Among these attempts are the developments of silicon sheets, which avoid the wafering of bulky Si ingots, a very expensive and wasteful process. Ribbon sheets have already reached a noticeable fraction of the market with two companies: RWE in Germany/USA (leading) and Evergreen Solar in the USA.

Continuing down the efficiency axis we come to the three leading thin-film PV contenders, Cu(InGa)Se_2 (CIGS) (Chapter 13), CdTe (Chapter 14), and a-Si (Chapter 12), in that order. The main motivation for interest in thin-film photovoltaics has always been the possibility of lower cost, not higher performance. Their champion cell performance has always been a factor of about 2 lower than Si-wafer technologies until ~2000, when Cu(InGa)Se_2 cells with efficiencies of 19% were reported, putting them in potentially close competition with multi-Si, although there are vast differences in the manufacturing experience base between Cu(InGa)Se_2 (no base) and multi-Si (large base). The benefits and challenges of thin-film PV technologies are discussed in detail in Section 1.9. Finally, we note that the category of "Si film" solar cells in Figure 1.8 is a special case of solar cells developed entirely by one company (Astropower in the USA), in which they are attempting to achieve the high performance of polycrystalline Si with the low-cost approach of thin films. More information about thin-film Si technology is given in Chapter 8.

The results in Figure 1.8 clearly show that there are many promising technologies in terms of their possibility of achieving rather high efficiency. But the reality is that, as seen in Figure 1.9, almost 90% of the world's PV power modules are either single c-Si or multi c-Si. The evolution shows a trend away from c-Si towards the multicrystalline-Si technology with the market share of Si sheet also increasing. About 10% of worldwide PV sales are a-Si/a-Si or a-Si/a-SiGe multijunctions and the remaining <1% is Cu(InGa)Se_2, CdTe, and concentrators. The multijunction concentrators based on GaInP/GaAs cells have yet to find commercial application on Earth but nonconcentrating GaInP/GaAs cells are commonly used for space missions where their high efficiency is more important than their high cost. High performance GaInP-based technology is discussed in Chapter 9 and PV space power is described in Chapter 10.

Who is making all the PV modules? Figure 1.10 shows the breakdown by the three major geographic regions of Europe, Japan, and the United States. Note that this is a logarithmic scale, indicating very steady growth for the past decade of 20 to 30%. Production in 2001 was actually 36% higher than in 2000. The USA has had steady growth and led the world in photovoltaics between 1992 and 1998 when Europe and Japan

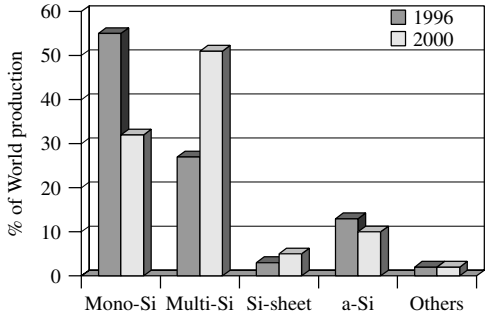

Figure 1.9 Distribution of the PV market by technologies