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Towards the Shockley-Queisser limit for single-junction crystalline silicon based solar cells

In 2024, the newly installed photovoltaic solar power plant capacity was about 600GWp, together with this the
total global PV power capacity was over 2 Terawatt peak. In 2025, it is expected that a new photovoltaic installation could reach 700Gwp in 2025 [1]. The last two decades, p-n junctions manufactured on single crystal (mono) silicon wafers have been dominating silicon photovoltaic (PV) cells technologies with over 95% share [2]. The scenarios for annual global PV installations towards 2050 have been made according to the new and innovative technologies and cost reduction. In the case of high technology and innovation scenario, a CAGR
is expected to be ~6% and the 2050 annual would reach ~1000GWp [3]. In 2024 in Türkiye, the cumulative solar power plant installations have overpassed 20GWp, and the 77Wp planned cumulative PV power installations in the next ten years is announced in 2025 [4].
For a single-junction PV cell, the maximum theoretical the Shockley-Queasier efficiency limit efficiency is around 33.7%. Towards the Shockley-Queisser limit for single-junction crystalline silicon based solar cells efficiencies with commercially acceptable stabilities have been a challenge for over the years. [5]. In recent decades, the evolution of PV cell technologies on single crystalline silicon had been starting from Aluminium Back Surface Field (Al-BSF), continuing as Passivated Emitter and Rear Contact (PERC), Passivated Emitter Rear
Totally-Diffused (PERT), Tunnel Oxide Passivated Contact (TOPCon), Heterojunction Technology (HJT), Interdigitated Back Contact (IBC), Heterojunction Back Contact (HBC), Metal-wrap through (MWT), Tunnelling
Oxide Passivated Back Contact (TBC). Although each technology has its own manufacturing, stability and commercial strengths and weaknesses [6,7].
This review discusses the technological differences in the front runner silicon photovoltaic cells and makes an
attempt to foresee a direction of the race in short-term, mid-term and long-term utilizing the available data and reviews in 2025.

Primary author: Prof. OKTIK, Şener (Maltepe University)

Presenter: Prof. OKTIK, Şener (Maltepe University)