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NEWS

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Research Highlights

In 1997, the U.S. Environmental Protection Agency (EPA) issued new National Ambient Air Quality Standards for airborne particles less than 2.5 mm in diameter (PM2.5). These standards are based on evidence of associations between outdoor PM2.5 concentrations and adverse health effects. However, the relationship between indoor and outdoor concentrations of these fine particles is poorly understood and has important implications for public health.

Understanding the Indoor Concentrations of Outdoor Aerosols in Residences

Although the standards involve outdoor concentrations, people spend, on average, about 90 percent of their time indoors—70 percent of that in homes. The extent to which indoor concentrations of airborne particles track outdoor concentrations over time is not well understood. Perhaps more importantly, even less is known about the behavior of important chemical species that make up the particulate matter. It is suspected that some chemical species are more harmful than others. If the type and condition of residences affect indoor concentrations, then relevant regulations need to be reevaluated in light of scientific research focused on indoor exposures.

Figure 1. The test house, a single-story residence in Clovis, California, a suburb of Fresno.

With support from the U.S. Department of Energy through the National Petroleum Technology Office and the Western States Petroleum Association, a team of Environmental Energy Technologies Division (EETD) scientists, led by Tracy Thatcher and Melissa Lunden, has been investigating indoor particulate matter that originates outdoors. The objective of the study is to characterize the fate and transport of outdoor PM2.5 in the indoor environment. The team conducted a series of intensive field experiments in an unoccupied, single-story residence in Clovis, California, a suburb of Fresno, in the San Joaquin Valley (Figure 1). Figure 2 shows a schematic representation of the numerous physical processes that affect the transport and fate of outdoor aerosols that travel indoors.

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Indoor Concentrations of Outdoor Aerosols

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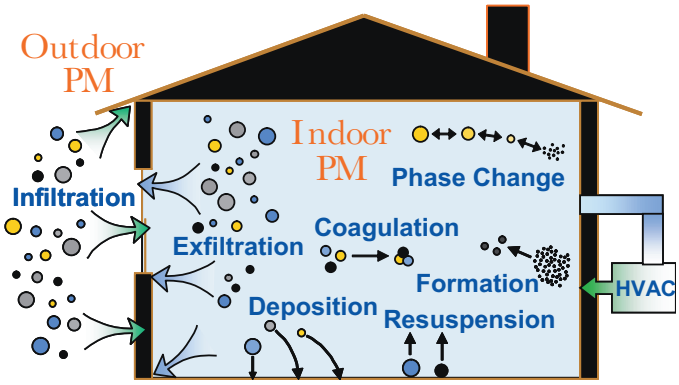

Figure 2. Schematic of the Clovis, CA research house showing the important processes that affect the indoor concentration of outdoor PM2.5.

Field Study Methods

The field study collected time and chemical data on both indoor and outdoor concentrations of PM2.5, while ventilation, heating and cooling conditions were manipulated in the house. Measurements were made in October and December of 2000 and January of 2001. The house was unoccupied during these measurements to remove any confounding effects of indoor sources.

The research house was outfitted with a number of instruments to characterize particle size and chemistry simultaneously both indoors and outdoors, as well as meteorological variables including temperature and relative humidity. In addition, the house was instrumented to continuously measure ventilation rate. A new instrument, developed in part for this study, was key to characterizing the time-resolved behavior of important chemical species. Developed by Aerosol Dynamics Inc. (Berkeley CA), the instrument is an integrated collection and vaporization cell (ICVC) that enables measurement of concentrations of ammonium sulfate, ammonium nitrate, and carbonaceous aerosols with 10-minute time resolution.

Variability in Indoor Aerosol Concentrations

Figure 3 shows results from the ICVC system, which show the variation in indoor and outdoor aerosol concentrations for a four-day period during the December measurement effort. The figure also shows the ventilation rate, indicated as air changes per hour (ACH). The results show that there is considerable variability in both the indoor and outdoor concentrations of all three species as well as in the magnitude of the difference between the indoor and outdoor concentrations.

In general, during periods of increased ventilation rate, the difference between the indoor and outdoor concentrations decreased. The most striking feature of Figure 3 is that the individual chemical constituents of PM2.5 behave differently after entering into the residence. The difference between indoor and outdoor ammonium nitrate concentrations is much greater than the differences measured for sulfate or carbon. Ammonium nitrate is a chemically active species that exists in equilibrium with gaseous nitric acid and ammonia. Upon entering the residence, the ammonium nitrate dissociated into its gas phase precursors, which were subsequently lost to the house surfaces by diffusion.

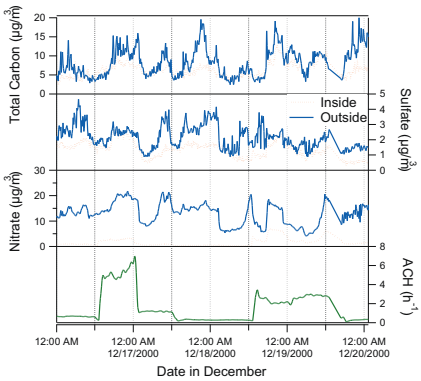

Figure 3. Data from the ICVS showing the variation in indoor (blue solid line) and outdoor (red dotted line) carbon, sulfate, and nitrate for a four-day period during the December intensive. The bottom plot shows air exchange rate as a function of time.

The differences in behavior between individual PM2.5 chemical species and the dissociation of the ammonium nitrate aerosol illustrate that an exposure assessment based on total particle mass measured outdoors may not accurately represent actual human exposures to indoor particles of outdoor origin and may obscure the causal relationships involved. Ammonium nitrate is a significant outdoor pollutant in the Western United States. The extent to which it may or may not be a significant source of indoor exposure has important policy implications for control of sources that lead to ammonium nitrate formation. These results emphasize the need for chemical characterization of PM2.5, and further studies of the physical and chemical transformation processes influencing the indoor concentration of particles that originate outdoors.

—Melissa Lunden

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Nancy Brown served as principal investigator for this research, and Rich Sextro along with Susanne Hering (of Aerosol Dynamics Inc. of Berkeley CA) were co-principal investigators. Other EETD scientists who contributed to the project are Marc Fischer, David Littlejohn, Lara Gundel, Thomas Kirchstetter, and Ray Dod.

This research was funded by the Department of Energy through the National Petroleum Technology Office and the Western States Petroleum Association.

EETD Develops New Commercial Duct-Sealing Technology

Environmental Energy Technologies Division (EETD) researchers have invented an aerosol-based system for sealing ducts in large commercial buildings. The mobile aerosol-sealant injection system (MASIS) is based on an aerosol sealing device previously developed by EETD researchers for reducing energy losses through leaky ducts in residential and small commercial systems. MASIS incorporates two new, patented technologies that permit effective sealing in the larger, more complicated duct systems of commercial buildings: a series of compact aerosol injectors and a new atomizer that uses high-velocity heated gas to prevent clogging of the injection nozzle.

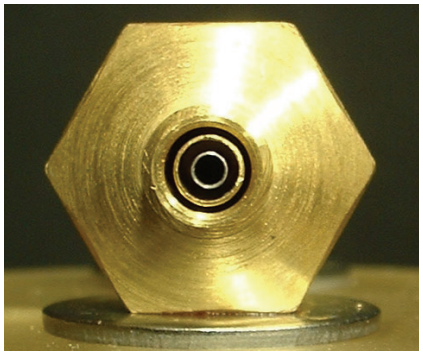

Figure 1. The prototype induced-cooling pneumatic atomizer is made with standard tube fittings.

EETD scientist Duo Wang developed the new technology with assistance from Mark Modera, the scientist who developed the original sealing system for residential buildings. Carrier Aeroseal has licensed MASIS exclusively to seal ducts in commercial buildings.

Modera and colleagues first developed aerosol-based technology for sealing the ducts of heating, ventilating, and air-conditioning (HVAC) systems in residential and small commercial buildings during the 1990s. Their research showed that homes with leaky ducts in contact with outside air wasted, on average, 20 percent of all heating and cooling energy in the United States. They pioneered a system to seal these ducts remotely and inexpensively, using an aerosol that is injected through a home's heat register. The aerosol flows through the duct system, gradually building up flexible seals at holes, tears, and other leaks.

The team successfully tested the technology in the field and licensed it to a start-up company called Aeroseal, which was eventually acquired by Carrier Corporation. Residential duct sealing that uses the EETD technology is available through contractors trained by Carrier.

Addressing Leaky Ducts in Commercial Buildings

The research by Modera and his colleagues suggested that energy losses in the ducts of large commercial buildings are probably as large in scale as the losses in residential ducts. Although research to quantify the losses in commercial buildings is continuing, EETD scientists estimate that sealing ducts in commercial buildings could save large amounts of energy.

Large commercial buildings present special problems that the original residential duct sealing technology could not address. "The HVAC duct system in large buildings typically has a large trunk duct system and a number of smaller sub-duct systems connected to it," says Wang. "Trunk duct systems are longer and have a larger cross-section than residential systems, and they are connected to many branched duct systems. One problem is that large aerosol particles from a residential-scale duct sealer would fall out of the air stream too quickly to seal leaks effectively in these larger commercial ducts. Another problem is that the branch systems often contain heating or cooling coils that cannot be exposed to aerosol sealants.

"To increase the flow of aerosol sealant in larger ducts, we designed a sealing system that uses a number of compact aerosol injectors," Wang explains. "Several of these are installed along the trunk line of a commercial building duct, injecting aerosol simultaneously. This substantially increases the sealing rate of leaks in the duct system."

A New Aerosol Atomizer

The researchers also developed a new atomizer to adapt the original aerosol-based sealer to commercial buildings (see Figure 1). The residential system spray nozzle converts the sealant into an aerosol and sends it flowing into the duct system. The commercial system needed a nozzle that could inject sealant at a smaller spray angle and a higher flow rate than the residential system. Unable to find an appropriate commercially available nozzle, the research team developed its own design, the induced-cooling pneumatic atomizer, which provides the necessary particle size and flow rate at the correct spray angle, without clogging.

MASIS consists of a sealing-process monitoring system and portable injectors. In one design, each injector unit consists of an air compressor and a cart that carries an aerosol sealant injector wand, a liquid sealant tank, a peristaltic pump, a control box, and a dedicated toolbox. In another design, the injectors are all fed by a central station and are daisy-chained via umbilical cords.

To seal the trunk system, injectors are installed along the duct and run simultaneously. To seal the branch duct systems, injectors are installed downstream of the heating and cooling coils, which are usually located in variable air volume boxes. Each branch seals independently, and all of the injectors can operate simultaneously.

The induced-cooling atomizer is licensed to Carrier Aeroseal for aerosol duct sealing only. Licenses are still available for other applications, such as dehydration of products, drying of waste streams, and atomizing of liquids for industrial processes. Information about licensing is available from Lawrence Berkeley National Laboratory's Technology Transfer Department.

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Ultraclean Low-swirl Combustion Will Help Clear the Air

A unique type of clean-burning combustion technology called ultra-clean low-swirl combustion (UCLSC), developed by Lawrence Berkeley National Laboratory (Berkeley Lab) researcher Robert Cheng, is entering the marketplace after years of research and development. UCLSC emits 10 to 100 times less nitrogen oxide (NO_x) than conventional burners do. This new technology will reduce air pollution and allow industry to meet clean air requirements easily and economically. Because conventional combustion theory does not account for the features of the new technology, UCLSC has prompted advances in theoretical studies to explain its underlying principles.

Nitrogen oxides generate photochemical smog and haze, so controlling these gases is a high priority for air quality management districts throughout the United States. Although vehicle emissions are responsible for a large part of NO_x emissions, stationary sources that burn natural gas also emit a significant amount of NO_x; UCLSC's contribution to reducing emissions from these sources will greatly help the fight against photochemical smog.

Figure 1. Laboratory UCLSB prototype with 5 cm internal diameter, firing at a rate of 15 kilowatts. This burner is made entirely out of plastic components to showcase its unique lifted flame feature.

U.S. homes, businesses, industry, and power generators burned nearly 23 trillion cubic feet of natural gas in 2000, generating 22.6 quadrillion British Thermal Units (BTUs) of energy and emitting nearly 22 million metric tonnes of NO_x. Natural gas burners used in boilers and furnaces are the primary energy source for manufacturing, industrial processing and space heating, and commercial and residential space heating and hot water. Natural-gas-burning turbines are also increasingly being used to produce electricity.

Combustion expert Cheng, a scientist in Berkeley Lab's Environmental Energy Technologies Division, has been studying UCLSC for more than 10 years. The research originated in a U.S. Department of Energy (DOE) Office of Science experimental program to investigate the intricate coupling between fluid mechanical turbulence and combustion heat release; that work has led to numerous practical applications.

UCLSC not only burns cleanly, but it is also as cheap as (or cheaper than) many existing burners. UCLSC could be scaled for use in devices as small as home furnaces and boilers and as large as gas-fired power generators. DOE's Office of Energy Efficiency and Renewable Energy is currently funding research to adapt this technology to heating and power generation.

"Currently, natural gas industrial equipment emits on the order of 100 parts per million (ppm) of NO_x. Ultra-clean low-swirl combustion for industrial processes can reduce the average mission to well below 10 ppm NO_x," Cheng says. "In the U.S. alone, this would remove 340,000 tons per year of NO_x from our atmosphere." That is equivalent to the NO_x emissions of forty-five 1,000-MW, coal-fired power plants. Adapting this technology to residential and commercial applications as well as to power generation could remove an additional 400,000 tons of NO_x per year.

The ultra-clean low-swirl burner (UCLSB) (Figure 1) employs a novel combustion method that uses lean premixed flames; air and fuel are combined in ratios that burn completely when they reach the flame. The burner's operating principle, overall flame behavior, and turbulent flow features have been studied using laser methods.

"The most distinct characteristic of the burner is a detached flame that is lifted above the burner," Cheng says. "This feature defies a long-held notion that a lifted flame is inherently unstable. Until the discovery of low-swirl combustion, flame detachment was considered a prelude to combustion instability and flame-out. Therefore, a burner that generated a lifted flame was deemed unsuitable for commercial use." Through laboratory experiments, Cheng has proven that low-swirl combustion operates on a new and entirely different principle from the one that underlies conventional burners. "We are conducting research to develop a broader theoretical foundation to explain this combustion," says Cheng.

According to Cheng, the UCLSB provides the most stable platform for lean premixed turbulent flames to propagate in their natural state without interference resulting from flame interaction with burner components. Because the flame does not touch the UCLSB, no energy is lost to the burner, so the technology converts energy very efficiently.

Marketplace Attention Grows

Depending on the application in which it is used, low-swirl

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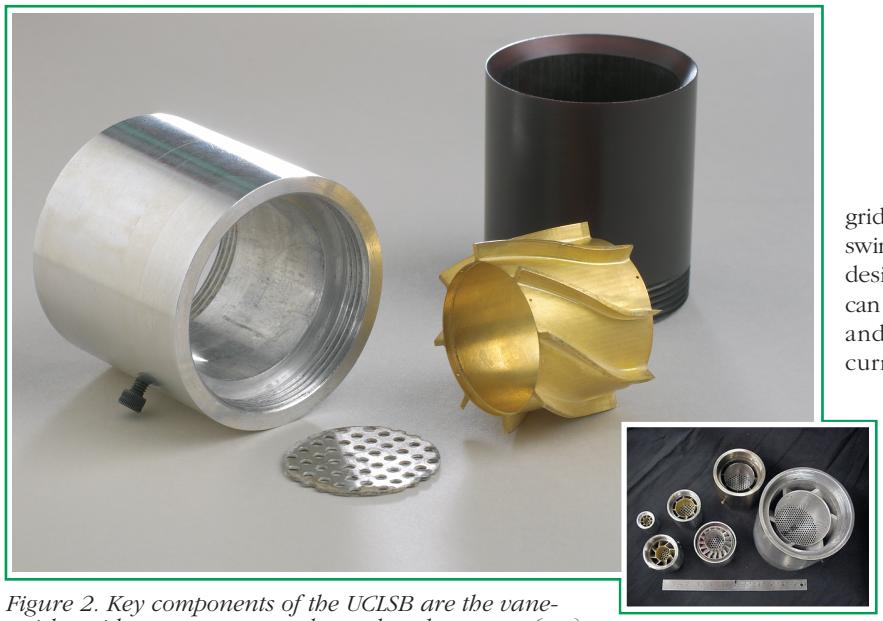

Figure 2. Key components of the UCLSB are the vane-swirler with an open center channel and a screen (top). Shown at the bottom are six UCLSBs from 2.54 cm (top left) to 12.7 cm (right). Variations in the number of swirl vanes and centerbody sizes show this to be a robust and easily adaptable technology.

combustion emits 10 to 100 times less NO_x than is produced by conventional combustion systems. Maxon Corporation (Muncie, Indiana) has licensed the UCLSC technology for industrial process heaters, which are used in many industrial baking and drying ovens. These ovens consume more than 9.8 quadrillion BTUs of natural gas per year in the United States.

Maxon's ultra-low NO_x burner, which will come out later this year, will meet stringent air quality regulations requiring NO_x emissions of less than nine parts per million at three percent oxygen. (See Figure 3.) Maxon is also developing larger-capacity low-swirl burners for other industrial heating processes.

Another manufacturer recently evaluated a UCLSB with a diameter of five centimeters for domestic use in a 15-kilowatt spa heater. The results show that the UCLSB reduces NO_x emissions from 150 ppm to less than 12 ppm, with the same overall thermal efficiency as standard technology.

Cheng is working with several boiler manufacturers to engineer and adapt UCLSBs for their products. They tested a UCLSB with a 12.7-centimeter diameter in six different boiler configurations and determined that UCLSBs could be used in industrial hot water and steam generation (Figure 4).

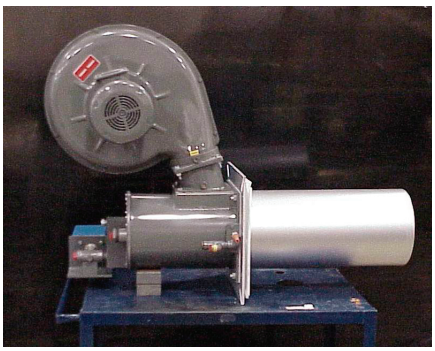

Figure 3. The Maxon MPAKT Ultra Low NO_x Burner is the first product that uses the ultra-clean low-swirl combustion technology.

Gas Turbines

With industrial partner Solar Turbines of San Diego, California, Cheng recently demonstrated the technology's potential in gas turbines, which are increasingly being used to generate electricity for the power grid. Cheng and his partners successfully fired a "low-swirl injector" (LSI) prototype — a version of UCLSB designed for power turbines — and showed that it can match the emissions of the much more expensive and less durable catalytic combustors that are currently considered the best available technology.

The LSI reduced NO_x emissions by a factor of five to 10 and emitted less than five ppm of carbon monoxide, which is comparable to the performance of the catalytic technology. These tests suggest that this ultra-clean technology could have an impact on gas turbine and micro-turbine development as demand is increasing for electricity generation using ultra-clean gas turbines.

The UCLSB's relative dimensions can be varied to some degree without affecting the burner's performance, and the burner can be made using standard, stock materials. These characteristics mean that engineers have many options for choosing economical fabrication and manufacturing methods, which could allow the technology to be adapted to products ranging from household boilers to gas power turbines. Low-temperature materials can be used in some applications because the detached flame means that the burner itself does not receive or retain much heat. Cheng expects that the lack of exposure to excessive heating will protect the UCLSB's components from degrading substantially over the life of the burner, so the UCLSB will be comparatively inexpensive to operate and maintain. This technology is also more energy-efficient than current technologies because it requires less fan power to push the fuel mix through the burner.

Figure 4. A 12.7-cm UCLSB designed for water and steam boilers. The flame is highly lifted to optimize performance in boiler tubes.

"We are continuing our studies of the theoretical underpinnings of the technology," says Cheng, "but field demonstrations have already proven its potential to reduce pollution emissions from the burning of natural gas. We hope to see these burners become a useful tool in the marketplace for reducing emissions."

—Allan Chen

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For information on licensing this technology, see http://www.lbl.gov/tt/success_stories/practical_application/burner.html

Functional Testing Guide Aids Buildings Teams

Commissioning complex commercial buildings—understanding the many test procedures involved and the energy use that they assess—requires an in-depth understanding of building heating, ventilation, and air-conditioning (HVAC) systems in particular. To communicate this understanding to the building commissioning industry, scientists and researchers in the Environmental Energy Technologies Division (EETD) have developed the *Functional Testing Guide and Model Functional Test for Air-Handling Systems (FT Guide)*. The guide presents a series of model functional tests that describe many common air-handling system configurations. It was developed as part of a large building-commissioning research project currently under way (see *EETD News*, Vol. 2, No. 4, Summer 2001).

Commissioning is a valuable method of ensuring building performance; reducing energy use; and improving indoor air quality, occupant comfort, and productivity. As the commissioning industry continues to expand, so does the need for tools to deliver quality services at reduced costs. One way to reduce costs is to produce project-specific test protocols from standardized templates.

To meet this need, researchers Mary Ann Piette and Norman Bourassa, among others, worked with Portland Energy Conservation Inc. to compile a library of standardized functional test procedures, with funding from the California Energy Commission's Public Interest Energy Research Program (PIER) and the U.S. Department of Energy (DOE). Pacific Gas and Electric Company (PG&E) recently completed this library, which is called the Commissioning Test Protocol Library (CTPL). The team then used the library to produce the *FT Guide*, which reviews the basic concept of functional testing, including references to other tests, along with information such as why a test is important, when it should be performed, and what its costs and benefits are. The guide will also help commissioners understand the possible outcomes of a test sequence.

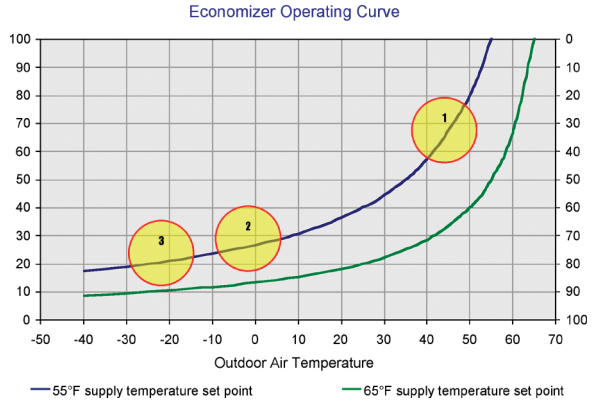

Figure 1. The FT Guide provides details on air-handler component design and operation. This example illustrates how economizers operate. The amount of outdoor air needed to maintain a supply temperature set point depends on the outdoor air temperature (Circles 1 and 2). Typical office environments do not require preheating until it is cold outside (Circle 3). Most economizers in California buildings do not perform at optimal levels; understanding their operation can lead to significant energy savings. The FT Guide explains these and other issues in depth.

The *FT Guide* covers air-handling systems only and emphasizes energy efficiency because air-handling equipment can often consume 30 to 50 percent of a building's energy. The majority of HVAC systems have some form of air-handling equipment and distribution system. Control requirements are also discussed in a section of the guide that addresses integrated operation of the control system and the components of the air-handling unit. An example is shown in Figure 1.

Designed to assist users in choosing the appropriate levels of testing, the *FT Guide* is oriented toward commissioning of new construction but can be useful for recommissioning as well. Together with the CTPL, the *FT Guide* is a step toward standardization and quality control, which continue to be significant issues in the commissioning industry.

—Ted Gartner

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Motor System Optimization in China: Building a Model for Industrial Energy Efficiency

Industrial electric motor systems in China consume more than 600 billion kilowatt hours (kWh) annually, accounting for more than 50 percent of that nation's electricity use. If these systems were optimized, their efficiency could be improved by 20 percent or more. Responding to this opportunity in late 2001, the Chinese government established the China Motor Systems Energy Conservation Program, in cooperation with the United Nations Industrial Development Organization (UNIDO), the United Nations Foundation (UNF), the U.S. Department of Energy (DOE), and the Energy Foundation.

The China Motor Systems Energy Conservation Program's pilot efforts aim to develop and test the effectiveness of a variety of education materials, analysis tools, and standards for promoting motor system optimization in China and to create a local delivery infrastructure in two provinces (Shanghai and Jiangsu) to raise awareness, conduct plant assessments, and develop projects that improve the efficiency of industrial motor-driven systems. During a second phase of the program, the pilot program participants will be prepared to expand the program's activities by training Chinese engineers in other provinces.

Aimee McKane, of the Environmental Energy Technologies Division (EETD) was selected as the Chief Technical Advisor to the three-year pilot program. Lawrence Berkeley National Laboratory (Berkeley Lab) provides technical and developmental support to the DOE Industrial Technologies program for its international activities, which have recently focused on China. The lessons learned from the pilot program will influence the development of both Phase II of this effort and, ultimately, a national program. Within approximately 10 years, the Chinese government plans to establish and train a network of motor system optimization experts throughout the country who will assist individual factories with motor system improvements.

Figure 1. Fan expert Ron Wroblewski (right) demonstrates how to conduct fan flow measurements.

The program focus through the spring of 2003 was on building an infrastructure of trained system optimization experts in Shanghai and Jiangsu provinces. International experts, typically in teams of three, spent a total of 34 person-weeks in China between April 2002 and March 2003, training 22 Chinese engineers in optimization techniques for pumps, fans, motors/drives, and compressed air systems. This training combined classroom instruction, hands-on practice with measurement equipment, and on-site assessment of motor-driven systems at selected Chinese factories. In addition to teaching, the visiting experts prepared the factory sites for on-site training and conducted follow-up visits to review plant assessment and measurement techniques. Despite the considerable challenges posed by language differences and industrial practices, as well as the physical difficulties of conducting on-site training in noisy factory environments, this instruction model has been successful.

After completing the program, the Chinese engineers will provide awareness training for approximately 400 Shanghai and Jiangsu factory managers and engineers as well as technical assessments to at least 32 Shanghai and Jiangsu factories to assist them in identifying and undertaking their own motor system optimization projects. As part of the program, the Chinese engineers will also implement and evaluate a series of eight to 12 demonstration projects in different industrial sectors in Shanghai and Jiangsu and prepare case studies. Some of these demonstration projects have been completed, including a pumping system optimization project at the Shanghai New Asiatic Pharmaceuticals Company, Ltd. New pumps and variable-speed control on a cooling tower pumping system in this project are reducing pumping energy consumption by almost 50 percent at this facility, saving the equivalent of approximately US$80,000 per year.

For the remainder of 2003, the primary program focus of the Chinese engineers will be on conducting 16 plant assessments in each province, completing four to six projects and case studies on the demonstration projects described above, and training 200 factory representatives in each province. A study tour of the United States is also planned for the Chinese engineers in late 2003. Development of national standards for the efficient operation of motors, fans, and pumps has begun and will be completed in 2004.

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Capturing and Tracking Energy-Savings Project Goals with the Design Intent Tool

There is an increasing understanding in the buildings community that it is necessary but not sufficient to specify technologies or design features that can effectively realize energy savings in buildings. Successful implementation of energy-saving features is often thwarted by the absence of explicit direction from the building's owner, misunderstandings or inconsistent visions among design team members, and ambiguously defined energy-performance targets. The lack of clarity created by these problems hampers the post-construction processes of commissioning and measurement and verification. Robust documentation of the design intent for a building's energy performance can result in a comprehensive and holistic design process that achieves its energy-savings goals. A new computer-based Design Intent Tool developed by Environmental Energy Technologies Division (EETD) researchers addresses these needs by documenting key building design information in a centralized, accessible format, increasing the likelihood that a building will be constructed and perform as designed.

Why Document Design Intent?

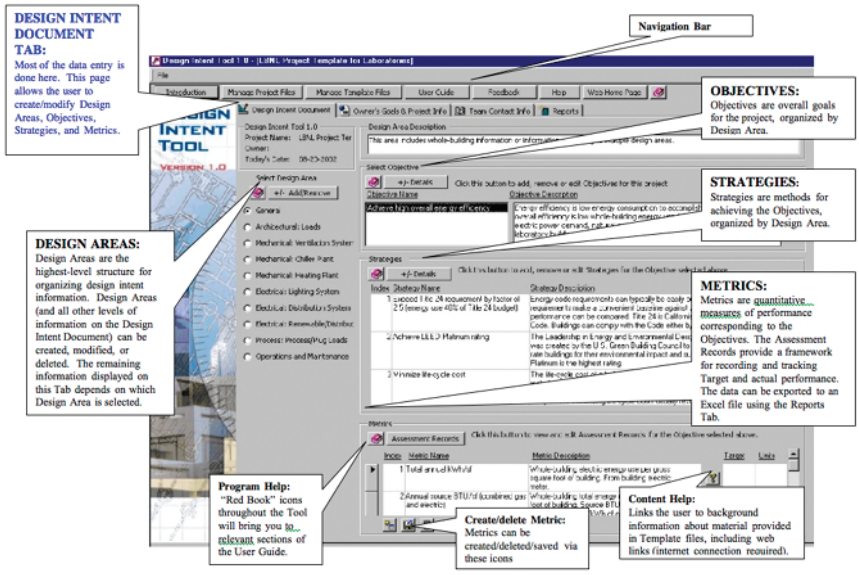
Design documents evolve as a project moves through programming, design, construction, building occupancy, and potential future renovations and retrofits. Design intent documentation is crucial for verifying the proper installation, operation, and performance of energy-saving features, ensuring that energy performance objectives are realized and can be maintained over time. Ideally, quantifiable metrics are defined that can be used to assess the success of the design and its implementation in meeting the project's energy-efficiency objectives.

Documenting design intent is a team effort. All key stakeholders need to be involved, including the building owner, occupants, design team members, facility operators, construction manager, and commissioning agents. Design documentation forms the basis for communication and contractual obligations among these team members.

Benefits

A building design process that does not incorporate quantitative feedback is unlikely to detect or correct problems. Effective documentation of design intent captures and preserves key information across the building's life cycle, helping to ensure that:

- project participants are able to clearly articulate desired energy-performance objectives during formative planning phases.
- evaluations of proposed design options are supported, and the resulting decisions (including rejection of recommendations) are recorded and shared among design team members.
- design changes during construction and operations and maintenance (O&M) can be effectively assessed.
- the commissioning process is comprehensive and cost effective because it is supported by reference to clearly specified energy-performance targets.
- O&M evaluation of day-to-day system performance and early detection and diagnosis of maintenance problems are enhanced through energy-performance benchmarking.
- performance contracting and measurement and verification are supported in a structured, proactive manner.
- post-occupancy evaluation is easily performed with reference to documented objectives.
- critical information is not lost when a facility changes hands.



The Design Intent Tool

The heart of the new Design Intent Tool is a computerized framework in which design goals for energy-consuming systems can be described in terms of *Objectives* (overall goals), with subordinate *Strategies* (specific means of achieving the goals) and *Metrics* (measurable performance targets).

This tool helps the user create a design intent document as well as a series of reports (in MS-Word and MS-Excel format), including a "Data Tracker" module to ensure that the achievement of the owner's goals is periodically assessed though measurement of energy performance. Optional

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Microgrids: Reliable Power in a Small Package

In 1996, a sagging power line in Oregon brushed against a tree; within minutes, 12 million customers in eight states lost power. Such is the vulnerability of today's electricity grid, in which a disturbance can propagate instantly through large portions of the system.

To address this vulnerability, Environmental Energy Technologies Division (EETD) scientists are helping to develop a new approach to power generation in which a cluster of small, on-site generators serve the electricity, heating, and cooling needs of office buildings, hotels, small industrial facilities, and possibly even homes. Called a microgrid, this new approach could help slake the nation's growing thirst for electricity—predicted to jump by almost 400 gigawatts by 2025—without overburdening aging transmission lines or building the 1,000 new power plants that would be required to meet this demand. Microgrids may make statewide blackouts a thing of the past or at least ensure that service to critical equipment and facilities is maintained during outages.

"Catastrophic loss of power to all systems like the 1996 blackout should be impossible," says Chris Marnay, an EETD scientist. "If we sat down today to devise a power system from scratch, our design wouldn't resemble the one we have."

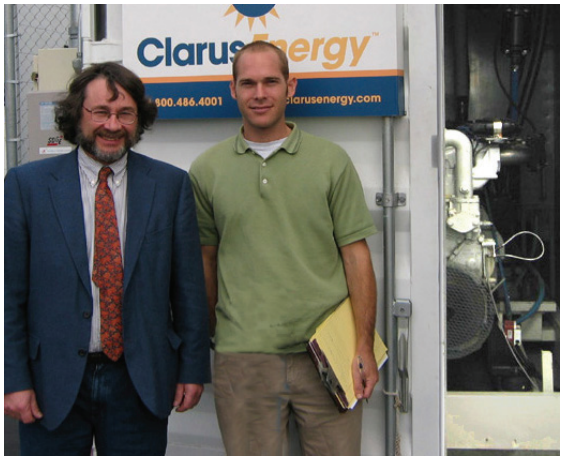

Figure 1. Chris Marnay (left) and Ryan Firestone of Berkeley Lab's Environmental Energy Technologies Division stand in front of generators that power and heat a laboratory at BD Biosciences in San Diego CA. The Consortium for Electric Reliability Technology Solutions (CERTS) is studying this project as an early example of on-site power generation.

Instead of relying solely on large power plants, the nation's electricity system could meet a portion of the demand for power using small generators such as ordinary reciprocating engines, microturbines, fuel cells, and photovoltaic systems. A small network (microgrid) of these generators, each of which typically produces no more than 500 kilowatts, could power a postal sorting facility, a commercial office building, or potentially a whole grouping of customers.

The microgrid appears to the larger power grid as if it's any other single customer. And it can quickly switch between operating on or off the larger grid; when the grid offers cheap electricity, the microgrid can purchase it, but if prices rise or there's a power failure, the microgrid can isolate itself and continue to serve its participants. It can also temporarily shed unimportant equipment such as refrigerators during power shortages, ensuring uninterrupted power to the critical computers, communications infrastructure, and control systems that drive today's economy.

"Everything is interdependent. For example, if vital communications go down, other sectors falter," Marnay says. "But if sensitive equipment is powered locally, our vulnerable, centralized power system becomes much less critical and is a less attractive terrorist target."

Microgrid Pioneers

The microgrid concept is being pioneered by the Consortium for Electric Reliability Technology Solutions (CERTS), a collaboration of national lab, university, and industry participants convened by the U.S. Department of Energy in 1999 to explore ways to improve power system reliability. The consortium, which is also supported by the California Energy Commission and centered at Berkeley Lab, is developing several innovative strategies in addition to microgrids, including managing power grids in real time. CERTS is also researching how the emerging competitive electricity market affects reliability.

CERTS will conduct the first microgrid bench test in early 2004, in which three microturbines and several end loads will be linked together at a utility-grade testing facility. If this test succeeds, it will be followed in 2005 by the first microgrid field test.

Marnay and colleagues are also developing a computer model that predicts who is most likely to adopt a microgrid and why. Their work underscores the fact that air-quality regulatory restrictions, building code constraints, and site limitations mean that some microgrids will be able to use only clean, quiet generators, instead of the natural-gas-fired reciprocating engines and microturbines being installed today.

A microgrid's many advantages will likely win fans. One selling point is the possibility of capturing waste heat to serve energy loads. Between 60 and 80 percent of the energy consumed by power plants isn't converted to electricity, or leaks away between the generator and the socket. The heat that power plants produce, unlike the electricity, is neither transportable nor easy to use locally. But in a microgrid, waste heat could feed a small, adjacent heat load such as a

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Research Highlights

Environmental Energy Technologies Division Wins "R&D 100" Awards for EnergyPlus Software

R&D Magazine has announced the winners of the 41st annual R&D 100 Awards, honoring the 100 most technologically significant new products of the year. One of the 2003 awards, which have been called the "Oscars of Invention," has gone to the EnergyPlus Building Simulation Program, developed by Environmental Energy Technologies Division (EETD) scientists and their collaborators.

EnergyPlus is a computer program that models expected energy use in commercial and residential buildings. Energy use in buildings accounts for a third of the nation's total energy use and two-thirds of its electricity use. Thus, even small gains in efficiency translate into enormous savings. A predecessor of EnergyPlus called DOE-2 has already saved an estimated $20 billion in energy costs since 1980. Over the next decade EnergyPlus is expected to exceed those savings.

Architects, engineers, and researchers use EnergyPlus to model complex heating, cooling, and lighting systems for innovative buildings that are more energy efficient, more comfortable, and have lower energy costs than traditional buildings. EnergyPlus also calculates indirect environmental effects, such as atmospheric pollutants, associated with a building's energy use. More than 12,000 users have downloaded the free software since it was released. In addition, more than 50 licenses have been issued to collaborative developers, and eight commercial licenses have been issued.

EnergyPlus development was led by Fred Buhl, Joe Huang, and Frederick Winkelmann of EETD. Collaborators include Curtis Pedersen, Richard Liesen, and Richard Strand of the University of Illinois at Urbana-Champaign; Linda Lawrie of the U.S. Army's Construction Engineering Research Laboratory; Drury Crawley of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy; Donald Shirey of the Florida Solar Energy Center; Daniel Fisher of Oklahoma State University; William Bahnfleth of Pennsylvania State University; William Beckman of the University of Wisconsin; and Michael Witte and Jason Glazer of GARD Analytics, Inc.

More information:
http://www.eere.energy.gov/buildings/energyplus/
http://gundog.lbl.gov/

2003 World Technology Award for Energy Goes to Environmental Energy Technologies Division

The World Technology Network (WTN) has announced that the Environmental Energy Technologies Division (EETD) at Lawrence Berkeley National Laboratory (Berkeley Lab) has won the 2003 World Technology Award for Energy, in the corporate category. Selection as a winner also means that Berkeley Lab's EETD has been elected as a corporate member of the WTN. The competition this year included more than 50 innovative companies and organizations involved in creating technologies that have impacts in the real world.

The WTN is a London-based organization that was created to encourage "serendipity" (happy accidents) among those individuals and companies deemed by their peers to be the most innovative in the technology world.

"We're very pleased to have our nearly 30-year history of research on energy-efficient technology and environmental impacts recognized by the World Technology Network," says Mark Levine, Director of EETD. "We hope that our participation in the WTN will help inspire new avenues of research and development toward increasing the energy efficiency of the global economy."

Nominees were identified through an intensive, global process in which current WTN members (primarily winners and finalists of previous awards cycles) nominated and voted for the most innovative candidates in each particular field.

Last year, EETD's Ashok Gadgil won an individual award in the energy category for his achievements in developing energy-efficient technologies.

More information:
www.wtn.net

EETD Develops New Commercial Duct-Sealing Technology

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—Allan Chen

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Microgrids: Reliable Power

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water heater. In a microgrid, "We'd place power generation where heat is needed, rather than where we can conveniently discard it," Marnay says.

Recovered waste heat could also cool and dehumidify buildings, using thermally activated processes. This is doubly advantageous. Cooling buildings places tremendous strain on the power grid; if a microgrid shares some of this load, it will help both the microgrid customer and everyone using the larger grid.

This leads to another selling point. Microgrids could become "model citizens" on the larger power grid, injecting power and other services into the system, rather than from it. This would lessen stress on the overall system during periods of high demand and help maintain local service quality.

This transformation will not happen overnight, but it demonstrates how microgrids—along with increased end-use energy efficiency, improved energy transmission, and use of renewable resources—can help shepherd the nation from decades of centralized power generation to a new era of decentralized, flexible, and environmentally friendly power generation.

—Dan Krotz

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This research is funded by the Consortium for Electric Reliability Technology Solutions.

Dan Krotz is a writer in Berkeley Lab's Public Information Department.

Motor System Optimization in China

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In the final year of the pilot program (2004), a comprehensive evaluation will be completed. It is anticipated that the pilot program model will be refined and applied in other countries with an emerging industrial sector.

—Aimee McKane and Vestal Tutterow

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Primary funding for this work is from the United Nations Foundation (UNF), with substantial in-kind contributions from U.S. DOE and China's State Development and Planning Commission. Additional funding comes from the Energy Foundation.

Vestal Tutterow works for EETD's Washington D.C. Projects Office and the Alliance to Save Energy.

Design Intent Tool

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templates for laboratory-type facilities and Leadership in Energy and Environmental Design (LEED) guidelines of the U.S. Green Buildings Council are packaged with the tool.

During development of the tool, design intent documentation was carried out for proposed cleanroom and laboratory facilities at Sandia National Lab, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, the Honolulu Laboratory Renewal Project, and a physical sciences laboratory at the University of California (UC) at Santa Cruz. In a demonstration of the finished tool, several individuals from the design team prepared a 24-page design intent document for a planned Science and Engineering laboratory facility at the UC Merced campus, including more than 36 Objectives, 106 Strategies, and 54 Metrics. The architect for this project noted that the tool filled an important "gap" in the current design documentation process.

The Design Intent Tool was developed by the Applications Team at Berkeley Lab, with primary sponsorship from the California Energy Commission. The California Institute for Energy Efficiency sponsored initial conceptual development of the tool. Portland Energy Conservation Inc. collaborated on an earlier version of the tool.

—Evan Mills

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To download a free copy of the Design Intent Tool, see http://ateam.lbl.gov/DesignIntent/home.html

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With more than 4,000 employees, Berkeley Lab's total annual budget of nearly $400 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 nine Nobel laureates. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of 400 and a budget of $40 million.

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Environmental Energy Technologies Division

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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