Lawrence Berkeley National Laboratory

Fall 1999

Environmental Energy Technologies Division News

Air Quality Advanced Technologies Building Technologies Energy Analysis Indoor Environment

Special Issue Buildings

High-Performance Commercial Buildings

More and more, computer-based tools affect the design, construction, operation, and financing of commercial buildings. If properly deployed, an integrated set of such computer tools can help design, enhance, and maintain the operation of energy-efficient buildings. In addition to providing increased comfort and health and safety to the building's occupants, these tools should be interoperable throughout the building life cycle, contributing substantially to overall reduced energy demand and building performance.

The Present Situation

With national annual costs of more than $90 billion, commercial buildings account for 33% of electricity consumption. New buildings consume roughly 25% less electricity than those constructed 20 years ago, but this reduction in energy use is far below technical and economic potentials. EETD researchers Philip Haves, Mary Anne Piette, and Stephen Selkowitz posit that greater energy savings can be captured in several different ways. If only tune-ups and performance monitoring of existing buildings were performed, average energy use could be reduced by ~20%. If proven efficiency measures were applied when a building is retrofit (usually about every 15 years), an additional 50% reduction could be attained. Efficiency measures designed and constructed into new buildings could bring about an energy reduction of as much as 75%.

Studies show that significant savings are unlikely without the adoption of a systems perspective on building procurement and operation, leading to the consistent application of new tools and

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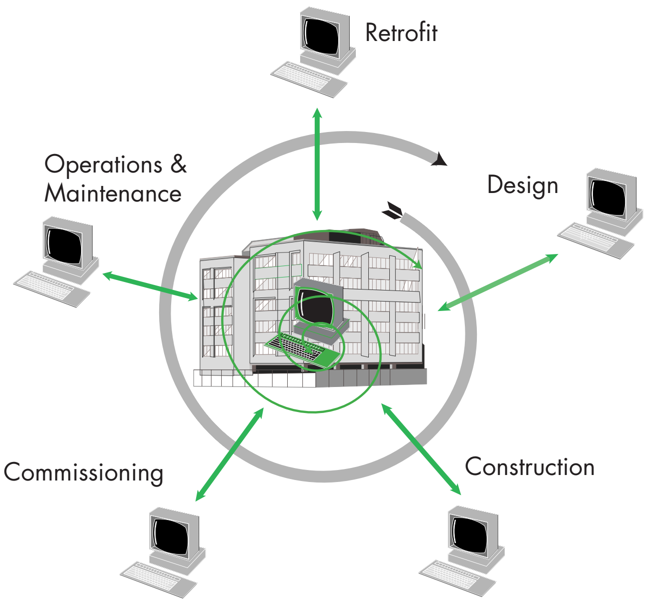
This is a special issue of the Environmental Energy Technologies Division News focusing on information technologies for buildings and high-technology buildings, both of which are growing areas of the Division's research. EETD's long history of work in this field begins with the development, starting in the 1970s, of the DOE-2 building energy simulation model, the de facto standard software of the building design world. Since then, EETD has developed a variety of other software programs for efficient building design; studied building commissioning as a way of improving the performance of new buildings; examined the energy use of and investigated energy-efficient technologies for laboratory and cleanroom facilities; pioneered the building life-cycle approach to designing buildings; and begun to develop technologies to optimize the energy use, comfort and productivity of commercial buildings throughout their life cycles. Some of this work is profiled here; you will find more information by visiting our Web site, eetd.lbl.gov.



Computers help manage, archive and provide access to data that is generated during the life-cycle of a commercial building.

In this Issue

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

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technologies across a building's life cycle. High-performance design solutions are not sufficient by themselves; effective commissioning and operating procedures are required to ensure that the design intent is realized.

EETD research identifies the critical R&D tasks needed to change commercial sector performance:

- High-performance components and systems;
- A set of interoperable tools that facilitate decision making in design, construction, commissioning, operation, and retrofit;
- An information infrastructure that facilitates information management.

Continuing development of low-energy technologies and systems is an important part of this R&D. However, the vision of efficient and productive commercial buildings cannot be achieved simply by deploying technology solutions. A comprehensive approach that accounts for how building decisions are made is required. A linked set of computer-based tools is needed to support decision-making at each phase of the building life-cycle.

New Tools and Integrated Building Technologies

Interoperable building tools must run the gamut from design to commissioning to operation to retrofit. Simulation-based tools are needed, not only for design, but also to verify energy performance as part of commissioning and during operation and to evaluate retrofit opportunities. Using the perspective developed by EETD, a series of new integrated technologies will be developed to reduce building energy use to a minimum. As an example, compare the following scenarios: At present, when a building is contracted, designers rarely perform energy simulations to investigate the potential savings of newer technologies. Building components are treated individually instead of as parts of an integrated system, and most individual systems are consequently oversized to guard against future complaints. When problems arise, individual systems are adjusted in isolation and no performance monitoring is carried out. Since utility bills are paid in single installments, there is little awareness of energy use.

Under an integrated approach, a client accepts a set of quantitative performance targets for the building based on monitored performance of other buildings. The design is then rendered with state-of-the-art simulation tools, incorporating cutting-edge technologies like low-energy façades, efficient lighting, and daylight-responsive devices. Savings are realized from the downsizing of the chillers. Comprehensive commissioning is completed before hand-over and continuous monitoring of building performance leads to the correction of minor problems or equipment failures. As a result, building owners and operators have the information they require to keep their buildings running efficiently.

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Lawrence Berkeley National Laboratory

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 laboratories, LBNL is located in the hills above the campus of the University of California, Berkeley.

With more than 3,800 employees, LBNL's total annual budget of nearly $330 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, LBNL has had nine Nobel laureates. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of more than 300 and a budget of $36 million.

Diagnostics for Building Commissioning and Operations

Many buildings fail to perform as well as expected because of problems that arise at various stages of the life-cycle, from design planning to operation. These problems originate in different parts of the building, including the envelope, the HVAC system and the lighting system. Consequences include increased energy costs, occupant discomfort, poor productivity, health problems and higher maintenance costs. Examples include leaking ducts, stuck dampers and disabled or poorly tuned control loops. Such faults can be detected either by active testing, for example as part of building commissioning, or by passive monitoring during day-to-day operation.

Fault detection involves a determination that the observed performance of a system or component differs significantly from the expected performance. A human operator can make this determination by inspecting and analyzing measurements from a building, for example temperatures and flow rates in an air-conditioning system, or the process can be automated using computer-based methods. Most computer-based fault detection methods use a model of correct or intended operation to predict the expected behavior, as shown in Figure 1. If these models can be configured using design information or manufacturers' data, they can be used during commissioning to verify that the design intent has been achieved and that this level of performance is maintained during operation. Once a fault has been detected, the next step is to diagnose its cause by combining information from different sensors and operating conditions. The final step is to estimate the cost and benefits of fixing the fault in order to estimate the urgency of effecting a repair.

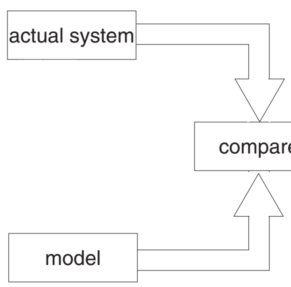

Figure 1. A model-based fault detection scheme

Information Monitoring and Diagnostic System

LBNL has been leading a multi-institutional research project in the diagnostics area for several years. The project involves partnering with an innovative building operator to evaluate a prototype Information Monitoring and Diagnostic System (IMDS) installed in a commercial office building. The IMDS archives measurements from high-quality sensors every minute. It includes a powerful data visualization tool, which can be used on-site or accessed via the Web. The IMDS has been used to identify and correct a series of control problems. It has also allowed the operators to make more effective use of the building control system, freeing up time to take care of other tenant needs. They believe they have significantly increased building comfort, potentially improving tenant health and productivity. The reduction in the time required to operate the building is worth about $20,000/year, which could pay for the IMDS in about five years. A control system retrofit based on findings from the IMDS is expected to reduce energy use by 20% over the next year, worth over $30,000/year. The project has also included the evaluation of simple chiller models for fault detection, concluding that such models can be used as reference models to monitor operation and detect faults. The ability of the IMDS to measure cooling load and chiller power to 1% accuracy with a one-minute sampling interval permits the detection of faults that would otherwise go undetected. A virtual tour of the IMDS can be found at http://eetd.lbl.gov/EA/IIT/diag/

On-Line Model-Based Performance Analysis

As part of a recent analysis of the Philip Burton Federal Building in San Francisco, EETD researchers have developed simulation models of the building subsystems such as the air-handling units. A comparison of simulated performance and actual performance has proved useful for performance validation and operational analysis. As an extension to this work, we have developed an on-line implementation of the simulation models that can be used for performance analysis of air-handling units in real time.

The simulation models are based on first principles and can be configured from normally available design information. Researchers have incorporated the models into a software tool that can be used to improve the control of air-handling systems and validate performance at the same time. The software tool is in the form of an add-on for conventional feedback control loops, and has been developed using the BACnet protocol for communication with the building control system. Use of the BACnet standard potentially allows the tool to be deployed on a variety of different systems without having to reengineer the communication interfaces for each new application. Field trials of the tool are now being carried out in the Phillip Burton Federal Building.

—Philip Haves, Mary Ann Piette, Tim Salsbury

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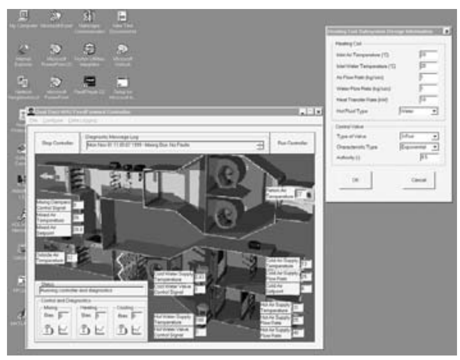

Figure 2: Screen shot showing an implementation for a dual-duct air-handler system

Information Management for Performance Metrics

Buildings often do not perform as well in practice as expected during pre-design planning, nor as intended by design. It is difficult to quantify the impacts and long-term economic implications of a building in which performance does not meet expectations. Current building construction and operational practices are devoid of quantitative feedback that could be used to detect and correct problems both in an individual building and in the building process itself.

A key element in this situation is the lack of a standardized method for documenting and communicating information about the intended and actual performance of a building. This deficiency leads to several shortcomings in the life-cycle management of building information. Planners do not clearly specify their expectations. Designers do not concisely document their design intent. Commissioning personnel have no standardized method for documenting the results of performance testing. Post-occupancy building performance cannot readily be compared to expectations in an attempt to evaluate and improve design and operation decisions. Last, without quantification of the magnitude of performance problems, it is difficult to motivate building process participants to alter their current practice.

We are currently developing two prototype tools intended to address this situation. *Metracker* is a tool for documenting and tracking performance metrics across the building life cycle. The *Design Intent Tool* assists owners and designers in identifying their design objectives for energy-efficient laboratories, and documents quantitative performance criteria for verifying that the objectives have been achieved.

Performance Metric Tracking with Metracker

A building project begins with a consideration of the various performance objectives of interest to building stakeholders (e.g., owners, designers, operators, occupants). A wide spectrum of objectives should be at least informally considered at this stage, including life-cycle economics; energy-efficiency; environmental impact; occupant health, comfort and productivity; and building functionality, adaptability, durability, and sustainability. Performance metrics can be used to explicitly represent these objectives, using quantitative criteria, in a dynamic, structured format that provides value across the life cycle of a building project. A guiding principle in defining a performance metric is to identify a critical variable that measures, reflects, or significantly influences a particular performance objective. To be useful across the building project life cycle, each metric must also be capable of being either predicted or measured at various stages of the project so that the achievement of each objective can be evaluated.

Metracker provides an environment for establishing a hierarchy of performance metrics and their benchmark values that document the intended performance of a building and its systems. During construction, these metrics aid the commissioning process by identifying what should be measured in the building, and what level of performance is expected for each measurement. Using Metracker to document the results of commissioning then provides an archive of measured building performance to support the detection and diagnosis of operation and maintenance problems. Metracker's data visualization facilities graphically display a history of intended and actual performance of a building across its life cycle. Metracker is based on the International Alliance for Interoperability's (IAI) Industry Foundation Classes (IFC), an evolving data model intended to facilitate the sharing of information between building industry software tools.

Design Intent Tool for Energy-Efficient Laboratories

A related tool that builds on the performance metric concept and tailors it to laboratory-type spaces, is the Design Intent Tool for Energy-Efficient Laboratories. This tool is designed to help owners develop and compile their anticipated performance objectives for laboratory spaces in a narrative, prose format to direct the design team's efforts. The design team can then use the tool to document their design concepts for approval by the owner and other designated stakeholders. In addition, the tool documents quantitative performance metrics that can be used to verify achievement of the objectives. The tool also provides a unique method to assist designers and energy consultants in identifying and applying advanced energy-efficiency features in laboratory-type environments by linking to a Design Guide for Energy-Efficient Research Laboratories. The Design Intent Tool is being co-developed with Portland Energy Conservation Inc.

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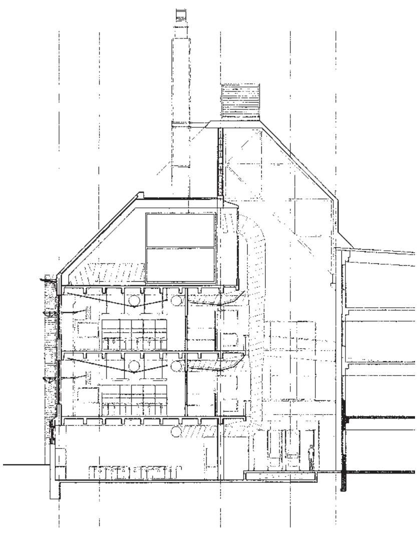
EPIcenter: Montana State University's Green Building Project

The availability of "green" building technologies such as those that are energy-efficient or water-conserving, of renewable energy sources, and sustainable building materials, has created the opportunity to make new buildings into green showcases. Montana State University at Bozeman has seized this opportunity with a project called EPIcenter.

MSU plans to construct a new multidisciplinary educational building whose goal is to be the prototype of a 21st century academic laboratory facility, incorporating advanced design principles and sustainable building construction and practice. Berkeley Lab's EETD is one of MSU's partners in the project's design phase, providing expertise in energy-efficient building technology and design.

Awarded a NIST (National Institute of Standards and Technology) "Green Building" Demonstration Planning Grant in 1994, the planning process for EPIcenter is well underway. MSU plans to house a National Resource Center for Sustainable Building and Cold Climate Technologies (an MSU-NIST collaboration) as well as other research centers, labs and teaching facilities in the 250,000-square-foot building.



Pilot Project

Before work begins on the EPIcenter building itself, MSU and the project architect, Bob Berkebile and BNIM Architects of Kansas City, Missouri, plan a smaller 28,000-square-foot pilot facility using sustainable design principles that will house educational facilities for the Department of Chemistry and Biochemistry. A team of EETD researchers, including principal investigator Dale Sartor, Karl Brown, Geoffrey Bell, Stephen Selkowitz, Eleanor Lee, Vladimir Bazjanac, Francis Rubinstein, and Kostas Papamichael, will work with the University to identify technology appropriate for the buildings goals and provide specific design assistance in a wide variety of areas, including laboratory air management, fume hood design and air distribution; advanced window and daylighting systems, and building design tools.

Windows, Lighting, Ventilation

"In the area of lighting and windows," says Selkowitz, Head of the Division's Building Technologies Department, "we are working with the design team to identify appropriate daylighting strategies for the pilot building and are using simulation programs such as Radiance to evaluate their performance. We'll also provide technical assistance in specifying high-performance window systems, and evaluating their performance."

According to Sartor, "We may also help them specify requirements and provide design review for lighting controls, using the experience we've gained with control systems at the Philip Burton Federal Building testbed in San Francisco [see *Center for Building Science News,* Winter 1997, p.4] as well as our observations of other lighting control systems. Building commissioning will also be an important part of the process—making sure that the building is functioning according to design specification after the building has been built." Sartor is leader of the Division's Applications Team (A-Team).

A second significant area of EETD assistance will be in fume hood contaminant technology. Laboratory buildings almost universally use fume hoods, and EETD researchers have recently been developing an energy-efficient version of this technology [see *EETD News,* Fall 1999, p. 11]. The new design has been undergoing testing for compliance with various codes and standards such as ASHRAE 110, and the development team is fabricating and refining the alpha generation of the fume hood. The team will mock up and specify a beta version of the fume hood, to be designed and manufactured by Fisher Hamilton Inc., for field-testing at the EPIcenter pilot facility.

"Bringing the work of the national laboratory to commercialization is a jointly held goal of the project and LBNL. With Fisher Hamilton, Inc.'s help, we will be able to dramatically change the energy efficiency of fume hoods, while protecting the health and safety of the researchers and laboratory personnel," says Kath Williams, Executive Director of the EPIcenter project.

Other Support

Identifying the best existing technologies for the pilot project is an important part of the design process. Berkeley Lab's assistance will include evaluating information technologies such as building control and monitoring systems, building lifecycle tools to seamlessly transfer information about design specifications to the building commissioning and operation stages, and design and analysis software. The EETD team's expertise also includes advanced heating, ventilation and air-conditioning systems, and high-efficiency task and ambient lighting. The pilot project is scheduled to begin construction in mid-2000.

"Montana State is excited about the partnership with LBNL. The scope of work and expertise that the A-Team bring to our team will make the EPIcenter a much better demonstration of sustainable building practices," says Williams.

—Allan Chen

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Bild-IT: An Integrated Design Tool for the HVAC Industry

EETD is involved in an international joint development project to create a computer-based tool called Bild-IT that supports integrated building design. The tool will link an architectural CAD system, a computational fluid dynamics (CFD) program and the building energy simulation program EnergyPlus, which is currently being developed by the U.S. Department of Energy. The structure of a prototype version of the tool is shown in Figure 1. Standard methods of exchanging design information within the tool and with other software tools will be developed, based on the International Alliance for Interoperability's Industry Foundation Classes, in order to provide an open, interoperable environment for equipment selection and HVAC system analysis. The other partners are the Canadian branch of AEA Technology, a UK-based CFD developer, the Halton Group, a Finnish manufacturer of HVAC equipment, and Olof Granlund, a Finnish building services consulting firm. The work is being supported by the U.S. Department of Energy and the Finnish research agency TEKES.

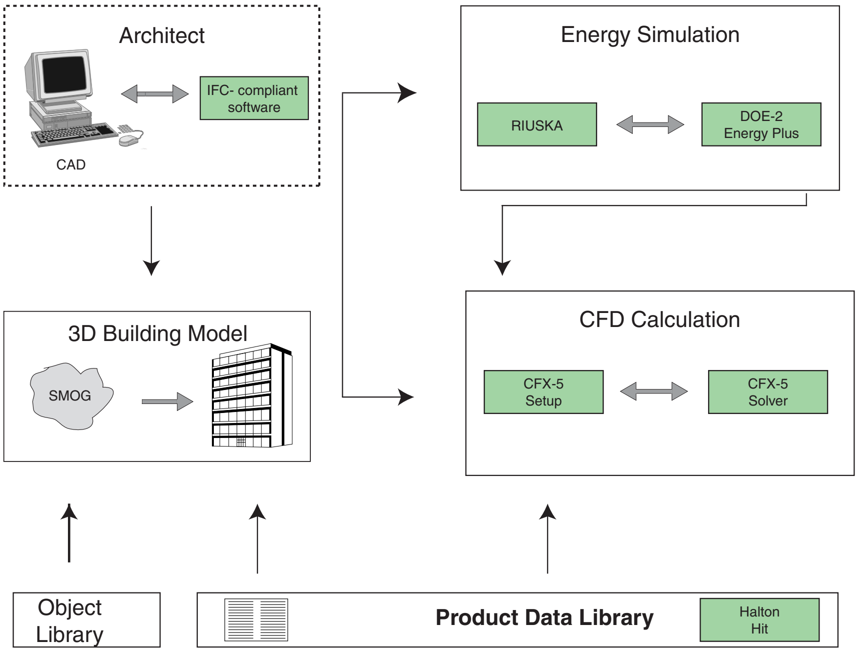

Figure 1. Architeture of the integrated design tool.

The first phase of development will concentrate on understanding the requirements for tools to support the integrated design of commercial buildings and demonstrating a prototype tool to the industry. Successive phases of the project will involve developing and implementing the tool for specific applications. As an example, in the food service industry, this software package will permit the user to make a floor plan, define food preparation requirements and then equip a kitchen according to manufacturers' specifications. With this information, the designer will then perform an energy analysis on the building envelope and HVAC system performance, use an CFD tool to resolve indoor air quality/comfort/control issues, compare different equipment package performance and make easy-to-understand presentations on results to both building owners and architects.

This tool is intended to accelerate the pre-design and design phases in building projects and to improve communication between key players from various disciplines. It will provide the comprehensive computational capabilities required to address complex IAQ, comfort, energy conservation and productivity issues. This project will make advanced technology that is already widely used in other industries available to the HVAC industry.

In order to enhance the capabilities of the tool, the development team is collaborating with MIT—School of Architecture, Fisher Consultants, and the International Facility Manager's Association. Together, this group provides the wide distribution of complementary skills and expertise necessary to achieve the goal of an integrated design tool. Throughout the project, industry input will be solicited through a dialogue with the key players and feedback from product performance testing.

EETD's role is focussed on the use of standard methods to couple energy simulation programs such as EnergyPlus to CAD programs and to CFD programs. Automatic transfer of geometrical and other information from CAD systems is expected to overcome one of the main barriers to the use of simulation in building design, namely the time-consuming and error-prone process of entering the necessary input data. This automatic transfer requires the adoption of a standard way of describing buildings and building systems, which requires the definition of data models and the development of interfaces to simulation and other analysis programs that support these data models. EETD is currently developing an interface for EnergyPlus that will allow it to read files from leading CAD programs that are compatible with the Industry Foundation Classes.

EETD is also working on methods of coupling EnergyPlus to CFD programs, in collaboration with MIT. This will allow the simulation of systems in which the operation of HVAC equipment and the heat flow through the building envelope influence the temperature and flow fields in the space, and vice versa. This coupling is complicated by the fact that CFD programs are much more demanding computationally than building energy simulation programs such as EnergyPlus. The coupled programs will be run at selected full and part load operating conditions and the results characterized in some way, possibly by means of a simplified model, for use in simulating the long term system performance using EnergyPlus on its own.

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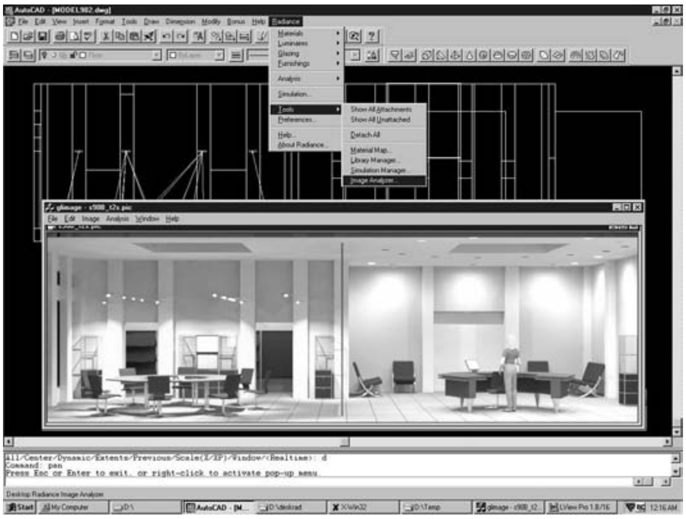
Desktop Radiance

To make decisions on the use of lighting and daylighting strategies and technologies, designers need to simulate their performance with respect to several quantitative and qualitative criteria related to comfort, energy, aesthetics, economics, etc. Radiance allows designers to accurately predict lighting and daylighting performance in spaces of arbitrary geometric complexity, as well as generate photometrically accurate renderings for qualitative assessment. Studies show that the Radiance is the most accurate daylighting simulation software available today.

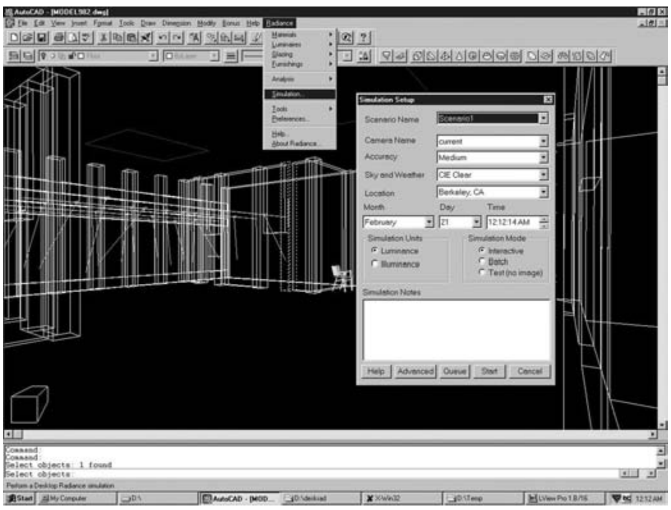
The Radiance software was originally developed by researchers for research purposes. It was developed for use under the UNIX operating system and it lacks a user-friendly interface. It expects the description of building geometry, surface material properties, glazings properties, electric lighting luminaires geometry, position and photometric characteristics, etc., in an input file, using specific keywords and syntax. The input file is then processed by Radiance through a variety of UNIX commands, depending on the type of simulation desired. The requirement of a UNIX workstation and the complexity of using Radiance are the two major barriers in realizing a more widespread use of Radiance by building designers.

Desktop Radiance is a Windows 95/98/NT software application, which facilitates the use of the Radiance lighting simulation and rendering software on personal computers. Desktop Radiance includes links to AutoCAD®, a popular commercial CAD software package, and electronic libraries of materials, glazings, electric lighting luminaires and furniture. Desktop Radiance users specify the geometry of the building surfaces using the AutoCAD software. They can then access all of Desktop Radiance functionality through a single “Radiance” menu in AutoCAD’s menu bar. Through a graphical user interface, Desktop Radiance allows users to select materials from a library and attach them to the AutoCAD surfaces. They can also select and place glazings, as well as electric lighting luminaires and furniture items. Finally, they can place “cameras” and “light sensors” into the AutoCAD scene and request Radiance computations, specifying location, time of the year, sky condition, desired accuracy, etc.

The Desktop Radiance software automatically prepares the Radiance input file and activates the Radiance algorithms for the computation of the desired output, which is also controlled through a graphical user interface. Through a “simulation manager,” it supports easy management of multiple simulations, storing all input specifications and results into a project database. The Radiance output can be further manipulated to display quantitative and qualitative information in different ways, such as by superimposed illuminance/luminance iso-contours, false color displays and adjustment of images to account for the sensitivity and adaptation of the human eye.



These two simulations show a comparison between two alternative lighting designs for the same space.



Users can control the Radiance algorithms through a graphical user interface accessible from with AutoCAD.

The Desktop Radiance software is targeted to building designers that want to consider daylighting strategies and technologies for the design of commercial buildings. Its use is intended to contribute to the general market transformation efforts of the California Utilities. Beta versions of Desktop Radiance have been distributed to a large number of reviewers for comments and suggestions. It is available to the general public at http://kmp.lbl.gov/DT-Rad. The initial version of the software is scheduled for release at the end of 1999.

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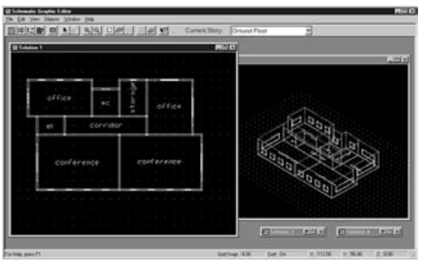
Building Design Advisor

To make decisions, building designers need to predict performance with respect to various performance considerations, such as comfort, safety, aesthetics, cost, etc. To accurately predict energy and environmental impact performance, designers need to use sophisticated simulation tools, like the DOE-2 building energy simulation and the Radiance lighting/daylighting simulation and rendering software. These tools, developed by researchers, for research purposes, are not easy to use.

Most sophisticated simulation tools expect the description of the building and its context in input files that use specific keywords and syntax. The preparation of the input files requires significant time, even for experienced users. Depending on the complexity of the building, it may take several days to prepare a DOE-2 input file. Since each tool uses a different building representation, the use of multiple of tools requires repetitive preparation of input files, using different formats and keywords, which is even more time-consuming. Finally, sophisticated tools require significant details about the building and its operation, which are not usually available in the early, schematic phases of building design, when decisions may greatly affect energy and environmental performance.

The Building Design Advisor (BDA) is a Windows 95/98/NT software application, which facilitates the integrated use of multiple building performance prediction and analysis tools, from the initial, schematic phases of building design to the detailed specification of building components and systems. The BDA software uses an expandable, object-based representation of the building and its context, which is mapped to the different representations of different simulation tools, like DOE-2 and Radiance. Based on a comprehensive design theory, the BDA acts as a data manager and process controller, automatically preparing the input to and handling the output from multiple simulation, visualization and analysis tools, allowing building designers to benefit from their prediction capabilities throughout the building design process.

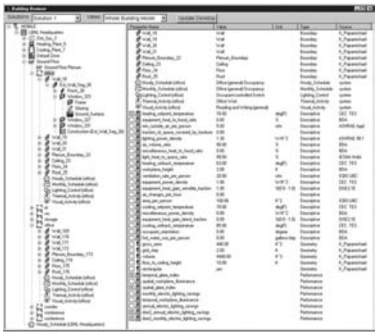


The Schematic Graphic Editor.

The BDA has a simple Graphical User Interface that is based on two main elements, the Building Browser and the Decision Desktop. The user interface is complemented by a Schematic Graphic Editor (SGE), a separate application that communicates continuously with the BDA and allows designers to quickly and easily specify the geometry of basic building elements, such as walls, windows, overhangs, etc.

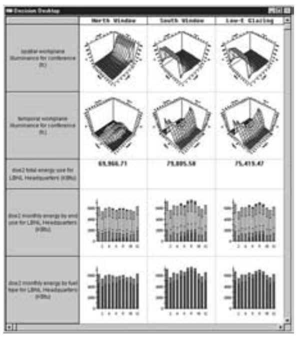
As users specify the geometry of the building in SGE, the BDA automatically assigns "smart" default values to all non-geometric parameters required by the analysis tools from a Prototypical Values Database. These default values can be easily reviewed and changed through the Browser. In this way the BDA supports the use of sophisticated tools from the initial, schematic phases of building design.

The Browser allows building designers to quickly navigate through the multitude of descriptive and performance parameters addressed by the analysis and visualization tools linked to the BDA. Through the Browser the user can edit the values of input parameters and select any number of input and output parameters to display in the Desktop.



The Browser

The Desktop allows building designers to compare multiple designs with respect to multiple criteria, as addressed by the analysis and visualization tools linked to the BDA. The Desktop offers graphic display of data, supporting a large variety of data types, including 2-D and 3-D distributions, images, sound and video.



The Desktop

The initial version of the BDA software had links to a simplified Daylighting Analysis Module, an HVAC Auto-sizing Module, and a simplified Energy Analysis Module and was released in January 1999 through the Internet. The 2.0 version of the BDA, currently under development, is linked to the DOE-2 building energy simulation program. Beta versions are available for review and evaluation at http://kmp.lbl.gov/BDA. Work is also under way to link the BDA to the Desktop Radiance day/lighting simulation and rendering program and the ATHENA materials life cycle and environmental impact software. Plans for the future include the development of links to commercial CAD software, electronic product catalogs of building components and systems, cost databases and estimating modules, and building rating systems.

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Software Roundup

Many of the U.S. Department of Energy's Office of Building Technology, State and Community Program (BTS) programs develop software tools to help researchers, designers, architects, engineers, builders, code officials, and others involved in the building life-cycle in evaluating and ranking potential energy-efficiency in new or existing buildings. A few of these tools are featured in this Newsletter. The following list provides information about additional buildings-related energy tools available to the buildings industry developed by Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division.

The energy tools include databases, spreadsheets, component and systems analyses, and whole-building energy performance simulation programs.

ADELINE

ADELINE is an integrated lighting design computer tool developed by an international research team within the framework of the International Energy Agency (IEA) Solar Heating and Cooling Programme Task 12 and 21. It provides architects and engineers with accurate information about the behavior and the performance of indoor lighting systems. Both daylight and electrical lighting problems can be solved, in simple rooms or the complex spaces.

ADELINE produces innovative and reliable lighting design results by processing a variety of data (including: geometric, photometric, climatic, optic and human response) to perform light simulations and to produce comprehensive numeric and graphic information. ADELINE is available for purchase from LBNL at $450.00 per site license.

http://radsite.lbl.gov/adeline/HOME.html

COMIS

COMIS (Conjunction Of Multizone Infiltration Specialists) models the air flow and contaminant distributions in buildings. The program can simulate several key components influencing air flow: cracks, ducts, duct fittings, fans, flow controllers, vertical large openings (windows, doors, or both), kitchen hoods, passive stacks, and "user-defined components."

COMIS allows the user to define schedules describing changes in the indoor temperature distribution, fan operation, pollutant concentration in the zones, pollutant sources and sinks, opening of windows and doors, and the weather data. The flexible time step implemented in COMIS enables the modeling of events independent of the frequency with which the weather data are provided. The COMIS air flow calculation is based on the assumption that indoor air flows reach steady-state at each time step. The contaminant transport is based on a dynamic model and has its own time step, based on the time constant of the most critical zone. The two models are coupled. Results for air flows and contaminant levels are reported in terms of tables by COMIS and in graphical form by some of the user-interfaces.

COMIS was developed in 1988-89 by ten scientists from nine countries, during a twelve-month workshop hosted by the Lawrence Berkeley National Laboratory.

http://epb1.lbl.gov/comis/

DOE-2

The DOE-2 program for building energy use analysis provides the building construction and research communities with an up-to-date, unbiased, well-documented public-domain computer program for building energy analysis. DOE-2 is a portable FORTRAN program that can be used on a large variety of computers, including PC's. Using DOE-2, designers can quickly determine the choice of building parameters which improve energy efficiency while maintaining thermal comfort. A user can provide a simple or increasingly detailed description of a building design or alternative design options and obtain an accurate estimate of the proposed building's energy consumption, interior environmental conditions and energy operation cost.

http://simulationresearch.lbl.gov/

EnergyPlus

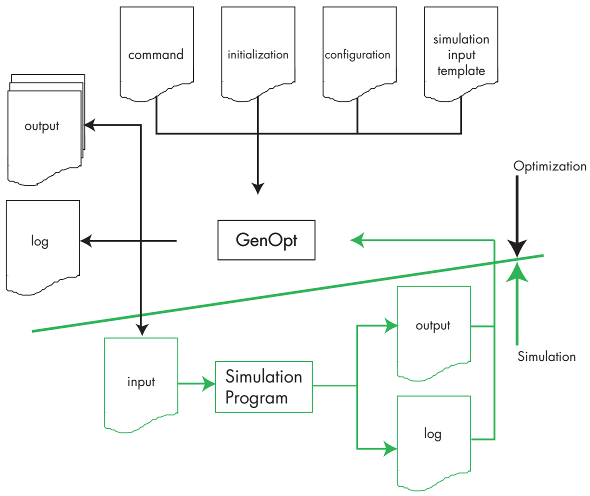
EnergyPlus is a new-generation building energy simulation program based on DOE-2 and BLAST, with numerous added capabilities. It is being written in Fortran 90 with structured, modular code that is easy to maintain, update, and extend. EnergyPlus' developers are the Simulation Research Group at Berkeley Lab, the Building Systems Laboratory at the University of Illinois, the U.S. Army Construction Engineering Research Laboratory, and the U.S. Department of Energy.

http://simulationresearch.lbl.gov/

GenOpt

GenOpt® is a generic optimization program developed by the Swiss Academy of Engineering Sciences, the Swiss National Science foundation, and the Simulation Research Group at Berkeley Lab. It is designed for minimization of a so-called objective function, such as annual energy use, that is calculated by an external simulation program. GenOpt determines the values of the system parameters that lead to optimal operation. It can identify unknown parameters in a data-fitting process. The software also offers an interface for implementing its own optimization algorithms in its library.

http://simulationresearch.lbl.gov/



Home Energy Saver

The Home Energy Saver (HES) is designed to help consumers identify the best ways to save energy in their homes and find the resources to make the savings happen. The HES was the first Internet-based tool for calculating energy use in residential buildings. The HES quickly computes a home's energy use on-line. By changing one or more features of the modeled home, users can estimate how much energy and money can be saved and how much pollution prevented by implementing energy-0efficiency improvements. All end uses (heating, cooling, major appliances, lighting, and miscellaneous uses) are included.

The HES's Energy Advisor calculates energy use and savings opportunities, based on a detailed description of the home provided by the user. Users can begin the process by simply entering their ZIP code and in turn receive instant initial estimated for about 250 locations. By providing more information about the home, the user receives increasingly customized results along with energy-saving upgrade recommendations.
http://HomeEnergySaver.lbl.gov

Users begin by inputting their ZIP code into the Energy Advisor, which begins their interaction with the Home Energy Saver.

RESEM

RESEM, the Retrofit Energy Savings Estimation Model, is a PC-based tool designed to allow Department of Energy Institutional Conservation Program (ICP) staff and participants to reliably determine the energy savings directly caused by ICP-supported retrofit measures implemented in a building. RESEM incorporates several innovative techniques into an interactive tool designed to ease completion of this demanding analytical task. For maximum accuracy and validity, energy savings are calculated directly from actual utility data, with sophisticated corrections for weather and use variations between the pre-retrofit and post-retrofit utility data collection periods.
http://eetd.lbl.gov/btp/resem.htm

RESFEN

RESFEN is a computer tool that can help consumers and builders pick the most energy-efficient and cost-effective window for a given application. It calculates the heating and cooling energy use and associated costs as well as the peak heating and cooling demand for specific window products. Users define a problem by specifying the house type (single-story or two-story), geographic location, orientation, electricity and gas cost, and building configuration details (such as wall type, floor type, and HVAC systems). Window options are defined by specifying the window's size, shading, and thermal properties: U-factor, solar heat gain coefficient, and air leakage rate. RESFEN calculates the energy and cost implications of the windows compared to insulated walls. The relative energy and cost impacts of two different windows can be compared against each other.
http://windows.lbl.gov/software/resfen/resfen.html

SPARK

SPARK (Simulation Problem Analysis and Research Kernel) is an equation-based, object-oriented simulation environment for building models of complex systems. It allows you to quickly build models of complex physical processes by connecting calculation objects.

SPARK is available in two versions with different interfaces: WinSPARK and VisualSPARK. Both have graphical user interfaces that simplify building and running SPARK models. WinSPARK runs under Windows 95/98/NT and is available from Ayres Sowell Associates. VisualSPARK runs under Windows 95/98/NT and UNIX and is available for beta testing from Berkeley Lab. SPARK was developed by the Simulation Research Group at Berkeley Lab and Ayres Sowell Associates with support from the Office of Building Technology, State and Community Programs, Office of Building Systems of the U.S. Department of Energy.
http://simulationresearch.lbl.gov/

SUPERLITE 2.0

SUPERLITE 2.0 is a powerful lighting analysis program designed to accurately predict interior illuminance in complex building spaces due to daylight and electric lighting systems. It enables a user to model interior daylight levels for any sun and sky condition in spaces having windows, skylights or other standard fenestration systems. The principle new feature of Version 2.0 is the capability to calculate electric lighting levels in addition to the daylighting prediction. This allows lighting performance simulation for integrated lighting systems. Daylighting and electric lighting systems can also be modeled separately. The program calculates lighting levels on all interior surfaces, as well as on planes that can be arbitrarily positioned to represent work surfaces or other locations of interest to the user. SUPERLITE 2.0 is intended to be used by researchers and lighting designers, who require detailed analysis of the illuminance distribution in architecturally complex spaces. SUPERLITE continues to be enhanced to address current program limitations.
http://eetd.lbl.gov/btp/superlite20.html

THERM

THERM is a state-of-the-art, Microsoft Windows™-based computer program developed at Berkeley Lab for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, one can model two- dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of con-

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Current Status of Software Interoperability and DOE Tools

The International Alliance for Interoperability (IAI) started the development of a universal object data model that describes buildings more than five years ago. LBNL has actively participated since the beginning of this effort . In the last two and a half years the organization has grown from six to nine international chapters (in North America, United Kingdom, Germany, France, the Nordic region of Europe, Japan, Korea, Singapore and the Austral-Asian region). The international membership has grown from 400 to over 650 companies and organizations. During this period the IAI has released two new versions of its Industry Foundation Classes (IFC), the object data model it is developing: IFC 1.5.1 and IFC 2.0 (the latter was released in April 1999).

The IFC 1.5.1 model enabled the exchange of building geometry among IFC 1.5.1-compatible software applications. This means that two or more software applications that have implemented interfaces between the IFC object data model and their own model structure can read and write *.ifc format files that can contain all the information about a building's geometry. In that way the information developed by one such application (for example, by a CAD tool used by the architect to design the building) can be seamlessly imported by another compatible software application (such as an energy performance simulation tool). This shortens the time and eliminates error in preparing the input for the receiving application, which substantially reduces the cost of its use.

The IFC 2.0 model expands on that and enables the exchange of some of the non-CAD data used by applications that primarily generate and manipulate non-geometric information. These include classes (object/attribute/relationship sets) that describe surface properties for architectural visualization and lighting simulation, and equipment performance metrics for tracking the performance of mechanical systems. Such classes are particularly important to simulation tools LBNL has been developing with funding from DOE.

A number of IFC-compatible software products have been released primarily on the European market in the last 18 months. These are all CAD-based applications that support one of the earlier IFC releases: IFC 1.0 or IFC 1.5 that have been of little use in North America. All major CAD vendors, including Autodesk, are now developing products that will be IFC 1.5.1-compatible. Autodesk already offers an IFC Input/Output Utility with its new Architectural Desktop 2 that is IFC 1.5-compatible. Its next release will include an IFC 1.5.1-compatible Utility. The only IFC 2.0-compatible CAD tool expected on the North American market in the near future is Visio 2000 Technical, which is now in beta testing. With this tool the user will be able to create a quasi-three-dimensional representation of a building from two-dimensional drawings saved in *.dwg, *.dxf and other proprietary CAD file formats, and save the result as an *.ifc file. This tool will be able to "populate" *.ifc project files with geometry and some other types of data needed by "downstream" applications.

EnergyPlus will be the first LBNL IFC-compatible simulation tool. Work to map IFC geometry to the EnergyPlus data structure is in progress. The interface itself will be developed pending further funding from DOE. Once the interface is in place (and IFC-compatible CAD tools like Visio 2000 Technical are on the market) an EnergyPlus user will be able to import the entire building geometry directly from CAD files, interactively define thermal zoning and proceed with the simulation much sooner than without the interface. LBNL is also working towards making Bild-IT (an integrated HVAC design tool that will incorporate CFD and thermal analyses) IFC-compatible.

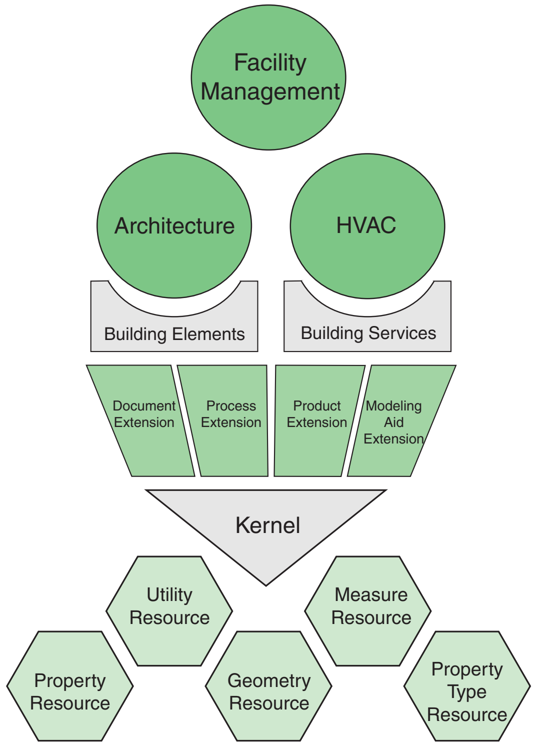

Figure. Architecture of the IFC object data model.

The IAI is currently "stabilizing" the structure of the IFC object data model: Classes that all participating software implementers agree upon now will be left unchanged for at least the next two years. During that period all new additions to the model will be in form of "domain extensions" (Figure 1) to the "core" model and "interoperability level." HVAC equipment and systems are only partially defined in the current Building Services schemata. That precludes the development of an interface that would allow seamless acquisition of other non-geometric data needed by a building energy performance simulation tool like EnergyPlus or Bild-IT. LBNL plans to complete the HVAC schemata within the IFC object data model and thus solve this problem.

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Some aspects of the latter scenario could be achieved relatively quickly. In others, factors ranging from the need for field-testing to the need to develop standards by consensus will limit the rate of progress. Present R&D has already contributed a number of computer-based tools that could enable some of the future scenario. However, development of tools is by itself insufficient; transformation of the market is required before these tools will be widely used. Demonstration projects, adoption of such strategies by government, partnerships and education, and innovative financing are needed to bring about acceptance of such an innovative concept.

——Ted Gartner with Philip Haves

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cern. THERM's heat-transfer analysis allows evaluation of a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity. THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products.
http://windows.lbl.gov/software/therm/therm.html

WINDOW 4.1

WINDOW 4.1 is a publicly available IBM PC-compatible computer program for calculating total window thermal performance indices (i.e., U-values, solar heat gain coefficients, shading coefficients, and visible transmittances). WINDOW 4.1 provides a versatile heat transfer analysis method consistent with the rating procedure developed by the National Fenestration Rating Council (NFRC). The program can be used to design and develop new products, to assist educators in teaching heat transfer through windows, and to help public officials in developing building energy codes.
http://windows.lbl.gov/software/window/window.html

Bound paper copies of the entire set of the *Center for Building Science News*, the publication that preceeded the *Environmental Energy Technologies Division News*, are now available free to anyone interested while supplies last. Quarterly issues from 1993 through summer 1998 cover energy efficiency research. Please email JoAnne Lambert, jmlambert@lbl.gov, and included your name and mailing address.

Sources

EREC: Energy Efficiency and Renewable Energy Clearinghouse
P.O. Box 3048, Merrifield, VA 22116
call toll-free: (800) 363-3732; **fax:** (703) 893-0400
email: doe-erec@nciinc.com; **http://www.eren.doe.gov**

Energy Crossroads
Energy-efficiency resources on the Web:
http://eetd.lbl.gov/EnergyCrossroads

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