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Researchers at the U.S. Department of Energy"s National Renewable Energy Laboratory (NREL) created a solar cell with a record 39.5% efficiency under 1-sun global illumination. This is the highest efficiency solar...

Solar-cell efficiency is the portion of energy in the form of sunlight that can be converted via photovoltaics into electricity by the solar cell.

The efficiency of the solar cells used in a photovoltaic system, in combination with latitude and climate, determines the annual energy output of the system. For example, a solar panel with 20% efficiency and an area of 1 m2 will produce 200 kWh/yr at Standard Test Conditions if exposed to the Standard Test Condition solar irradiance value of 1000 W/m2 for 2.74 hours a day. Usually solar panels are exposed to sunlight for longer than this in a given day, but the solar irradiance is less than 1000 W/m2 for most of the day. A solar panel can produce more when the Sun is high in Earth"s sky and will produce less in cloudy conditions or when the Sun is low in the sky; usually the Sun is lower in the sky in the winter.

As of 2024, the world record for solar cell efficiency is 47.6%, set in May 2022 by Fraunhofer ISE, with a III-V four-junction concentrating photovoltaic (CPV) cell.[7] This beat the previous record of 47.1%, set in 2019 by multi-junction concentrator solar cells developed at National Renewable Energy Laboratory (NREL), Golden, Colorado, USA,[8] which was set in lab conditions, under extremely concentrated light. The record in real-world conditions is held by NREL, who developed triple junction cells with a tested efficiency of 39.5%.[9][10]

The factors affecting energy conversion efficiency were expounded in a landmark paper by William Shockley and Hans Queisser in 1961.[11] See Shockley-Queisser limit for more detail.

Solar cells with multiple band gap absorber materials improve efficiency by dividing the solar spectrum into smaller bins where the thermodynamic efficiency limit is higher for each bin.[15]

When a photon is absorbed by a solar cell it can produce an electron-hole pair. One of the carriers may reach the p-n junction and contribute to the current produced by the solar cell; such a carrier is said to be collected. Or, the carriers recombine with no net contribution to cell current.

The internal quantum efficiency (IQE) gives insight into the internal material parameters like the absorption coefficient or internal luminescence quantum efficiency.[17] IQE is mainly used to aid the understanding of the potential of a certain material rather than a device.[17]

Quantum efficiency is most usefully expressed as a spectral measurement (that is, as a function of photon wavelength or energy). Since some wavelengths are absorbed more effectively than others, spectral

measurements of quantum efficiency can yield valuable information about the quality of the semiconductor bulk and surfaces.

Quantum efficiency is not the same as overall energy conversion efficiency, as it does not convey information about the fraction of power that is converted by the solar cell.

A solar cell may operate over a wide range of voltages (V) and currents (I). By increasing the resistive load on an irradiated cell continuously from zero (a short circuit) to a very high value (an open circuit) one can determine the maximum power point, the point that maximizes V×I; that is, the load for which the cell can deliver maximum electrical power at that level of irradiation. (The output power is zero in both the short circuit and open circuit extremes).

Another defining term in the overall behaviour of a solar cell is the fill factor (FF). This factor is a measure of quality of a solar cell. This is the available power at the maximum power point (Pm) divided by the open circuit voltage (VOC) and the short circuit current (ISC):