production. Significant departures from the projection might result from new technological development, such as thin-film modules or concentrator technology.

Some recent experiences [12] with PV systems with capacities in the range of 70 to 236 kW_p showed that system costs dropped by 14% from 1996–1997 to 1998–1999 ($\$9.77/W_p$ to $\$8.46/W_p$). These systems included both fixed and one-axis tracking systems, which were mounted both on buildings and on the ground, and included modules and inverters from several manufacturers. Three of the most recent projects had installed costs below $\$7/W_p$.

Siemens has stated [10] that it is planning on a long-term annual growth rate of 15% for installed PV. Their projection is that a 15% to 25% rate would result in PV contributing to 1% of the world's electricity between 2025 and 2040, which they estimate as 300 TWh in 2025. They state that one-third of this energy could provide for the basic needs of two-billion people not served by a grid.

Another view of the potential for PV can be gained from some figures published by the US government. Recent progress and long-term goals for the US PV program [13] are shown in Table 21.9. Meeting these goals would increase cumulative US sales by the year 2030 to 20 times the year 2000 level, and correspond to about a 12% compounded annual rate of sales growth. The average annual sales from 1996 to 2000 would be about 65 MW/year, and from 2001 to 2030 would be roughly 315 MW/year. The US share of the world market for PV was about 41% in 1995[13]. If this share was maintained till 2030, the cumulative capacity would be about 25 GW. Assuming an average of 2000 h/year of sunlight, the annual generated energy would be 50 TWh by 2030. This is substantially lower than the Siemens estimate given above, but the difference is largely explained by the difference in the 12% annual growth rate and the Siemens estimate of 15% to 25%. Starting at the same 500-MW cumulative sales in 2000, using a constant 41% market share and 2000 h/year of sunlight, a 15% growth rate results in about 80 TWh/year of generated energy. Using a 25% growth rate, the energy is about 645 TWh. There is obviously a lot of uncertainty in making such projections, and the truth no doubt lies somewhere in the range of these estimates.

Some additional insight into the potential contribution of PV to the world's electric-energy needs can be had from data published by the US Energy Information Administration [14]. The world's net electricity consumption in 1999 was 12 833 TWh. Of this total, industrialized countries consume 59%, eastern Europe and the former Soviet Union, consume 11%, and developing countries account for 30%. If the cumulative PV capacity

Table 21.9 Photovoltaic progress and program goals (1995$) US department of energy [13]

	1991	1995	2000	2010–2030
Electricity price (¢/kWh)	40–75	25–50	12–20	<6
Module efficiency[a] (%)	5–14	7–17	10–20	15–25
System cost ($/$W_p$)	10–20	7–15	3–7	1–1.5
System lifetime (years)	5–10	10–20	>20	>30
US cumulative sales (MW)	75	175	400–600	>10 000

[a]Range of efficiencies for commercial flat-plate and concentrator technologies