Dear Editors,

Appropriateness for the diverse readership: The increasingly severe weather seen throughout the world is a conspicuous reminder of the urgency of reducing global CO2 emissions by transitioning from fossil fuel-based energy production to renewables. Photovoltaic (PV) solar energy conversion will be a key part of the planetary solution of this challenge. Accordingly, tremendous scientific effort has been expended worldwide on increasing the efficiency of the PV modules. However, since today's world record efficiency of about 27% is rapidly approaching the theoretical maximum of about 31%, and attempts to improve it for the 20 years after 1995 all failed, it is clear that further efficiency gains will be very hard to achieve. To achieve further progress, we point out that reducing the degradation of the efficiency by as little as 0.5%/year has the same effect on the Levelized Cost Of Energy as increasing the efficiency by 1%-2%: degradation suppression has the same effect as efficiency enhancement. Curiously, however, only sporadic scientific effort has been directed towards slowing the long-term degradation of the efficiency of PV cells and thus extending their lifetime. Therefore, we propose that a much more intense and extensive scientific effort needs to be dedicated to analyzing the degradation of PV cells. Such an analysis can be then used to design and implement structural changes that will mitigate the degradation. Our paper is an example-setting effort for a comprehensive degradation analysis, as well as for how to use this analysis to develop a design-change proposal to minimize PV cells degradation.

Importance: Among the industry-standard silicon solar cells, heterojunction cells hold the world efficiency record close to 27%. However, their market acceptance is hindered by the anomalously high 0.5 %/yr degradation rate of their open circuit voltage $V_{oc}$. Surprisingly, this degradation has not been analyzed yet, and to date lacks explanation. Our paper reports the first comprehensive study of the performance degradation of c-Si/a-Si:H heterojunction stacks. We achieved this by having developed "SolDeg", a multiscale, hierarchical, machine-learning-based integration of seven layers of numerical and analytical modeling that is capable of describing the degradation dynamics from femtoseconds to gigaseconds, over 24 orders of magnitude in time scales. Our analysis identified the likely mechanism responsible for this degradation, an unappreciated Si density gradient across the junction interface. Based on this discovery, we developed and propose a simple design change that promises to reduce the $V_{oc}$ degradation rate from 0.5%/yr to 0.1%/yr.

For the above reasons, we respectfully submit that our work is both important and appropriate for the diverse readership of Nature Energy.

Sincerely
*Gergely T. Zimanyi*
for the authors

- The authors do not have any related manuscripts under consideration or in press elsewhere.
- None of the authors have had any contact with a Nature Energy editor regarding this work.
- We do not wish to participate in a double-blind peer review.
- The authors do not have any excluded reviewers. Experts who are widely recognized leaders in the broader field of this paper include the following.

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