for building-integrated photovoltaics, liters per day for water pumping, or low light-level operation for consumer electronics [4].

The actual output of a PV module or system in the field is a function of orientation, total irradiance, spectral irradiance, wind speed, air temperature, soiling, and various system-related losses. Various module- and system-rating methods attempt to ensure that the actual performance is comparable to the rated performance to keep the resulting level of customer satisfaction high.

16.2.1 Standard Reporting Conditions

The PV performance in terms of SRC is commonly expressed in terms of efficiency. At the research level, an internationally accepted set of SRC is essential to prevent the researcher from adjusting the reporting conditions to maximize the efficiency. The procedures for measuring the performance with respect to SRC must be quick, easy, reproducible, and accurate for the research cell fresh out of the deposition system or for the module on a factory floor with production goals. The PV conversion efficiency (η) is calculated from the measured maximum or peak PV power ($P_{\max}$), device area (A), and total incident irradiance (E_{tot}):

$$\eta = \frac{P_{\max}}{E_{\text{tot}} A} 100 \tag{16.1}$$

The term *reporting*, rather than *reference* or *test*, is used because a measurement can be performed at conditions other than SRC and then carefully corrected to be equivalent to being measured at SRC. The SRC for rating the performance of cells and modules are summarized in Table 16.1 [1, 5–15]. The direct, global, and AM0 reference spectra are summarized in Figure 16.1 and Tables 16.2 and 16.3.

As a matter of shorthand, the global and direct terrestrial reference spectra are often referred to as AM1.5 G and AM1.5 D, respectively. Many groups often just refer to the reference spectrum as AM1.5. This can be confusing without a reference because numerous different AM1.5 reference spectra have been proposed and used in the past. It should be noted that neither the direct reference spectrum nor the global reference spectrum actually integrates to exactly 1000 Wm^{-2} [10, 12, 13, 17]. The global reference spectrum integrates to approximately 963 Wm^{-2} and the direct reference spectrum

Table 16.1 Standard reference conditions for rating photovoltaic cells, modules and systems

Application	Irradiance [Wm^{-2}]	Reference Spectrum	Temperature [°C]
Terrestrial			
Cells	1000	Global [5]	25 cell [5, 6, 11]
Modules, systems	1000	Global [11, 13]	25 cell [7] or NOCT [7]
Modules, systems	1000[a]	Prevailing	20 ambient
Concentration[b]	>1000	Direct [10]	25 cell [5]
Extraterrestrial[c]	1366 [8], 1367 [14]	AM0 [8, 14, 15]	25 [15], 28 cell [16]

[a] Linear regression of power to project test conditions, 850 Wm^{-2} with a 5° field of view for concentrator systems
[b] At present, no consensus standards exist although ASTM and the European Community are developing standards
[c] At present no consensus standards exist although there is an ISO draft standard [15]