ITIF | INFORMATION TECHNOLOGY & INNOVATION FOUNDATION
CENTER FOR CLEAN ENERGY INNOVATION

Perovskite Solar Photovoltaic Cells

Climate-Tech to Watch

LINH NGUYEN | NOVEMBER 2021 | ITIF.ORG/CLIMATE-TECH

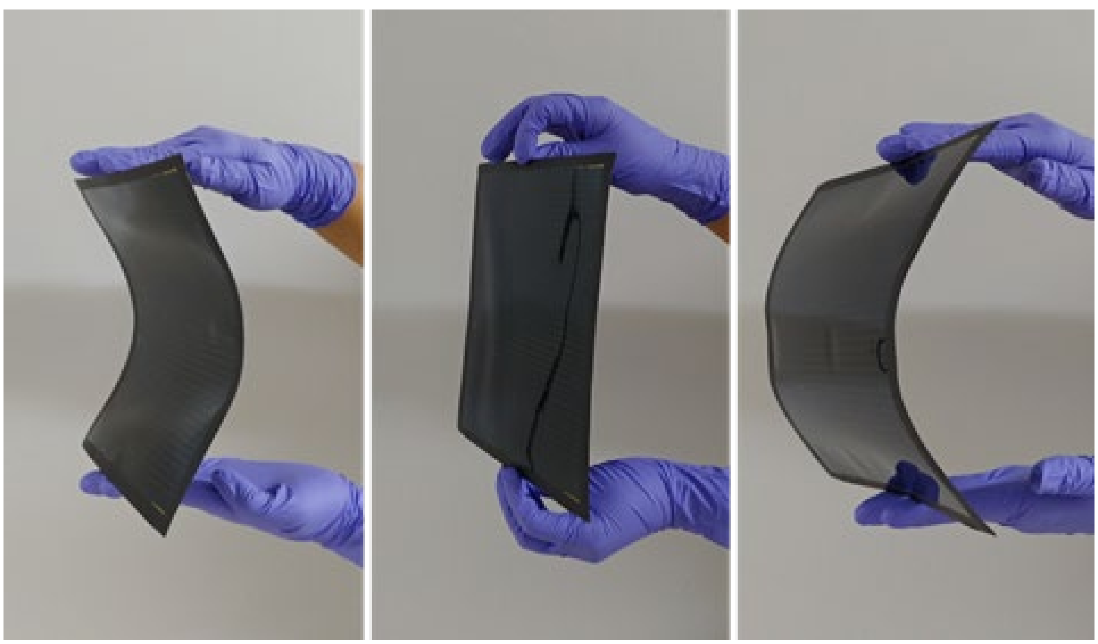
WHAT ARE THEY?

Perovskite is one of the most exciting materials for making better solar photovoltaic (PV) cells. It is a naturally occurring mineral, but also can be synthesized from abundant and cheap chemicals. Perovskite solar cells can be fine-tuned to absorb different colors of the solar spectrum, converting sunlight to energy with high efficiency. They can also be produced at a low cost with relatively simple machinery and processes. Silicon has been the dominant material in solar cells for decades. But silicon PV technology is reaching its practical efficiency limits. Perovskite solar cells could be a game-changer, offering the tantalizing possibility of more efficient, cheaper solar power.

TYPES OF PEROVSKITE SOLAR PV CELLS

Two major types of perovskite solar cells have been developed over recent decades: single-layer, thin-film perovskite solar cells and perovskite tandem solar cells.

Figure 1: Thin-film perovskite solar cells developed by the Korea Research Institute of Chemical Technology[1]



Thin-film perovskite solar cells use a single layer of perovskite material to convert light to usable energy. Figure 1 shows thin-film perovskite solar cells developed by the Korea Research Institute of Chemical Technology that are about 200 times thinner than traditional silicon solar cells.

Thin-film perovskites could potentially penetrate the market for building-integrated PV (i.e., roofs and windows that could generate power), eliminating the need to devote large land areas to solar farms while drastically downsizing the impact on the power grid.[2]

Perovskite tandem solar cells place a perovskite layer over a layer of perovskite, silicon, or other PV materials. Perovskite has a flexible bandgap, allowing it to absorb different parts of the solar spectrum to provide greater combined efficiencies with other PV materials. When paired with silicon—which has an inflexible bandgap—solar cells could reach over 30 percent efficiency.

PEROVSKITE SOLAR PV CELLS IN THE ENERGY TRANSITION

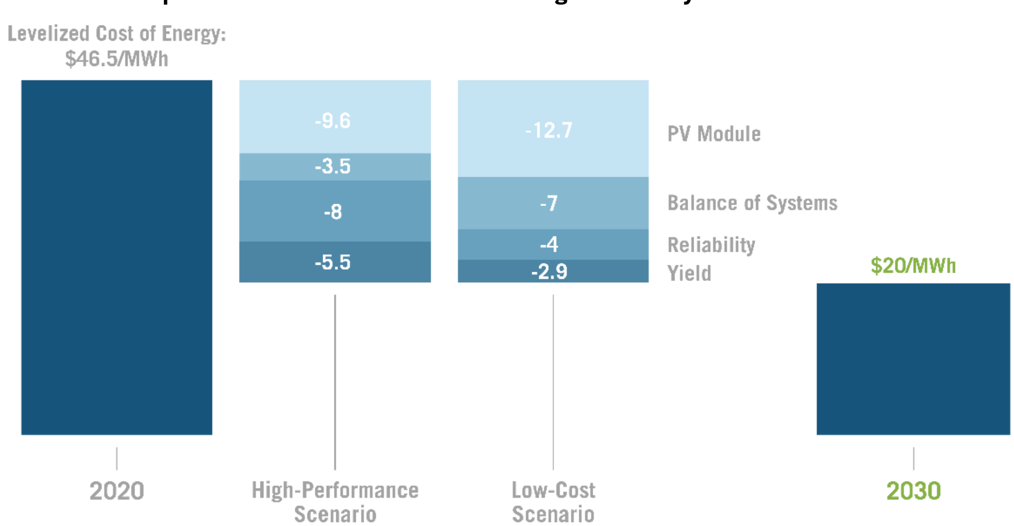
To achieve net-zero emissions globally, the International Energy Agency finds that solar PV must become the largest power source by 2050.[3] By 2030, 630 gigawatts (GW) of annual solar capacity additions will be needed, nearly four times the record levels set in 2020.[4] While silicon solar cells currently dominate the market—taking around 95 percent of the market share—silicon is not the best solar material. It has an efficiency limit of about 30 percent, is thick and bulky, and is made through a complex and energy-intensive process. The U.S. Department of Energy's (DOE's) Solar Futures Study finds that new PV cell technologies are essential to compensate for the limits of silicon.[5]

Perovskite solar cells could be the high-efficiency PV technology the world needs to drive down solar PV costs aggressively. In March 2021, DOE's SunShot Initiative announced an ambitious target to reduce utility-scale solar PV costs by more than half by 2030.[6] DOE identifies two technology trajectories to reach this goal:

- **The high-performance scenario** assumes novel high-efficiency solar cells will reduce the levelized cost of energy (LCOE) of solar PV through higher energy yields and reliability (i.e., longer service life).
- **The low-cost scenario** assumes existing solar cells will continue their downward cost trends, and LCOE reductions will mainly come from non-cell components of a PV system (see figure 2).

DOE's *Solar Futures Study* finds that perovskite could contribute to the high-performance scenario, pushing down costs by enabling the production of more power per solar panel.[7]

Figure 2: Two example cases that achieve the 2030 target for utility-scale PV LCOE[8]



The production process of perovskite solar cells is much simpler as well. Producing silicon solar cells involves refining silicon under high heat, infusing it with other materials, and slicing it into wafers. On the other hand, perovskite solar cells can be made at low temperatures and used in liquid form to coat flexible materials like plastic, enabling a roll-to-roll manufacturing process like newspaper printing (figure 3). Tandem perovskite-on-silicon solar cells create the opportunity to maintain the existing silicon production process to maximize the chance of market acceptance and avoid additional capital costs.

Figure 3: Perovskite solar cells printed on thin films developed by Swansea University researchers[9]

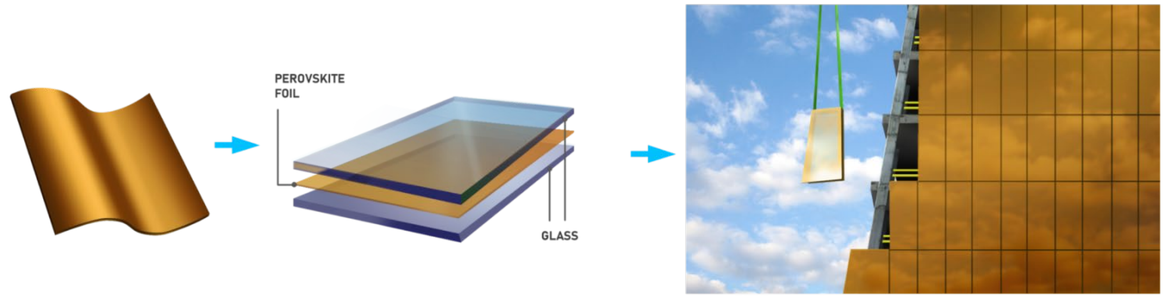
Perovskite solar cells are far from perfect, though. They are very sensitive to oxygen, moisture, and heat, making them less durable than silicon solar cells. Scientists have yet to demonstrate the ability to make high-efficiency perovskite solar cells in a large-area format. Perovskite efficiency records are set on tiny samples no larger than a postage stamp. The current record lab silicon solar cell, by comparison, measured 79cm^2 and could reach up to 180cm^2 with just a tiny efficiency drop.

Private investors are often skittish about funding novel technologies with performance uncertainties, presenting a significant barrier in bringing this promising technology from lab to market. Publicly funded technology validation and testing are essential to increase private investor confidence in the bankability of perovskite solar cells.

PROGRESS GLOBALLY

Many companies around the world are working to improve perovskite solar cells and manufacturing processes. UK-based Oxford PV broke the world record efficiency for perovskite-on-silicon tandem solar cells at 29.52 percent in December 2020.[10] And South Korea's Ulsan National Institute of Science and Technology and the Swiss Federal Institute of Technology achieved a record 25.6 percent efficiency for single-layer perovskite solar cells.[11]

Figure 4: Saule technologies' power-generating windows made with perovskite solar cells



New applications for perovskite solar cells are emerging. Poland's Saule Technologies, one of the leaders in the perovskite market, has some exciting products in the works. They developed an ink-jet printing process for manufacturing perovskite solar cells encased in flexible and transparent plastic. A panel containing Saule's cells is about a tenth as heavy as a silicon panel of the same size. These thin and lightweight cells can be overlayed with layers of glass to make building windows that can generate electricity (see figure 4). They can also be used to produce energy-harvesting blinds that can block and absorb intense summer sunlight while making power when needed.[12]

PROGRESS IN THE UNITED STATES

Perovskite solar cells have yet to reach commercialization in the United States, but several U.S. companies are taking significant strides toward producing perovskite solar cells at scale. For example, CubicPV, formed in 2021, is dedicated to bringing perovskite-on-silicon tandem solar cells to market.[13] And Energy Materials Corporation is focusing on developing high-speed printing of perovskite solar cells on paper-thin flexible glass.[14]

In August 2020, DOE's Solar Technologies Office (SETO) announced $20 million to advance perovskite solar technologies. And in March 2021, DOE SETO announced $40 million for perovskite research and development (R&D), including $14 million for a testing center to provide neutral, independent performance validation for new perovskite devices. Funded projects will focus on improving perovskites' conversion efficiency and stability, addressing the challenges with manufacturing perovskite modules, and validating the technology to ensure long-term performance.[15]

In December 2020, Congress passed the Energy Act of 2020, which authorizes $300 million annually for fiscal years 2021 through 2025 for SETO to boost innovation in solar cell technologies. It directs DOE to explore a range of advanced solar energy technologies, including perovskite solar cells and thin-film devices.[16]

KEY POLICY ISSUES

Even with significant performance improvements, perovskite solar cells may face significant roadblocks to become competitive in a global market flooded with cheap silicon. China became the dominant silicon solar PV manufacturer during the 2010s thanks in part to excessive government subsidies. This subsidy-powered competition eliminated many innovative companies and kept alternative solar PV technologies from coming to market.[17]

The Information Technology and Innovation Foundation's (ITIF's) 2020 report "The Impact of China's Production Surge on Innovation in the Global Solar Photovoltaics Industry" recommends the United States and other R&D-intensive countries focus on increasing public investments for perovskites R&D, among other new PV technologies, to ensure technological diversity in PV production. ITIF concluded that technological diversity in PV production is essential to address the climate crisis because PV is too important to fail.[18]

Policies that create demand alternatives to silicon solar PV are also critical to scale perovskite deployment. Market-pull policy options include carveouts for perovskite PV technologies within renewable portfolio standards, tiered tax incentives and feed-in-tariffs that award a higher level of support, and loan guarantees for project developers deploying them. These are the same tools that governments used to build the current PV industry in the United States and abroad.[19]

LOOKING FORWARD

To achieve a future solar-dominated power grid, solar cells must become cheaper. And to do that, they must be more efficient than is likely possible with silicon. Improvements in power conversion efficiency, costs, and degradation rates could allow perovskite solar cells to be one of the high-performance, low-cost solutions to meet renewable energy targets.

FURTHER READING

- Colin Cunliff and Linh Nguyen, "Federal Energy RD&D: Solar Energy" (ITIF, 2021), http://www2.itif.org/2021-budget-solar.pdf.
- David M. Hart, "Impact of China's Production Surge on Innovation in the Global Solar Photovoltaics Industry" (ITIF, 2020), https://itif.org/publications/2020/10/05/impact-chinas-production-surge-innovation-global-solar-photovoltaics.
- Robert Rozansky, "An Innovation Agenda for Advanced Renewable Energy Technologies" (ITIF, 2020), https://itif.org/publications/2020/12/21/innovation-agenda-advanced-renewable-energy-technologies.
- Varun Sivaram, *Taming the Sun: Innovations to Harness Solar Energy and Power the Planet* (The MIT Press, 2018), https://mitpress.mit.edu/books/taming-sun.

Acknowledgments

The author wishes to thank David M. Hart for providing input to this briefing. Any errors or omissions are the author's alone.

About the Author

Linh Nguyen is a research assistant for clean energy innovation with ITIF. She previously worked for Climate Advisers and Resource Energy. She holds a master's degree in energy policy from Johns Hopkins University.

About ITIF

ENDNOTES

1. Edward Gardner, "New record efficiency for flexible perovskite solar cells," *Chemistry World,* December 7, 2020, https://www.chemistryworld.com/news/new-record-efficiency-for-flexible-perovskite-solar-cells/4012858.article; Image by Jangwon Seo at the Korea Research Institute of Chemical Technology.
2. Mark Hutchins, "Sensing an opportunity for indoor PV," *PV Magazine*, July 17, 2019, https://www.pv-magazine.com/2019/07/17/sensing-an-opportunity-for-indoor-pv/; Robert Rozansky, "An Innovation Agenda for Advanced Renewable Energy Technologies" (ITIF, 2020), https://itif.org/publications/2020/12/21/innovation-agenda-advanced-renewable-energy-technologies.
3. International Energy Agency (IEA), *IEA Net Zero by 2050 – A Roadmap for the Global Energy Sector* (Paris: IEA, 2021), 18, https://www.iea.org/reports/net-zero-by-2050.
4. Ibid, 14.
5. Department of Energy (DOE), *Solar Futures Study,* (DOE, September 2021), 16 https://www.energy.gov/eere/solar/solar-futures-study.
6. DOE, "DOE Announces Goal to Cut Solar Costs by More than Half by 2030," *news release,* March 25, 2021, https://www.energy.gov/articles/doe-announces-goal-cut-solar-costs-more-half-2030.
7. Department of Energy (DOE), *Solar Futures Study,* (DOE, September 2021), 16 https://www.energy.gov/eere/solar/solar-futures-study.
8. Ibid, figure 6 – 5, p 144.
9. Swansea University, "Printing Solar Cells on Thin Films for Cheaper and More Efficient Solar Energy," *Sci Tech Daily*, July 14, 2020, https://scitechdaily.com/printing-solar-cells-on-thin-films-for-cheaper-and-more-efficient-solar-energy/.

10. Maria Gallucci, “Perovskite Solar Out-Benches Rivals in 2021,” *IEEE Spectrum*, January 1, 2021, https://spectrum.ieee.org/oxford-pv-sets-new-record-for-perovskite-solar-cells; Oxford PV, “Oxford PV hits new world record for solar cell,” *news release*, December 21, 2020, https://www.oxfordpv.com/news/oxford-pv-hits-new-world-record-solar-cell.
11. Emiliano Bellini, “UNIST, EPFL claim 25.6% efficiency world record for perovskite solar cell,” *PV magazine*, April 6, 2021, https://www.pv-magazine.com/2021/04/06/unist-epfl-claim-25-6-efficiency-world-record-for-perovskite-solar-cell/.
12. Saule Technologies, “Our Products,” accessed November 2, 2021, https://sauletech.com/product/.
13. CubicPV, “About,” accessed November 2, 2021, https://cubicpv.com/about/.
14. Yoana Cholteeva, “Record-breaking solar perovskites,” *Power Technology*, May 6, 2021, https://www.power-technology.com/features/record-breaking-solar-perovskites/.
15. DOE, “DOE Announces Goal to Cut Solar Costs by More than Half by 2030,” *news release,* March 25, 2021, https://www.energy.gov/articles/doe-announces-goal-cut-solar-costs-more-half-2030.
16. Consolidated Appropriations Act, 2021. Division Z, Sec. 3004. https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf; Colin Cunliff and Linh Nguyen, “Federal Energy RD&D: Solar Energy” (ITIF, 2021), https://www2.itif.org/2021-budget-solar.pdf.
17. David Hart, “Impact of China’s Production Surge on Innovation in the Global Solar Photovoltaics Industry” (ITIF, 2020), 28, https://itif.org/publications/2020/10/05/impact-chinas-production-surge-innovation-global-solar-photovoltaics.
18. Ibid, 29.
19. Ibid, 30.