Table 22.1 Typical efficiencies for modules. These values are obtained under standard test conditions. Different orientation in BIPV applications may result in lower performance

Cell type	Typical efficiencies [%]
Monocrystalline silicon	12–15
Multicrystalline silicon	11–14
Amorphous silicon	6–8
Cadmium telluride	7–10
Copper indium gallium diselenide	8–12

plates or flexible rolls of stainless steel or plastic, giving a wide range of mechanical strength, weight, and flexibility. The substrate is not visible since it is behind the solar cell. The cells have a uniform typically black appearance. These cells have no grids. Flexible substrates are ideal for curved surfaces and rollable "fold-away" modules. Amorphous silicon modules have lower efficiency than mono or poly silicon (Table 22.1) but better performance at higher temperatures [43, Chapter 12] as often occurs in BIPV applications.

Other thin film PV materials presently include $CuInGaSe_2$ and CdTe. They have a uniform nearly black appearance, indistinguishable visually from amorphous Si modules. They also have lower efficiency compared to mono or poly silicon. $CuInGaSe_2$ cells can be deposited on flexible plastic or metal foils.

Semitransparent cells for BIPV can be manufactured in two ways. Mono silicon wafers can have a series of deep grooves on the front and back which are perpendicular to one another. Where they intersect, light will be transmitted through the holes. Polycrystalline silicon cells with 2% transmission have been reported [44] but higher values should be possible with larger holes. Another approach is to make very thin amorphous silicon layers on glass with transparent contacts so the entire module is semitransparent. However, the transmitted light will have an orange or red tint because the blue and green portion of the spectrum is absorbed in the silicon layers. Such modules could only be used in applications where this color of light was acceptable such as sun-roofs for automobiles. A better method is to selectively remove part of the amorphous silicon layer using laser ablation. Unfiltered white light transmission of 5–15% have been reported for laser scribed amorphous silicon in BIPV applications [43].

22.3.2.2 Module temperature

Module efficiency, therefore electricity produced, decreases as the temperature increases for mono and poly silicon cells but not for amorphous silicon cells. In many non-BIPV applications, modules are mounted on free-standing frames with ambient air on both sides, allowing for cooling on both sides. In contrast, some BIPV applications install the modules in close contact to building material like roofs or wall insulation. The lack of circulating air increases the module temperature. Relative losses of $>5\%$ are possible [45]. A good design criterion for mono or poly silicon applications is to allow as much