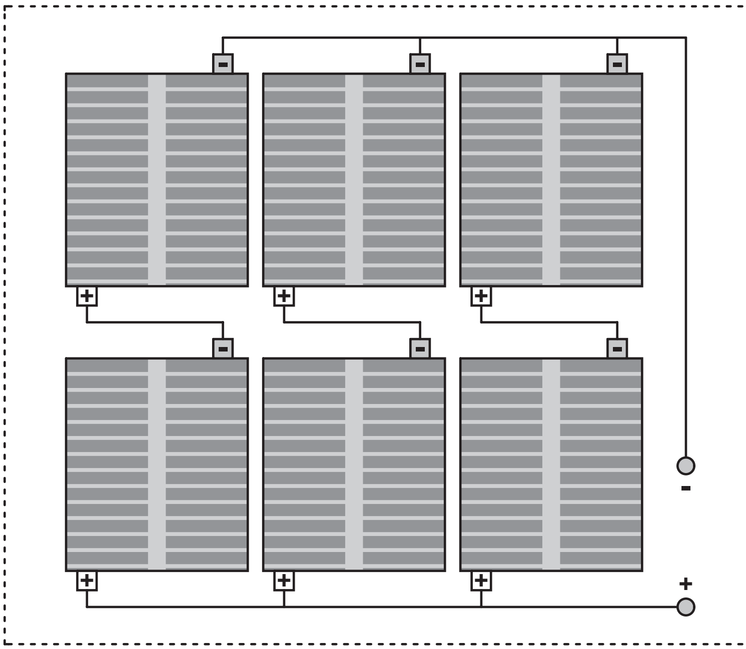
The current (I_i) running through all cells (i) in a string is identical, and each cell's voltage (U_i) is added to that of the others to produce the module's voltage (U). The module's characteristic curve can thus be easily elaborated on the basis of the curve of one single cell:



A module's characteristic curve composed of the individual curves of its 36 cells (intensity of radiation *E* = 400 W/m2, *T* = 300 K)

In order to increase the maximum current available, strings must be wired in parallel within the module. Of the six solar cells shown in the illustration below

- **two are wired in series producing → double voltage**
- **three are wired in parallel producing → triple current**

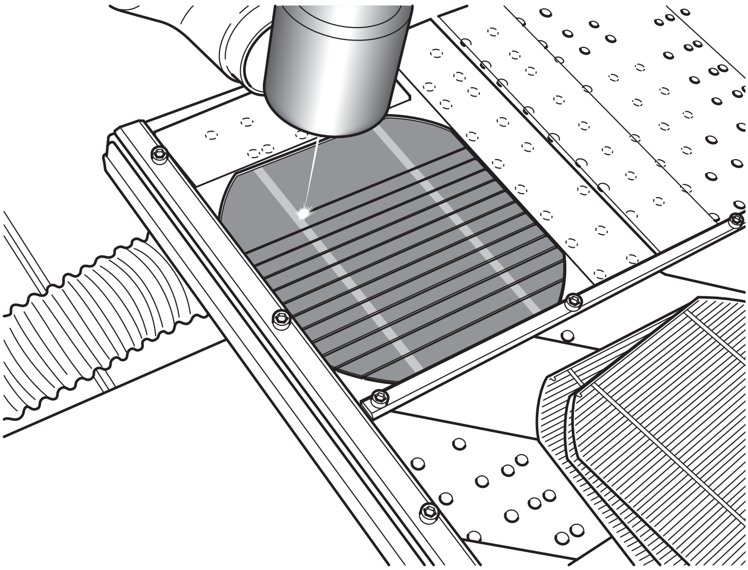


Strings are wired in series or in parallel depending on the current and voltage required. The most common solar modules are used to produce

- **12 V: with 36 cells and operating voltage of approximately 15 to 20 V**
- **24 V: with 72 cells and operating voltage of approximately 30 to 40 V**

Output varies, with the smallest modules capable of producing a peak output power < 1 wattpeak (Wp), and the largest > 200 Wp. On the other hand, the larger the module, the more difficult it is to deploy.

For small modules (e. g. with an output power of 10 Wp), the cells must first be sliced into pieces to produce the correct ratio between voltage and output power.



Using a laser to slice a solar cell

manufacturing a solar module

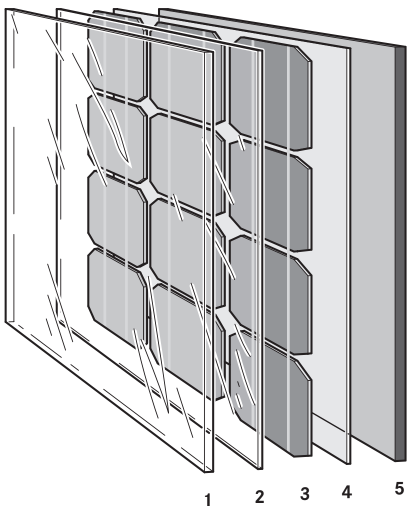
Once they have been tested, solar cells are given ratings according to their output. Cells with like ratings are wired in series/parallel to produce strings, which are then assembled into modules as follows.

step 1 Clean the front cover, which is made of relatively thin glass (3–4 mm), tempered to withstand hail and, extremely translucent.

step 2 Apply a coating of transparent, electrically insulating thermoplastic polymer, typically ethylene vinyl acetate (EVA) with a thickness of 0.46 mm.

step 3 Mount the strings.

step 4 Attach cross-connectors to bind the strings together and connect the cell to a junction box.



1 Tempered glass
2 EVA
3 Cells
4 EVA
5 Multi-layer back sheet

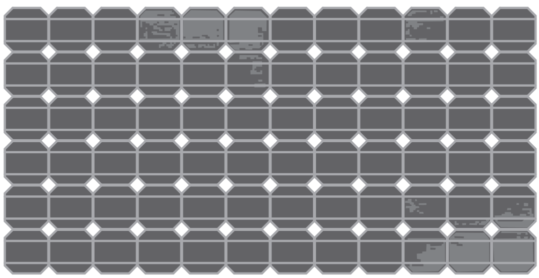
step 5 Apply a second coating of EVA and a coating of Tedlar to the back of the cell (in glass-glass modules, the back is made of glass).

step 6 Laminate the module below atmospheric pressure at approximately 150°C. In the process, the EVA layer becomes a heat-resistant, airtight artificial coating firmly affixed to the glass top and the back coating and encapsulating the cells.

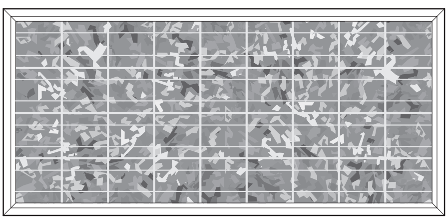
step 7 Once the cells have been laminated, the overlapping film is trimmed from the edges.

step 8 Mount the junction box and equip the module with by-pass diodes (to protect it from thermal damage).

step 9 Frame the module (e. g. in aluminium or other artificial material) to lend it mechanical solidity and protect its edges.



Monocrystalline solar module



Polycrystalline solar module

step 10 Rate the module: its (peak) output is measured under test conditions and expressed in peak power units (Wp = wattpeak).

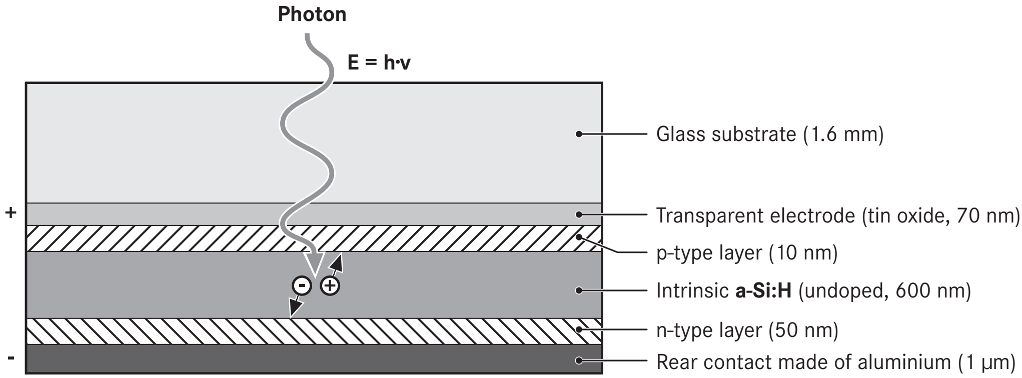
lifespan

The lifespan of a crystalline solar module depends largely on the quality of its production. The performance of cheaply produced modules often declines after a few years, and their lamination may disintegrate.

As a rule, manufacturers guarantee perfect performance between two and five years, and 80% performance up to at least 25 years.

6 manufacturing solar cells with amorphous silicon

In amorphous silicon cells the p-type layer is separated from the n-type layer by an undoped silicon layer known as intrinsic or i-type, hence the designation p-i-n solar cell. The silicon layer is intended to absorb the light. The thinnest possible p-type or n-type layers are required to allow the light to reach the intrinsic layer; at the same time, they must also be thick enough to allow electrons to move about freely.



Since the production of material needed to manufacture wafers of crystalline silicon, highly pure silicon, has grown scarce in recent years, the production of amorphous cells has been stepped up, for use to date mainly in small devices such as pocket calculators.

Amorphous solar cells consist of a thin, non-crystalline (amorphous) layer of silicon, and are thus also known as thin-film cells. They can be manufactured by depositing the silicon layer onto the vector material (glass) by means of evaporation or 'sputtering,' among other methods.

Their manufacture thus does not involve the time-consuming and wasteful process of slicing ingots. The use of a treated glass plate does not produce individual cells, but rather a so-called module panel, ready for use.

While amorphous solar cells are much less expensive to manufacture than their crystalline counterpart, they are considerably less efficient. In order to generate an equivalent output, therefore, a greater surface area is required.

Note as well their behaviour as they deteriorate: the efficiency of amorphous solar cells declines sharply at the beginning of a solar radiation phase (by as much as 25%) and is not stabilized until some three to five months have passed.

On the other hand, amorphous solar cells perform better in weak or diffused light.

Amorphous solar module