LETTERS *(continued from page 15)*

oceans keep rising at current rates, in a few hundred years most of the farmland will be underwater, so who cares? Next we consider clouds and then deep water currents, which are pertinent and very interesting.

Of course the big problem, which goes unmentioned, is how are we going to generate power in the 21st century without producing greenhouse gases and other pollutants? Certainly fuel cells are not going to be able to generate large quantities of energy, and where is all the fuel for the fuel cells coming from? The article suggests biomass, solar and wind power. A quick calculation of the usable solar power input to the Earth indicates we are now consuming power at about the same order of magnitude as we receive it. Since there is no thought of serious population limitation at this time, we can expect the power demand to rise according to the estimated population growth. Therefore we need a clean energy source, or a drastic reduction in our standards of living will result.

I am disappointed at PHYSICS TODAY for treating such a serious problem so lightly, especially when the issue was titled as it was. Let us try again soon.

LEWIS E. HOLLANDER JR
Bend, Oregon

THE GUEST EDITOR OF THE NOVEMBER 1994 ISSUE REPLIES: My goal for the special issue on physics and the environment was to show where physicists might contribute to the generation of new knowledge. The five articles I commissioned dealt with open questions in environmental science (the nitrogen cycle, clouds, deep ocean currents) and in technology (fuel cells for mobile and stationary power, industrial restructuring to retain materials longer within the industrial system). Opportunities for physicists to contribute in these areas are abundant.

For the answer to Lewis Hollander's question about the source of fuel for fuel cells, I refer him to Sivan Kartha and Patrick Grimes's reply to Gary W. Harding's letter in the March issue (page 11).

As for the scale of our future energy needs, Hollander's "quick calculation" is off by a factor of 10 000. The solar flux of 1350 W/m^2 is intercepted by the Earth at a rate of 1.7×10^{17} W; 65% of this energy flow, 1.1×10^{17} W, is absorbed, not reflected, and thereafter drives the Earth's chemical and thermal processes. By comparison, humans consume commercial energy at a rate of 1×10^{13} W (roughly 2 kW per capita). It follows that solar energy (as photovoltaic photons, photosynthesized biomass, wind or heat) is sufficiently abundant to meet all global commercial needs. As with nuclear fission and fusion, important uncertainties surround the economic, social and environmental costs of today's and of future technologies. By not explicitly highlighting nuclear energy (which I acknowledged in the introduction to the special issue has "the potential . . . to loosen at least a few of the environmental constraints" on our energy-consuming activities), I was implicitly advocating that the efforts of physicists should be distributed across all the energy sources, including fossil fuels, and energy efficiency.

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Triggering Mosquitoes and Initial Butterflies

I thoroughly enjoyed Paul Nahin's letter (March, page 132) in which he relates Lorenz's butterfly from chaos theory to Lord Kelvin's mosquito, of whom it was said, "if all the matter in the Universe were reduced to its ultimate atoms and equally divided through all space, the disturbance caused by the beating of the wing of [this] mosquito would bring about everything that we find in the material Universe today." However, I believe there is an important distinction between the two insects.

A uniform mass distribution filling all of space is a mechanically unstable configuration. Kelvin's mosquito is the *trigger* that perturbs this configuration and sends it irreversibly on its way. Lorenz's butterfly, on the other hand, makes up part of the *initial conditions* that must be exactly (and impossibly) specified before the evolution of a chaotic system can be predicted. Kelvin does not address the issue of sensitivity to initial conditions. Thus we need both creatures: the mosquito to precipitate the formation of a lumpy universe, and the butterfly to beat its wings so that we arrive at our present configuration, as opposed to one in which Earth orbits a black hole in some distant galaxy.

JEFFREY J. HAMILTON
University of Maryland at College Park

Corrections

May, page 19—The yellow band corresponds to CDF's results, the blue to D0's and the green to the overlap.

April, page 105—Jerome Wiesner was born on 30 May 1915. ■

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