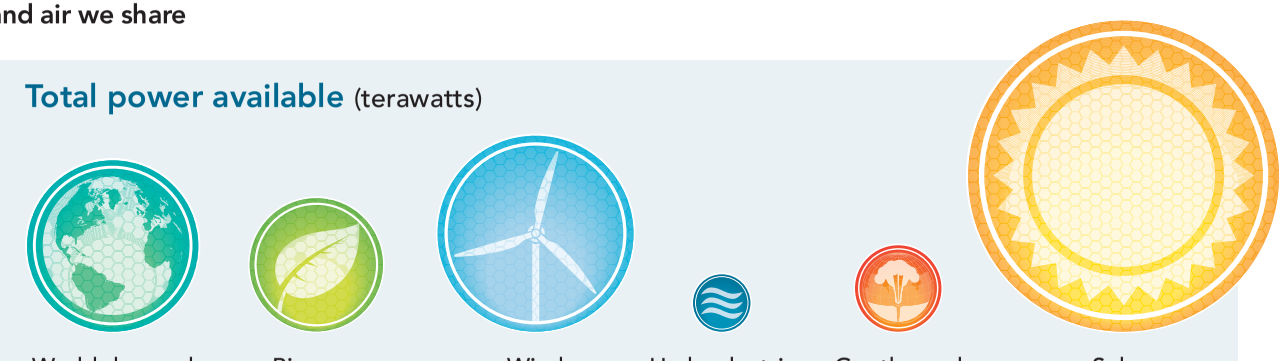
NEWS

Energy's Tricky Tradeoffs

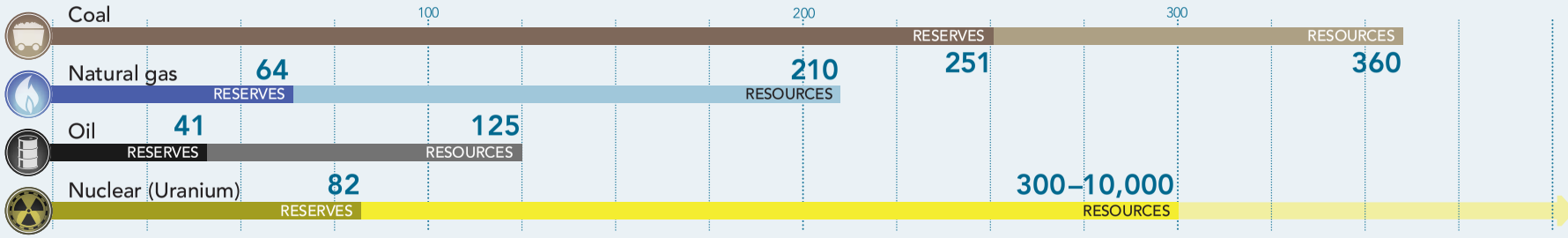
The world's "energy problem" is in fact a slew of technological and sociological challenges involving the use of the land, water, and air we share

I've got sunshine, plenty of sunshine ...
Sooner or later, humanity must move away from fossil fuels, finite resources that produce planet-warming greenhouse gases. At first blush, Earth appears to have power to spare. The total power from sunlight striking the ground is a whopping 101,000 terawatts, and experts estimate that we could capture enough of that to exceed by a wide margin the 15 terawatts of power that the world's population now consumes.

Total power available (terawatts)



How much is left? (years)



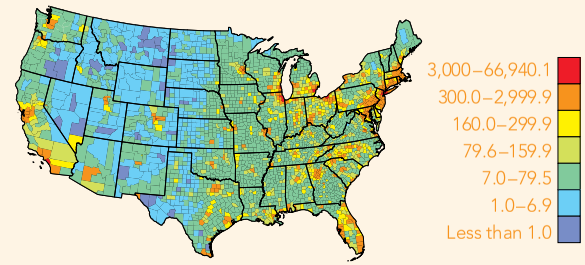
SOURCE: *WORLD ENERGY ASSESSMENT 2000*/UNDP; *WEA 2004*/UNDP; *REPORT OF THE INTL. GEOTHERMAL ASSOCIATION TO THE U.N. COMMISSION ON SUSTAINABLE DEVELOPMENT 2001*; SCLATER *ET AL., JOURNAL OF GEOPHYSICAL RESEARCH* **86** (1981); NASA

GLOBAL

Give me land, lots of land ...
Wind and sunshine deliver energy in a far less dense form than coal, oil, or natural gas. For example, San Jose, California, has just over 1 million residents and consumes an average of 740 megawatts of electrical power. To supply that power, coal mines and coal-fired power plants would have to cover 3,800 hectares of land. In comparison, a wind farm would have to cover 53,000 hectares, an area bigger than the city itself. Unlike a coal mine, however, the wind farm could be used to grow crops at the same time.

Another issue: The sun doesn't necessarily shine the brightest and the wind doesn't blow the fiercest where most people live. And technologies have yet to emerge to store and transport vast amounts of energy generated from sunshine or wind. So delivering that energy where it's needed when it's needed remains a problem.

Population in the U.S. (per square mile)



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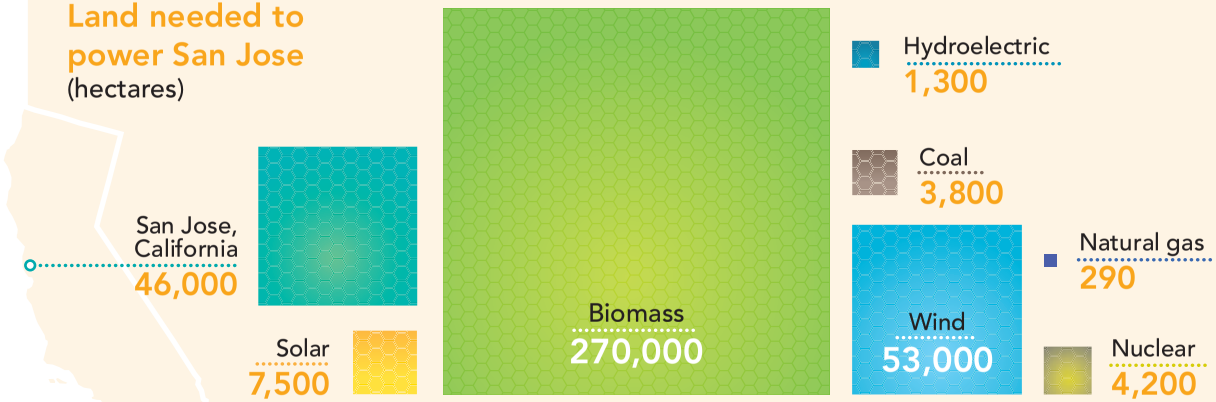
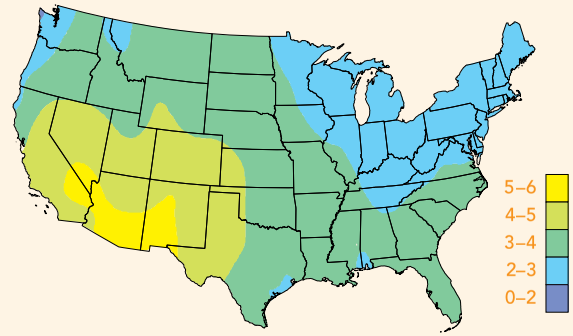
Land needed to power San Jose (hectares)



SOURCE: D. SPITZLEY *ET AL.*, UNIV. OF MICHIGAN CENTER FOR SUSTAINABLE SYSTEMS (2004); *ELECTRICITY FROM RENEWABLE RESOURCES*, NAS (2010); DOE

Average daily sunshine (kilowatts per square meter)

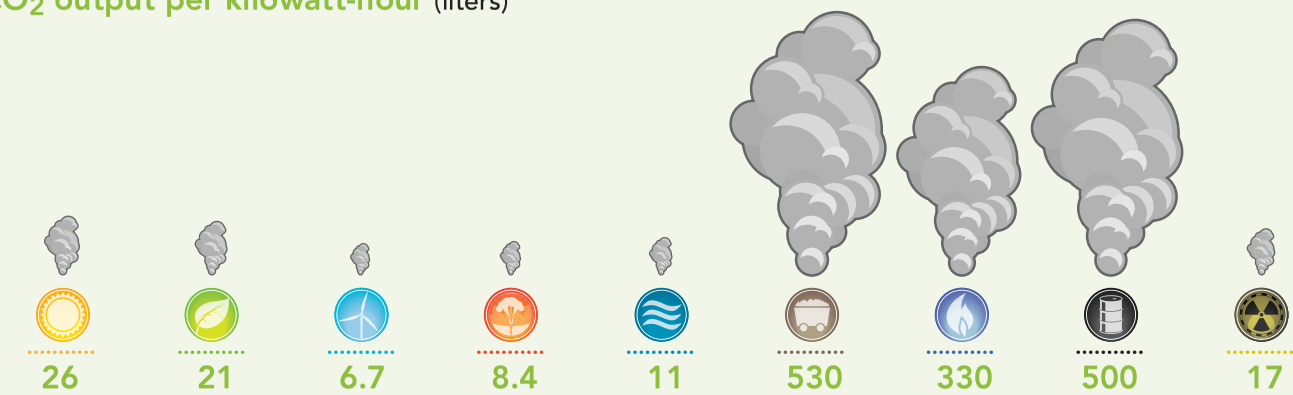


SOURCE: U.S. CENSUS BUREAU (TOP); NREL (BOTTOM)

REGIONAL

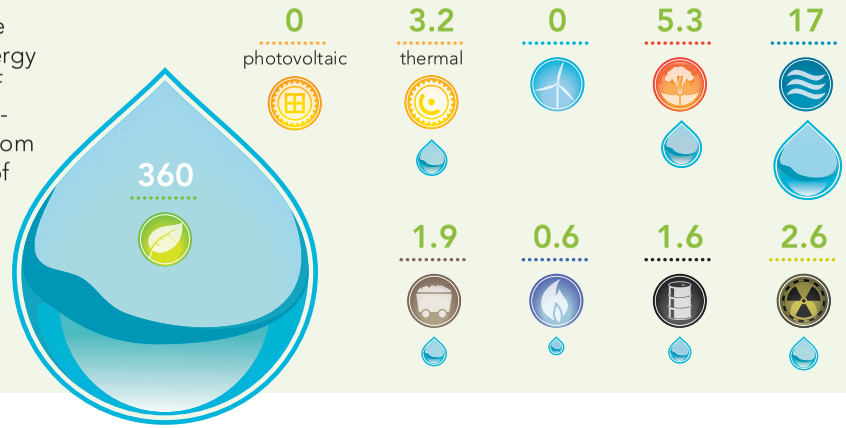
CO_2 output per kilowatt-hour (liters)

SOURCE (TOP): DOE; AWEA; DOE/EPA; *ELECTRICITY FROM RENEWABLE RESOURCES*, NAS (2010); (BOTTOM): DOE; AWEA



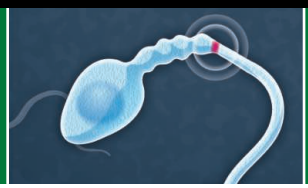
A river runs through it.
The energy problem is also a water problem. Work on your computer all day, and you'll use about 1 kilowatt-hour of electricity. If that energy comes from coal, you'll have used 1.8 liters of water. If it comes from solar thermal technologies, you'll use 68% more water. Use power from biomass crops and you'll also use hundreds of liters of water to grow the fuel. Of course, fossil fuels produce heat-trapping carbon dioxide gas. If your kilowatt-hour of energy comes from coal, it produces 0.9 kilograms or 530 liters of pure CO_2—enough to fill 265 large soda bottles.

Water consumption per kilowatt-hour (liters)



PERSONAL

No single solution.
To replace fossil fuels, most experts foresee using a mixture of energy sources and technologies. And they say that large gains can be made in improving the efficiency of existing technologies—as much as 60% in industrial processes. Still, reducing overall energy demand may not be easy. In 2007, the city of San Jose instituted a 15-year program that, among other things, seeks to reduce the per capita consumption of electricity and natural gas by 50%. After 2 years, such consumption was down by just 0.5%. **–ADRIAN CHO**



LETTERS

edited by Jennifer Sills

No Return from Biodiversity Loss

IN THEIR LETTER "BRAZILIAN LAW: FULL SPEED IN REVERSE?" (16 JULY, P. 276), J. P. METZGER and coauthors highlight the precarious plight of the Brazilian Forest Act (Código Florestal), embattled by new legislative reform that will effectively condemn old-growth remnants and forest regrowth in private landholdings throughout the largest tropical country on Earth. We would like to emphasize that the reforms could lead to irreversible loss of tropical biodiversity.

Rural private properties account for 39% of Brazil's ~8.5M-km^2 territory and represent an essential component of forest biodiversity conservation that is separate from formally protected areas. Sadly, the short-term interests of powerful economic groups, influential landowners, and politicians ignore the conservation value of private-sector forests by diluting the Brazilian Forest Act.

The detrimental environmental and social impacts of brushing aside scientific evidence are exemplified by the proposed reductions in protected forest area requirements for riparian forest (buffer strips) located adjacent to rivers and streams. Current proposals ignore pervasive edge effects, whereby the influences of neighboring habitats such as cattle pasture permeate into forest areas, gradually decimating the canopy tree population (*1*). The reduction in buffer strips means that these landscape features will have decreased ability to both retain and connect forest species (*2*) and maintain water quality and flows (*3*). Landowners who comply with the new legislation would increase landscape fragmentation and reduce the value of their properties as a result of property-scale soil erosion and poor water catchment regulation within watersheds (*4*).

Brazilian biodiversity at risk. Proposed legal reforms could cause irreversible loss of biodiversity and reduce the value of private properties.

There is a glimmer of hope: The scientific community, environmental nongovernmental organizations, and the Ministry of Environment can still reconcile with the staunch proponents of Brazilian Forest Act reform. We need better communication among all segments of society to develop wise land-use management of the existing agro-pastoral matrix, thereby sparing the need for further expansion of new deforestation frontiers.

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Overuse Could Leave Southwest High and Dry

IN THEIR PERSPECTIVE "DRY TIMES AHEAD" (25 June, p. 1642), J. Overpeck and B. Udall highlight serious water availability issues the western region of the United States may soon face in the form of less precipitation, longer drought patterns, and decreased snow pack. There is another risk as well: overapportionment.

In the Colorado River Basin, the water lifeline of southwestern United States, long-term planned use of the river's water exceeds the reliably available supply. Use agreements for the water in the Colorado and Rio Grande River basin are governed by laws and compacts between the southwestern states. Most of these agreements are 50 to 100 years old and were drafted on the basis of then-current water resource data, without taking demographic and climatic trends into account (*1*). Climate change is projected to increase the likelihood of a shortage (*2*). This situation could be worsened by the fact that the states in or adjacent to this corridor include some of the states with the highest population growth rates. The U.S. Census Bureau has projected

Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 3 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.

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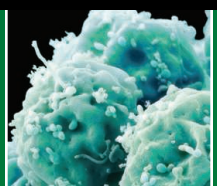
Expanding stem cells
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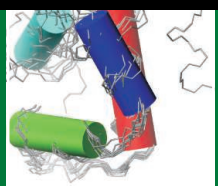
An exciting shift
1295

that an additional 10 to 13 million people will reside in these regions by 2030 (*3*). To add another layer of complexity, the possibility of basing an integrated industrial ecology on biofuels (such as algae and lignocellulose) has received increased attention in southwestern United States (*4*). However, the water footprint represents a major sustainability challenge for future biofuel production (*5*–*7*). In the future, increased demand for water for civic, agricultural, and even energy needs coupled with a decreasing supply could result in conflicts between states regarding water sharing, management, and use.

To address these issues and facilitate sustainable production of clean energy, state and federal governments should implement strict guidelines and a regulatory framework for water-use permits and water recycling. Commercial biofuel production permits should be given to companies and units that have implemented modern technologies for water recycling and conservation. New policies and regulations for water management and use should be a high priority for the sustainable development of a biofuel sector in order to meet liquid fuel needs in the United States without hampering the regional hydrologic pattern in the southwestern region of the country.

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Test Ban Results Could Be Negative

P. S. CORDEN'S HOPE THAT BANNING NUCLEAR tests will somehow bring nuclear peace ("Banning Nuclear Tests," Editorial, 21 May, p. 953) ignores much history. He neglects to acknowledge that three new states have developed nuclear capability (and Iran is soon to join them, apparently) after the United States signed but did not ratify the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Furthermore, the Stockpile Stewardship Program has not shown that our weapons are reliable, because its conclusions are based on simulations that have never been checked by direct testing.

If the United States ratifies the CTBT, how will we or anyone know that our stockpile is reliable in decades hence? Simulations and limited lab experiments provide some data but are not definitive. As history shows,

the CTBT does not slow those who join the nuclear club for reasons of their own. Tactical weapon reliability is the hardest to judge without tests, and may well be the most likely to be used. Ignoring this is folly.

It is also folly to imagine that total nuclear disarmament is stable—it is far too easy to cheat, even with no testing.

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Response

I DID NOT CLAIM THAT THE COMPREHENSIVE Nuclear-Test-Ban Treaty (CTBT) will "bring nuclear peace," as Benford suggests. The CTBT is one step toward a nuclear weapon–free world. Others will be required, and each must promote stability and be verifiable. The process depends on a benefit-risk calculus of how best to ensure security.

Of the three states that have tested most recently, India and Pakistan did so in 1998, and only North Korea (in 2006 and 2009) did so after the Senate voted against the CTBT. In each case, it is arguable that prior U.S. ratification would have influenced the decision to test, particularly if U.S. ratification had led to ratification by China and others.

Benford claims that a direct (nuclear) test is necessary to ensure weapon reliability. This is not the case. Since 1996, the Stockpile Stewardship Program has been the basis for an annual certification of confidence in the reliability of nuclear weapons, both strategic and tactical (there are no technical differences between them that would affect confidence), without testing. The April 2010 Nuclear Posture Review foresees no future need for nuclear testing for maintaining such confidence, a position that the directors of the three nuclear weapons laboratories have endorsed (*1*). The Stockpile Stewardship Program has no direct correlation to constraining testing by potential adversaries, whereas the CTBT does. Such testing, and its damage to global stability, is not in the U.S. interest.

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1. Tri-Lab Directors' Statement on the Nuclear Posture Review, Los Alamos, New Mexico, 9 April 2010; www.lanl.gov/news/releases/tri_lab_directors_statement_on_the_nuclear_posture_review.html.

CORRECTIONS AND CLARIFICATIONS

Special Section on Scaling Up Alternative Energy: News: "Sending African sunlight to Europe, special delivery" by D. Clery (13 August, p. 782). The figure 12,000 gigawatts, cited as the amount of concentrating solar power needed to meet Europe's energy demand by 2050, in fact refers to worldwide demand.

Special Section on Scaling Up Alternative Energy: News: "Energy's tricky tradeoffs" by A. Cho (13 August, p. 786). The units for the map of average daily sunshine in the United States should be kilowatt-hours per square meter, not kilowatts per square meter.

Table of Contents: (16 July, p. 251). The one-sentence summary for the Report by C. K. Savile *et al*. was incorrect. The correct summary is "An engineered enzyme offers substantial efficiency advantages in the production-scale synthesis of a drug."

Reports: "Single-crystal x-ray structure of 1,3-dimethylcyclobutadiene by confinement in a crystalline matrix" by Y.-M. Legrand *et al*. (16 July, p. 299). The parent host structure G_4C and related solvent-inclusion compounds were reported recently: Y. Liu, M. D. Ward, *Cryst. Growth Des*. **9**, 3859 (2009).