Shockley–Queisser Limit paper assignment

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1. What are the author's assumptions in their approach?

- "photons with energy greater than hv_g produce precisely the same effect as photons of energy hv_g, while photons of lower energy will produce no effect".
- That only a single p-n junction solar cell is used. Something like a silicon solar cell with a potential barrier of 0.7V.
- All photons are emitted with blackbody radiation spectrum.
- The authors also analyse the IV characteristics of the cell with a few assumptions. They detail five processes that affect the relationship of current and voltage. The relationship is defined then according to the detailed balanced theory when all these processes sum to zero.

2. What does the term "ultimate efficiency" mean?

The ultimate efficiency is defined for a given band gap x_g. It's a ratio between the power delivered to the solar cell in photons with enough energy to create electron-hole pairs per second over the number of photons incident upon the cell.

- Q_s which is the number of quanta of frequency greater than or equal to v_g incident upon an area per unit time for blackbody radiation at temperature T_s.
- P_s is the total energy density falling upon unit area in unit time for blackbody radiation at temperature Ts.
- v_g is the frequency of the photon that can create an electron-hole pair (or can bridge the band gap).
- h is Planck's constant.
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$$u(x_g) = \frac{hv_g Q_s}{P_s}$$

3. What is the "nominal efficiency"?

- The nominal efficiency tries to take into account the expected IV characteristics of the cell with the limitations of recombination and spectral losses.
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$$\frac{V_{oc} * I_{sc}}{P_s}$$

- This is similar to what we've used in class where we look at power conversion as $\frac{P_{max}}{P_{in}}$, P_{max} as the $V_{oc} * I_{sc}$ scaled by the Fill factor.

4. What kind of losses does this approach take into account?

- Recombination losses, introducing a factor f_c that presents the fraction of electron-hole recombination not contributing to current. This factor plays a role in defining short circuit current and open circuit voltage. It's used to scale the photons that can bridge the band gap for Q_c and Q_s which is the flux of photon's that can create electron-hole pairs.
- Losses due to the spectrum of radiation emitted by the sun. Not all of the sun's radiation carries a quanta of energy greater than or equal to the band gap of the cell.

5. Where is the true physical limit of silicon cell efficiency and what processes determine it?

- The author's answer both these questions in the conclusion but I was unable to follow their logic fully.
- They seem to point mainly to recombination as the difficulty in reaching maximum efficiency. They also highlight evidence that impurities might also determine physical limits on efficiency.