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Editorial

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Back to the Photovoltaic Future with Perovskites

It will not be too long before rooftop solar panels will become a preferred option for new construction of houses in the U.S. and elsewhere. Many recent projections of new energy installations predict a surge in wind and photovoltaic (PV)-based installations during the next 25 years. The availability of affordable PV panels is rendering the installation of solar panels on residential rooftops a more common occurrence in the U.S. and elsewhere. According to the recently released *Solar Marketplace Intel Report* by Energy Sage (https://www.energysage.com/news/energysage-marketplace-intel-report), the average gross cost of PV installation now ranges from $3.21 to 4.37 per watt, with an average payback time of 7.5 years. In 2015 alone, homeowners with installed PV units met ~85% of their electricity needs.

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The necessity to decrease the carbon footprint in the energy sector and market economically competitive PV panels will drive the growth of renewable energy in the future. The DOE Annual Energy Outlook 2015 (http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf) points out a robust annual growth of 6.5% for PV technology. The DOE projections of the 2013–2040 new energy installations based on various economic and oil price scenarios are shown in Figure 1. Of these new additions, the share of renewable energy will range from 22% in the High Oil and Gas Resource case to 51% in the High Oil Price case. In the Reference case, it projects 109 GW of renewable energy as the newly installed capacity, of which 48 GW will come from solar technology. The recent Bloomberg energy report (http://www.bloomberg.com/company/new-energy-outlook/) also concludes a similar growth scenario for renewables. According to this report, 54% of the newly installed energy capacity worldwide will come from renewables.

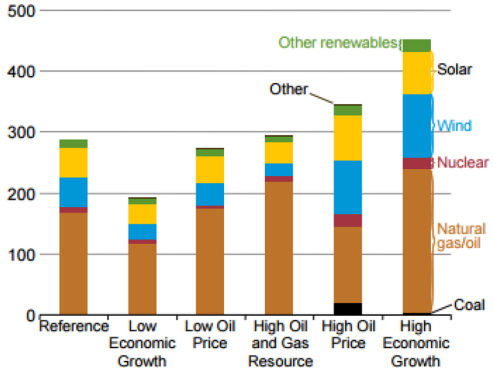

Figure 1. Cumulative additions to electricity generation capacity by fuel in six cases between the years of 2013–2040. The numbers on the *Y*-axis are in gigawatts. Reproduced from DOE "Annual Energy Outlook 2015 with projections to 2040 (http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf).

So far, silicon-based photovoltaic devices have dominated the solar panel installations market. Thin-film solar cells not only offer lower cost but also reduce the carbon footprint from their manufacture. While the power conversion efficiency of thin-film solar cells is slightly lower than that of silicon solar cells, new materials such as organic metal halide perovskites are showing greater promise. For example, methylammonium lead iodide based solar cells have exhibited a power conversion efficiency greater than 20%, thus making them possible contenders in thin-film photovoltaic technology. The early success of achieving high-efficiency PV devices has necessitated better understanding of the structural characteristics, photoinduced charge separation, and charge-transport properties.

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J. Phys. Chem. Lett. has led the field of perovskite photovoltaics through its rapid publication of new scientific advances. The initial developments in perovskite solar cells were covered in earlier perspectives (see Table 1). Three perspectives in the current issue of *J. Phys. Chem. Lett.* focus on the fundamental understanding of perovskite solar cells. Control over the solution processing of perovskite thin films with well-tuned morphologies has been the key in designing high-efficiency solar cells.

Padture and co-workers (Padture, N. P.; et al. *J. Phys. Chem. Lett.* **2015**, *6*, 4827–4839. DOI: 10.1021/acs.jpclett.5b01843) provide an excellent overview of the fundamental phenomena pertaining to nucleation/growth, coarsening, and microstructural evolution for solution-processed thin films. They also discuss the challenges and opportunities in determining the role of such solution processing in controlling the defect sites. Rappe and co-workers (Rappe, A.; et al. *J. Phys. Chem. Lett.* **2015**, *6*, 4862–4872. DOI: 10.1021/acs.jpclett.5b01830) discuss strategies for improving the performance and stability of organic metal halide perovskites. They also discuss material innovation strategies for improving the performance of perovskite photovoltaics. Green and co-workers analyze absorption properties of organic metal halide perovskites and provide insight into energy band structures, binding energies,

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J. Phys. Chem. Lett. 2015, 6, 4874–4875

Table 1. *JPC Letters* Perspectives on Organic Metal Halide Perovskite Photovoltaics

author(s)	perspective title	citation	DOI
Nam-Gyu Park	Organometal Perovskite Light Absorbers Toward a 20% Efficiency Low-Cost Solid-State Mesoscopic Solar Cell	*J. Phys. Chem. Lett.* **2013**, *4*, 2423−2429	10.1021/jz400892a
Henry J. Snaith	Perovskites: The Emergence of a New Era for Low-Cost, High-Efficiency Solar Cells	*J. Phys. Chem. Lett.* **2013**, *4*, 3623−3630	10.1021/jz4020162
Yixin Zhao and Kai Zhu	Solution Chemistry Engineering toward High-Efficiency Perovskite Solar Cells	*J. Phys. Chem. Lett.* **2014**, *5*, 4175−4186	10.1021/jz501983v
Pablo P. Boix, Shweta Agarwala, Teck Ming Koh, Nripan Mathews, and Subodh G. Mhaisalkar	Perovskite Solar Cells: Beyond Methylammonium Lead Iodide	*J. Phys. Chem. Lett.* **2015**, *6*, 898−907	10.1021/jz502547f
Jeffrey A. Christians, Joseph S. Manser, and Prashant V. Kamat	Multifaceted Excited State of $CH_3NH_3PbI_3$. Charge Separation, Recombination, and Tapping	*J. Phys. Chem. Lett.* **2015**, *6*, 2086−2095	10.1021/acs.jpclett.5b00594
Jinsong Huang, Yuchuan Shao, and Qingfeng Dong	Organometal Trihalide Perovskite Single Crystals: A Next Wave of Materials for 25% Efficiency Photovoltaics and Applications Beyond?	*J. Phys. Chem. Lett.* **2015**, *6*, 3218−3227	10.1021/acs.jpclett.5b01419

and excitons (Green, M. A.; et al. *J. Phys. Chem. Lett.* **2015**, *6*, 4774−4785. DOI: 10.1021/acs.jpclett.5b01865).

The two Viewpoints published in this issue put forth new proposals to explain long charge carrier lifetimes, inverse temperature dependence of carrier mobilities, and low carrier scattering rates of organic metal halide perovskites. Brenner et al. argue that, given their low effective masses, the charge carriers in typical hybrid perovskite materials have modest mobilities (Brenner, T. M.; et al. *J. Phys. Chem. Lett.* **2015**, *6*, 4754−4757. DOI: 10.1021/acs.jpclett.5b02390). They propose that the origin of this lies in the recently measured "soft" mechanical and vibrational properties of hybrid perovskites and the resulting electron−lattice coupling mechanisms active at room temperature. As a consequence, charge carriers can be scattered by acoustic phonons and/or polarons that limit their mobility. Zhu and Podzorov in their Viewpoint present a large-polaron hypothesis (Zhu, X.-Y.; et al. *J. Phys. Chem. Lett.* **2015**, *6*, 4758−4761. DOI: 10.1021/acs.jpclett.5b02462). They propose that the enhanced effective mass of the large polaron is likely to provide a "protective shield" against scattering with phonons. These arguments lay down experimental and theoretical challenges to further validate many intriguing properties of organic metal hybrid perovskites. The discussion points raised in these Viewpoints should open up new dialogues to offer better understanding of perovskites' unusual carrier properties.

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Notes

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