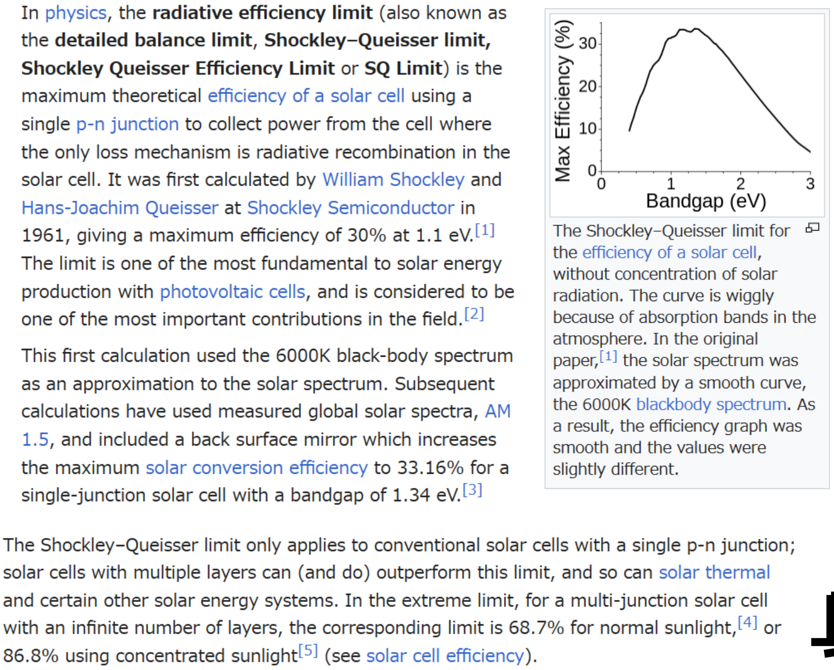
Shockley and Queisser Model of Solar Cell Quantum Efficiency

Shockley–Queisser limit - Wikipedia



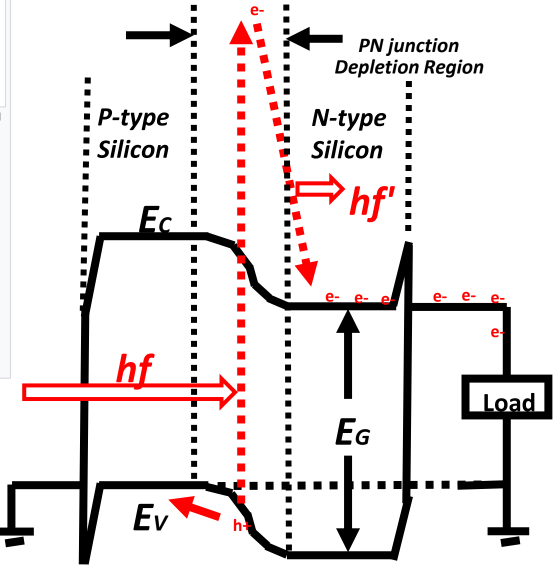
In physics, the **radiative efficiency limit** (also known as the **detailed balance limit**, **Shockley–Queisser limit**, **Shockley Queisser Efficiency Limit** or **SQ Limit**) is the maximum theoretical efficiency of a solar cell using a single p-n junction to collect power from the cell where the only loss mechanism is radiative recombination in the solar cell. It was first calculated by William Shockley and Hans-Joachim Queisser at Shockley Semiconductor in 1961, giving a maximum efficiency of 30% at 1.1 eV.[1] The limit is one of the most fundamental to solar energy production with photovoltaic cells, and is considered to be one of the most important contributions in the field.[2]

This first calculation used the 6000K black-body spectrum as an approximation to the solar spectrum. Subsequent calculations have used measured global solar spectra, AM 1.5, and included a back surface mirror which increases the maximum solar conversion efficiency to 33.16% for a single-junction solar cell with a bandgap of 1.34 eV.[3]

The Shockley–Queisser limit for the efficiency of a solar cell, without concentration of solar radiation. The curve is wiggly because of absorption bands in the atmosphere. In the original paper,[1] the solar spectrum was approximated by a smooth curve, the 6000K blackbody spectrum. As a result, the efficiency graph was smooth and the values were slightly different.

The Shockley–Queisser limit only applies to conventional solar cells with a single p-n junction; solar cells with multiple layers can (and do) outperform this limit, and so can solar thermal and certain other solar energy systems. In the extreme limit, for a multi-junction solar cell with an infinite number of layers, the corresponding limit is 68.7% for normal sunlight,[4] or 86.8% using concentrated sunlight[5] (see solar cell efficiency).

$$hf = hf' + e\,E_G$$



$$(\text{Quantum Efficiency}) = (eE_G)\,(N_{\text{solar Cell}})/(P_{\text{Sunlight}})$$

(eE_G) = Electronic Energy of One Photon available for Solar Cell

$$e\,E_G = hf - hf'$$

(P_{Sunlight}) = Total Photon Energy from Sun as Blackbody Radiation

$$d(P_{\text{Sunlight}}) = (hf)\,d(N_{\text{Sunlight}})$$

$$(P_{\text{Sunlight}}) = \int_0^{\infty} (hf)\ d(N_{\text{solar Cell}})$$

$$d(N_{\text{Sunlight}}) = (2\pi/c^2)\,\frac{f\ df}{\exp(hf/kT)\ - 1}$$

$(N_{\text{solar Cell}})$ = Total Number of Photons with energy greater than eE_G available for Solar Cell per unit area per unit time

$$(N_{\text{Solar Cell}}) = \int_{e\,E_G}^{\infty} d(N_{\text{Solar Cell}})$$