On the other hand, the radiator is illuminated by a bundle of rays, coming from the sun, of étendue $H_{sr} = H_{rs}$ and by the radiation emitted by the cell itself, of étendue $H_{cr} = H_{rc}$. Also, the cell may emit some radiation into the cavity, which returns to the cell again. This radiation is therefore not accounted for as an energy loss in the cell. In addition, we shall assume that the cell is coated with an ideal filter that allows only photons with energy ε and within a bandwidth $\Delta\varepsilon$ to pass through, while the others are totally reflected. In this situation the energy balance in the radiator becomes

$$\dot{E}(T_s, 0, 0, \infty, H_{rs}) + \dot{e}(\varepsilon, T_a, qV, H_{rc})\Delta\varepsilon = \dot{e}(\varepsilon, T_r, 0, H_{rc})\Delta\varepsilon + \dot{E}(T_r, 0, 0, \infty, H_{rs}) \tag{4.55}$$

where the first equation member is the net rate of energy received by the radiator and the second member is the energy emitted.

Using $\dot{e}(\varepsilon, T_r, 0, H_{rc})\Delta\varepsilon - \dot{e}(\varepsilon, T_a, qV, H_{rc})\Delta\varepsilon = \varepsilon\Delta i/q = \varepsilon\Delta\dot{w}/(qV)$, where Δi is the current extracted from the monochromatic cell and $\Delta\dot{w}$ is the electric power delivered, it is obtained that

$$\frac{\varepsilon\Delta\dot{w}}{qV} = \frac{H_{rs}\sigma_{\mathrm{SB}}}{\pi}(T_s^4 - T_r^4) \Leftrightarrow \frac{\varepsilon^2\Delta i}{qH_{rc}\Delta\varepsilon} = \frac{H_{rs}\varepsilon}{H_{rc}\Delta\varepsilon}\frac{\sigma_{\mathrm{SB}}}{\pi}(T_s^4 - T_r^4) \tag{4.56}$$

This equation can be used to determine the operation temperature of the radiator, T_r, as a function of the voltage V, the sun temperature T_s, the energy ε and the dimensionless parameter $H_{rc}\Delta\varepsilon/H_{rs}\varepsilon$. Notice that the left-hand side of equation (4.56) is independent of the cell étendue and of the filter bandwidth (notice that $\Delta i \propto H_{rc}\Delta\varepsilon$).

Dividing by $H_{rs}\sigma_{\mathrm{SB}}T_s^4/\pi$, the solar input power, allows expressing the efficiency of the TPV converter as

$$\eta = \left(1 - \frac{T_r^4}{T_s^4}\right)\left(\frac{qV}{\varepsilon}\right) = \left(1 - \frac{T_r^4}{T_s^4}\right)\left(1 - \frac{T_a}{T_c}\right) \tag{4.57}$$

where T_c is the equivalent cell temperature as defined by equation (4.24). As presented in Figure 4.8, this efficiency is a monotonically increasing function of $H_{rc}\Delta\varepsilon/H_{rs}\varepsilon$. For $(H_{rc}\Delta\varepsilon/H_{rs}\varepsilon) \to \infty$, $\Delta i \to 0$ and $T_r \to T_c$. In this case an optimal efficiency [40] for $T_s = 6000$ K and $T_a = 300$ K is found to be 85.4% and is obtained for a temperature $T_c = T_r = 2544$ K. This is exactly the same as the optimum temperature of an ideal solar thermal converter feeding a Carnot engine. In reality, the ideal monochromatic solar cell is a way of constructing the Carnot engine. This efficiency is below the Landsberg efficiency (93.33%) and slightly below the one of an infinite stack of solar cells (86.8%).

It is worth noting that the condition $(H_{rc}\Delta\varepsilon/H_{rs}\varepsilon) \to \infty$ requires that $H_{rc} \gg H_{rs}$, and for this condition to be achieved, the cell area must be very large compared to the radiator area. This compensates the narrow energy range in which the cell absorbs. This is why a mirrored cavity must be used in this case.

4.5.3 Thermophotonic Converters

A recent concept for solar conversion has been proposed [3] with the name of thermophotonic (TPH) converter. In this concept, a solar cell converts the luminescent radiation