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Editorial
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Energy Outlook for Planet Earth

Growing economies and increasing population will necessitate an increased energy supply in the coming years. A recent BP report of the 2030 Energy Outlook suggests that an additional 1.3 billion people will become new energy consumers by 2030.[1] If the current energy growth of 1.6% per year continues, this would require the energy production to double in about 40 years. In fact, Exxon's 2040 Energy Outlook projects an 85% increase in global electricity demand over the period of 2010–2040.[2] Developing (nonOECD) countries alone will experience a 150% surge in electricity demand. The sheer magnitude of this energy demand will require us to make some tough choices: either continue to build the same number of coal and nuclear power plants or explore the production of renewable energy coupled with improved efficiency of energy usage (Chart 1).

The obvious question that one needs to answer is what choice we should make to meet our energy demand in the coming decades. Because of economic benefits, fossil fuels have remained the popular choice in the power generation sector. The recent exploration of natural gas by fracking has energized many economists to portray a rosy scenario for fossil-fuel-based power plants.[4–6] Contrary to the prediction of the models that infer a lifetime of 40 years, many wells produce 80–95% less gas after just 3 years.[7] Given this rapid decline in natural gas production from newly drilled wells, it would be necessary to drill 7200 wells per year at a cost of 42 billion dollars so that the current level of natural gas production could be sustained.[7] One should seriously consider such economic factors as well as the environmental impact before portraying natural gas as the savior of the energy crunch.

> If the current energy growth of 1.6% per year continues, this would require the energy production to double in about 40 years.

The BP Energy Outlook report also projects a hefty 27% growth in renewable energy in the power sector, slightly ahead of coal (26%) and natural gas (21%) during the period of 2011–2030.[1] Although renewable energy will still play a minor role as a component of the total energy mix (contributing only about 6% by 2030), its contribution in the power sector will be realized more as we step into the coming decades. Already, wind and solar are making an impact here in the U.S., Europe, and elsewhere.

Chart 2 shows the annual production of solar and wind during the period of 2005–2012 followed by the projected growth in 2013 and 2014. It is interesting to note that both wind and solar production of electricity have doubled during the last 3 years (2009–2012). For instance, the solar energy supply in the U.S. increased from 29 TW h in 2009 to 62 TW h in 2012.[3] The electricity produced from solar energy during the last year alone has avoided burning of ~7.6 million tons of coal! As the awareness of clean energy production continues to grow, we will see an increased interest in harvesting wind and solar energy.

During the past decade, scientists and engineers have shown increased interest in harvesting solar photons as chemical and electrical energy. The exploration of new catalyst materials and

Chart 1. What Choice Will We Be Making to Meet the Increasing Energy Demand in the Future?

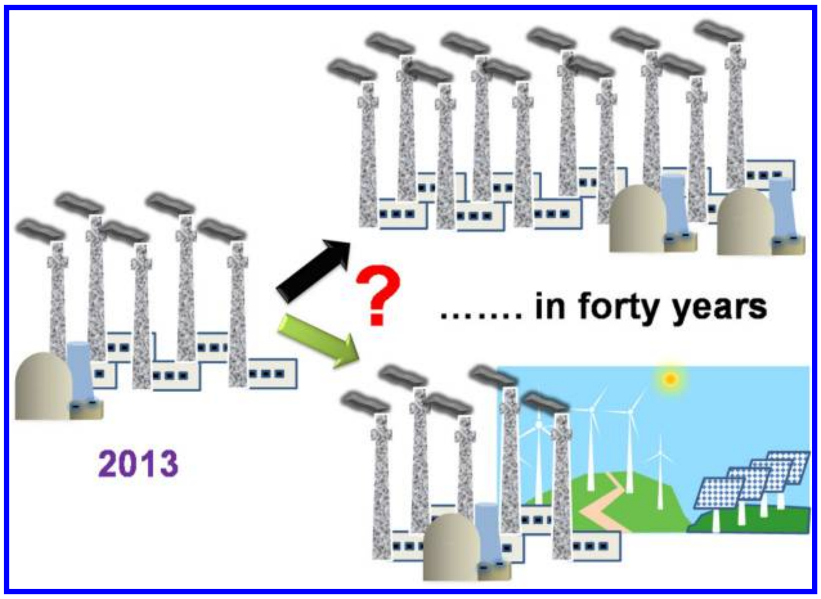

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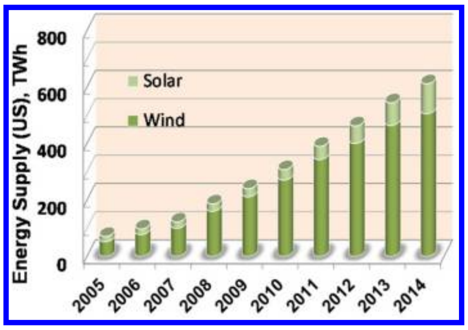
Table 1. Recent *JPCL* Perspectives on Energy Conversion and Storage

topic	title	reference
Guest Commentary	Nanocarbon Hybrids: Interactions with Luminophores to Applications in Energy Harvesting and Solar Fuel Production	D'Souza, F. *J. Phys. Chem. Lett.* **2013**, *4*, 842−843
	Nano-Enabled Photovoltaics. Progress in Materials and Methodologies	Bisquert, J. *J. Phys. Chem. Lett.* **2013**, *4*, 1051−1052
	Lithium Economy: Will It Get the Electric Traction?	Shukla, A. K.; Kumar, T. P. *J. Phys. Chem. Lett.* **2013**, *4*, 551−555
	In Charge of the World: Electrochemical Energy Storage	Manthiram, A.; Fu, Y.; Su, Y.-S. *J. Phys. Chem. Lett.* **2013**, *4*, 1295−1297
	Fracking: What Can Physical Chemistry Offer?	Yethiraj, A.; Striolo, A. *J. Phys. Chem. Lett.* **2013**, *4*, 687−690
Dye-Sensitized Solar Cells	Intermolecular Interactions in Dye-Sensitized Solar Cells: A Computational Modeling Perspective	Pastore, M.; De Angelis, F. *J. Phys. Chem. Lett.* **2013**, *4*, 956−974
	Modeling Dye-Sensitized Solar Cells: From Theory to Experiment	Le Bahers, T.; Pauporté, T.; Lainé, P. P.; Labat, F.; Adamo, C.; Ciofini, I. *J. Phys. Chem. Lett.* **2013**, *4*, 1044−1050
Organic Photovoltaics	Elucidating Operating Modes of Bulk-Heterojunction Solar Cells from Impedance Spectroscopy Analysis	Garcia-Belmonte, G.; Guerrero, A.; Bisquert, J. *J. Phys. Chem. Lett.* **2013**, *4*, 877−886
	High-Resolution Photocurrent Imaging of Bulk Heterojunction Solar Cells	Mukhopadhyay, S.; Das, A. J.; Narayan, K. S. *J. Phys. Chem. Lett.* **2013**, *4*, 161−169 (Video Link)
	Luminophores and Carbon Nanotubes: An Odd Combination?	Mohanraj, J.; Armaroli, N. *J. Phys. Chem. Lett.* **2013**, *4*, 767−778
	Graphene Films for Flexible Organic and Energy Storage Devices	Lee, S.-K.; Rana, K.; Ahn, J.-H. *J. Phys. Chem. Lett.* **2013**, *4*, 831−841
Quantum Dot Photovoltaics	Quantum Dot Solar Cells. The *Next Big Thing* in Photovoltaics	Kamat, P. V. *J. Phys. Chem. Lett.* **2013**, *4*, 908−918 (Video Link)
	All-Oxide Photovoltaics	Ruhle, S.; Anderson, A. Y.; Barad, H.-N.; Kupfer, B.; Bouhadana, Y.; Rosh-Hodesh, E.; Zaban, A. *J. Phys. Chem. Lett.* **2012**, *3*, 3755−3764
Solar Fuel	Graphene-Based Photocatalysts for Hydrogen Generation	Xiang, Q.; Yu, J. *J. Phys. Chem. Lett.* **2013**, *4*, 753−759
Fuel Cell	Physical Chemistry Research Toward Proton Exchange Membrane Fuel Cell Advancement	Swider-Lyons, K. E.; Campbell, S. A. *J. Phys. Chem. Lett.* **2013**, *4*, 393−401 (Video Link)
	Designing Enhanced One-Dimensional Electrocatalysts for the Oxygen Reduction Reaction: Probing Size- and Composition-Dependent Electrocatalytic Behavior in Noble Metal Nanowires	Koenigsmann, C.; Scofield, M. E.; Liu, H.; Wong, S. S. *J. Phys. Chem. Lett.* **2012**, *3*, 3385−3398 (Video Link)
Energy Storage	Graphene Materials for Electrochemical Capacitors	Chen, J.; Li, C.; Shi, G. *J. Phys. Chem. Lett.* **2013**, *4*, 1244−1253 (Video Link)
	Microscopic Insights into the Electrochemical Behavior of Nonaqueous Electrolytes in Electric Double-Layer Capacitors	Jiang, D.-e.; Wu, J. *J. Phys. Chem. Lett.* **2013**, *4*, 1260−1267 (Video Link)
	High-Energy Cathode Materials (Li_2MnO_3−$LiMO_2$) for Lithium-Ion Batteries	Yu, H.; Zhou, H. *J. Phys. Chem. Lett.* **2013**, *4*, 1268−1280
	Vanadium Flow Battery for Energy Storage: Prospects and Challenges	Ding, C.; Zhang, H.; Li, X.; Liu, T.; Xing, F. *J. Phys. Chem. Lett.* **2013**, *4*, 1281−1294 (Video Link)

Chart 2. U.S. Renewable Energy Supply for the Period of 2005−2014[a]



[a] The quadrillion Btu presented in the original table has been converted to terawatt hours (1 Quad = 293 TW h). Source: Short-Term Energy Outlook, April 2013,[3] http://www.eia.gov/forecasts/steo/data.cfm?type=figures.

semiconductor nanostructures has rejuvenated great interest in developing next-generation solar cells. The Perspectives in this issue provide four different themes of current research in solar energy conversion.

Hydrogen is often referred to as the fuel of the future. It should be possible to tap resources such as water and light for producing hydrogen if a suitable photocatalyst can be identified. Oxide semiconductor photocatalysts coupled with cocatalysts are able to split water under UV−visible irradiation only under applied bias potential. One of the major hurdles in achieving greater photoconversion efficiency in the water splitting reaction is the proton-coupled four-electron oxidation process. Oxide semiconductors such as Fe_2O_3 and $BiVO_4$ absorb light in the visible, but they exhibit greater overpotential for interfacial charge transfer. Sivula in his Perspective examines the role of surface treatments that are designed to either passivate surface traps or increase reaction rates of semiconductor photocatalysts (Sivula, K. Metal Oxide Photoelectrodes for Solar Fuel Production, Surface Traps, and Catalysis. *J. Phys. Chem. Lett.* **2013**, *4*, 1624−1633).

There has been significant interest in developing organic photovoltaic devices as a viable solution for transformative photovoltaics. A recent report of achieving 8−10% efficiency has put these bulk heterojunction devices in the forefront of next-generation photovoltaics.[8] While OLED (organic light-emitting diodes) have been successfully implemented in devices, their counterpart OPV has yet to roll out flexible solar sheets or panels.

Hutchison and co-workers in their Perspective discuss computationally driven design methods for OPV materials (Kanal, I. Y.; Owens, S. G.; Bechtel, J. S.; Hutchison, G. R. Efficient Computational Screening of Organic Polymer Photovoltaics. *J. Phys. Chem. Lett.* **2013**, *4*, 1613−1623). The methodology of the screening procedure in the first stage allows them to identify diverse candidate compounds, including both synthetic and property-based measures. Nayak, Narasimhan, and Cahan in their Perspective discuss factors that contribute to efficient free carrier generation, following exciton dissociation at organic−organic interfaces (Nayak, P. K.; Narasimhan, K. L.; Cahen, D. Separating Charges at Organic Interfaces: Effects of Disorder, Hot States, and Electric Field. *J. Phys. Chem. Lett.* **2013**, *4*, 1707−1717). Jung and Lee discuss some of the recent advances and emerging strategies for designing high-efficiency dye-sensitized solar cells (DSSCs) (Lee, J.-K; Jung, H. S. Dye Sensitized Solar Cells for Economically Viable Photovoltaic Systems. *J. Phys. Chem. Lett.* **2013**, *4*, 1682−1693). This Perspective provides further insight into the challenges involved in large-scale production of DSSCs.

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In recent years, the infusion of new funding by the government agencies for renewable energy has resulted in increased research activity all over the world. Renewable energy research has been at the forefront of recently published articles in *JPCL* and other major journals. The design of semiconductor and metal nanostructures is of immediate interest to this field. Organic hybrid assemblies are another class of light harvesters that are being explored for photoconversion efficiencies. *The Journal of Physical Chemistry* (*J. Phys. Chem. A/B/C/Lett.*) remains a preferred choice of many leading scientists to disseminate scientific advances that include detailed mechanistic insights of the energy conversion and storage. *JPCL* recently published several thematic issues with Perspectives on energy conversion and storage from leading experts. A few of the key Perspectives and Guest Commentaries published in recent issues are listed in Table 1. Conversion of light energy into electricity and solar fuels and the design of new materials for energy storage will continue to dominate research activity in the near future.

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Notes

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(4) Yethiraj, A.; Striolo, A. Fracking: What Can Physical Chemistry Offer? *J. Phys. Chem. Lett.* **2013**, *4*, 687−690.

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