



Scientific American

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Scientific American News

Circulation of LHC Beams Could Resume in Earnest over the Weekend

HIGH ENERGY, HIGH STAKES: Personnel in the CERN control room track the movement of the first particle beam to wend its way through the Large Hadron Collider in more than a year.

CERN

The Large Hadron Collider, the world's most powerful particle accelerator, is drawing near to its long-awaited reboot. More than a year after the European collider's initial start-up was quashed by a helium leak caused by a faulty electrical connection, particle beams have been injected into the collider, known as the LHC, and may be guided fully through its rings in the coming hours.

"We're hoping to have beam overnight in the LHC," James Gillies, a spokesperson for CERN, the European particle physics lab that operates the LHC, said Friday. "So, all being well, we will wake up tomorrow morning and there will be circulating beams." By 3:30 P.M. Eastern Standard Time on Friday, a beam had completed a full lap of the tunnel in the clockwise direction, with a counterclockwise beam still to come, according to CERN's *Twitter* feed.

Proton beams have been run through segments of the collider's 27-kilometer underground circumference near Geneva this fall, but putting the entirety of the collider ring through its paces as is now underway will be a much truer test of the machine's fortitude. In September 2008 it was just nine days after beam circulation that the LHC experienced its crippling breakdown. Since that time the LHC's minders have been dealing with the aftermath of the helium leak, painstakingly repairing, upgrading and recommissioning the machine to get it back in working order and to try to forestall a repeat incident.

If all goes according to plan, the LHC's operators could break new ground with the machine in short order. "One thing we didn't do last year was use the LHC as a particle accelerator," Gillies says. "Last year we injected beams and circulated beams before we had the breakdown,

but we didn't accelerate them. So once we've got a beam circulating, we'll start testing the acceleration systems of the LHC."

Although the LHC is designed to accelerate protons to a whopping seven TeV (tera-electron volts), CERN has long said that it plans to work the machine's energy up over time. The initial target for accelerated beams will be 1.2 TeV, which would already surpass the current top dog among particle accelerators, the Tevatron collider at Fermi National Accelerator Laboratory in Batavia, Ill.

Particle collisions, accomplished by steering a clockwise particle beam into a counterclockwise one, are "the other capability that must be demonstrated before we can really say the LHC is up and running," according to Gillies. Whether the first collisions will be conducted with 1.2 TeV beams or with scaled-down energies has not been decided, he says. "Either way, any collisions that we do this year is really calibration work. It's not new physics, if you like," Gillies adds. "The real physics research program doesn't get underway until January."

Among the tantalizing discoveries that could await the LHC are the Higgs boson, which lends mass to other particles, and a possible identification of dark matter, an invisible material thought to pervade the universe that has not been observed directly.

New physics or not, the prospect of simply getting the machine running is cause for excitement at CERN, where many years and billions of dollars have been spent in anticipation of the LHC's arrival. "There's a buzz about the place, I must say," Gillies says. "It's been a long time."

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How Long Can a Nuclear Reactor Last?

OLDIE BUT GOODIE: Extending the life span of aging nuclear power plants could be essential to meet the nation's energy needs.
WIKIMEDIA COMMONS/GREUDIN

Could nuclear power plants last as long as the Hoover Dam?

Increasingly dependable and emitting few greenhouse gases, the U.S. fleet of nuclear power plants will likely run for another 50 or even 70 years before it is retired -- long past the 40-year life span planned decades ago -- according to industry executives, regulators and scientists.

With nuclear providing always-on electricity that will become more cost-effective if a price is placed on heat-trapping carbon dioxide emissions, utilities have found it is now viable to replace turbines or lids that have been worn down by radiation exposure or wear. Many engineers are convinced that nearly any plant parts, most of which were not designed to be replaced, can be swapped out.

"We think we can replace almost every component in a nuclear power plant," said Jan van der Lee, director of the Materials Ageing Institute (MAI), a nuclear research facility inaugurated this week in France and run by the state-owned nuclear giant EDF.

"We don't want to wait until something breaks," he said. By identifying components that are wearing down and replacing them, he said, suddenly nuclear plants will find that "technically, there is no age limit."

Indeed, as U.S. regulators begin considering the extended operations of nuclear plants -- the Nuclear Regulatory Commission (NRC) expects the first application for an 80-year license could come within five years or less -- perhaps the largest lingering question is one of basic science: How do heavy doses of radiation, over generations, fundamentally alter materials like steel and concrete?

"It's taken many years for us to understand the problem," said Gary Was, the director of the University of Michigan's Phoenix Energy Institute and an expert in aging materials. "Thirty years ago, we didn't have techniques to see these changes."

Until recently, such research has not been a priority. But within the past few years, the Department of Energy began a program looking at "long-term operations," as it is known in the industry. And provisions in

the Senate's climate bill call for DOE to increase these investigations in the hope of extending plant lives "substantially beyond the first license extension period."

DOE collaborates in this research with France's MAI and the U.S.-based Electric Power Research Institute (EPRI), a nonprofit funded by many nuclear utilities. U.S. leadership in the field is natural, given the sheer age of America's reactors, many of which are already coming close to exceeding their intended operating lives.

The oldest commercial plants in the United States reached their 40th anniversary this year, and the average plant has operated for 30 years. Already, more than half of the nation's more than 100 reactors have seen their initial licenses extended for an additional two decades. Nearly all the country's plants are expected to eventually win such extensions.

As companies have encountered few hurdles toward ensuring 60 years of operation, according to one 2007 survey, a majority of executives say that it is very likely their plants will operate for 80 years or longer. It is a fairly natural progression, according to Was.

"If they last till 60, maybe they can last to 80," Was said. "Heck, maybe 100?"

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Novel Nova: Stellar Blast Powered by Helium May Leave a Tantalizing Remnant

BOW TIE IN THE SKY: The rapidly expanding shell of V445 Puppis marks a violent explosion that likely arose from a white dwarf accreting material from a nearby helium star. The image above shows the ejected shell from the nova as it appeared in 2005.

ESO/P.A. Woudt

A stellar explosion known as a nova that was detected in 2000 formed a two-lobed shell of material ejected from the star. Shaped like a bow tie, it continues to swell at great velocity. But, curiously, the coat of ejecta flowing outward from the star lacks hydrogen, the most common gas in the universe.

Such a nova had never been observed before, says Danny Steeghs, an astrophysicist at the University of Warwick in England. The object, known as V445 Puppis, is known as a helium nova after the gas that dominates its makeup in the absence of hydrogen.

Helium novae are thought to arise from a binary star system in which one member is a hydrogen-depleted star, which relies mostly on helium to generate light, and one is a white dwarf, an ultradense remnant of an exhausted star. The white dwarf steadily accretes helium from its neighbor until it reaches a density and temperature sufficient to trigger a nuclear explosion. If the white dwarf grows large enough to exceed the critical so-called Chandrasekhar limit—roughly 1.4 times the mass of the sun—it will ignite in a catastrophic nuclear blast known as a type Ia supernova. But if the explosion is localized to a compressed shell of accreted helium on a somewhat smaller white dwarf, a helium nova is the result, and the dwarf survives. Such novae had been predicted to occur but had never been seen before the 2000 V445 Puppis detonation.

In the November 20 issue of the *Astrophysical Journal*, Steeghs and his colleagues, led by astronomer Patrick Woudt of the University of Cape Town in South Africa, describe the rapidly expanding shell of the helium nova V445 Puppis and what it indicates about the progenitor system. Drawing on years of ground-based observations, Steeghs and his co-authors estimate that V445 Puppis is some 27,000 light-years distant. The lobes of the shell, the authors conclude from their campaign, are moving at more than 6,000 kilometers per second, with knots at the end of each

lobe zooming outward even faster.

One consideration making helium novae more than just an astronomical curiosity is the suggestion that they might serve to explain anomalously young binary star systems that yield type Ia supernovae. That class of explosions is hotly studied, because as so-called standard candles, type Ia supernovae form the basis of cosmological distance measurements, although their underlying mechanisms are not well understood.

The white dwarf in V445 Puppis has been estimated to be close to the 1.4-solar mass limit, the point at which a white dwarf is thought to explode in a type Ia supernova. So assuming the white dwarf continues to feed on its helium-rich neighbor, and that it did not eject too much mass in the nova outburst, it might one day become a type Ia. "While we can't guarantee it, all the ingredients are there in the V445 Puppis system," Steeghs says. "You are basically loading up a white dwarf in this binary system, and it's receiving material at a rather large rate from this helium star."

University of Oklahoma astrophysicist David Branch calls the observations of the nova "exquisite" but stops short of calling the binary a compelling candidate for a type Ia precursor. The rate of mass transfer in the system is unclear, so it is not known how the binary will evolve. But the new study provides "significant observational support" for the model in which a helium star, bound in an orbital pair with a white dwarf, could indeed lend the compact white dwarf enough matter to initiate an explosion.

If V445 Puppis is on the path to supernova, just how long that path will be is an open question, Steeghs acknowledges. The problem in solidly pinning down the system's future is that astronomers have yet to take a clear look into the heart of the nova, where its stellar progenitors reside. The stars remain clouded by a haze of obscuring dust. "We need to wait for that to become visible when the shell thins," Steeghs says. "If we knew the mass of the white dwarf and the mass of the star next to it, and its orbital period, then we could sort of forward calculate how long it would take in that configuration to explode. But at this point we don't know that number."

It may be a few years yet before the binary system in V445 Puppis

becomes visible. Ordinary novae containing hydrogen usually open up to view in a year or two, Steeghs notes. "It's been nine years, and we still can't see the binary whatsoever," he says. "Because it's the first time we've seen a helium nova, there is no real benchmark. I guess we should maybe not be surprised that we don't quite know how long it will take and what it's doing."

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Cracked Corn: Scientists Solve Maize's Genetic Maze

A TOUGH KERNEL TO CRACK: Although mapping the corn genome was a challenging project for researchers to sink their teeth into, other plants, such as wheat and pine, promise to be even more genetically complex.

WIKIMEDIA COMMONS/JOHANN JARITZ

The complex corn genome—coming in at a hearty two billion base pairs (compared with the human genome's 2.9 billion base pairs)—has been mapped by more than 150 researchers, who worked for years to decipher the grain's genetic code. It's the most complicated plant genome to be deciphered to date and promises to increase the efficiency of the crop itself.

"It sets up our ability to start using three million to five million years of diversity" rather than a few hand-selected traits to improve production, says Ed Buckler of Cornell University and a collaborator on the research. "That's going to allow us to make lots of improvements," he says.

The four-year project, which was supported by various government agencies (including \$30 million from the National Science Foundation) and prompted in the 1990s by the National Corn Growers Association, promises to contribute a veritable cornucopia of new insights useful to many industries, including agriculture, energy and even manufacturing. The results were published online November 19 in a series of papers in *Science* and *PLoS Genetics*.

Deep into the maize

Getting to the bottom of this staple's DNA, however, was no small task. The corn genome actually has 12,000 more genes than humans do and manages to stuff them onto 10 chromosomes (as opposed to humans' 23). All of this data, and the repetitiveness of corn's code, made the task a daunting one. The team used a combination of physical and optical mapping to arrive at the findings.

After locating and characterizing the cereal's 32,000 genes, researchers now anticipate a new bounty of genetically tuned varieties. "Having the genome sequence is like having part of the instruction manual," says study author Richard Wilson of Washington University in Saint Louis (W.U.), echoing the famous 2000 comment of then Human Genome

Project leader Francis Collins, who called knowledge of our genome a "glimpse of our instruction book."

A better understanding of the plant's biochemical pathways may even be able to inspire totally new uses. "We're really excited that we've been able to generate a large number of markers that people can work with," says Buckler, who is also part of the U.S. Department of Agriculture's Agricultural Research Service. "We're going to be able to do genome-wide association studies very rapidly, which have already taken off in humans." The findings may also help researchers solve the mystery of hybrid vigor, the as-yet unsolved puzzle as to why a hybrid offspring proves to be a better grower than what would be expected from the sum of its parents' genetic assets.

This information will certainly speed up the development time of new corn varieties. Both academic and corporate researchers will now be able to do genetic tests on seeds to see if they are exhibiting desired traits rather than wait through a full growing season, Wilson explains. Buckler notes one breeding program that is already underway to increase the vitamin A content in corn after discovering a relevant allele last year. "Once we find a good gene with good alleles, we can breed with it immediately," he says.

Digging into corn's genetic past

The new picture that has emerged of the plant also helps researchers better understand its evolution and history. The crop was domesticated from a Central American grass called teosinte some 10,000 years ago. Much of the genetic diversity of maize, however, reaches nearly five million years back, Buckler says. Others had previously pointed to a few genes that were likely integral in domestication (such as those for ear size or kernel tenderness), but the new map suggests at least 100 to 200 genes have been involved in the domestication and selective breeding of the plant, Buckler notes. And as it turns out, "a lot of the genes have to do with making it a big ear," he says, citing the growth from the historical few inches to today's grocery store varieties that can regularly reach more than a foot in length.

Researchers selected the B73 variety of hybrid corn to map, which was developed in the 1970s at Iowa State University in Ames. It is "a favorite lab strain" in which a lot of the groundwork research had already been

done, Wilson notes.

Unlike mammals, mated corn varieties can have fairly vast genetic differences and still produce viable offspring. A partial sequencing of 27 other varieties revealed some striking variances. The Mo17 variety, for example, did not have at least 180 genes that appear in B73. "Any two maize varieties are as diverse from each other as humans are from chimpanzees," Buckler says.

An abundance of genes

It may seem strange that the number of DNA bases in humans should tally up nearly negligibly higher than they do in corn, but as Wilson points out, it's important "to not get hung up on the numbers." If we based our understanding of sophistication purely on these rankings, he says, "we pale in comparison to the pine tree." It's how the genomes are organized that is important. "Human genes are so much more complicated," points out Wilson, who is the director of The Genome Center at W.U.'s medical school.

Other theories about the relative complexity of some plants to vertebrates call on genetic efficiencies. Advanced animals can usually move out of a suboptimal environment (or in the case of humans, even change it). On the other hand, "a plant essentially has to stand there and take it," Buckler says. "In certain aspects that's more complex—you can't run away from the pathogens that are attacking you, so you have to create a diversity of options to deal with those things."

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Can Flywheels Help Balance Electricity Supply and Demand?

ROUND AND ROUND: Electricity from renewable sources, like wind turbines, could be stored in new flywheel facilities.

ISTOCK/SHARPLYDONE

Beacon Power Corp. broke ground today on a 20-megawatt, energy-storage facility in southeastern New York.

The Rensselaer County project, slated for completion in 2011, would be the first in the nation to use a "flywheel" frequency regulation system to balance electricity supply and demand, according to the Tyngsboro, Mass.-based company. The \$69 million facility would store electricity as kinetic energy in a matrix of massive discs when grid supply outstrips demand.

The ability to move power in and out of the system and maintain proper electricity frequency -- about 60 cycles per second -- will make the nation's electricity grid "smarter," Beacon President and CEO Bill Capp contended in a written statement.

"Our flywheel systems provide an essential grid-stabilizing service, and they do it faster and much more efficiently than today's conventional methods, most of which consume fossil fuel and produce harmful [carbon dioxide] greenhouse gas emissions," he added.

In July, the Department of Energy conditionally approved a \$43 million federal loan for Beacon's project. DOE has not issued final approval of the loan guarantee but aims to do soon, a department spokeswoman said today.

In August, Beacon applied for two grants, totaling up to \$46.7 million, under DOE's Smart Grid Demonstration program. If approved, each grant would fund up to 50 percent of the cost of Beacon's second and third 20-megawatt plants, the company noted in a filing with the U.S. Securities and Exchange Commission. Company officials did not return phone calls or e-mails seeking comment for this article.

A recent report by GTM Research projects that "power oriented" energy storage -- used mainly to regulate short-term changes to grid frequency - - will grow quickly in the near term but will be constrained in the long

term by a limited market. Conversely, "energy oriented" storage -- in which energy use is shifted to other times of the day -- has a massive total market size and is only beginning to emerge.

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Sinking Global Warming: Is There a Reliable Way to Track Atmospheric Carbon Dioxide Levels?

NATURAL "SINK": Scientists hope to precisely measure both how much greenhouse gases get dumped in the atmosphere as well as how much natural "sinks," such as the forest pictured here, absorb.

NOAA

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The planet soaks up excess carbon dioxide via oceans, plants and soils, among other natural systems, locking away some of the greenhouse gases emitted by burning fossil fuels. In fact, every year these natural "sinks" absorb a larger and larger tonnage of emissions—but thanks to the increasing amount of CO₂ and other greenhouse gases dumped in the atmosphere by human activity, the proportion that is reabsorbed is beginning to dwindle, according to new studies.

As efforts get underway to craft a global treaty that begins to reduce man-made greenhouse gas emissions, precise and accurate measurements of the emanations, along with their sources and sinks are increasingly important. Novel technologies as well as new scientific efforts are contributing to that project—although the recent loss of NASA's Orbiting Carbon Observatory caused a setback.

First and foremost, greenhouse gas emissions worldwide continue to grow, according to a new report from the Global Carbon Project (GCP) published online by *Nature Geoscience* on November 17. (*Scientific American* is part of the Nature Publishing Group.) From 2000 to 2008, such discharges jumped by 29 percent and, in spite of the onset of the Great Recession, still managed to rise 2 percent in 2008 alone (although they are expected to fall back to 2007 levels this year), according to oceanographer Corinne Le Quere of the University of East Anglia in England. In fact, global emissions from fossil-fuel burning and deforestation are now roughly 37 billion metric tons of CO₂ per year—or 41 percent higher than in 1990.

Le Quere and her colleagues' research also hints that the portion of CO₂ remaining in the atmosphere may be on the rise, as well—creeping from around 40 percent in 1959 to roughly 45 percent in 2008. That translates to roughly 14 billion metric tons of CO₂ a year, or a 1.8-part-per-million increase in atmospheric concentration annually.

Part of the reason for that rise may be explained by a slowing in the amount of CO₂ absorbed by the world's oceans, particularly the Southern Ocean surrounding Antarctica, whose frigid waters absorbed 40 percent of the nearly nine billion metric tons of CO₂ sequestered by the seas last year. Reconstructing the record back to 1765, oceanographer Samar Khatiwala of Columbia University's Lamont-Doherty Earth Observatory and his colleagues estimate that the proportion of fossil-fuel emissions absorbed by the sea has declined 5 percent already in the first years of the 21st century, according to a new paper published November 19 in *Nature*.

This might indicate that the natural ocean sink—whose carbon dioxide uptake increased in the 1950s—is unable to cope with increasing greenhouse discharges produced by human activity. "The more carbon dioxide you put in, the more acidic the ocean becomes, reducing its ability to hold CO₂," Khatiwala said in a prepared statement. Seawater's average pH—a measure of acidity—has dropped to 8.1 from roughly 8.2 in the 19th century.

That is balanced, in some part, by an apparent rise of roughly four billion metric tons of CO₂ absorbed by land-based sinks, possibly due to CO₂ being used by growing plants. Then again, the researchers' estimate for land uptake of carbon is suspect, given that it is based on what has not been absorbed by the oceans or remains in the atmosphere.

This kind of estimate is endemic to climate research and is perhaps best exemplified by the national emission inventories, which are often based on emissions factors—mathematical formulas for the amount of CO₂ produced by burning a particular type of coal, for example. Simply multiplying consumption figures for such coal by these factors is the primary way the U.S. and other nations estimate the greenhouse gas load they contribute to the problem.

"Those emission estimates are not very accurate compared to high-calibration devices," says Michael Woelk, CEO of Picarro, a California-based manufacturer of such a device for measuring CO₂ emissions. "No country today is using scientific instruments to monitor and calibrate the effect of policy," not even the European Union, which has an emissions trading scheme for greenhouse gases.

The U.S. uses similar technology to precisely monitor emissions of acid rain-causing sulfur dioxide or smog-forming nitrogen oxides as part of its trading programs for those pollutants. And the World Meteorological Organization has opted to employ Picarro's "cavity ring-down spectroscopy" technology—a computerlike device that measures isotopes to determine both amount and source, whether man-made or natural, of greenhouse gases—to ensure that its global measures are accurate.

The devices depend on the fact that carbon dioxide generated from fossil-fuel consumption has less of the isotope known as carbon 13 than other forms of the gas, thanks to plants preferentially absorbing the lighter version, known as carbon 12. By measuring this ratio, scientists might be able to determine more accurately the proportion of human contribution to climate-warming gases.

But a lot of variability in such isotopes remains; for example, the ratio of these isotopes can vary significantly in natural gas alone, potentially throwing such measurements into dispute. And a paper in the November 7 issue of *Geophysical Research Letters* from earth scientist Wolfgang Knorr of the University of Bristol in England argues that the ocean's uptake of carbon dioxide has not slowed at all in the last 150 years, making it possible that natural systems could compensate for human emissions.

Ultimately, what will matter most is how much the oceans and other natural sinks can buffer the human contribution from fossil-fuel burning. If greenhouse gas emissions continue on their current trajectory, global average temperatures could be 6 degrees Celsius warmer by the end of the century, Le Quere says.

As oceanographer Richard Feely of the National Oceanic & Atmospheric Administration's Pacific Marine Environmental Laboratory, a contributor to the GCP, noted: "We're concerned that if the natural sinks can't keep

pace with the increased CO₂ emissions, then the physical and biological impacts of global warming will accelerate over the next century."

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Ultrathin, Now Ultraflat: Ripple-Free Graphene May Hold Key to Material's Mysteries

WAVE OF THE FUTURE? Graphene, a single atomic layer of carbon, could find use in many electronics and materials applications, but physicists are still investigating its fundamental properties. A team of researchers has eliminated its characteristic surface waves, which should allow for an analysis of the ripples' effect on the physics and chemistry of graphene.

TEAM05 via Wikipedia

Graphene has been a hot topic in physics and materials science since its discovery five years ago. The sheets of carbon, just an atom thick, have a host of intriguing properties, including transparency, strength and a structure that lets electrons zip through almost unimpeded. Graphene's characteristics and near two-dimensionality recommend it for use in next-generation displays, electronics or structural composites, but like many materials du jour, it has yet to find applications on a significant scale.

One problem slowing graphene's rollout to implementation is an incomplete understanding of its physical, electronic and chemical properties. In 2007, for instance, researchers found that graphene was not truly planar but had a characteristic roughness in the form of nanometer-size surface ripples. (A nanometer is a billionth of a meter.) Some researchers have hypothesized that the ripples might hinder electron flow through graphene, but that assertion has proved difficult to test.

Now, a team from Columbia University, writing in the November 19 issue of *Nature*, reports creating ultraflat samples of graphene in which the material's ripples are suppressed. (*Scientific American* is part of the Nature Publishing Group.) By comparing ordinary graphene with the new uncorrugated version, the study's authors wrote, researchers should be able to unpack the effects of graphene's roughness on its other properties.

Mikhail Katsnelson, a physicist at Radboud University Nijmegen in the Netherlands who did not contribute to the new research, has hypothesized that graphene's ripples are one possible source for scattering of charge carriers in the material. That scattering, whatever the

cause, limits graphene's inherent ability to swiftly transport electrons.

If the flat graphene sample turns out to have the same electron mobility as regular rippled graphene, then the ripple-scattering theory would be sunk. "If, oppositely, the mobility will be much higher," Katsnelson says, "it will be a direct confirmation of our hypothesis about ripples as the main limiting factor for electron mobility." If that were the case, then ironing out graphene's ripples would prove to be an important step toward using the novel material in electronics.

Tony Heinz, a Columbia physicist and study co-author, says that graphene's ripples have also been implicated in other puzzling properties that the material exhibits. For instance, "they have been suggested as the reason for the difference in reactivity of mono- and multi-layer graphene," Heinz says. Single graphene sheets are chemically reactive, but stacked layers of graphene—otherwise known as graphite, or pencil "lead"—are inert. "To date it has been difficult to provide definitive proof of the role of ripples, because ultraflat samples for comparison have not been available," he adds.

Heinz says that the key to flattening graphene is simply to deposit it on an exceptionally smooth substrate. Whatever intrinsic tendency to crumple the substance may have, it is overcome by the interfacial interactions with an atomically flat surface. Heinz's group used mica, a silicate mineral that can be cleaved to produce smooth surfaces many microns across. Once a flat mica terrace has been established, Heinz says, it is no more difficult to prepare graphene on that substrate than on traditional, somewhat rougher substrates such as silicon dioxide.

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Researchers Try to Solve the Mystery of HIV Carriers Who Don't Contract AIDS

ELITE CONTROLLERS: The immune systems of perhaps 50,000 Americans somehow control HIV for long periods of time such that these people don't get sick from the virus.

iStockphoto

More than half a million people in the U.S. have died from HIV infection, and more than a million currently live with the virus, but a relative handful of people infected with HIV never get treatment for it and never get sick from it. The immune systems of this small population—perhaps 50,000 Americans—somehow control the virus for long periods of time. Of course, there is typically a bell curve of response to any disease, but figuring out how these people control the virus is one of the most vexing mysteries of the AIDS pandemic. Solving it might unlock new ways to prevent and treat HIV infection, and now several research teams are going after the answer.

Ten years after infection with HIV, a typical person has progressed to where tens if not hundreds of thousands of copies of the virus can be found in a single milliliter of their blood and more than three quarters of their CD4 immune cells are destroyed, if they have not started drug therapy.

"Long-term nonprogressors" is a category of persons whose disease progresses less rapidly than average. Researchers originally used the term broadly but now they have been able to tease out two subsets of patients within a hierarchy:

"Viremic controllers" are the next segment down the curve. After 10 years, one can find only 50 to 2,000 copies per milliliter of HIV in their blood; their CD4 count may be stable or may have declined, sometimes significantly. At the far end of the curve are "elite controllers," people whose immune system suppresses HIV below 50 copies per milliliter; their CD4 cells have not declined, even a decade or more after initial infection.

Studying HIV controllers, however, is difficult. Testing for HIV is not part of routine medical care; an estimated quarter to a third of those infected with the virus in the U.S. do not know they are carrying it; and

many learn of their infection only when they suffer an opportunistic infection that is typical of advanced HIV disease.

Thus, controllers are likely to be disproportionately represented among those who do not know their HIV status. Other controllers have been put on therapy early, perhaps before they needed to be. Doctors and patients simply do not know enough about this type of response and where to refer these patients to participate in a study. And finally, privacy laws hamper communications between controllers who might otherwise help to push the research forward. All of these contribute to making it difficult to identify and study HIV controllers.

Their rarity became apparent in a recently published analysis of HIV-positive soldiers serving in the U.S. military. Elite controllers were just 0.55 percent of the 4,586 persons in the military cohort (viremic controllers made up 3.34 percent). This population offers perhaps the best natural history that scientists are likely to obtain, because all soldiers are regularly screened for HIV and all infections are identified fairly soon after they occur.

It's in the genes

The virus carried by HIV controllers is less fit; it reproduces less rapidly than virus in people who do not control HIV as well, according to Douglas Kwon. It is not that these people were fortunate to become infected with a less fit virus but rather "the immune system drives it to a less fit variant," he adds. Kwon is part of the research team assembled by Howard Hughes Medical Institute investigator Bruce Walker of the Ragon Institute at Massachusetts General Hospital. They are analyzing the genes and immune function of HIV controllers, about 1,600 so far.

Host genes of the major histocompatibility complex (the genes that determine how mammals respond to pathogens) play a significant role in how the immune system responds to all pathogens. Several variants, such as the HLA B*5701 allele, have been associated with the pace of HIV disease progression in both controllers and "normals."

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Fish Kill: Nanosilver Mutates Fish Embryos

SILVER NANOBULLET: New research suggests that silver nanoparticles can harm fish embryos.

ISTOCK/DANBRANDENBURG

Smaller than a virus and used in more than 200 consumer products, silver nanoparticles can kill and mutate fish embryos, new research shows.

Tiny particles of silver – potent anti-microbial agents that can kill bacteria on contact – are becoming increasingly popular in consumer goods, including washing machines, refrigerators, clothing and toys.

But as use of these microscopic silver particles grows, some scientists now are raising concerns about potential effects on the environment and human health.

Many nanoparticles, including nanosilver, wash down drains and are not removed by sewage treatment, so they are discharged into lakes and rivers, where fish and other aquatic life are exposed. Research into the environmental implications of these silver nanoparticles has begun, but there are no answers yet about what happens when they enter ecosystems.

“I think we jumped the gun” by creating such large volumes of nanoparticles, said University of Utah researcher Darin Furgeson. “We should take more time and really look at these new nano-systems before we start to throw them into personal products and shoot them into these ecosystems.”

Nanotechnology is projected to be a trillion dollar industry by 2015, with some saying it will be the focus of the next industrial revolution. The number of products – including sunscreens, paints, vitamins, food additives, electronics, vehicles and appliances – that use nanomaterials has increased almost 380 percent since 2006, according to the Project on Emerging Nanotechnologies, a Washington, D.C.-based non-profit group that tracks nanotechnology.

Nanoparticles are pieces of metal or other substances that are engineered to measure less than 100 nanometers in length. A nanometer is one-billionth of a meter. In comparison, a human blood cell is about 8,000

nanometers and the HIV virus is about 130.

The U.S. Environmental Protection Agency recently announced a new research strategy to better understand the environmental effects of these microscopic particles. In addition, last year, the EPA and the National Science Foundation established two new centers, led by UCLA and Duke University, to examine the environmental implications of nanotechnology.

“The same special properties that make nanoscale materials useful are also properties that may cause some nanoscale materials to pose potential risks to humans and the environment, under specific conditions. At this point not enough information exists to fully assess these risks,” said an EPA report released in January. The report summarized the EPA’s Nanoscale Materials Stewardship Program, which collected voluntary information from companies that manufacture or use nanoparticles.

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E-Transportation Jump-Start: Coalition Seeks to Pave the Way for Electric Vehicles

ELECTRIFICATION COALITION With the number of vehicles on the planet expected to grow from 600 million today to 2.5 billion by 2050, a group of companies sees electric vehicles as the best alternative, given concerns of foreign oil dependency, oil prices and climate change.
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Although the widespread adoption of electric vehicles and their related infrastructure has always suffered from chicken-and-egg syndrome, Nissan and FedEx, along with several utilities and technology companies have formed a coalition to break the stalemate. At a press conference Monday in Washington, D.C., the Electrification Coalition announced its formation as well as a new 130-page report on the dangers of oil dependence, the benefits of electric vehicles, and ways to overcome roadblocks that have kept these vehicles from being deployed en masse.

Sixty percent of the petroleum used by the U.S. daily comes from foreign sources, FedEx CEO Fred Smith said at the launch event, adding that 90 percent of all U.S. transportation is petroleum-powered. Smith made clear his position that reliance on foreign oil is "in no small way related" to the wars in Iraq and Afghanistan. This energy mentality has to change because the U.S.'s dependence on foreign oil has created what amounts to a security risk for the country as a whole, said Sen. Byron Dorgan (D-N.D.), who also spoke at Monday's event.

The coalition's position is that a move to electric vehicles would help the U.S. combat the economic, environmental and national security vulnerabilities caused by the country's petroleum dependence. The coalition's "Electrification Roadmap" report predicts that if by 2040, 75 percent of light-duty vehicle miles traveled in the U.S. are covered by electric vehicles, oil consumption in that fleet would be reduced by more than 75 percent, and "U.S. crude oil imports could effectively be reduced

to zero."

The coalition estimates there will be 2.5 billion vehicles on the planet by 2050, up from 600 million this year. Smith pointed out that the continued economic development of India, China and Brazil will lead to a "staggering increase" in the number of vehicles on the world's roads. If they are powered by internal combustion engines, "we are on an unsustainable path," he added. "When you look at the alternatives that are available, electrification of short-haul transportation becomes the only viable alternative."

Smith acknowledged that electric vehicle owners, including his own company, pay a premium today for their fleets—whereas a hybrid pickup and delivery van costs about \$90,000, FedEx can buy a diesel vehicle for about \$60,000.

The problem with mass-producing the number of electric vehicles that would drive down costs has always been the standoff among carmakers, consumers and utilities—none of which are willing to invest in the technology until they are sure it is ready to meet their needs, both logistically and economically. "Car companies have not wanted to build cars in bulk for infrastructures that don't exist, while infrastructure companies such as ourselves don't want to build infrastructures for cars that don't exist," said David Crane, chief executive of coalition member NRG Energy, Inc. Still, the risk of doing nothing has become apparent. For 2008 the U.S. net trade deficit in crude oil and petroleum products was \$388 billion, Crane said, adding, "I don't think anyone in America is happy about that."

Legislation to control carbon emissions, public concern over the environment, and high gas prices are driving the demand for electric vehicles, said Carlos Ghosn, chief executive of coalition member Nissan Motor Co., whose all-electric Leaf is set to debut in the U.S. in 2010 (although it will not be widely available until 2012).

The coalition's proposed solution is in part to deploy fleets of 100,000 to 200,000 electric vehicles in six to eight U.S. cities that can invest in the necessary infrastructure. If this limited investment of resources leads to increased interest in driving electric cars, the coalition hopes to expand its program to 20 or 25 cities. Although the coalition did not reveal which

urban areas it is planning to use as its initial test bed, the U.S. Department of Energy has already promised to provide \$99.8 million to a project led by Electric Transportation Engineering Corporation (eTec), a subsidiary of Scottsdale, Ariz.-based ECotality (not a member of the coalition), for installation of up to 12,750 charging stations across five markets: Tennessee, Oregon, San Diego, Seattle and the Phoenix–Tucson region. The project also includes the deployment of up to 1,000 Nissan Leafs in each market.

Coalition test runs in the selected cities will also provide the parties involved with a better understanding of just how extensive the infrastructure needs to be, not to mention how much it will cost. There may not be a need for that many fast-charging stations, given that 90 percent of Americans drive fewer than 65 kilometers each day, Crane noted. He pointed to a project in Tokyo where the installation of fast charging stations throughout the city boosted electric vehicle use, even though the stations were hardly ever used.

In the end, the drivers themselves will make the final judgment on whether electric vehicles succeed, Dorgan said. The image of the rugged American cruising along in a gas-guzzling vehicles transposed against the stereotype of bookish hybrid drivers has been an impediment to electric vehicle adoption. "There's been a notion that real men dig and drill," the senator said, "but I think things have changed a lot."

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Renewed Hope for an AIDS Vaccine

SMALL VICTORIES: The massive Thai AIDS vaccine trial showed that a combination of two vaccines may work better than one, but the inoculations had only slight--if any--protective value. Are such slim successes enough to keep the vaccine hunt going?

WIKIMEDIA COMMONS/UNITED STATES ARMY

The long search for an AIDS vaccine has produced countless false starts and repeated failed trials, casting once bright hopes into shadows of disenchantment. The now familiar swings appeared in high relief this past fall, with news of the most recent, phase III trial in Thailand. Initial fanfare for a protective outcome gave way to disappointment after reanalysis showed that the protection could be attributed only to chance. But rather than dashing all hopes for an AIDS vaccine, the trial has heartened some researchers, who see new clues in the battle against the fatal illness.

Costing \$105 million and enrolling more than 16,000 subjects, the Thai clinical trial was the largest AIDS vaccine test to date. It began in 2003, and early results released in September showed a slim but statistically sound benefit from the vaccine (a series of inoculations with drugs known as ALVAC-HIV and AIDSVAX B/E). But in October the full report, with various statistical analyses, was released in a Paris meeting to greater skepticism. Specifically, 74 people who had received the placebo became infected with HIV in the trial period, compared with the 51 people who became infected after receiving the vaccine, which makes for a protective effect of 31.2 percent. By including, however, the seven people who turned out to have had HIV at the start of the trial (two in the placebo group and five in the vaccine group), the effectiveness drops to 26.4 percent.

"There are still a huge number of uncertainties surrounding this trial," says Dennis Burton, an immunologist at the Scripps Research Institute in La Jolla, Calif. The subjects were in low- and moderate-risk groups, such as heterosexuals in monogamous relationships, rather than higher-risk groups such as intravenous drug users. "The numbers involved are small," he adds, noting that statistically the protective effects could be the result of mere chance.

Still, many researchers are convinced that the trial has provided plenty

of data to run with. "This contributes more evidence that an AIDS vaccine may be possible," says Jerome Kim of the Walter Reed Army Institute of Research and co-author of the Thai trial study (which appeared in the *New England Journal of Medicine* in October). "We've taken a very small step," Kim says. "It's not a home run, but it opens the door to future work." Vaccine proponents also point to the lessons learned from the failed Merck STEP trial. That vaccine test, halted in 2007, got only as far as phase II, but even so it did not leave researchers back at square one. It suggested, he notes, how some HIV strains could be blocked from infecting cells and offered data that could help in the interpretation of the Thai results. And a new analysis of the stopped STEP trial, published online Monday in *Proceedings in the National Academy of Sciences*, provides a warning that the very vectors (adenoviruses, which are also employed in other vaccine development) used to distribute the inactive HIV strains can actually prime the immune system to be infected by recruiting susceptible T cells to mucous membranes, where they are more likely to be infected during sexual activity.

Finding a vaccine has become an increasingly urgent undertaking. Despite advances in therapies, HIV/AIDS is still incurable. Some 7,000 people worldwide contract HIV every day, and in the U.S. about 66,000 new cases are reported every year. Preventing people from getting the virus would save millions of lives as well as greatly reduce health care costs associated with treatment. "It's really the only optimal method of control for this dreadful pandemic," Raphael Dolin, of the Beth Israel Deaconess Medical Center in Boston who also wrote an editorial accompanying the October paper, says of a vaccine.

Vaccines work by priming the immune system to recognize the target pathogen and attack it when detected. To fend off HIV, researchers introduced one vaccine (ALVAC-HIV) to induce a T cell response—thereby alerting the immune system—and another (AIDSVAX B/E) later to spur an antibody response. In a previous phase III trial in intravenous drug users, AIDSVAX did not work. ALVAC, from Sanofi Pasteur, had not been tested alone.

Using these two drugs together raised eyebrows in the vaccine community. Burton, along with 21 other researchers, co-authored a 2004 paper in *Science* criticizing the choice to proceed to phase III with two

vaccines that had never demonstrated any effectiveness alone. The trial collaborators, however, based their decision on previous research that a combined approach can boost helper T cell response better than a single vaccine.

Despite his earlier doubts, Burton has been inspired by the trial results. "I feel more optimistic than I have in some time," he says. Researchers are now embarking on a host of new experiments to put the Thai findings to work. Volunteers from the trial will now be examined for immune responses—particularly neutralizing antibodies as well as cellular immunity in T cells—and some will get subsequent booster shots to see if protection can be sustained. In the lab, researchers will try to re-create the Thai results in monkeys to validate a new animal using multiple low doses. Other recent research has shown that the number of antibodies needed to provide protection is lower than previously believed, possibly making a vaccine easier to create.

Indeed, entirely new and promising candidates are now in animal trials, including those by the U.S. military to address subtypes A, C and E (rather than the Thai subtype B). Other organizations—including the International AIDS Vaccine Initiative (IAVI), the Karolinska Institute and the Swiss nonprofit EuroVacc—and manufacturers also have other vaccines in the works. "The science is really moving," says [Seth Berkley](#), a professor in the Department of Epidemiology at Columbia University's Mailman School of Public Health and who is also president of IAVI. All those confronting the epidemic hope that the momentum leads to a payoff sooner rather than later.

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Nanodevices Bend under the Force of Light

MIND THE GAP: Low-power laser light, when passed through the ring-shaped resonators, induces significant changes in the gap between them.

G. Wiederhecker, L. Chen, A. Gondarenko and M. Lipson

A team of researchers has fabricated a micron-scale device that deforms significantly under the force of light, a technology that could form the basis for tiny light-actuated switches or filters in future optical devices.

In recent years several groups have engineered novel structures on scales so small that the force of light passing through them actually wields an appreciable force. The devices harness the so-called gradient optical force, by which a light beam can exert a push or pull in a direction transverse, or perpendicular, to the direction of the light's propagation. In a recent example, outlined in *Nature* last year by a team from Yale University and the University of Washington in Seattle, laser light routed through a tiny bridge-shaped resonator induced the bridge to vibrate up and down within a range of a few nanometers. (*Scientific American* is part of the Nature Publishing Group.)

The new approach, described in a paper published online Sunday in *Nature*, uses a pair of wagon wheel-shaped ring resonators, separated by a gap, to achieve much greater displacement. (The shape of the device is similar to one described in July by a group from the California Institute of Technology.) In addition, postdoctoral associate Gustavo Wiederhecker and his Cornell University Nanophotonics Group colleagues achieved static displacement—that is, they were able to bend and hold their structure in place rather than causing it to move back and forth.

"A lot of groups are starting to learn how to vibrate structures using light," says Cornell physicist Michal Lipson, a study co-author and the leader of the nanophotonics group. "But what we decided to do is instead of just vibrate, to really control the structure—to bend or move the structure—and keep it static just like that." Running low-power laser light, akin to that from a typical laser pointer, through the rings generates a tunable response—either attractive or repulsive, depending on the wavelength—that changed the size of the gap between the rings

by as much as 20 nanometers. (A nanometer is one billionth of a meter.)

By modulating the intensity of the laser light, Lipson says, the gap can be opened or closed to varying widths. "You can completely control the amount of bending with the amount of incident power that you have," she says. Such controlled deformation could be used to form tiny switches driven by light rather than electricity.

Hong Tang, an assistant professor of electrical engineering at Yale who co-authored last year's nanobridge paper in *Nature*, sees these devices possibly forming the basis for tunable optical filters. By using a laser to induce movements that change a structure's resonance, he explains, the passage of light from another source—say, an optical communication channel—can be controlled.

Tang calls the new application of the gradient force "very innovative." He points out that the ring structure, which Lipson says is designed for both low mass and malleability, harnesses the optical force on a greater scale than the smaller vibrating beam did. "There are different field applications, and there is a trade-off," Tang says. "We pushed the limit to small, and they pushed the limit to large displacement."

"The displacement demonstrated in this device is 20 nanometers, which is really significant," Tang says. "This is really a big change for the optical force-induced displacement."

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Can Alternative Energy Save the Economy and the Climate?

RENEWABLE WINDFALL: Utility companies are investing in diverse renewable energy projects with or without success at Copenhagen.
ISTOCKPHOTO/JLGUTIERREZ

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BRIGHTON, Colo. - The low-carbon economy has already arrived on the windy prairie north of this fast-growing Denver 'burb. It's here that Danish wind-turbine giant [Vestas](#) converted 298 acres of hayfield into the West's largest turbine factory - and turned Brighton into a magnet for "green" energy companies.

It's part of a \$1 billion investment by the company in the United States, what [Colorado Gov. Bill Ritter](#) touts as a "new energy economy."

"We have a caseload of 56 prospects. Of those, a majority are energy-related industries," said Raymond Gonzales, president of the [Brighton Economic Development Corporation](#). "People are looking. They're not slowing down. And they're aggressively looking at the United States."

Some say these efforts - not the upcoming [Copenhagen](#) climate treaty talks - provide the most promising route to energy independence, climate change mitigation and job creation.

Regardless of whether delegates emerge next month with a comprehensive [replacement for the Kyoto Protocol](#), industry's full-throttle acceleration toward a low-carbon future will continue, they say.

Vestas isn't the only company spending millions of its capital. Several utilities are investing some \$1 billion on an industrial-scale carbon capture and storage tests at coal [plants](#) in Wisconsin, West Virginia and Oklahoma. The race to perfect the batteries that will power the next generation of automobiles and buses has manufacturers in Europe, the United States and China scurrying to build plants and research centers.

"The vast majority of the utility industry (has) pretty much accepted the reality that CO2 is something they have to cope with," said [Revis James](#), director of the energy technology assessment center for the Electric Power Research Institute, or EPRI, a California-based nonprofit that helps drive long-range development and is coordinating carbon capture experiments at coal plants in the Midwest and Southeast.

[Failure in Copenhagen](#) won't "substantially stop what's going to happen," James added. "The utilities have to deal with (carbon emissions). They have to respond one way or another."

Many business leaders and policy analysts counter the status quo - a piecemeal, federated approach to carbon and energy emissions - doesn't carry enough of a signal to produce the revolution required of our economic and energy sectors.

Private-sector investments and regional and local government efforts to boost "green" technology are good, they say. But that's just the down payment: The transformative change necessary to avoid the worst warming won't come until the international community firmly sets a global standard in place.

"What you want is something sustainable, predictable and long-term," said Roby Roberts, spokesman for Vestas Americas. "That's what you want out of the climate rules, but that's going to be a few years away."

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Heavy Metal: Researchers Try to Get the Lead out of Piezoelectronics

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LOTS OF POTENTIAL: This high-resolution transmission electron microscopy image depicts the phase boundary in bismuth ferrite with [left to right] areas with tetragonal, rhombohedral and tetragonal structure.

© SCIENCE/AAAS

Gadget makers often rely on piezoelectricity—the ability that some solids have to produce voltage when pressure is applied to them—to power tiny embedded systems, such as a BlackBerry Storm 2's touch screen or a car's airbag sensor. Whereas lead-based compounds typically have the greatest piezoelectric potential, the heavy metal has fallen out of favor as device-makers push to eliminate it from all electronics in an attempt to reduce toxic waste.

"Driven by global environmental concerns, there is currently a strong push to discover practical lead-free piezoelectrics for device engineering," a team of University of California, Berkeley, researchers posit in a study to be published Friday in *Science*. The researchers report finding a viable alternative in specially prepared bismuth ferrite film that has piezoelectric properties on par with lead-based compounds.

Finding alternatives to lead has not been easy. Although the European Union's (E.U.) Restriction on the Use of Certain Hazardous Substances (RoHS) went into effect in 2006—effectively banning new electronics (pdf) that contain certain levels of lead, cadmium, mercury and other toxic chemicals—lead has been difficult to phase out due its versatility. (It serves as an ingredient in solder and plastic, for example.) In fact, lead in electronics is so pervasive that the RoHS had to include a list of exemptions to the metal's ban, most notably in piezoelectronic devices (pdf).

Although researchers have known for years about bismuth ferrite's piezoelectric properties, it could not be made to produce enough voltage

to be considered as a replacement for lead, says [Ramamoorthy Ramesh](#), a professor of physics and of materials science and engineering at U.C. Berkeley who contributed to the research led by [Robert Zeches](#), one of Ramesh's graduate researchers at Berkeley's Department of Materials Science and Engineering. "No one could control the structure of bismuth so that it could perform as well as lead and lead-based compounds as a piezoelectric substance," he adds.

By experimenting with bismuth ferrite films of different thicknesses grown on different types of substrates, Zeches was able to create a film that could generate more piezoelectric "strain"—measured in terms of charge generated—than previously possible. The key was finding a thickness-substrate combination that caused the film to form with the right mixture of tetragonal- and rhombohedral-shaped crystals. (Tetragonals are characterized by having three axes at right angles to one another, two equal in length and the third a different length; rhombohedrals resemble a cube stretched or flattened along one diagonal axis.) Piezoelectric strain is created when pressure is applied to bismuth ferrite, forcing its tetragonal crystals to change shape into rhombohedrals (and vice versa). As strain is increased more electricity is produced by the piezoelectric effect. "Robert took a big step forward by finding the right combination of bismuth ferrite crystal shapes to boost the amount of strain produced," Ramesh says.

The researchers are now trying to determine which factors—substrate type, film thickness or crystal composition and position—influence the film's piezoelectric potential the most, Zeches says. "The sweet spot is in intermediate thickness films," he adds, "which is where you get the mixed crystal formations that have the greater piezoelectric effect."

The Berkeley research is too early in its development to determine when bismuth ferrite-based materials might be incorporated into consumer electronics or how it might affect cost. Most likely, continued success with the compounds would more immediately result its use in nanoscale data storage devices.

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Engineering the Planet to Dodge Global Warming

SULFUROUS SOLUTION?: Climate scientists urge for research into geoengineering schemes, like injecting sulfur into the atmosphere, to thwart climate change.

ISTOCKPHOTO/ZVOZDOCHKA

Failure to make difficult choices to cut greenhouse gas emissions exposes humanity to an increasingly dire set of climate scenarios. But there is a way to buy time: Geoengineering.

The idea of tinkering with planetary controls is not for the faint of heart. Even advocates acknowledge that any attempt to set the Earth's thermostat is full of hubris and laden with risk.

Some ideas are the stuff of science fiction: 15 trillion mirrors positioned in orbit to shield the planet from the sun's rays; a fleet of blimps 20 kilometers up feeding a constant stream of sulfur into the stratosphere; a navy of robot-controlled ships prowling the world's oceans, spraying seawater skyward to generate reflective clouds.

Others are more mundane: Plant trees to soak up carbon dioxide or paint roofs white to reflect sunlight. Most are unproven. All have major drawbacks. None offset ocean acidification.

But the concept is gaining more traction as politicians, confronted with the ugly reality of trying to wean economies off fossil fuels, cast about for a strategy that will work if climate changes quickly or in nasty ways.

"Most analysts who examined the options closely had concluded that it would be reckless to mess with the planet," said David Victor, a professor of international relations at the University of California, San Diego, who specializes in energy and climate policy. "That is changing."

It's changing, in large part, because the chances of any sort of international agreement on radical emissions cuts are plummeting even as scientists find evidence that these emissions have the potential to destabilize the Earth's climate to a degree unforeseen in human history.

If those predictions come true, scientists fear any hand-wringing over the consequences of planet-wide mitigation will pale in comparison to the

inconsolable pleas of populations facing rising seas, searing dust storms and savage famines, scientists warn. The world needs to know of geoengineering's pitfalls before desperate leaders turn to an untested technology.

Practical applications date to the Cold War, when both Russian and American military started seeding clouds in an attempt to induce rain. When President Lyndon Johnson was briefed about the dire effects of global warming, geoengineering was the only solution prescribed by his scientific advisors.

For years, however, it was taboo - on the fear that, if climate control was seen as a viable option, pressure on world leaders to reduce emissions might ease.

That changed in 2006 with the publication of a seminal essay in the journal *Climatic Change* by Nobel laureate Paul Crutzen, emeritus professor at the Institute for Marine and Atmospheric Systems at Utrecht University in the Netherlands.

Emissions cuts are the first priority, Crutzen repeated throughout his eight-page essay. But given climate change's catastrophic implications for ecosystems - and the "grossly disappointing" international political response to necessary emissions cuts - geoengineering must be explored as a potential escape route.

"Its possibility should not be used to justify inadequate climate policies," he wrote, "but merely to create a possibility to combat potentially drastic climate heating."

Crutzen and other climate scientists draw a bright bold line between the need to undertake geoengineering research and the decision to engage in actual geoengineering.

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Out of Africa: The Tobacco War's New Battleground

BURNING HOPES: Anti-tobacco advocacy groups peg Africa as a region of high concern due to its residents' growing habit. A man, pictured here, smokes a cigarette rolled in newsprint.

ISTOCKPHOTO/MANOAFRICA

Africa is already beleaguered by infectious diseases, such as AIDS and malaria, but now the continent's residents face growing health threats from preventable illnesses brought on by lifestyle changes, such as from poor diets and smoking.

In an effort to stave off these maladies, advocates have turned their sights on tobacco use, which is on the rise throughout Africa and projected to double by 2021. Of the approximately one billion people across the world who use tobacco, 60 million to 80 million live in Africa.

Along with lobbying for higher tobacco taxes and broader public health messages, advocates are hoping to eliminate smoking in public places in an effort to protect people from both first- and second-hand smoke.

About a billion people worldwide live in municipalities where smoking is outlawed in public places, according to a report published Tuesday by Global Smokefree Partnership (a joint initiative backed by the American Cancer Society, Johns Hopkins Bloomberg School of Public Health, Johnson & Johnson, Pfizer and 14 other entities) and announced in time for the African Organization for Research and Training in Cancer's (AORTIC) "Cancer in Africa" conference taking place this week in Dar es Salaam, Tanzania. Reducing secondhand smoke exposure can reduce the rates of lung cancer, heart attacks and breathing trouble in populations.

"It's one of the most frustrating things," Thomas Glynn, director of International Cancer Control for the American Cancer Society (ACS) and acting head of the Global Smokefree Partnership says, about knowing that many nicotine-related illnesses can be prevented—especially among those who do not smoke—with the right laws and education.

A few countries in Africa have taken a firm stance on public smoking. the Indian Ocean nation, Mauritius, and South Africa have passed strong national smoke-free laws, and Nigeria's capital, Abuja, has a local ordinance in effect. But in many areas throughout the continent,

politically connected and economically strong tobacco companies—and their addictive products—are shaping up to be a substantial opponent (British American Tobacco, a member of the industry group the Tobacco Institute of Southern Africa, did not repond to request for comment).

A hit on health

Tobacco causes about 5.4 million deaths worldwide each year, according to the World Health Organization (WHO), a number that is set to rise in the coming decades even as use decreases in many developed countries. But it is not just the smokers who suffer from the ill effects of their habits.

Since 1986 secondhand smoke has been recognized internationally as a contributor to lung cancer and, in 2006, the U.S. Surgeon General went so far as to say "there is no safe level of exposure to secondhand smoke." These findings, however, have not widely been put into regulatory action, leaving some 90 percent of Africans without local or national smoke-free laws, the new report notes. For example, in Tunisia, where tobacco use is especially high, even teachers and doctors smoke at work, according to a report issued earlier this year by the Economist Intelligence Unit, a London-based firm that provides business and market research, and backed by Pfizer.

Aside from the millions of tobacco-related deaths annually, the range of long-term disability that tobacco smoke exposure can induce also takes a toll on health and productivity. "We focus on lung cancer deaths, but more people are disabled by emphysema and heart disease and can't provide for their families," Glynn says.

In developed countries, heart attacks in areas with smoke-free laws dropped by 36 percent three years after laws went into effect, according to a report released in September by the American Heart Association. California, one of the first states in the U.S. to institute substantial local laws banning public smoking, has seen a reduction in lung cancer, Glynn notes. "From a biological plausibility standpoint, there's no reason we wouldn't see a similar decrease" in African countries, he says.

"The science is established," Glynn says. "It's now the legal and regulatory issues that are being dealt with." But in cities such as Abuja, where more than half of school students do not know that secondhand

smoke can be hazardous, creating public support for laws and enforcement can be challenging. And in countries that grow tobacco, such as Tanzania, where about 6 percent of the country's income is tied to the crop, limiting the product's range can be met with formidable financial resistance.

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Can Local Governments Solve Global Warming?

PROTESTING FOR THE PLANET: Residents of Boulder, Colo. rally for leaders to find ways to shrink the city's carbon footprint.
FLICKR/350.ORG

BOULDER, Colo. Here's what this affluent Rocky Mountain city of 100,000 does about a revenue shortfall in the darkest economic hour since the Great Depression:

It raises its carbon tax.

The city just west of Denver was the first in the nation to slap a levy on carbon emissions so it could meet Kyoto Protocol obligations. As it became apparent this summer the city was slipping and needed more cash to revitalize emissions-cutting programs, town leaders raised the modest tax - tacked to city utility bills - to its maximum.

With diplomatic efforts to seal a post-Kyoto accord approaching a decidedly uncertain fate this December in Copenhagen, state and local leaders pushing their own emissions reductions efforts see only one choice: Proceed.

The number of cities and regional governments undertaking this transition to a low-carbon economy is growing. These efforts, leaders vow, will continue whatever the outcome of political debates in Copenhagen, Brussels or Washington, D.C.

There are, in other words, two trains heading out of the station: Those driving local change are confident their programs will continue to accelerate even if global discussions get waylaid in Copenhagen next month.

"The community is on board with this," said Sarah Van Pelt, author of Boulder's climate action plan who is now a special projects coordinator for the city's environmental division. "Right now our biggest detractors are saying why aren't we doing enough."

San Diego is tying recycling, water use and energy efficiency to climate; Berkeley, Calif. has rewritten property rules to boost solar installations; New York and California are shifting state policy to encourage a new,

low-carbon economy. Twenty-nine other states have some sort of a renewable fuel standard, requiring utilities to mix a certain percentage of those fuels into their power mix.

"If nothing happens on the federal level, it's unfortunate but it's not the end of the world," said Cara Martinson, legislative analyst for the California State Association of Counties. "We'll start to see a lot more of these regional activities. It'll start to be a bottom-up approach if the national framework breaks down."

Need for a global solution

Whether these local efforts can produce the reductions required to avert the worst climate disruption is much debated. Many climate experts are skeptical. The necessary cuts are substantial, they require economy-wide transformation and the initiatives need to be policed by a fixed, enforceable global treaty.

"It's hard to see how they could be sufficient," said Doug Boucher, director of tropical forests and climate initiative at the Union of Concerned Scientists.

The Copenhagen talks are seen as crucial for several reasons. It's the date the international community - after years of negotiations - set as the time to draw up a comprehensive global solution to climate disruption.

Industry and governments need to know where emissions targets are headed post-Kyoto. December is the last chance to get a treaty ratified and in place before Kyoto expires in 2012, said Jennifer Morgan, director of the World Resources Institute's climate and energy team who has been involved in global climate talks for more than a decade.

Local efforts help, she agreed. But the global problem needs a global solution.

"It's a huge problem around the share of the commons in the atmosphere, and it's a very large economic issue," she said. "Countries need to have a sense that other main contributors to the problem - and their competitors - are moving together toward a solution."

"It's more than just the sum of the parts."

California, even more than Boulder, exemplifies local determination to curb emissions regardless of national or international stalemate. The state of 37 million people agreed in 2006 to tackle global warming. It has a mandatory greenhouse gas reporting system covering 90 percent of the state's industrial emissions. By law, the state has to ratchet those emissions down to 1990 levels by 2020 - a 24 percent cut from business-as-usual projections.

But scientists say the world needs to slash emissions 80 percent by 2050 to avoid catastrophic climate change. Boulder hasn't met Kyoto's modest target of a 7 percent cut over 1990 levels despite its tax and one of the nation's most eco-conscious populations, though city leaders say they expect to get close.

California faced a \$26 billion spending hole earlier this summer that it filled in part by pulling money from local governments. While the state managed to protect many of its climate programs, local efforts aren't so lucky.

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Planets May Affect the Chemistry of Their Stars

Planets are, by and large, at the mercy of their stars. Not only do stars provide a ready energy source of radiated light and heat, but the mass and gravitational pull of stars flat-out dwarfs the summed masses and pulls of any orbiting companions. In our solar system, which has more planets—regardless of where one stands on the Pluto debate—than any other planetary system we know of so far, the sun still makes up more than 99.8 percent of its system's mass.

But a new survey of stellar chemistry in solar-type stars reveals at least one way that pip-squeak planets can strike back, affecting the evolution of their parent stars. A paper in the November 12 issue of *Nature* shows that lithium is greatly depleted in stars known to host planetary systems compared with otherwise similar stars that appear to be barren of planets. (*Scientific American* is part of the Nature Publishing Group.)

A correlation between stellar lithium abundances and the presence of planetary systems had been suspected for years—our lithium-weak sun, for one, certainly fits the bill. But the catalogue of stars with such extrasolar planets, or exoplanets, was too small to evaluate the relationship with statistical confidence. In the past dozen years, however, numerous exoplanetary discoveries have been announced, including a suite of 30 new planets unveiled in October by the European Southern Observatory's HARPS planet-finding collaboration that boosted the full set of known exoplanets to more than 400.

Study co-author Nuno Santos, an astrophysicist at the Center for Astrophysics at the University of Porto in Portugal, and his colleagues took chemical-abundance data, derived from precision light spectra, on 133 stars of roughly sunlike temperature from the HARPS survey, 30 of which are known to harbor planets. (They also added more than two dozen other stars to the population to boost the sample size.) The vast majority of stars with planets were excessively depleted in lithium, whereas most "single" stars were only partly depleted. And in a subset of the 84 stars closest to the sun's temperature, the correlation was even stronger.

The researchers suspect that the presence of orbiting planets may increase convective mixing in the host star, plunging the lithium into its

hotter regions where nuclear reactions consume the light element as fuel. "We know that lithium depletion in a star is dependent on the history of the star, how it rotates through its history," Santos says. "The presence or formation of planets could change this rotational history of the star."

But might lithium-depleted stars simply be more amenable to planet formation? Not likely, Santos says. "I don't think that's the reason, because actually lithium is not supposed to play any role in planet formation," he says. "There are only very small quantities of lithium, so it's not acceptable that lithium is, by itself, influencing planet formation. The idea is that things come the other way around. By some process, the planet-formation process is influencing the depletion of lithium in the atmosphere of the stars."

Whatever the reason, a simple lithium measurement—in concert with characteristics such as stellar mass and other chemical abundances—might aid future exoplanet hunters in pegging the stars that are most likely to bear planetary fruit.

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What Would Failure at Copenhagen Mean for Climate Change?

DIPLOMACY OR DROUGHT?: The destiny of our planet depends on successful talks at Copenhagen.

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This is the consequence of failure at Copenhagen: A marked shift in scientific effort from solving global warming to adapting to its consequences, a hodge-podge of uncoordinated local efforts to trim emissions - none of which deliver the necessary cuts - and an altered climate.

Climate experts, scientists and negotiators say that, absent international agreement, the children and grandchildren of those living today will negotiate a world where planetary geo-engineering is a part of daily life, sea-walls defend coastal cities, the world's poor are hammered by drought, floods and famine and our planet is heading toward conditions unseen for the last 100 million years.

The December talks are, in other words, the last, best chance to change course before chaos descends.

"The choice facing the present generation is an awesome one," said former Vice President Al Gore during a speech before the Society of Environmental Journalists last month. "Never before has a single generation been asked to make such difficult and consequential decisions that will have implications for all succeeding generations."

Failure, Gore added, would be "catastrophic" - not only given the urgency of changes already underway, but because it challenges the

efficacy of the rule of law as "an instrument of redemption."

Collapse in Copenhagen could not just become an obstacle to further progress, however. It also might force society to confront choices and decisions few in the scientific and policy world want to face.

"Copenhagen is mitigation," said Guy Brasseur, director of the Climate Service Center in Hamburg, Germany. "If that fails, we move to adaptation and geo-engineering."

Adaptation will require hundreds of billions of dollars on the low end. It will force a vast transfer of wealth, technology and aid from industrialized countries to developing ones. That buys no more than a Band-aid for those most at risk, said Saleemul Huq, head of the climate change group at the London-based International Institute for Environment and Development.

"We've failed our primary task of preventing harm," said Huq, lead author of the adaptation and mitigation chapter of the Intergovernmental Panel on Climate Change's fourth assessment report. "Now we are going to be tasked with protecting those most vulnerable to harm. And soon we are going to be confronted with globally catastrophic harm."

"There really is nothing to do but adapt today."

That's where Copenhagen comes in.

The diplomatic gathering, from Dec. 7 to 18, has one goal: create an "ambitious global agreement incorporating all the countries of the world" to succeed the 1997 Kyoto Protocol, which expires in 2012.

It will be the 16th in a line of negotiations extending back 20 years, some more successful than others, all aimed at curbing humanity's appetite for fossil fuel.

There is deep pessimism that it will succeed. Deep divides on how best to tackle the problem exist between developed countries. Even deeper divides separate developed from developing worlds.

But there have been surprises before.

At the 2007 talks in Bali, all signs pointed to failure until delegates awoke the day after the talks were to end and discovered key players had worked through the night to reach an agreement.

"You don't know the answer before you actually get there, and very often you don't know the answer before the last couple of days," said Doug Boucher, a climate expert for the Union of Concerned Scientists who has participated at several international talks.

"It's really the extreme pressure of the final deadline that gets countries to make the compromises, make the bargains necessary to get to the final agreement."

And there will be pressure.

Previous negotiations all pointed to 2009 as the year to draw a line in the sand, but it's more than just a diplomatic deadline. By virtually every metric - emissions, deforestation, fuel use, land development, economic growth - business-as-usual projections point to catastrophe.

"Civilization will experience the greatest disruption in its history," said Jeffrey Kiehl, a senior scientist at NCAR's climate change research program. "We're applying a forcing to the planet that it hasn't seen for tens to hundreds of millions of years, ... when there was no ice at either pole."

"I don't think we want to go down that path."

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Faster Than a Speeding Particulate: Why Powdery Materials Disperse So Fast on Liquids

FLOUR POWER: The rapid dispersion of flour particles across water is shown in a still frame from an experimental video taken 0.03 second after the flour was released onto the liquid surface.

P. SINGH, D. JOSEPH, S. Gurupatham, B. Dalal and S. Nudurupati

Here's one you can try at home: Fill a dish with water and drop a small amount of flour onto the surface. The flour particles disperse rapidly, like a tiny starburst, and spread out over the liquid surface.

This simple procedure, described in a paper set to be published online by the *Proceedings of the National Academy of Sciences*, reveals a physical phenomenon that is common to many small particles and liquids but that had remained a mystery to the study's authors.

So Pushpendra Singh and his colleagues set out to unravel the underlying mechanism. Singh, a mechanical engineer at the New Jersey Institute of Technology, explains that the explosive dispersion arises from vertical capillary forces pulling the particles into a floating equilibrium on the liquid.

"When a particle comes in contact with a liquid surface, it reduces the amount of liquid surface area, because some portion is now occupied by the particle," Singh says. "Basically what that means is that the total energy of the system is reduced. That energy has to go somewhere, and it actually is acquired by the particle."

In low-viscosity liquids such as water, particles tend to overshoot their equilibrium and bob up and down like a weighted spring, reaching surprisingly rapid vertical velocities in the process. The interfacial forces, Singh and his co-authors determined, can accelerate a nanoscale particle to roughly 160 kilometers per hour. (The smaller the particle, the greater the velocity it can reach under the surface forces.)

Those oscillations drive repulsive hydrodynamic forces that push the particles apart at a rapid clip, albeit not with the extreme velocities seen in their smaller vertical motions. "A particle is sitting on the surface, it's vibrating up and down, and it moves everything away from it," Singh explains. "If you drop more than one particle, then each one is doing that

same thing." He estimates that the horizontal velocity of a particle dispersing by this mechanism is about an order of magnitude lower than the particle's vertical velocity.

Surprisingly, the height from which the particle is dropped has little influence on its energetic dispersion once it reaches the air-liquid interface. "This is not an issue, how high you drop them," Singh says, noting that in experiments where the particles settled slowly through a layer of oil floating on water the same rapid dispersion was observed when the particles reached water. "You can do some simple analysis to show that the kinetic energy the particle has because you're dropping it from some height is actually negligible compared to the interfacial energy it acquires when it's captured."

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