The effect of the solar cell band gap on power yield

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Content

- Solar irradiance calculations
  - Theoretical efficiency limit for single p-n junction solar cell
  - Radiative recombination
- What is the Shockley-Queisser limit
- Why this paper
- Results
- Conclusion
- Questions
Extinction of the solar irradiance

- $O_2$
- $CO_2$
- $O_3$
- $H_2O$

- Rayleigh Scattering
- Mie Scattering
Extinction examples

Incoming light
Ozone Absorption
Aerosol Scattering
Calculating the solar irradiance
Sunlight Spectral Shift

http://cdme2032lukehickling.blogspot.com/
Sunlight irradiance components

W/m²/nm

diffuse
direct
ET

wavelength (nm)
Photovoltaic cell

Photon with energy less than the band gap

Photon with energy greater than the band gap

Valance Band

Conduction band

Not to scale
Absorbed = Irradiance \times \text{Response}

\begin{align*}
\text{Absorbed} &= \text{Irradiance} \\
\text{Absorption Factor} &= \text{Irradiance} \\
\end{align*}

\begin{align*}
\text{Energy} \quad \text{W/m}^2/\text{nm}
\end{align*}
Radiative recombination

Electrons can drop back into the Valance band and release that energy as light.
Effect of radiative recombination on absorption factor

![Graph showing the effect of radiative recombination on absorption factor. The x-axis represents wavelength in nm, ranging from 0 to 1500. The y-axis represents absorption factor, ranging from 0.0 to 1.2. The graph includes two lines: one representing the ideal solar cell and the other the ultimate efficiency.](attachment:image)
Noteworthy Calculations of Bandgap vs. Efficiency

- Ultimate Limit (6000 K black body)
- Shockley-Queisser Limit (6000 K black body)
- Shockley-Queisser Limit (NREL)
Why this paper?

- Single solar spectrum used
- Creating single optimal peak
- Solar spectrum changes with zenith angle and with atmosphere composition
- Thus the optimal band gap will differ for different locations and different atmospheric conditions
- How much will it differ for South Africa
De Aar 21 June vs NREL1.5AM

- Higher air mass
- Lower precipitable water

![Graph showing W/m²/nm vs wavelength (nm) for NREL and This Work.](image-url)
Shockley-Queisser limit for different times of day

Absorption factor vs. band gap (nm)

Times of Day:
- 07:30
- 08:00
- 09:00
- 10:00
- 11:00
- 12:00
Result for 21 June

- 10 minute intervals
- Optimal band gap - 1089 nm
- Efficiency for band gap 925nm – 31.67%
- Efficiency for band gap 1089nm – 33.34%
- Thus 5.3% higher energy yield
## Results

<table>
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<tr>
<th>Date</th>
<th>Efficiency for 925nm [%]</th>
<th>Optimal efficiency [%]</th>
<th>Optimal band gap [nm]</th>
<th>Increase in power [%]</th>
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Conclusion

- There is significant variance in optimal bandgap with atmospheric conditions.
- Bandgap should be considered when designing solar power plants.
- Target location should be considered when designing solar cells.
- For South African conditions, a lower energy bandgap is optimal.
  - High latitude
  - Peak power demand in winter
Questions ?