# Energy Quarterly

News and analysis on materials solutions to energy challenges

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Inside:





"Materials opportunities and challenges for low-energy computing: Devices" title image: Scientists introduce a hybrid concept called mixed-precision in-memory computing, which combines a von Neumann machine with a computational memory unit. Credit: IBM Research and *Nature Electronics*.

"Gone with the wind: The life and death of a wind turbine rotor blade" title image credit: Shutterstock.

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## Shifting the energy paradigm

Nearly all societies have an insatiable demand for energy to transport ourselves and goods, entertain and communicate with each other, and moderate our environment. Globally, a well-established energy paradigm exists for production, consumption, transmission, and storage. The coupling of technologies, infrastructure, markets, and governmental policies reinforces this paradigm through a mature, vast, and complex system.

In the United States, more than 80% of energy consumption is sourced from natural gas, coal, or petroleum. In Europe and China, the distribution of energy sources varies. Europe relies less on natural gas in lieu of renewables, nuclear, and hydro; whereas coal supports nearly 60% of China's energy usage. Notwithstanding these variations and the growth of renewables (e.g., solar-energy production increased ~600% in the United States from 2010 to 2018), the global picture is clear: fossil fuels reign supreme.

The developed world was served well by this system during the previous century. Fossil fuels provided inexpensive electricity, transportation, and heating fuels; however, associated negative environmental, geopolitical, and climate impacts are well-documented. As we enter the third decade of the 21st century, it seems a good, albeit somewhat arbitrary, time to evaluate our policies, research, development, and contemporary concept of energy in society. It is time for a new energy paradigm.

This requires political and social determination to make the necessary changes toward a long-term sustainable solution. Energy markets and regulations will need to be redesigned for optimal impact; nevertheless, science and technology must play a critical role. Consider the US transportation market. Only 20% of energy (95% sourced from fossil fuels) is used in service of propulsion; the rest is rejected as waste. It is easy to see space for enormous beneficial technological advances.

My own research concentrates on the structure–processing–properties relationship of materials in solid-oxide fuel cells (SOFCs), to which Carnot cycle limitations do not apply and provide high-temperature exhaust heat for combined cycle processes, and next-generation energy-storage chemistries (e.g., magnesium ion batteries) to reach beyond the capabilities of lithium ion. I am driven by the question: How can materials be engineered for desired properties while maintaining manufacturability? I hope to be an important contributor to energy science advances, but it will take all the diversity of thought and experience across the entire scientific community to provide a portfolio of possibilities for an array of specific global energy challenges. Recent advances in computational materials design, machine learning, and *in situ* characterization probes are essential tools in service to this quest.

I am reminded that humans are infinitely resourceful and creative, which is truly our greatest strength. We can shift to an enduring and sustainable energy paradigm that meets our desire to ship mangoes to supermarkets in northern latitudes, stream viral cat videos, and use air conditioning at the height of a hot summer afternoon.

**Brian J. Ingram**