Sunlight is a spectrum of photons distributed over a range of energy. Photons whose energy is greater than the band gap energy (the threshold energy) can excite electrons from the valence to conduction band where they can exit the device and generate electrical power. Photons with energy less than the energy gap fail to excite free electrons. Instead, that energy travels through the solar cell and is absorbed at the rear as heat. Solar cells in direct sunlight can be somewhat (20–30°C) warmer than the ambient air temperature. Thus, PV cells can produce electricity without operating at high temperature and without mobile parts. These are the salient characteristics of photovoltaics that explain safe, simple, and reliable operation.

At the heart of any solar cell is the *pn* junction. Modeling and understanding is very much simplified by using the *pn* junction concept. This *pn* junction results from the "doping" that produces conduction-band or valence-band selective contacts with one becoming the *n*-side (lots of negative charge), the other the *p*-side (lots of positive charge). The role of the *pn* junction and of the selective contacts will be explained in detail in Chapters 3 and 4. Here, *pn* junctions are mentioned because this term is often present when talking of solar cells, and is used occasionally in this chapter.

Silicon (Si), one of the most abundant materials in the Earth's crust, is the semiconductor used in crystalline form (c-Si) for 90% of the PV applications today (Chapter 5). Surprisingly, other semiconductors are better suited to absorb the solar energy spectrum. This puzzle will be explained further in Section 1.10. These other materials are in development or initial commercialization today. Some are called thin-film semiconductors, of which amorphous silicon (a-Si) (Chapter 12), copper indium gallium diselenide ($Cu(InGa)Se_2$ or CIGS) (Chapter 13), and cadmium telluride (CdTe) (Chapter 14) receive most of the attention. Solar cells may operate under concentrated sunlight (Chapter 11) using lenses or mirrors as concentrators allowing a small solar cell area to be illuminated with the light from larger area. This saves the expensive semiconductor but adds complexity to the system, since it requires tracking mechanisms to keep the light focused on the solar cells when the sun moves in the sky. Silicon and III-V semiconductors (Chapter 9), made from compounds such as gallium arsenide (GaAs) and gallium indium phosphide (GaInP) are the materials used in concentrator technology that is still in its demonstration stage.

For practical applications, a large number of solar cells are interconnected and encapsulated into units called PV modules, which is the product usually sold to the customer. They produce DC current that is typically transformed into the more useful AC current by an electronic device called *an inverter*. The inverter, the rechargeable batteries (when storage is needed), the mechanical structure to mount and aim (when aiming is necessary) the modules, and any other elements necessary to build a PV system are called the *balance of the system* (BOS). These BOS elements are presented in Chapters 17 to 19.

1.3 SIX MYTHS OF PHOTOVOLTAICS

Borrowing a format for discussing photovoltaics from Kazmerski [2], in this section, we will briefly present and then dispel six common myths about photovoltaics. In the following sections, we identify serious challenges that remain despite 40 years of progress in photovoltaics.