tolerance of the glass. For example, the light-generated current in CdTe cells deposited on borosilicate glass is 2 mA/cm^2 higher than on soda lime glass, owing to high absorption in the soda lime glass above 600 nm. However, the high-transparency glasses, such as borosilicates, fused quartz, and Vycor, require more refining and are thus significantly more costly than the soda lime glass commonly used for windowpanes. A review of the optical properties of these and other glasses is found in Reference [183]. In addition, low-cost soda lime glass exhibits a lower softening temperature, restricting its application for high-temperature processing. Reducing the iron content in soda lime glasses improves the transparency at wavelengths greater than 600 nm and raises the melt temperature, at a lower cost than borosilicate or other highly refined glass types.

Commercialization of CdTe PV modules will rely on a constant supply of affordable raw materials, especially cadmium and tellurium. In terms of the material requirements, a facility with 1 MW/year manufacturing capacity, with 100% utilization of Cd and Te species using a 2-μm-thick absorber layer, will require approximately 1 metric tons of CdTe, which translates to 0.4 metric ton of cadmium and 0.6 metric ton of tellurium. Both elements are obtained as the by-products in the smelting of ores; cadmium is obtained from zinc, copper, and lead refining, while tellurium is primarily obtained as a product of the electrolytic refining of copper and skimmings from lead production [184]. Tellurium is the scarcer and more costly component, however, tellurium availability is estimated to be ∼1600 metric tons per year [185]. At present, the costs for ∼95% pure cadmium and tellurium are ∼$US 12/lb ($US 24 000/ton) and ∼$US 20/lb ($US 40 000/ton), respectively. Thus, the total cadmium and tellurium costs for the 1-MW capacity plant would be ∼$US 34 000, which amounts to less than $US 0.10 per watt. This is significantly less than the price of the superstrate glass/TCO for the 100 000 m^2 required for 1-MW capacity, which is currently $US 10.80/m^2 [186], equaling $US 1.08 per watt. A detailed analysis of PV-manufacturing costs is presented in Reference [187].

Present-generation CdTe PV modules are typically ∼1 m^2 in area and have achieved efficiencies above 10%, with peak power on the order of 90 W. At the time of this writing, the only commercial CdTe cells are manufactured by Matsushita Battery Company in Japan, with an annual production of 1.2 MW [188]. Three CdTe module manufacturers are entering production: First Solar, L.L.C., in Toledo, Ohio; BP Solar, in Fairfield, California; and Antec Solar GmbH, in Germany. The module dimensions and output of prototype superstrate CdTe modules from these companies are listed in Table 14.4.

The First Solar module utilizes vapor transport deposition of CdTe onto moving substrates to achieve a high growth rate while maintaining high substrate temperature. The

Table 14.4 Summary of CdTe module performance, compiled by Zweibel. Consult the listed references for module fabrication details

Manufacturer	Country	CdTe method	Per-module power [W]	Aperture efficiency [%]	Module size [m^2]	Reference
Antec	Germany	CSS	47	7.0	0.66	[189]
BP Solar	USA	ED	92	11.0	0.84	[4]
First Solar	USA	VTD	67	10.1	0.66	[3]
Matsushita	Japan	Screen	59	11.0	0.54	[190]