it should increase with increasing luminous flux. However, in practice, ohmic resistance losses caused by the handling of large currents limits the efficiency increase. Thus, cells for concentrator applications must be carefully designed to minimize such losses and therefore they become more expensive. Yet, the small area of cells used in a concentration system, or alternatively, the large amount of electric power produced by each cell, allows for paying higher costs for the cells, and therefore allows them to incorporate many refinements in order to make such cells very efficient.

One factor that reduces the system efficiency is the loss associated with the optical hardware used to concentrate the light. Additionally, only the direct sunbeam is collected since scattered (diffuse) light is not focused. This again reduces the electric output by at least 15%. However, this last reduction is compensated for in many sunny locations by the fact that the tracking system always aims the cell directly at the sun (at least for two-axis tracking systems). In contrast, with the more typical stationary modules, the output power varies like the cosine of the angle of the sun, so this is very low in morning and late afternoon, when the sun is at an oblique shallow angle relative to the module (equations describing the sun's motion and the relative illumination on a module versus time of day or time of year is given in Chapter 20). Accounting for these gains and losses, it is generally found that concentrator efficiency today tends to be somewhat higher than flat module efficiency and this tendency will increase in the future with the adoption of higher efficiency cells. It is also believed that concentrators should ultimately be cheaper than flat module silicon solar cells. However, this statement has not been confirmed in practice due to the lack of a real market, apart from a few purchases for demonstration purposes.

Actually, concentrators are appropriate for relatively large installations while the PV market has evolved so far in smaller installations such as grid-connected houses, remote homes, or telecommunication applications whose size is seldom bigger than 5 kW. Therefore, only very few companies fabricate concentrator cells today, and their prices are very high because they have large general costs for very small production volumes. However, the situation may change. The general increase of the PV markets will probably stimulate the appearance of niches better adapted to concentrators.

The difficulty of developing concentrators must not be underestimated. Combining the requirement for high performance with the low cost is a formidable challenge. In particular, the optics must be low cost, yet permit highly accurate focussing, high optical efficiency, and equal illumination in all cells. The tracking structure must be cheap and accurate, cells must be efficient and not too expensive, and finally the cooling and current extraction must be effective and cheap. Chapter 11 deals in detail with concentrator issues.

1.11 BALANCE OF SYSTEMS

A photovoltaic system consists of more than PV modules composed of solar cells. In addition, it requires elements that are generically known together as "*Balance Of System*" (BOS). The BOS is, typically, composed of the battery, the control unit and the inverter, the mechanical support structure, the electric cabling, and protection devices such as fuses, grounding rods, and disconnect switches. We present in Figure 1.13 the cost of a PV stand-alone installation with storage, as presented in Chapter 2.