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# Tropical fires

The article in Briefs, "Tropical fires feed global warming" (*The Industrial Physicist*, June/July 2002, pp. 11–12) belongs in *The National Enquirer*, not in a publication for scientists. As far as I can tell, the jury is still out on global warming, so let's call it what it is—a theory of global warming, just as we call Darwin's concept the theory of evolution.

Next, I have to question a science magazine that includes statements such as "Humidity in the stratosphere has doubled during the past 50 years, with half the increase due to the oxidation of increased amounts of methane." Really? Says who? The writer saw fit to reference an article in *Science* that shows a relation between crystal size and humidity, but leaves readers wondering what body of evidence supports the sentence I quoted above. Likewise, the author draws on the work of a Yale University geophysicist, but nowhere do we have a reference to his scholarly work.

For balance, the author should have included information about other research, if any, that takes an opposing view. If no such research exists, readers should know that, too.

Frankly, I have to question the value of work based partly on temperature maps that show a hot spot south of the Hawaiian Islands. Has someone started to deforest Palmyra Atoll without our knowing? Without explaining that hot spot, I have a difficult time treating the other thermal data seriously.

You can do much better.

Jon Titus
Milford, Massachusetts

[*Researcher replies*: I thank Mr. Titus for his interest in climate research. A few scientific issues deserve further comment.

As far as the "jury being out" on global warming, the tendency of various gases (carbon dioxide, methane, water vapor, etc.) to direct more energy toward Earth's surface and less to space is an uncontested matter of basic physics that has been known for over a century. So we can confidently compare one "greenhouse" gas with another in terms of relative ability to influence climate; in this regard, increases in stratospheric water vapor since the 1950s are competitive with, though still not as important as, carbon dioxide. Where the "jury is still out" is on how the planet will respond in an absolute sense to such forcing and whether we will notice it (what we call "climate sensitivity"). My study addressed only the cause, not the consequences, of stratospheric humidity changes.

Regarding the observed humidity trend, evidence has been accumulating for decades. A recent comprehensive analysis (Rosenlof, K. H., et al., *Geophys. Res. Lett.*, 2001, *28*, 1195–1198) by an international group of scientists leaves little doubt that it is real. Stratosphere researchers have been reluctant over the years to accept the observations, due to the lack (until now) of a plausible physical explanation for the trend.

As for the data point that the sharp-eyed Mr. Titus observes over Hawaii, cloud properties are quite variable in nature and it is difficult to observe locally a small systematic effect due to pollutants (witness the inability, after decades of effort, to prove or dis-

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prove the efficacy of cloud seeding). A thorough global analysis is required to draw conclusions. Anyone who wants to vet the research should consult the detailed, peer-reviewed papers (Sherwood, S., *Science*, **2002**, *295*, 1271–1275; *J. Climate*, **2002**, *15*, 1051–1063).

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## Moon power

As co-author of *The Moon: Resources, Future Development, and Colonization* (Wiley-Praxis, 1999), I strongly support the concept of a lunar power system as put forward by David Criswell in the April/May 2002 issue of *The Industrial Physicist* ("Solar Power via the Moon," pp. 12–15). As he pointed out, there are many problems with our continued dependence on Earth's stores of fossil and fission fuels. By taking the long view, and relying on existing technologies, I agree with him that it may be possible to supply all of the Earth's future energy needs from a solar power system based on the moon.

The first lunar base (probably sited in the highlands of the south polar region) will represent a significant milestone in human development. It will establish the critical linkage between our human technological/cultural expertise and the virtually unlimited material and energy resources of space. From that basis, we will be able to supply the Earth with its future energy needs and substantially improve quality-of-life standards for all people. We will also be able to undertake the exploration and settlement of the moon within a few decades and begin migration to Mars and other locations in the solar system.

All of this can be accomplished with existing resources and technologies—it's just a matter of vision, organization, and resource allocation.

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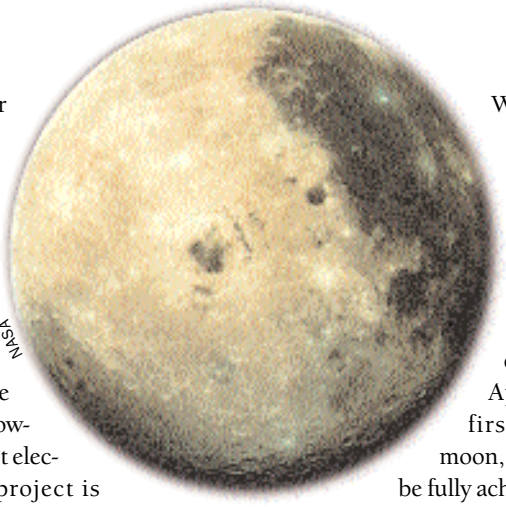
NASA

The Lunar Solar Power (LSP) System, a world-scale megaproject, proposes to serve the needs and enhance the lives of the populations of some 185 nations through the provision of clean, low-usage-cost, abundant electrical power. The project is doable—the design and construction of the ground facilities on the Earth and on the moon are within the expertise of world-class engineering construction firms.

A rejuvenated transport capability is needed to set up the ground facilities on the moon, even though, as the article states, LSP component manufacture on the moon using in situ lunar material is maximized, along with robotic processing and assembly. In the political spectrum, the project complies well with the status of the moon as the common heritage of mankind.

It can be of advantage to recall historical contexts. In earlier America, the frontier was the start line of what was called the "wilderness"—then. In short order, though, the frontier and wilderness came beckoning, as wagons rolling west opened up the wealth of a continent. In our own age, the rocket replaces the wagon, making the immediately adjacent "wilderness" of the moon accessible for commercial and industrial enterprise on the new "high frontier." The LSP System, which has many merits, may also be the lead project that would usher in other enterprises in a profitable Earth-moon economy.

In sum, the strategy of the LSP System supports burgeoning energy needs in a world of diminishing natural resources and increasing environmental concerns. Go for it!

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It is encouraging to see articles such as David Criswell's on lunar solar power. While the goal is hard, it is hard only in engineering terms. The scale of the project is huge, although the first 10 years would be no more difficult than the Apollo mission that first took us to the moon, and the goal would be fully achievable in the much larger economy of the 21st century, should a commitment be made to it. The spin-off effects would boost the host country's economy and enhance the subsidies thereby given to knowledge-based industry support—and in a manner that would be acceptable to the new and tighter rules of the World Trade Organization.

What is missing in Criswell's documents are the milestones, steps, and strategies to get there from here, which would enable progress to come in steps that are manageable, assessable, and more easily digested for political, operational, and financial purposes.

I hope that such issues will form part of the forward thinking and program of more scientists and engineers—and as a result the forward publishing program of the American Institute of Physics.

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[*Author replies*: Work done to date confirms that the Lunar Solar Power System is reasonable from the standpoint of the basic physics, engineering, environmental benefits, and profitability. I agree with Professor Wigan that it is time to begin significantly larger programs to fully define the milestones, steps, and strategies for implementing it. Some of these are summarized in the second reference of my article in *The Industrial Physicist* and the citations therein. Visit the Web site http://www.worldenergy.org/wec-geis, and search on Lunar Solar Power or Criswell.

David R. Criswell]

[David Criswell gives a longer response to readers in "Return to the moon" on page 31—*Ed.*]

## Geothermal energy

In the article by Paul Grant, "Energy for the city of the future" (*The Industrial Physicist*, February/March 2002, pp. 22–25) and in the responses by your readers, nobody mentioned in an appropriate manner an energy resource that is safe, environmentally clean, reliable, and virtually unlimited—geothermal energy. Is it too easy to convert clean water into steam and generate electricity and heating for industry and homes at every location on mother Earth? Instead, we waste valuable fossil resources by burning coal and oil. All the other future energy options discussed involve impressive dangers, limits, and restrictions, as well as the spending of immense amounts of taxpayer money on R&D. As long as narrow-minded leaders, politicians, and lobbyists offer only a tunnel vision for the taxpayer, it seems nothing will change.

The technology is available to pulse-drill inexpensive and fast holes 16 miles down into the crust of the Earth, using pulse-mixing to create strong and heat-resistant epoxy-ceramic pipes to protect the underground water table, and create an underground cavern big enough to heat and store the water–steam medium to supply energy to every city. The turbines generating the required electricity and hot water could be used for many heating purposes, as is already done on a small scale in some volcanic areas. Hypersonic pulse energy has the potential to open an unlimited energy window for mankind. The technology has been proven for many years in testbenches, heavy-duty construction equipment, and many other applications.

Where are the visionaries, the investors, the managers, and others to understand these simple concepts and participate in this much brighter energy future?

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[*Author replies*: Helmut Sieke takes me (and the previous respondents to my "SuperCity" *TIP* article) to task for not appropriately mentioning the potential of geothermal technology as a renewable energy source of the future.

His letter affords me an opportunity to expand my brief remark that tapping the most readily available, and therefore most economic, near-surface hydrothermal sources would be ecologically invasive. I am familiar with three such existing facilities—one in Napa County, California, called "The Geysers"; the second in Mexico near Mexicali, Cerro Prieto; and the third, also in Mexico, Los Azulfres, in the pine-forested hills south of the city of Morelia, capital of the state of Michoacan. All three occupy vast tracts of land. The Cerro Prieto location, comprising four generation plants, takes 30 minutes to drive across at freeway speed, and it has a total generating capacity of about 750 MW, less than three-quarters the capacity of a single one-acre nuclear reactor unit at Diablo Canyon on the California coast. The construction of Los Azulfres required the clear-cutting of a portion of the forests providing the home of the monarch butterfly. Most estimates I have seen put the potential at no more than 1% of future energy requirements for hydrothermal exchange of "geyser" liquid or gas thermal energy with secondary water to make steam for electricity generation. That is, if it were allowed and could overcome serious corrosion problems in the heat exchange piping.

However, the geothermal source I believe Mr. Sieke refers to principally relates to "deep well" or "hot dry rock" geothermal formations located adjacent to the Earth's mantle. Surface water would be heated at these extreme depths and returned to the surface for electricity production or stored, as Mr. Sieke suggests, at the subterranean thermal source. Several attempts have been made to exploit such sources. The project I have been most aware of, thanks to input from my Electric Power Research Institute and Department of Energy colleagues familiar with a spectrum of geothermal technologies, was the effort near Los Alamos National Laboratory that terminated in 1997. The study concluded that the cost for a 4-km well would run around $3.5 million and would "increase substantially" and nonlinearly with depth. Such a well located over a near-surface "hot dry rock" formation could generate possibly 2 MW of electric power.

Mr. Sieke proposes wells as deep as 16 miles (~ 26 km). Let's make the conservative assumption that about $20 million would be expended in drilling it. To produce 1,350 MW (the capacity of a single modern advanced boiling water reactor (ABWR) nuclear unit) would require 675 wells at a total drilling cost of $13.5 billion. The newest 1,350 MW ABWR unit in operation in Japan cost around $2,000/kW or $2.7 billion *for everything*. Thus, even if it were possible to drill to the depths Mr. Sieke suggests at present costs for more shallow wells, the wells alone would cost five times as much as a finished nuclear plant for a given potential power output.

If Mr. Sieke does indeed have a unique approach to boring and drilling, I would imagine there would be many interested parties who would like to know more.

Paul Grant] Ω

## Corrections

The following corrections have been made to the June/July issue of *The Industrial Physicist* that appears online:

In "Polymer LEDs," (Briefs) by Eric Lerner, p. 14, the final sentence should read, "'We also expect to increase the wavelength to 1.5 $\mu$m, the best wavelength for telecommunications,' says Tesslar."

In "Silicon–Germanium Gives Semiconductors the Edge," by Jennifer Ouellette, p. 24, under "Characterizing Silicon–Germanium," Rudolph Technologies is located in Flanders, New Jersey.

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