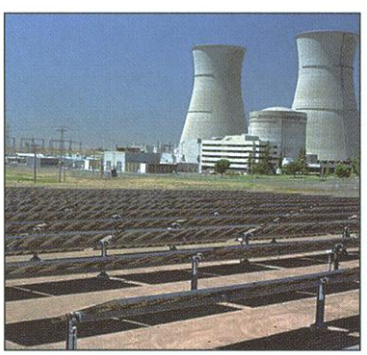
Choosing the Sources of Sustainable Energy

RENEWABLE ENERGY "WILL BE THE CENTRAL pillar of a sustainable high-technology civilization," says Terry Collins in his Essay "Toward sustainable chemistry" (*Science*'s Compass, 5 Jan., p. 48). This view, however, dismisses the potential long-term contributions of nuclear energy technologies. "Toxic elements are the prototypical persistent pollutants," says Collins; "long-lived radioactive elements are especially dangerous examples." But "danger" does not depend solely on toxicity—sources, pathways, and doses must also be factored into the equation.

When extrapolated to global scales, renewable energy technologies inherently involve large material flows that make it difficult to avoid discharging waste streams into the accessible environment. The fireplace is an example of a widely used, highly distributed renewable energy technology that has proven difficult to regulate effectively and is problematic for public health in urban areas and developing countries. In contrast, the nuclear energy technologies now in use involve much smaller mass flows and thus present realistic possibilities to permanently isolate high-level waste streams from the accessible environment. The upcoming U.S. Department of Energy's Generation IV Nuclear Energy Systems Initiative (*1*) is expected to identify fission technologies that combine substantially improved economics, safety, proliferation resistance, and waste minimization. When designed to use uranium resources with sufficient efficiency, such nuclear systems would qualify as sustainable.



CREDIT: WARREN GRETZ/DOE/NREL

If we strive to continuously improve nuclear energy technologies at the same time that we are working toward equivalent improvements in renewable technologies, we can provide future generations with a mix of energy sources that can be more readily optimized to meet the important goal of sustainability.

PER F. PETERSON
Department of Nuclear Engineering, University of California, Berkeley, CA 94720–1730, USA. E-mail: peterson@nuc.berkeley.edu

References and Notes
1. A description of the Initiative is available at http://www.inel.gov/resources/newsletters/inews-2000/12-05-00/1205gen42.htm

Response

WE FACE AN IMPORTANT CHOICE FOR ENERGY research: either we attempt to improve energy sources that are inherently flawed with respect to sustainability, such as fission or fossilized carbon, or we work toward new approaches for the sake of sustainability.

In my Essay, I argued for an emphasis on the latter course. In contrast, Per Peterson suggests that nuclear fission is sustainable; however, the persistence and toxicity of the radioisotopes involved amply justify the aversion of many nations to fission. If nuclear fusion can be developed free of long-lived radioisotopes, then it could contribute to sustainability.

Every 20 days Earth receives from sunlight the energy equivalent of the entire planetary reserves of coal, oil, and natural gas (*1*). Research on photochemical, photovoltaic, and passive and active solar technologies could speed our civilization toward sustainable energy. Last summer, engineers from Tokyo Denki University completed an 18,000-kilometer multicontinent journey in a solar cell–mounted electric car; 10% of the energy came from the sun, about the conversion efficiency of the silicon cells used. With expanded research support, more efficient photovoltaic materials could be discovered to allow cars to be completely solar powered. A catalyst/material ensemble capable of efficiently converting solar-irradiated water to hydrogen and oxygen could be found. Either development would revolutionize energy technology in favor of sustainability.

"We face an important choice for energy research..."

For many decades, the large established energy research communities have used most of the energy research funding to study nuclear and fossilized carbon approaches. If solar research had received anything like this colossal support, solar-rich California would almost certainly not now be experiencing energy shortages. However, even a leading fossil fuel provider like Royal Dutch/Shell has seen the light and is now making a 5-year, $0.5 billion commitment to solar research. Perhaps our future will be endowed with sustainable solar technologies and will not remain shackled to energy technologies that are devastating to the environment.

TERRY COLLINS
Department of Chemistry, Carnegie Mellon University, Pittsburgh, PA 15213, USA. E-mail: tc1u@andrew.cmu.edu

References and Notes
1. Royal Dutch/Shell Web site, at http://www.shell.com/royal-en/content/0,5028,25644-51311,00.html

Longisquama Fossil and Feather Morphology

THE TRIASSIC REPTILE *LONGISQUAMA* HAS blade-like integumental appendages that Terry D. Jones and colleagues propose in their report "Nonavian feathers in a Late Triassic archosaur" (*1*) are homologous with avian feathers. However, examination of their evidence suggests that this conclusion is flawed.

The authors refer to these appendages as "pinnate" but provide little support for this conjecture [see reference 5 in (*1*)]. I examined the *Longisquama* fossil with the authors in April 1999 and observed no evidence of branched structure. Rather, the appendages consist of a membraneous blade with a continuous, unfrayed "ribbon-like margin" and periodic (but not omnipresent) ripples radiating from a central shaft. Jones *et al.* propose that these ripples are separate branches that are distally fused in a manner similar to cer-