higher temperature means reduced performance. This is usually the most important performance loss.

But, prediction of the module response under different conditions is required to correctly assess the yearly production of a PV system in the field. The physical mechanisms of influence of temperature and irradiance on cell performance are well known, so that, in principle, prediction of module output could be rooted in physical models. This is however unpractical and would be a different approach if followed by PV system engineers.

Instead, very simple methods are used for translating the $I-V$ performance to different operating conditions and standardized procedures have been developed for PV modules of industrial technologies [133]. These methods are applicable within a limited range of temperature and irradiance conditions that are not very far from those met when testing the module and which require a small number of easily measurable parameters. The module datasheets from the manufacturers used to include some of these, allowing simplest estimates to be made, such as:

1. The steady-state power balance determines cell temperature: the input is the absorbed luminous power, which is partially converted into useful electrical output and the rest is dissipated into the surroundings. Convection is the main mechanism for heat dissipation in terrestrial, flat plate applications, and radiation is the second nonnegligible mechanism of heat dissipation. A common simplifying assumption is made that the cell-ambient temperature drop increases linearly with irradiance. The coefficient depends on module installation, wind speed, ambient humidity and so on, though a single value is used to characterize a module type. This information is contained in the Nominal Operating Cell Temperature (*NOCT*), which is defined as the cell temperature when the ambient temperature is 20°C, irradiance is 0.8 kW·m^{-2} and wind speed is 1 m·s^{-1}. *NOCT* values around 45°C are typical. For different irradiance values G, this will be obtained by

$$T_{\text{cell}} = T_{\text{ambient}} + G \times \frac{NOCT - 20^\circ\text{C}}{0.8\ \text{kW}\cdot\text{m}^{-2}}$$

2. The module short-circuit current is assumed strictly proportional to irradiance. It slightly increases with cell temperature (this stems from a decrease in band gap and an improvement of minority-carrier lifetimes). The coefficient α gives the relative current increment per degree centigrade. By combining both assumptions, the short-circuit current for arbitrary irradiance and cell temperature is calculated as

$$I_{\text{SC}}(T_{\text{cell}}, G) = I_{\text{SC}}(\text{STC}) \times \frac{G}{1\ \text{kW}\cdot\text{m}^{-2}} \times [1 + \alpha(T_{\text{cell}} - 25^\circ\text{C})]$$

   For crystalline Si, α is around 0.4% per degree centrigrade.

3. The open-circuit voltage strongly depends on temperature (the main influence is that of the intrinsic concentration), decreasing linearly with it. Knowledge of the coefficient, called β, allows the open-circuit voltage to be predicted by

$$V_{\text{OC}}(T_{\text{cell}}, G) = V_{\text{OC}}(\text{STC}) - \beta(T_{\text{cell}} - 25^\circ\text{C})$$

   The irradiance dependence is buried in T_{cell}. For crystalline Si, β is around 2 mV/°C per series-connected cell.