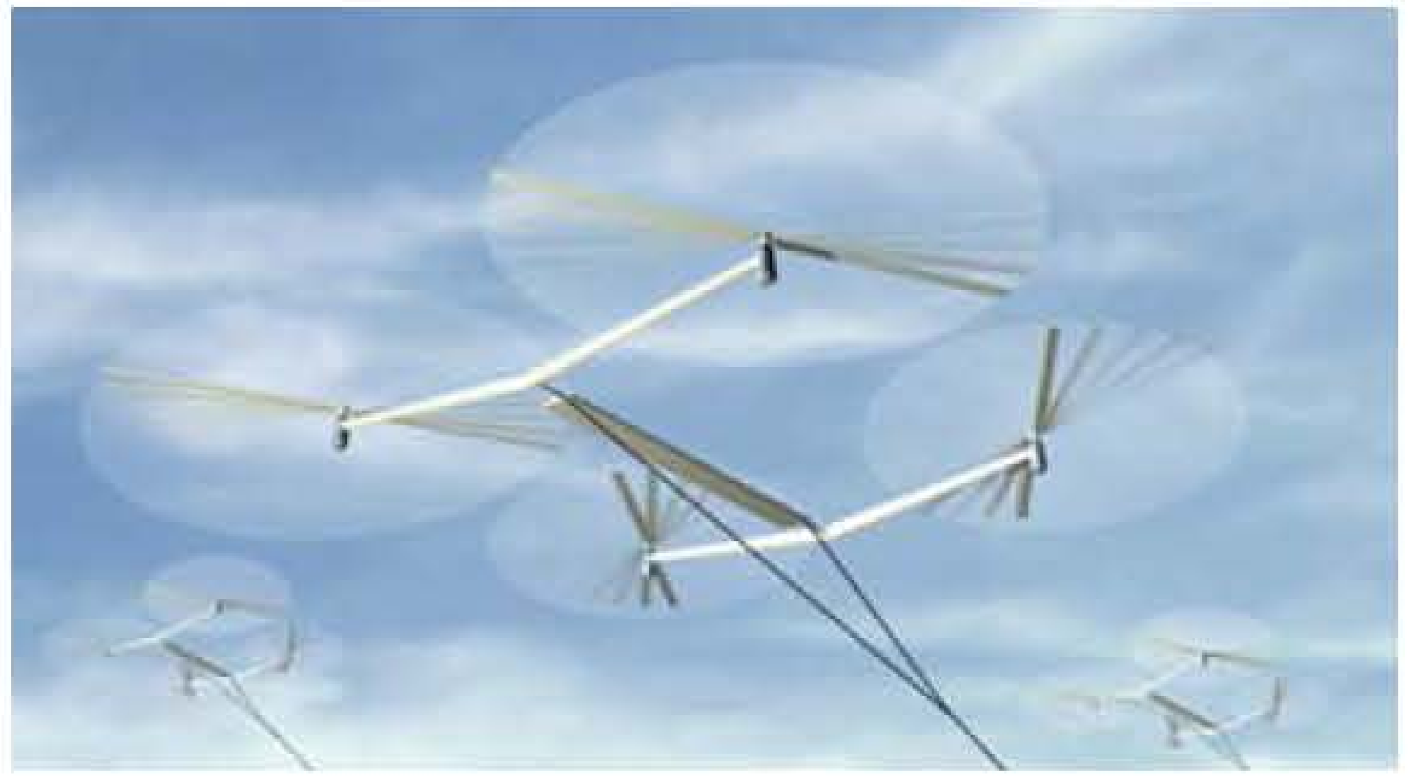
HIGH-ALTITUDE WIND

The most energetic gales soar far over the tops of today's turbines. New designs would rise higher—perhaps even to the jet stream



▲ Autogiros designed by Sky WindPower would use powered counterrotating blades to rise above 10,000 feet, then switch to generating mode. Computers adjust the pitch of the four blades to maintain the craft's position and attitude.

Wind is solar energy in motion. About 0.5 percent of the sunlight entering the atmosphere is transmuted into the kinetic energy of air: a mere 1.7 watts, on average, in the atmospheric column above every square meter of the earth. Fortunately, that energy is not distributed evenly but concentrated into strong currents. Unfortunately, the largest, most powerful and most consistent currents are all at high altitude. Hoffert estimates that roughly two thirds of the total wind energy on this planet resides in the upper troposphere, beyond the reach of today's wind farms.

Ken Caldeira of the Carnegie Institution of Washington once calculated how wind power varies with altitude, latitude and season. The mother lode is the jet stream, about 10,000 meters (33,000 feet) up between 20 and 40 degrees latitude in the Northern Hemisphere. In the skies over the U.S., Europe, China and Japan—indeed, many of the countries best prepared to exploit it—wind power surges to 5,000 or even 10,000 watts a square meter. The jet stream does wander. But it never stops.

If wind is ever to contribute terawatts to the global energy budget, engineers will have to invent affordable ways to mine the mother lode. Three high-flying designs are in active development.

Magenn Power in Ottawa, Ontario, plans to begin selling next year a rotating, helium-filled generator that exploits the Magnus effect (best known for giving loft to spinning golf balls) to float on a tether up to 122 meters above the ground. The bus-size device will produce four kilowatts at its ground station and will retail for about $10,000—helium not included. The company aims to produce higher-flying, 1.6-megawatt units, each the size of a football field, by 2010.

"We looked at balloons; the drag they produce seemed unmanageable in high winds," says Al Grenier of Sky WindPower in Ramona, Calif. Grenier's venture is instead pursuing autogiros, which catch the wind with helicopterlike rotors. Rising to 10,000 meters, the machines could realize 90 percent of their peak capacity. The inconstancy of surface winds limits ground turbines to about half that. But the company has struggled to gather the $4 million it needs for a 250-kilowatt prototype.

Still in the conceptual stages is the "laddermill," designed by astronaut Wubbo J. Ockels and his students at the Delft University of Technology in the Netherlands. Ockels envisions a series of computer-controlled kites connected by a long tether. The ladder of kites rises and descends, turning a generator on the ground as it yo-yos up and down. Simulations of the system suggest that a single laddermill reaching to the jet stream could produce up to 50 megawatts of energy.

Until high-altitude machines are fielded, no one can be certain how well they will hold up under turbulence, gusts and lightning strikes. Steep maintenance costs could be their downfall.

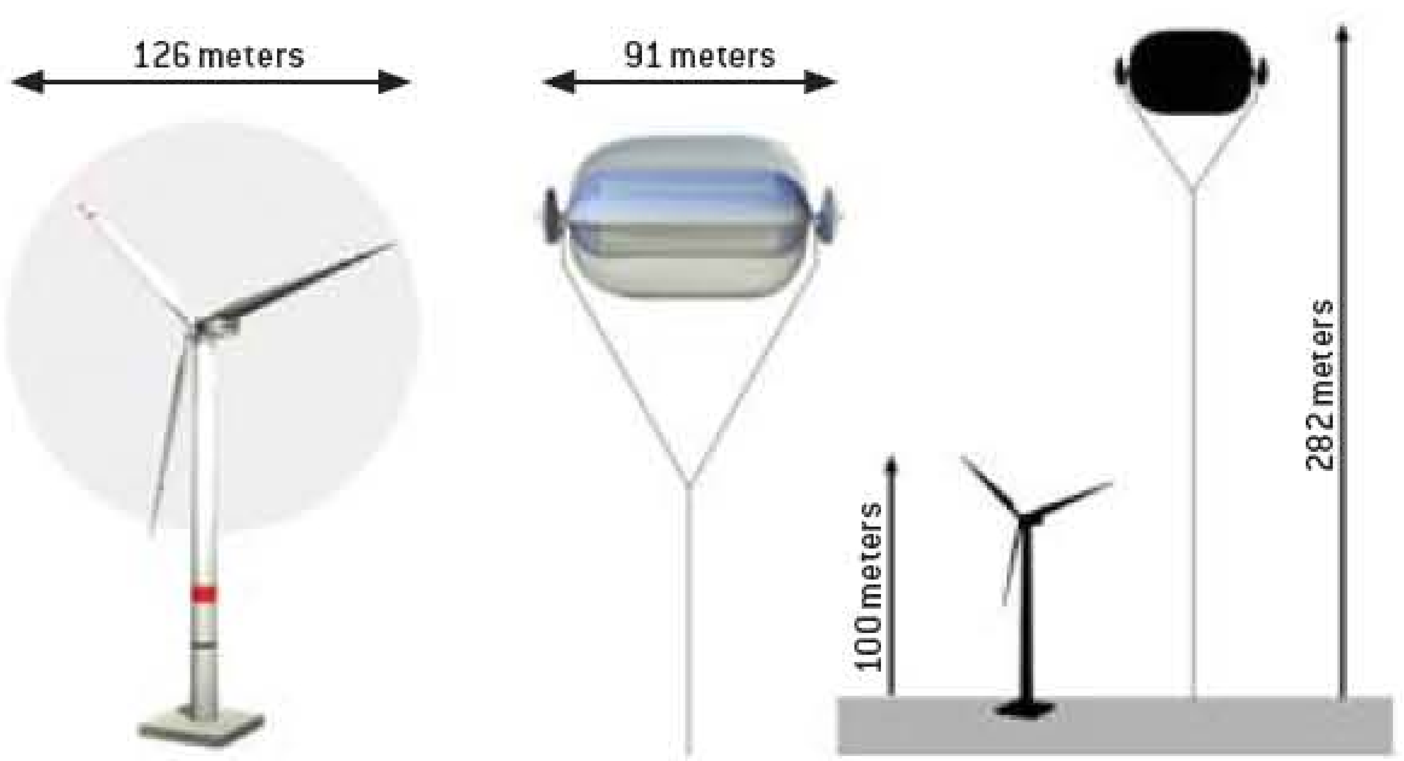
There are regulatory hurdles to clear as well. Airborne wind farms need less land than their terrestrial counterparts, but their operators must persuade national aviation agencies to restrict aircraft traffic in the vicinity. There is precedent for this, Grenier points out: the U.S. Air Force has for years flown up to a dozen large tethered aerostats at high altitude above the country's southern border.

By the standards of revolutionary technologies, however, high-altitude wind looks relatively straightforward and benign.

Fast Facts

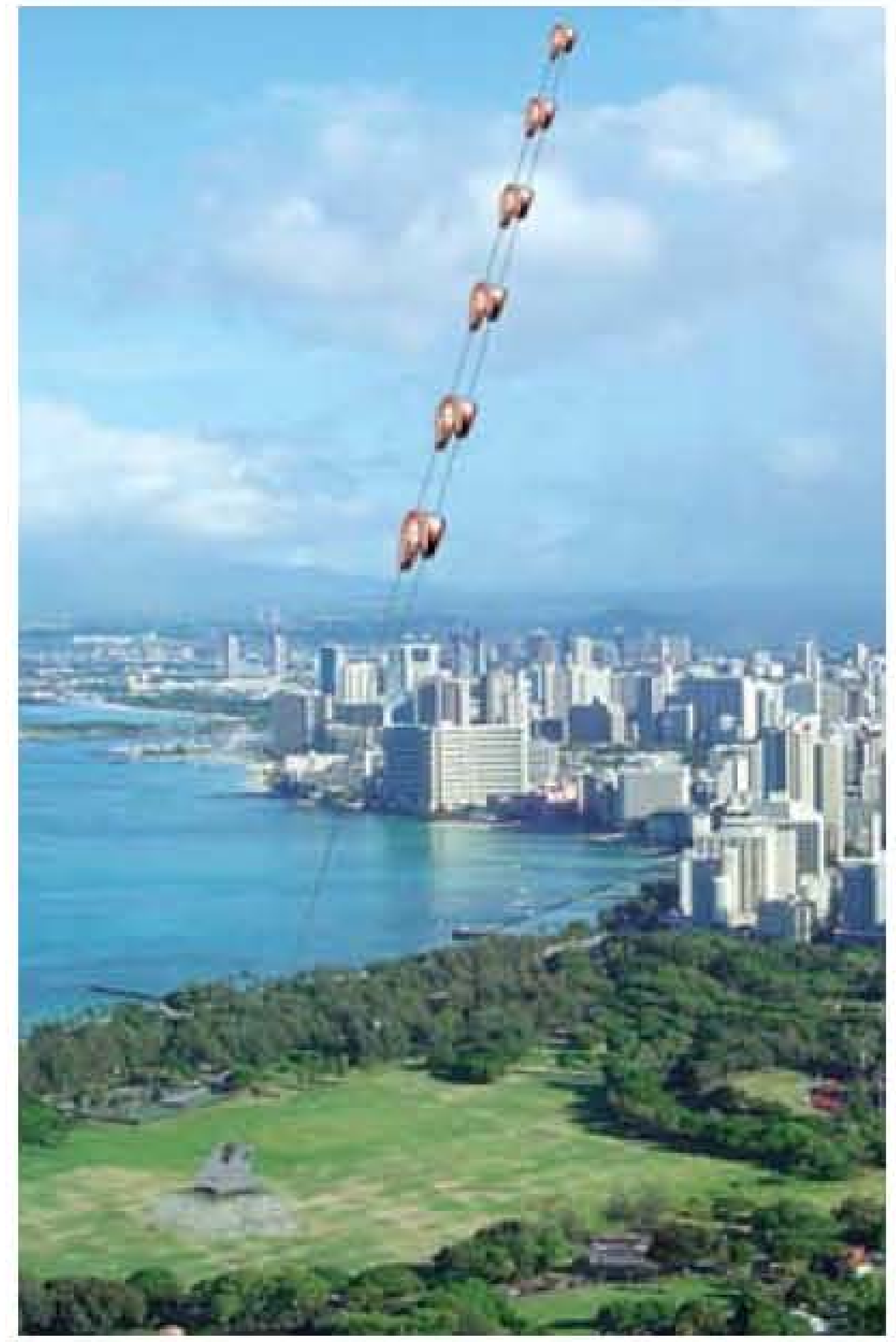
- Wind power capacity, currently about 58 gigawatts, is expected to triple by 2014.
- Helium-filled generators have to be refilled every few months.
- Number of tethered aerostats monitoring the U.S. border: 8.

REALITY FACTOR 4

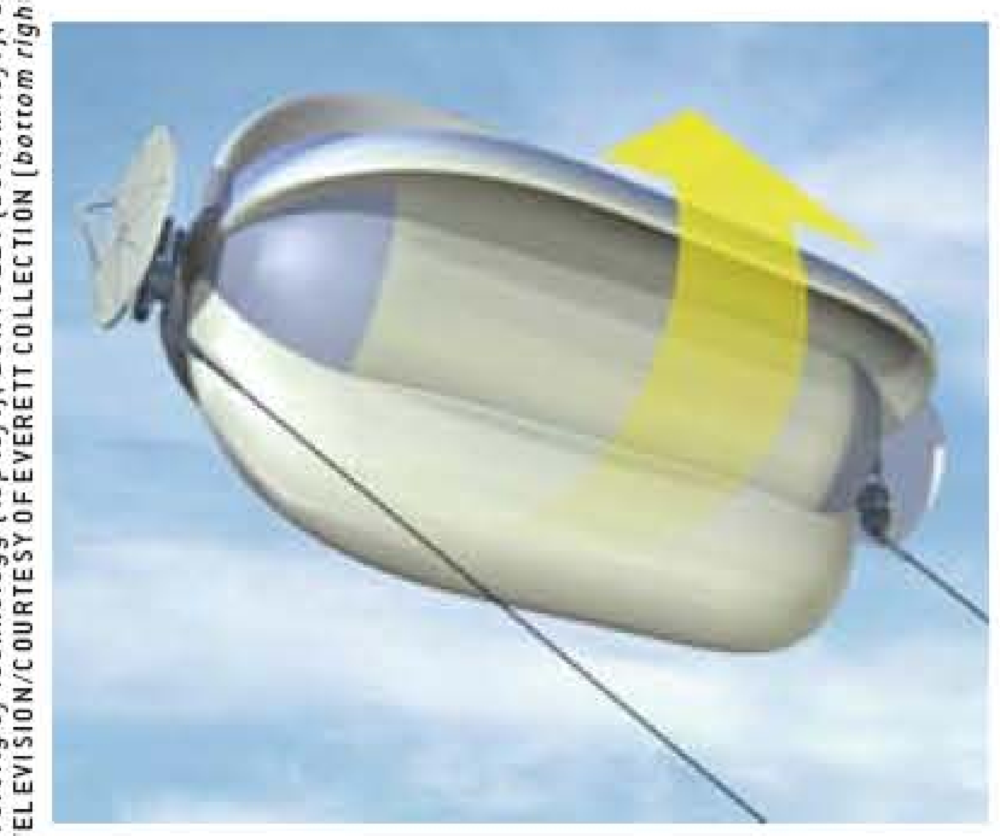


▲ Floating wind generators planned for 2010 production by Magenn Power would rise nearly twice as high as the largest turbines today but would be about two thirds as wide.

DON FOLEY; SOURCES: BEN SHEPARD *Sky WindPower Corporation* (top); MAGENN POWER (bottom)



▲ Laddermill wind power system would string C-shaped kites (*shown*), parasails or flying wings along the upper half of a wire. Each wing would use sensors and actuators for steering and pitch control as it climbed and then descended. The scheme would allow heavy generators to remain on the ground.



▲ Like a spinning blimp, a helium-filled rotor would catch the wind in fabric scoops, turning generators attached to tethers, which would then conduct the electricity to a transformer on the ground.

ASSET *Delft University of Technology* (top left); DON FOLEY (bottom left); GETTY IMAGES (top right); © PARAMOUNT TELEVISION/COURTESY OF EVERETT COLLECTION (bottom right)

SCI-FI SOLUTIONS

Futuristic visions make for great entertainment. Too bad about the physics

REALITY FACTOR 1

Cold Fusion and Bubble Fusion

B. Stanley Pons and Martin Fleischmann spun a tempest in a teacup in 1989 with their claim of room-temperature fusion in a bottle. The idea drew a coterie of die-hard supporters, but mainstream scientists have roundly rejected that variety of cold fusion.

▲ The bubbles keep bursting.

Theoretically more plausible—but still experimentally contentious—is sonofusion. In 2002 Rusi Taleyarkhan, a physicist then at Oak Ridge National Laboratory, reported in *Science* that beaming high-intensity ultrasound and neutrons into a vat of acetone caused microscopic bubbles to form and then implode at hypersonic speeds. The acetone had been made using deuterium, a neutron-bearing form of hydrogen, and Taleyarkhan's group claimed that the extraordinary temperatures and pressures created inside the imploding bubbles forced a few deuterium atoms to fuse with incoming neutrons to form tritium (hydrogen with two neutrons per atom). Another group at Oak Ridge replicated the experiment but saw no clear signs of fusion.

Taleyarkhan moved to Purdue University and continued reporting success with sonic fusion even as others tried but failed. Purdue this year investigated allegations that Taleyarkhan had interfered with colleagues whose work seemed to contradict his own. The results of the inquiry were sealed—and with them another chapter in the disappointing history of cold fusion. Other researchers hold out hope that different methods might someday turn a new page on sonofusion.

Matter-Antimatter Reactors

The storied *Enterprise* starships fueled their warp drives with a mix of matter and antimatter; why can't we? The combination is undoubtedly powerful: a kilogram of each would, through their mutual annihilation, release about half as much energy as all the gasoline burned in the U.S. last year. But there are no known natural sources of antimatter, so we would have to synthesize it. And the most efficient antimatter maker in the world, the particle accelerator at CERN near Geneva, would have to run nonstop for 100 trillion years to make a kilogram of antiprotons.

▲ A warped vision of reality.

So even though physicists have ways to capture the odd antiatom [see "Making Cold Antimatter," by Graham P. Collins; Scientific American, June 2005], antimatter power plants will never materialize.