This chapter is written for researchers and interested developers to be an instructive guide to the original literature in order to aid them in further development. It is not intended to be a stand-alone document. Most of the literature can be found in the various *Proceedings of the IEEE Photovoltaic Specialists Conferences* and the *European Photovoltaic Solar Energy Conferences*, along with a number of important books. Some of the material is less easily accessible in the form of various publications and reports of the US Department of Energy (DOE) and the Electric Power Research Institute (now called EPRI). Use of this latter type of material will be minimized.

The reader will be amazed at the variety of concentrator systems that have been explored. The concentration ratio (ratio of module aperture area to cell area) varies from 2 to 4 in static concentrator designs that require no sun tracking to over 1000 times in some two-axis tracking systems. The means of optical concentration includes a variety of two-axis and one-axis reflective and refractive approaches, as well as many novel means such as luminescent and holographic concentrators. While this wide variety gives support to the notion that a cost-effective approach will surely emerge, it nevertheless reminds the author of the early stage of many technology developments (such as airplanes) prior to the eventual emergence of the dominant concept (single wings with trailing rudder and elevator in the case of airplanes). In the same way as aircraft, the development of concentrators has been aided and impacted by the parallel development of materials and other technologies. For example, the once cumbersome aspect of finding and tracking the sun is now made relatively straightforward by the emergence of very low-cost computing technology, the Global Positioning System, and the like. On another path, developments in the global semiconductor industry often have direct application to concentrator cells. Examples include larger wafers, improved processing equipment, the emergence of organo-metallic chemical vapor deposition (OMCVD) for fabricating multijunction III-V cells, and improved packaging materials with superior thermal properties (e.g. AlN). Many of the technical issues facing further concentrator development can be thought of as material issues. These include the development of polymer reflectors with improved weatherability, lower cost molding methods for Fresnel lenses, and such. In other words, concentrator development takes place in the larger technology arena. New material and technology developments can come from any direction and make possible what was only a dream previously. Unfortunately, tracking the sun is still effected by the distinctly nineteenth-century technology of gears and motors. The necessity for tracking remains concentrating PV's Achilles heel.

11.1.1 The Concentrator Dilemma

In the 1970s, concentrators were originally conceived of as a technology for large power plants that provide wholesale electricity in competition with, or as replacement for, fossil fuel–generated power, that is, as a vehicle for reducing green house gasses, pollution, and for providing a renewable energy source as fossil fuels were depleted. PV markets, however, have evolved since the 1970s in a somewhat unexpected manner. Flat-plate (nonconcentrating) PV has emerged as an important and viable power source for small remote loads. In parallel, a subsidized, but vital and fast-growing, grid-connected market has emerged in many developed countries. Concentrators are not particularly suitable for these markets and have never gained a foothold in them. The issues of reliability and suitability for remote markets have plagued them from the start, and the new grid-connected