and concentrators).[1] Meanwhile, the Japanese PV industry began to take off. Production of c-Si modules and intensive research on thin-film technology in Japan led to many innovative device designs, improved materials processing, and growing dominance in the world PV market.

Along with the maturing of the solar cell technology, the BOS needed to grow. Many products like inverters, which convert the DC power into AC power, and sun trackers had only limited application outside of a PV power system, so once again there was only limited technical and financial resources for development. In many system evaluations, the inverter was repeatedly identified as the weak link in terms of reliability and AC power quality [41]. Their costs have not fallen nearly as fast as those for the PV modules. While much effort and resources had been focused on the solar cell cost and performance, little attention had been paid to installation and maintenance costs. It was quickly discovered that there was room for much improvement.

An early development that helped many companies was to sell PV cells for consumer-sized, small-scale power applications. The solar-powered calculator, pioneered by Japanese electronics companies as a replacement for battery-powered calculators in the early 1980s, is the best-known example. This led to the early use of thin-film a-Si PV cells for various applications. Another example was solar-powered outdoor lighting. These novel consumer applications, where portability and convenience were more valued than low price, allowed the PV companies to maintain some small income while continuing to develop power modules.

Another application was the rural electrification of remote villages in an attempt to help roughly one-third of the world's citizens to gain access to a modest amount of modern communication and lighting. Most of these PV installations were very small, on the order of 10 to 40 W per household (100 times smaller than the "needs" of a modern home in the developed world.) Most of these installations were funded by some international aid agency. Reviews and follow-up studies of these programs have indicated very large failure rates, primarily due to lack of technical infrastructure [42], training, cultural misunderstandings, design of the payment structure, and other nontechnical reasons [43]. Rarely have the PV modules failed. Even with subsidies from the international agencies, the high initial cost of ownership ($100–1000) was still a major barrier in much of the world where this represents a year's income for a family [44].

On the opposite end of the size scale were the MW-size PV plants installed by utilities in developed countries in the 1980s to evaluate their potential in two applications: as a peak-load-reduction technology, where the photovoltaics provides additional power primarily to meet the peak demand during the afternoon [45]; or as distributed generators, to reduce transmission and distribution losses [46]. Several American utilities investigated these applications, to assess the technical as well as financial benefits for photovoltaics in utility scale applications. Other novel configurations of grid-tied PV

[1] While this book was going to press in November 2002, BP Solar suddenly announced the closure of its two thin-film manufacturing efforts in the United States (a-Si in Virginia and CdTe in California) in order to focus more resources on its multicrystalline Si wafer PV production. This was a great disappointment to all those who worked so hard to establish these thin-film technologies and facilities, which were among the most advanced thin-film PV products in the world.