LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

In this issue of the *Environmental Energy Technologies Division News*, you will read about a diverse variety of research from across EETD's R&D portfolio—measuring greenhouse gas emissions regionally, the possible effect of mold and dampness on asthma incidence, the influence of building materials on indoor air quality, an award-winning technology to help gas-burning power plants reduce their emissions, and technical assistance to improve the energy efficiency of U.S. Congressional office buildings.

This issue also introduces a new web format for the newsletter. It allows the reader to print individual articles, or the newsletter as a whole, and to email others with the web URL whom you think might be interested in a particular article. Please let us know if you have any comments on these changes.

—Allan Chen

EETD News reports on research conducted at Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division, whose mission is to perform research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. The Division's staff of nearly 400 carries on research on energy efficiency in buildings, indoor environmental quality, U.S. and international energy issues, and advanced energy technologies. The newsletter is published on-line once a quarter. For more information, contact Allan Chen, (510) 486-4210.

The *Center for Building Science News* was published between 1993 and 1998. It covered news of the Division's research in energy efficiency and buildings, the indoor environment, and energy analysis. You'll find all back issues, from Winter 1993 through Summer 1998 available here [http://eetd.lbl.gov/newsletter/cbs_nl/cbsnews.html] .

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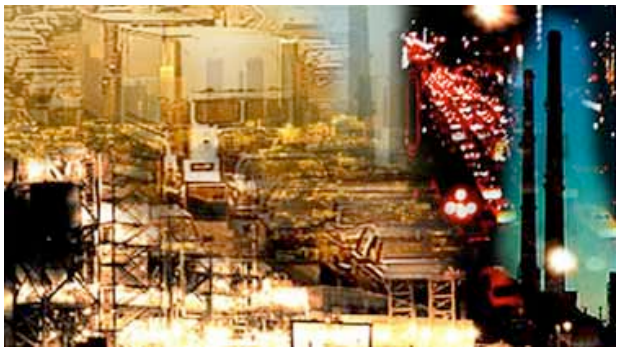
LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

CALGEM: Taking the Measure of California's Greenhouse Gas Emissions

To play its part in reducing the consequences of global warming, the state of California has embarked on a trailblazing effort to reduce its emissions of greenhouse gases (GHGs). Assembly Bill 32, recently passed by the California legislature and signed into law by Governor Arnold Schwarzenegger, requires the state to substantially reduce GHG emissions by the year 2030—and, by the summer of 2008, to develop a plan for accomplishing this.



Transportation and power plants are the principal sources of greenhouse gas emissions in California, but there are many other natural and artificial sources as well.

The bill requires California to reduce its carbon emissions to 1990 levels by 2020, a reduction of 25 percent. By 2050, carbon emissions must be reduced to 80 percent below 1990 levels. Given that California has the fifth largest economy in the world—with total greenhouse gas emissions estimated at around 500 million metric tons in 2004, the second largest of any state—both these targets require substantial reductions. Because California pioneered many of the current technologies for energy efficiency and renewable energy, it is reasonable to expect that the state can meet this challenge.

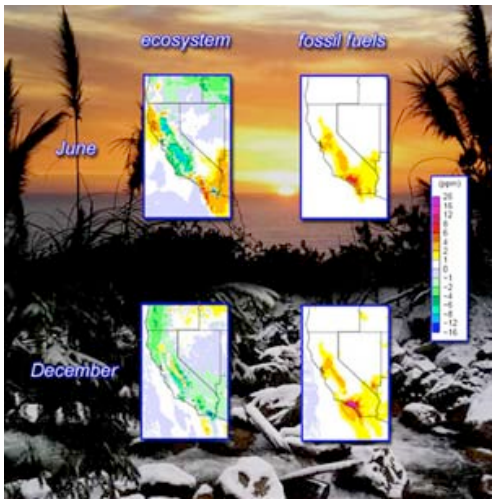
To prove that greenhouse gas reductions are actually taking place, it will be necessary to monitor emissions regionally. Scientists at the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory (Berkeley) recognized this need several years ago and began studying the problem. They are now taking the first steps toward creating a monitoring network with a pilot project called CALGEM: the California Greenhouse Gas Emissions Project.

Measuring net exchange of greenhouse gases

In 2003, a group led by Marc Fischer in EETD began an exploratory project with the California Energy Commission to develop a method of quantifying GHG emissions on regional scales. Fischer, William Riley of the Earth Sciences Division, and Shaheen Tonse of EETD designed a statewide network of atmospheric measurements to monitor carbon dioxide (CO_2) emissions, described in a report titled

"Development of an Implementation Plan for Carbon Monitoring in California."

Using data from existing sources, plus computer models for atmospheric gas transport, Fischer's group predicted variations in CO_2 concentrations across California. Atmospheric CO_2 is affected by both anthropogenic (human-caused) emissions, mostly the combustion of fossil fuels, and by the net ecosystem carbon exchange.



Computer-simulated maps developed at Berkeley Lab for the California Energy Commission show predicted CO_2 concentrations in the surface layer of atmosphere from net ecosystem carbon exchange and fossil fuel combustion. During the summer, CO_2 is actively removed from the atmosphere in some locations by photosynthesis, and released in others through respiration, as soil microbes decompose organic matter. During the winter ecosystem processes show different patterns, reflecting a combination of cooler temperatures, moister conditions, and the action of different plant groups. Fossil fuel CO_2 emissions, concentrated in urban areas across the state, are more constant across the seasons.
(Courtesy landandseaimages.com [http://landandseaimages.com])

In an actively growing ecosystem during the day, more CO_2 is removed from the atmosphere by photosynthesis than emitted back to the atmosphere by plant and soil respiration. At night, however, CO_2 is emitted back to the atmosphere by respiration. The lower atmosphere responds to additions and removals of CO_2 on daily to seasonal time scales, acting like a large mixing tank with a varying volume.

The team predicted variations of midday CO_2 from ecosystem exchange and fossil fuel emissions in the lower 100 meters (about 300 feet) of the atmosphere for two seasons. They showed not only that ecosystem and fossil fuel signals are large enough to measure, but also that these signals are sufficiently different in spatial and temporal variation that, by measuring CO_2 at many sites, human contributions could be identified. With the exploratory study as proof of concept, the Berkeley Lab group launched CALGEM.

"We will design an atmospheric measurement network to quantify greenhouse emissions, and estimate whether the atmospheric measurements are likely to provide sufficient accuracy and precision to tell whether GHG control strategies are working or not," says Fischer.

Greenhouse gases are many — and many are more potent than carbon dioxide

Carbon dioxide is not the only greenhouse gas. Many others, including methane (CH_4), nitrogen oxides,

and halocarbons, also contribute to global climate warming. These non-CO_2 greenhouse gases are estimated at 15 percent of the total emissions from the state of California.

Methane, CH_4, is the largest of the non-CO_2 GHGs. CH_4 is mostly emitted by microbial processing of feed in livestock, and as a byproduct of the breakdown of organic waste materials in landfills. Natural gas is predominantly CH_4; its delivery and use in industrial processes and transportation emit lesser amounts of methane, as does periodical flooding in agriculture and decomposition of organic material in natural wetlands. Methane's concentration in the atmosphere is now three times higher than it was in the pre-industrial era.

"The problem is that the emissions of CH_4 and other non-CO_2 GHG gases are poorly quantified," says Fischer. "Uncertainties range from 25 percent to a full order of magnitude." The emissions of these gases are not as large that of CO_2, but taken together they have an effect on climate change that is comparable to total CO_2 emissions. Accurately estimating their emissions over time is therefore crucial to the effort to measure the effectiveness of GHG reduction programs.

A network of measurements

Fischer, Riley, and Pieter Tans, of the National Oceanic and Atmospheric Administration's (NOAA's) Environmental Science Research Laboratory, will design a network of instrumentation to measure non-CO_2 GHGs in California. Atmospheric measuring techniques will be demonstrated at a subset of the sites in the final CALGEM network.

Two tall-tower sites, the Sutro Tower in San Francisco and a broadcast tower in the Central Valley near Sacramento, will be equipped with instruments for the CALGEM project.

Ground-based measurements will include continuous monitoring and flask sampling at tall towers. Dedicated instruments at one site will continuously measure CH_4 and CO_2, plus carbon monoxide (CO) as a tracer of combustion. Flasks will be collected twice a day, which NOAA will analyze for a host of GHG species. Aircraft and satellite remote sensing will provide estimates of the total amount of GHGs in the atmosphere.

Beyond the GHG measurements, one tower will also take measurements of radon (^{222}Rn) to monitor the rate at which GHGs are diluted in the atmosphere. Radon is a naturally occurring radioactive gas with a half life of 3.8 days. The short half life makes ^{222}Rn an excellent tracer of atmospheric mixing, and a

tracer of the origin of atmospheric air masses. For example, air masses coming to California from the ocean have much less radon gas than air masses coming from land. Similarly, air near the land surface has more ^{222}Rn than air in the upper atmosphere.

The ^{222}Rn measurements provide scientists with a tool to quantify how much contact a given air mass has had with the land surface, and therefore the change in GHG concentration expected from a given amount of emission. "Together, these measurements will provide an unparalleled tool for monitoring trends in atmospheric GHG concentrations in California," says Fischer.

Computer modeling to design a better network

Possible locations for the complete regional greenhouse gas measurement network include the San Francisco and Sacramento towers equipped by Berkeley Lab, existing measurement sites operated by other institutions on the North Coast and near San Diego, and several tower locations in the Central Valley and near Los Angeles that could be adapted to provide a complete measurement network in the future. Increased aircraft sampling and satellite remote-sensing measurements will supplement coverage from these ground stations.

To interpret the measurements and to plan an expanded network, the research team is undertaking a parallel effort in data analysis and modeling. Using initial measurements, this part of the work will quantify surface emissions and figure out which expansions to the network would best minimize uncertainty in future estimates.

"As in the initial exploratory project on CO_2," says Fischer, "we'll combine current 'bottom-up' models of surface greenhouse-gas emissions with regional-scale models of atmospheric transport, to predict atmospheric GHG concentrations for different sources in California."

The mathematical procedure adds noise to the model predictions to produce "pseudodata" of GHG concentrations, thus introducing uncertainties like those due to instruments or to imperfect knowledge of atmospheric transport of greenhouse gases. The scientists then calculate best estimates of surface emissions using "inverse-model" methods, which match the measured data as closely as possible to the noisy pseudodata.

Finally, the CALGEM team will design a future measurement network that reduces uncertainty in

emission estimates, using pseudodata calculations run on many different network designs. The completed project will provide several useful results to the people of California:

> "First the measurements will represent the beginning of a long-term record of GHG concentrations, representing California's contribution to global climate change," Fischer says. "Second, the modeling and analysis will provide an initial estimate of the current level of GHG emissions at the regional level, and provide recommendations for a more complete monitoring network."

As California implements reduction programs to achieve the goals of Assembly Bill 32, CALGEM will enable California to estimate how well the programs are working to reduce greenhouse gas emissions.

— Allan Chen

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"Development of an Implementation Plan for Carbon Monitoring in California [http://eetd.lbl.gov/newsletter/nl26/pdf/eetd-nl26-1.pdf] ," by Marc L. Fischer, William J. Riley, and Shaheen Tonse, was prepared for the California Energy Commission Public Interest Energy Research (PIER) Program.

This research is supported by California Energy Commission's Public Interest Energy Research Program.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Studies Confirm Large Public Health and Economic Impact of Dampness and Mold

EETD scientists estimate that number of asthma cases attributable to exposure in home is 4.6 million, at $3.5 billion annual cost

Scientific studies show that mold in the walls and ceiling of homes substantially raises the risk of a asthma and other respiratory problems and adds $3.5 billion to the annual national health bill.
Photo credit: Mike McNickle.

A pair of studies published in the journal *Indoor Air* have quantified the considerable public health risks and economic consequences in the United States from building dampness and mold.

One paper by William J. Fisk, Quanhong Lei-Gomez and Mark J. Mendell, all with the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory (Berkeley Lab), concludes that building dampness and mold raised the risk of a variety of respiratory and asthma-related health outcomes by 30 to 50 percent.

"Our analysis does not prove that dampness and mold cause these health effects," says Fisk. "However, the consistent and relatively strong associations of dampness with adverse health effects strongly suggest causation by dampness-related [pollutant] exposures."

The second paper, by David Mudarri of the U.S. Environmental Protection Agency (EPA) and Fisk uses results of the first paper plus additional data on dampness prevalence to estimate that 21 percent of current asthma cases in the U.S. are attributable to dampness and mold exposure.

"Of the 21.8 million people reported to have asthma in the U.S., approximately 4.6 million cases are estimated to be attributable to dampness and mold exposure in the home," says the study. In addition, this paper estimates that "the national annual cost of asthma that is attributable to dampness and mold exposure in the home is $3.5 billion." The paper also summarizes the considerable evidence of adverse health

effects from dampness and mold in offices and schools, and suggests that exposure to dampness and mold in those venues appear to have similar health impacts on those exposed.

Mudarri and Fisk suggest that "a significant community response" is warranted given the size of the population affected and the large economic costs. Preventative and corrective actions include:

- better moisture control during the building's design;
- moisture control practices during construction;
- improved preventive maintenance of existing buildings to include a comprehensive moisture control program including control of water intrusions from outside, plumbing leaks, condensation and humidity control, and other causes of moisture accumulation or mold growth.

William J. Fisk, Acting Division Director of Berkeley Lab's Environmental Energy Technologies Division, was head of EETD's Indoor Environment Department when this study was conducted.

The Berkeley Lab paper provides quantitative estimates of the increased risks of having current asthma, being diagnosed with asthma, and having related health effects when people live in homes with visible dampness or mold problems. These estimates are based on a statistical analyses of a large number of previously published studies, none of which by themselves are a suitable basis for overall risk quantification.

The EPA paper's results are based on the analyses of studies of this health issue cited in a 2004 report released by the Institute of Medicine (IOM) of the National Academy of Sciences and more recently published studies. The IOM report, which is considered the current consensus of the U.S. scientific community, concluded that excessive indoor dampness is a public health problem but did not offer any overall quantitative assessment.

Fisk is Acting Division Director of Berkeley Lab's Environmental Energy Technologies Division. When writing these papers he was head of the division's Indoor Environment Department. Mudarri was a senior economist and research program manager in the Indoor Environments Division at the U.S. EPA and has recently retired.

These studies are part of the Indoor Air Quality Scientific Findings Resource Bank project, funded by the Indoor Environments Division, Office of Radiation and Indoor Air of the EPA. The project is a cooperative venture between EPA and Berkeley Lab to quantify the health and productivity impacts of indoor air exposures and make those data publicly accessible.

The papers are available from the web site of the *Indoor Air* Journal [http://www.blackwellpublishing.com/journal.asp?ref=0905-6947] .

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For more about the research of Bill Fisk [http://eetd.lbl.gov/staff/fisk-wj.html] .

This research is supported by the Indoor Environments Division [http://www.epa.gov/iaq/] , Office of Radiation and Indoor Air of the U.S. Environmental Protection Agency.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Behind Closed Doors: Beware the Air

Those factors in the home that cause or exacerbate asthma and allergies in children are not well understood, but scientists agree they include allergens like dust mites, mold, and environmental tobacco smoke.

Mark Mendell, an epidemiologist in the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory, suggests that another set of factors is worth investigating: emissions from common indoor building and decorating products, such as composite wood materials that emit formaldehyde, flexible plastics that emit "plasticizers," or even a fresh coat of paint.

In a paper for the journal *Indoor Air*, Mendell conducted a review of epidemiologic studies published in scientific journals from 1989 through mid-2006, comprised of 21 studies mostly from outside the United States. These found associations between common indoor materials and increased risk of asthma, pulmonary infections, and allergies in children.

The growing body of research identified specific risk factors including organic chemicals like formaldehyde, benzene, and phthalate esters (the "plasticizers" that make some plastics flexible); indoor materials including carpet, paint, flexible flooring, and other plastics; and various activities related to installing and cleaning these materials indoors.

Mendell is careful to note that "causal relationships have not been demonstrated" in these studies. However, his review of these studies, most of which were conducted in Europe, suggests that U.S. scientists should take a closer look at emissions from indoor materials for their possible effects on children's health.

In addition to known allergens like mold, tobacco smoke, and dust mites, children's allergies may also be exacerbated by emissions from composite materials, the chemicals that make plastics flexible, and even paints.

Asthma Prevalence Growing

According to the Centers for Disease Control, the prevalence of asthma in children in the United States increased from 3.6 percent in 1980 to 6.2 percent in 1996. This is an average increase of 4.3 percent per year, a relatively high growth rate that worries health experts. Asthma can be a severe, life-threatening illness; moreover, both allergies and asthma are expensive to individuals and to society. Current science suggests that risk factors for developing asthma include genetic predisposition; specific allergens such as dust mites, cockroaches, and pet dander; moisture and mold; and environmental tobacco smoke. There could be other risk factors, as yet unknown.

A complication for researchers seeking the causes of the asthma growth rate is that while a few risks have been clearly demonstrated, the case for others is weak. "Sufficient evidence of a causal relationship" is the CDC's strongest level of evidence; "sufficient evidence of an association" and "limited evidence of an association" are weaker. The CDC also draws a distinction between factors that cause a condition, such as the development of asthma, and those that exacerbate an existing condition, for example by triggering asthma attacks.

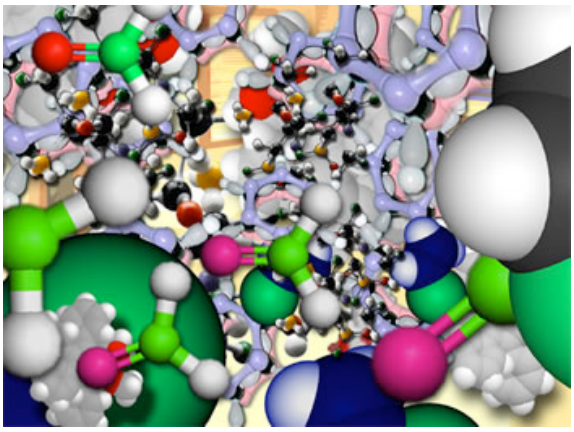
In an authoritative report published in 2000, the Institute of Medicine, part of the National Academy of Sciences, concluded that there is sufficient evidence for a causal relationship between the development of asthma in susceptible children and exposure to house dust-mite allergen. The report also concluded that there is sufficient evidence of an association between exposure to environmental tobacco smoke and development of asthma in younger children, a statement strong enough to suggest that parents should protect children from exposure to tobacco smoke. Except for environmental tobacco smoke, however, the CDC currently does not recognize association of chemical agents encountered in the home with asthma.

Building Materials are Emitters

"The most frequently identified risk factors related to indoor residential chemical emissions include formaldehyde or formaldehyde-emitting particleboards, plasticizers or plastic materials, and recent painting," says Mendell.

Pressed wood products include particleboard, medium density fiberboard, interior plywood, and interior hardwood paneling. The urea-formaldehyde resin within them releases formaldehyde over time. So do other indoor sources, including tobacco smoke, varnishes, paints, and carpets. Moisture on building materials can also accelerate the release of airborne formaldehyde. Painting and freshly painted surfaces release various volatile organic compounds into indoor air.

Formaldehyde emissions and particleboard were associated with asthma, chronic bronchitis, and other respiratory symptoms. Phthalate plasticizers, or the presence of phthalate-containing surface materials such as polyvinyl chloride or vinyl, as well as painting and other room renovation, were also associated in various studies with asthma, allergy, and respiratory symptoms.



Some common household substances and materials emit chemicals like those diagrammed here, including formaldehyde, benzene, phthalate esters, polyvinyl chloride, polyurethanes, and epoxy resins.

The studies that examined indoor material emissions differed widely in design and focus, says Mendell. Their methods varied from measuring actual chemical concentrations of indoor air or dust to simply observing the presence or absence of materials that emit organic chemicals. Thus there is a need for more rigorously controlled research to eliminate possible confounding factors; for example, other unmeasured factors could be the real explanation for the findings in some studies.

"Future studies will have to carefully measure formaldehyde and other chemicals indoors," says Mendell. "They will need to determine whether it's a specific chemical such as formaldehyde that causes the association, or some other emission that is always associated with the presence of that chemical. Formaldehyde emissions, for example, are known to come from particle board, but this material also emits other chemicals."

One chemical compound, or several working together, could be the cause of health conditions. Still, when all the studies are taken together, and considering both their strengths and weaknesses, "it is hard to imagine what else could explain these findings that is not related to indoor chemical emissions," Mendell says.

Mendell has been studying the associations between health and indoor environmental factors throughout his career. As an epidemiologist with the CDC's National Institute for Occupational Safety and Health, he studied the indoor factors associated with "sick building syndrome," a set of respiratory and other symptoms among workers in office buildings. Detailed by the CDC to Berkeley Lab in 2000, he continued to work on those issues and ultimately joined the staff of the Lab's Indoor Environment Department.

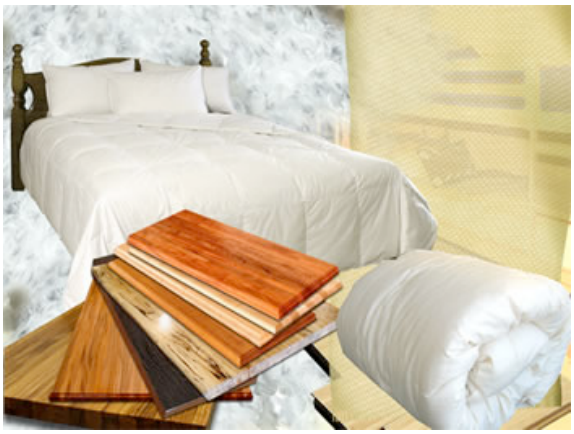
"I believe that studying health impacts of the indoor environment is one of the most important directions for building science," he says. Most employed people work indoors and indeed spend most of their lives indoors, yet the health effects of the indoor environment are not well understood. Berkeley Lab's Indoor Environment Department is one of the few research groups in the U.S. currently doing research in this field.

It was while considering literature relating indoor environments and respiratory health effects in children that Mendell noticed the large number of papers from outside the United States that seemed to implicate emissions from building materials. After carefully reviewing the available evidence, he says, "These studies justify conducting further research in this area, especially where the evidence is strongest — as with formaldehyde at levels commonly found in homes."

What Should Concerned Parents Do?

Currently there is not, in the CDC's phrase, "sufficient evidence of a causal relationship" between respiratory problems in children and building-material emissions. Yet some parents may want to take steps to minimize risks to their children before a scientific consensus on this question has formed. What are reasonable steps to take?

"I would think twice before repainting an infant's nursery or using pressed wood products in children's rooms," says Mendell. "Also, in the case of an asthmatic child, I would avoid wrapping the child's mattress in a vinyl product."



Strategies to reduce possible risks from chemical emissions include using natural bedding like feathers, which also harbor fewer dust mites, plus furniture made of real wood and flooring of real wood or authentic linseed-oil-based linoleum.

Wrapping a child's mattress and pillows is often recommended as a control measure to minimize factors that exacerbate asthma, because dust mites and other organisms known to be associated with biological risk factors tend to take up residence there. However, some of these wrappings are made of vinyl that emits phthalates over time, and the emissions could pose respiratory health risks to children.

Despite the common practice of providing children at risk for asthma with synthetic pillows and comforters, synthetic bedding has been consistently associated with greater occurrence of respiratory health effects than natural bedding like feathers. It is not yet clear if this is due to chemical emissions from synthetic bedding or to the enormously higher growth rate of dust mites in synthetic bedding than in feather bedding — a surprising finding, yet one demonstrated by substantial research.

Parents could also avoid putting particleboard furniture into children's rooms. Particleboard is sometimes covered in wood-grained vinyl in an attempt to reduce formaldehyde emissions, and the extensive use of these materials in mass-produced furniture means extra work for parents looking for furniture free of them. Alternatives are available, however.

Mendell also suggests choosing alternatives to PVC flooring for children's rooms — for example, real wood or authentic linoleum. Product selection can be tricky. For instance, most bamboo flooring, widely promoted as a "green" flooring material, contains the same formaldehyde-releasing glue as particleboard. Some manufacturers of bamboo, however, use the non-formaldehyde-emitting glues required for all composite wood products sold in Europe and Japan. The U.S. has not placed the same emphasis on controlling indoor emissions for health.

Mendell's hope is that further research in the U.S. will quantify these health risks to children, and to adults as well, helping guide informed consumers to take health-protecting actions.

— Allan Chen

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More about asthma's impact on children [http://www.cdc.gov/asthma/children.htm] from the Centers for Disease Control.

More about Indoor Environmental Research [http://eetd.lbl.gov/r-indoor.html] at Berkeley Lab.

This research is supported by the Indoor Environments Division, Office of Radiation and Indoor Air of the U.S. Environmental Protection Agency.

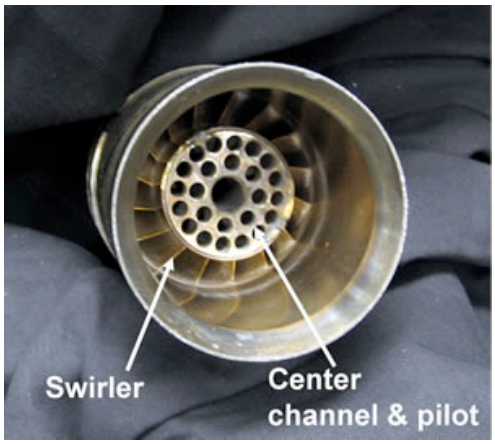
LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Berkeley Lab's Ultraclean Combustion Technology for Electricity Generation Fires Up in Hydrogen Tests

An experimental gas turbine simulator equipped with an ultralow-emissions combustion technology called LSI has been tested successfully using pure hydrogen as a fuel — a milestone that indicates a potential to help eliminate millions of tons of carbon dioxide and thousands of tons of NOx from power plants each year.



A prototype of the low-swirl injector. Fuel flows through the openings of the center channel. This simple design creates the low-swirl flow, with lower emissions of NOx the result.

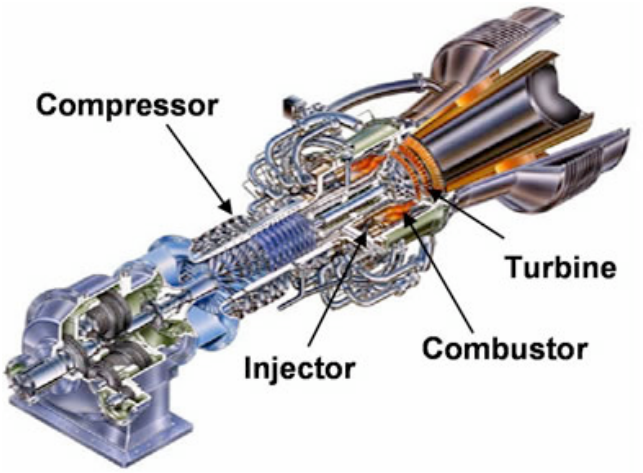
The LSI (low-swirl injector) technology, developed by Robert Cheng of the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory (Berkeley Lab), recently won a 2007 R&D 100 award from *R&D* magazine as one of the top 100 new technologies of the year.

The LSI holds great promise for its near-zero emissions of nitrogen oxides, gases that are emitted during the combustion of fuels such as natural gas during the production of electricity. Nitrogen oxides, or NOx, are greenhouse gases as well as components of smog.

The Department of Energy's Office of Electricity Delivery and Energy Reliability initially funded the development of the LSI for use in industrial gas turbines for on-site (i.e. distributed) electricity production. The purpose of this research was to develop a natural gas-burning turbine using the LSI's ability to substantially reduce NOx emissions.

Cheng, Berkeley Lab colleague David Littlejohn, and Kenneth Smith and Wazeem Nazeer from Solar Turbines Inc. of San Diego adapted the low-swirl injector technology to the Taurus 70 gas turbine that produces about seven megawatts of electricity. The team's effort garnered them the R&D 100 honor. It is continuing the LSI development for renewable fuels available from landfills, carbon-neutral fuels from

organic waste treatments, and for fuels from industrial processes such as petroleum refining.



A cutaway view of Solar Turbines' Taurus 70 engine. The research team has adapted the low swirl injector for use in this technology, which is similar to a jet engine, but is used to generate electricity in power plants on the ground.

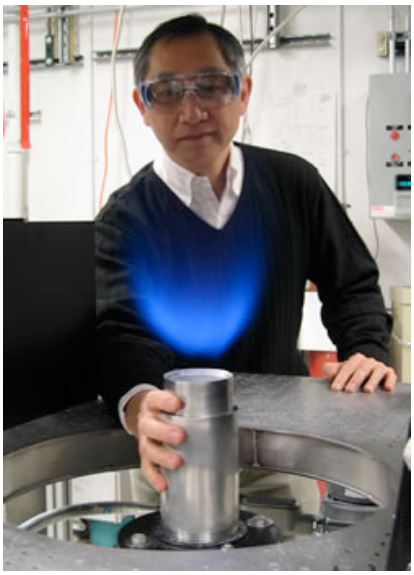
"This is a kind of rocket science," says Cheng, who notes that these turbines, which are being used to produce electricity by burning gaseous fuels, are similar in operating principle to turbines that propel jet airplanes.

DOE's Office of Fossil Energy is funding another project in which the LSI is being tested for its ability to burn syngas (a mixture of hydrogen and carbon monoxide) and hydrogen fuels in an advanced IGCC plant (Integrated Gasification Combined Cycle) called FutureGen, which is planned to be the world's first near-zero-emissions coal power plant. The intention of the FutureGen plant is to produce hydrogen from gasification of coal and sequester the carbon dioxide generated by the process. The LSI is one of several combustion technologies being evaluated for use in the 200+- megawatt utility-size hydrogen turbine that is a key component of the FutureGen plant.

The collaboration between Berkeley Lab and the National Energy Technology Laboratory (NETL) in Morgantown, WV, recently achieved the milestone of successfully test-firing an LSI unit using pure hydrogen as its fuel.

Because the LSI is a simple and cost-effective technology that can burn a variety of fuels, it has the potential to help eliminate millions of tons of carbon dioxide and thousands of tons of NOx from power plants each year.

In a letter of support to the R&D 100 selection committee, Leonard Angello, manager of Combustion Turbine Technology for the Electric Power Research Institute, wrote: "I am impressed by the potential of this device as a critical enabling technology for the next generation coal-based Integrated Gasification Combined Cycle power plants with CO_2 capture...This application holds promise for the gas turbines in IGCC power plants that operate on high-hydrogen-content syngas fuels or pure hydrogen."



Robert Cheng views an LSI flame. He is touching the burner, demonstrating that it stays cool because the flame is completely lifted from its body.

How the LSI Works

The low swirl injector is a mechanically simple device with no moving parts that imparts a mild spin to the gaseous fuel and air mixture that causes the mixture to spread out. The flame is stabilized within the spreading flow just beyond the exit of the burner. Not only is the flame stable, but it also burns at a lower temperature than that of conventional burners. The production of nitrogen oxides is highly temperature-dependent, and the lower temperature of the flame reduces emissions of nitrogen oxides to very low levels.

"The LSI principle defies conventional approaches," says Cheng. "Combustion experts worldwide are just beginning to embrace this counter-intuitive idea. Principles from turbulent fluid mechanics, thermodynamics, and flame chemistry are all required to explain the science underlying this combustion phenomenon."

Natural gas-burning turbines with the low-swirl injector emit an order of magnitude lower levels of NOx than conventional turbines. Tests at Berkeley Lab and Solar Turbines showed that the burners with the LSI emit 2 parts per million of NOx (corrected to 15% oxygen), more than five times less than conventional burners.

A more significant benefit of the LSI technology is its ability to burn a variety of different fuels from natural gas to hydrogen and the relative ease to incorporate it into current gas turbine design — extensive redesign of the turbine is not needed. The LSI is being designed as a drop-in component for gas-burning turbine power plants.

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This technology is available for license [http://www.lbl.gov/Tech-Transfer/techs/lbnl0916.html] for gas turbines

and certain other fields of use.

For more information about low-swirl combustion research [http://eetd.lbl.gov/aet/combustion/LSC-info/] .

For more information about DOE's FutureGen initiative [http://www.fossil.energy.gov/programs/powersystems/futuregen/] .

This research is supported by the Department of Energy's Office of Electricity Delivery and Energy Reliability, and by DOE's Office of Fossil Energy.

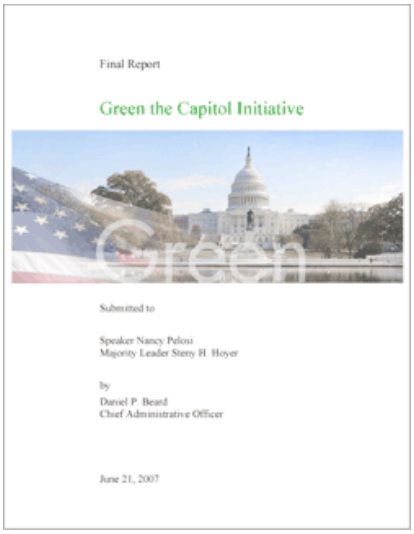
LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

'Greening the Capitol' Gets Technical Assistance from Berkeley Lab

The House of Representatives of the United States Congress has decided to set an example by reducing its carbon footprint, an announcement which came from House Speaker Nancy Pelosi and colleagues on April 19. Researchers at the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory (Berkeley Lab) provided technical assistance to House staff as they developed their plans.



Final Report

Green the Capitol Initiative

Submitted to

Speaker Nancy Pelosi
Majority Leader Steny H. Hoyer

by

Daniel P. Beard
Chief Administrative Officer

June 21, 2007

At the news conference, Speaker Pelosi accepted a "Green the Capitol Initiative" report prepared by the Chief Administrative Officer (CAO) of the House, Daniel Beard. The report provided a number of recommendations to reduce the environmental impacts of the House building complex. Beard's first recommendation was to operate the House in a carbon-neutral manner—this will require that the House takes steps to reduce its energy use through investing in energy efficiency, purchasing renewable sources of electricity, and finding additional ways to offset its total emissions of greenhouse gases.

The report identified a number of measures that the House could take to reduce its carbon emissions, including aggressively adopting energy efficiency and adopting sustainable business practices such as purchasing only ENERGY STAR™-qualified products and supplies.

"A sustainable House Capitol complex should recognize the full environmental impact of our decisions on energy and water consumption, materials, and the quality of our workplace," Beard wrote. "By taking these steps, we not only reduce the impact of House operations on the environment, but we also provide leadership by example."

Researchers in EETD worked with Beard's staff to analyze the current energy use and resulting carbon footprint of House facilities and offered some cost-effective measures to reduce it. Rick Diamond, a

scientist who coordinated the efforts of the EETD working group on this project, notes, "Both the Office of the CAO and the Architect of the Capitol had numerous ideas on how to improve energy use at the complex. Our job was to review their current energy use, look at the carbon impacts, and recommend early actions that could be taken."

Energy Use and the House Carbon Footprint

Using data provided by the Architect of the Capitol, the Lab's Evan Mills and others on the team determined that the House complex is responsible for emitting about 91,000 tons of carbon dioxide in 2006, equivalent to the annual emissions of 17,200 cars. The largest form of energy used is electricity (63 percent of total energy use), about half of which was generated from coal-fired power plants.

Scientist Francis Rubinstein, working with the CAO, found that replacing the incandescent bulbs in 12,000 desk lamps of the House complex could save $245,000 in electricity costs per year and remove the equivalent of 255 cars' worth of emissions of carbon dioxide. The report recommends immediate conversion of 2,000 lamps to compact fluorescent lights (CFLs), followed by conversion of the remaining 10,000 over the next six months. It also recommends eliminating the purchase of incandescent bulbs for use in standard (i.e., non-historic) fixtures.

The Cannon House Office Building Rotunda

Converting overhead ceiling lights to more energy-efficient fluorescent lamps could reduce lighting energy use by up to 50 percent, equivalent to removing 7,130 tons of greenhouse gas emissions, or those of 1,340 cars.

Craig Wray and Ryan Firestone examined the heating, ventilation, and air conditioning systems of the House buildings and Capitol Power Plant and recommended measures to improve their energy efficiency. One is to use aerosol-based duct sealing to make sure the building's duct system is tight, and wasting as little conditioned (heated or cooled) air as possible. Recent research at Berkeley Lab suggests that duct leakage can increase fan energy use 25 to 35 percent. Wireless control technologies can also improve the efficiency of fan ducts.

Applying Green Business Practices

Other Berkeley Lab researchers focused on analyzing the potential benefits to House operations from reorienting their purchasing to energy-efficient and environmentally friendly products. Christopher Payne, Alan Meier, and Bruce Nordman examined the opportunities available in office electronics. For example, one recommendation specified the purchase of Energy Star-qualified office equipment, which is in the top 25 percent of the market in terms of energy efficiency. Christopher Payne notes "These are equipment

purchases that will occur as a standard part of House business operations," Beard's report said. "By adopting these purchasing requirements, the House uses taxpayer dollars to reduce energy consumption, achieve significant cost savings, and help avoid pollution and greenhouse gas — all at what is often zero additional first cost."

The preliminary report is the first step toward implementing changes to achieve the goal of carbon-neutral House operations. Berkeley Lab researchers have continued to provide input to the Chief Administrative Officer, which issued another report in June. Implementation of some of these steps has begun. Steve Selkowitz noted that the Berkeley Lab team is excited about developing more detailed recommendations for the implementation phase. "Our team has been energized by the fast-track schedule we followed to assist the CAO in the first phase of the project," he said. "We now have a great opportunity to apply a wide range of 'lessons learned' from years of our DOE-supported buildings R&D activities to a new set of challenges and priorities in the Capitol complex."

Besides the names mentioned above, other EETD staff participating in the preparation of the report included Barbara Atkinson, Peter Biermayer, Brian Coffey, William Fisk, Philip Haves, Michael Holda, Eleanor Lee, Paul Mathew, Mary Ann Piette, Ryan Wiser, and Tom Wenzel.

— Allan Chen

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A copy of the reports can be downloaded from the "Greening the Capitol" [http://speaker.gov/issues?id=0023] page.

The press releases about the effort:

- Pelosi, Democrats Launch 100 Percent Carbon Neutral 'Green the Capitol Initiative' [http://www.speaker.gov/newsroom/pressreleases?id=0149]
- Pelosi: As Part of 'Green the Capitol' Initiative, House to Reduce Energy Consumption by 50 Percent in Just 10 Years [http://www.speaker.gov/newsroom/pressreleases?id=0222]

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Research Highlights

Low-swirl Injector Wins R&D 100 Award

EETD's Robert Cheng and David Littlejohn, along with Solar Turbines, Inc., have won one of R&D Magazine's prestigious R&D 100 Awards for 2007, which recognize the 100 most significant proven technological advances of the year. The winning technology is the LSI (low-swirl injector) (see article [http://eetd.lbl.gov/newsletter/nl26/eetd-nl26-4.html] this issue for more information).

The awards bring the total of Lawrence Berkeley National Laboratory's R&D 100 awards — also called the "Oscars of Invention" — to 44, plus two Editors' Choice Awards over the years.

A Flex Your Power Award for Cool Roofs

Hashem Akbari and Ronnen Levinson of EETD's Heat Islands Group won one of the 5th Annual Flex Your Power Awards [http://www.fypower.org/feature/awards/5th/profile.html?company=heatisland] for developing innovative cool roofing materials with solar reflecting pigments that will cut energy consumption in warm climates by 10-20%.

...And Honorable Mention for Data Centers

Three institutions won an Honorable Mention from the Flex Your Power Awards [http://www.fypower.org/feature/awards/5th/profile.html?company=ecos] committee for their work to improve the energy efficiency of data centers. Ecos Consulting, in coordination with Lawrence Berkeley National Laboratories and Electric Power Research Institute, and with support from the California Energy Commission, has demonstrated an alternative that could cut that use by 20%.

McKone Appointed to Biomonitoring Panel

Governor Arnold Schwarzenegger has appointed Thomas McKone to California's Scientific Guidance Panel on Contaminant Biomonitoring. McKone is the acting head of the Indoor Environment Department in Berkeley Lab's Environmental Energy Technologies Division. He is also an adjunct professor with the School of Public Health at the University of California, Berkeley. The role of the panel is to make recommendations regarding the chemicals that are priorities for biomonitoring in California, based on the likelihood of a chemical's being a carcinogen or environmental toxin with potential exposure to the public.

Press Release: Governor Schwarzenegger Announces Appointments [http://gov.ca.gov/index.php?/press-release/7314/]

Read an article about McKone's research [http://www.lbl.gov/Science-Articles/Archive/sabl/2007/Jan/pollutant-models.html] .

Report on Energy Service Companies Available

A report examining trends in the energy services companies (ESCO) industry has found that, after experiencing a slowdown in the late 1990s, ESCOs have experienced a recovery since 2004, thanks to increasing interest in energy efficiency, rising energy prices, and adoption of energy savings goals by large institutional facilities.

The authors note that investment in energy efficiency programs by utility programs and public-benefits funded programs, about $2.5 billion was roughly equivalent to the amount of private capital leveraged by ESCOs for investment in energy efficient goods and services.

It is titled "A Survey of the U.S. ESCO Industry: Market Growth and Development from 2000 to 2006 [http://eetd.lbl.gov/EA/EMP/reports/62679.pdf] ," by Nicole Hopper and Charles Goldman, Lawrence Berkeley National Laboratory, Donald Gilligan and Terry E. Singer, National Association of Energy Service Companies, and Dave Birr, Synchronous Energy Solutions. LBNL-62679.

U.S. Wind Power Report

The Department of Energy has released its annual report on "U.S. Wind Power Installation, Cost, and Performance Trends 2006." The primary authors are Ryan Wiser and Mark Bolinger of Berkeley Lab's Environmental Energy Technologies Division, with contributions from EETD's Galen Barbose and Andrew Mills. The report describes the rapid growth in U.S. wind power installations. In 2006, U.S. wind power capacity grew 26 percent, an investment of more than $3.7 billion.

Read a DOE press release [http://www.energy.gov/news/5091.htm] on the report, and download the report [http://eetd.lbl.gov/EA/EMP/reports/ann-rpt-wind-06.pdf] from the Electricity Markets and Policy web site.

LAWRENCE BERKELEY NATIONAL LABORATORY

Environmental Energy Technologies Division

NEWS

Sources and Credits

Sources

DOE's Consumer Information Fact Sheets

These web pages [http://www.eere.energy.gov/consumer/] provide information about energy efficiency and renewable energy for your home or workplace.

DOE's Energy Information Administration (EIA)

EIA [http://www.eia.doe.gov/] offers official energy statistics from the U.S. Government in formats of your choice, by geography, by fuel, by sector, or by price; or by specific subject areas like process, environment, forecasts, or analysis.

DOE's Fuel Economy Guide

This website [http://www.fueleconomy.gov/] is an aid to consumers considering the purchase of a new vehicle.

DOE's Office of Energy Efficiency & Renewable Energy (EERE)

EERE's [http://www.eere.energy.gov/] mission is to pursue a better energy future where energy is clean, abundant, reliable, and affordable; strengthening energy security and enhancing energy choices for all Americans while protecting the environment.

U.S. DOE, Office of Science [http://www.er.doe.gov/]

U.S. EPA, Energy Star Program [http://energystar.gov/]

California Energy Commission [http://energy.ca.gov/]

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The mission of the Environmental Energy Technologies Division is to perform research and development leading to better energy technologies and the reduction of adverse energy-related environmental impacts.

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Ernest Orlando Lawrence Berkeley National Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of the nine national laboratories, Berkeley Lab is located in the hills above the campus of the University of California, Berkeley.

With more than 3,800 employees, Berkeley Lab's total annual budget of nearly $500 million supports a wide range of unclassified research activities in the biological, physical, computational, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, Berkeley Lab has had 10 Nobel laureates. EETD is one of 17 scientific divisions at Berkeley Lab, with a staff of 400 and a budget of $40 million.

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