Continued Need for Higher Efficiency Photovoltaics

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As reported by the EIA last year,[1] solar photovoltaics (PV) are now the cheapest form of energy in most parts of the world. PV installations continue to accelerate with a record 134 GW of capacity installed and 821 TWh of energy generated in 2020.[2] However, the Net Zero Emission by 2050 Scenario will require 7000 TWh of generation by 2030, a difficult task given that it will require an average growth rate of 24% per year for the remainder of this decade.[2] The challenges to sustaining this level of growth may come from a number of areas, including the need for continued cost reductions in PV as measured by their levelized cost of electricity,[3] development of a circular economy for PV materials and devices as they begin to age and need replaced, and build-out of the necessary electricity grid and storage capabilities on national and global scales.

Underlying these broader issues is of course the power conversion efficiency of the photovoltaic device itself. Although silicon PV technology has been able to drive the tremendous progress over the last decade with module efficiencies of ∼20%, and it will continue to dominate the solar energy industry for the foreseeable future, there will be continued need to increase efficiencies to provide more power production per area from sunlight. It is a unique aspect of photovoltaic science that the efficiency limit with typical, single absorber, devices is seemingly low, ∼33% power conversion efficiency according to detailed balance of absorption and emission.[4] That large-scale, commercial silicon PV can reach reasonably close to this value is a wonder of modern technology and industry. However, what can be non-intuitive to new students in the field is that this efficiency is sufficient for a photovoltaic panel to generate 100s of watts per square meter under 1-sun illumination, making solar energy viable as a large-scale and cost-effective power source. For instance, ∼40% of the electricity needs of the U.S. could be met by roof-mounted solar panels of ∼16% efficiency.[5] Globally, it has been estimated that there is 27 PWh yr^{-1} of rooftop electricity generation potential.[6]

Research on new photovoltaic concepts[7] can open up pathways to the efficiency regime beyond the detailed-balance "barrier," enabling even more solar energy potential with less area, rooftop or land, required, and therefore less ecological and other impact. To that end, we invite submissions to our special section on Novel Photovoltaic Device Architectures,[8] which will showcase new device architectures, materials, and photon management strategies to help propel the field into a new era of high-efficiency devices. Now is the time for the field to utilize advances in our understanding of thermodynamic principles of solar energy conversion, in the synthesis and characterization of nanoscale structures, and in the use of quickly developing computational and machine learning tools, to take the field of photovoltaics to the next level.

References

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