VOLUME 23, NO. 4 • JULYY/AUGUST 2002 (PUB-439)

BUILDING ENERGY SIMULATION

User News

For Users of EnergyPlus, SPARK, DOE-2, BLAST, Genopt, Building Design Advisor, ENERGY-10 and their Derivatives

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EnergyPlus Version 1.0.2

To download a free copy of the program go to www.energyplus.gov

The following items have been addressed with the release of EnergyPlus 1.0.2

1. Auto sizing of Plant equipment (Boiler, Electric Chiller, Cooling Tower, Engine Driven Chillers)
2. Restriction for reveal on Triangular Windows, FullExterior (1.0.1) have been removed
3. Ground Temperatures and Slab constructions have been redone (in the Example Files) along the lines of the new Ground Temp Calc program
4. Ground Temp Calc program is included
5. User input of cooling and/or heating zone design air flow rates; mix and match with calculated rates; subsequent sizing calcs work as if user input were calculated.
6. Added simulation of a variable flow secondary loop and a constant flow primary loop simulation using existing simulation structure.
7. New input file example for each new feature.
8. Reflection of beam solar radiation from outside and inside window reveal surfaces.
9. Faster ReadVars program (post processing)
10. Bi-directional Shading devices
11. Warmest Zone supply air set point strategy; new Node output "System Node Setpoint Temp"
12. Water-to-water heat pumps
13. Current Detached Shading is also aka Fixed Detached Shading and added Building Shading (which will move with respect to building origin for "relative" coordinates)
14. Simple Ventilation (addition of simple ventilation--similar to what was done in BLAST with the addition of infiltration type coefficients to modify the flow rate based on temperature difference and wind speed)
15. Linux Version -- With EnergyPlus 1.0.2, we introduce a Linux version available by separate download. This will be compiled versions of the EnergyPlus and ReadVarsESO programs. While not extensively tested, the Linux version has been run on the full test suite and is showing only minor differences in most files.

EnergyPlus is being developed by University of Illinois, CERL, and Lawrence Berkeley National Laboratory, with the assistance of the Florida Solar Energy Center, GARD Analytics, the University of Wisconsin, Oklahoma State University and others. Development of EnergyPlus is supported by the U. S. Department of Energy, Dru Crawley, Program Manager.

Known Problems

While every effort has been made to clean up all the "defects" that have occurred during our testing, quite a few known (and even more unknown) probably remain. In particular, all the "known problems" from the last release have been addressed. If you are super interested in what has been addressed, the 22 issues resolved in this release are installed in the main EnergyPlus folder tab-delimited file V1-0-2-ResolvedIssues.xls. In the release of 1.0.1, we noted the following issues. All have been resolved.

1. RESOLVED -- Reveals in windows should not also specify the Solar Distribution "FullInteriorAndExterior" -- if it does, the solar distribution will be reduced to FullExterior with a warning noted. This has a very high priority to fix, so you can leave the specification there and note the warning message.
2. RESOLVED -- Ground Temperature calculation preprocess; at the last minute before release, we found some show-stopping deficiencies. These will be corrected very soon. In the meantime, using that option on the install will put a small "notice.txt" file in your install structure.
3. RESOLVED -- Several of the Test Suite results (ASHRAE RP1052 Analytical Tests) are farther out of line than we would like -- we have not tracked down all the causes yet. They may be simple differences in some assumptions with the test suites or may point to problems in EnergyPlus.
4. RESOLVED -- Incorrectly defined surfaces (such as a floor which is upside down) can cause invalid radiant exchange calculations. This condition is reported with the following error message:

   View factors not complete.

   Probably bad surface descriptions in zone=<zonename>

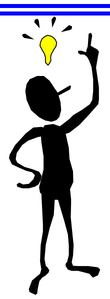
Ask An EnergyPlus Expert

Question:

In the Input-Output Reference Manual, under regular material IDF example on p. 39, the IDF input has “thermal absorptance,” but on p. 43 the IDF example names the same input as “thermal emittance.” Would you please clarify?

Answer:

The two properties are equal to each other since materials absorb and emit longwave radiation the same way, and this field is used both ways. Our intent has been to standardize on the term "absorptance.” Thank you for calling the inconsistency to our attention.



Question:

How can I incorporate an IDF file from the data set folder into the "main" IDF?

Answer:

The only way to do this is to open your project IDF file and the dataset IDF file in a text editor and copy/paste the desired objects into your project file. If you are using the IDF Editor, be sure to save changes and close the file in IDF Editor before editing it in the text editor.

Ask An EnergyPlus Expert

Question:

Since EnergyPlus does not have an input field for people latent heat gain, I was wondering what assumptions the program makes about people latent heat gain. The only discussion of latent gains I could find was a note for the Fraction Radiant field (p. 132 of the Input-Output Reference) which states, "Note that latent gains from people are not included in either the radiant or convective heat gains."

Answer:

Actually there is also a note under the PEOPLE LATENT GAIN output variable (unknown page number but just after the input fields for People). However, it's not much more helpful and states "an internal procedure is used..." The short answer (from looking at the code) is that the TotalPeopleGain = Number of Occupants * Activity Level (activity level is input as an hourly schedule value). Sensible People Gain then is a combination of internal coefficients applied to the activity level and the current mean air temperature in the zone.
Finally, the Latent is Total - Sensible.

And looking at the code tells us:

```
!     The function is based on a curve fit to data presented in Table 48 Heat Gain from
!     People of Chapter 1 of the Carrier Handbook of Air Conditioning System Design,
!     1965. Values of Sensible gain were obtained from the table at average adjusted
!     metabolic rates 350, 400, 450, 500, 750, 850, 1000 and 1450 Btu/hr each at
!     temperatures 82, 80, 78, 75 and 70f. Sensible gains of 0.0 at 96f and equal to the
!     metabolic rate at 30f were assumed in order to give reasonable values beyond the
!     the reported temperature range.
```

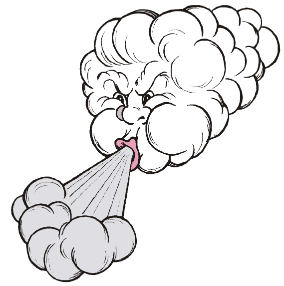
Question:

Does EnergyPlus consider wetness factor in calculating heat transfer (e.g., consider water absorption/evaporation from exterior building surfaces).

Answer:

We handle the boundary conditions for the exterior surface that is exposed to rain by increasing the exterior heat transfer coefficient to a high value and then exposing the surface to the wet bulb temperature instead of the dry bulb. This is done for either the CTF or the MTF solution for heat transfer. For moisture transfer the moisture boundary conditions will also have a high exterior mass transfer coefficient and the vapor density is calculated using the wet bulb and a Relative Humidity = 1.0. Bulk fluid flow is not handled with the MTF calculations so the only boundary conditions that will affect the model is the increased vapor density and high exterior mass transfer coefficient during the time that it is raining.

EnergyPlus Weather Data



The EnergyPlus development team is pleased to announce that our web site now offers more than 570 weather locations available for download and ready to use with EnergyPlus. There are 275 locations in the United States, 16 California thermal zones, 55 Canadian locations, and 233 international locations in more than 80 countries.

Go to www.energyplus.gov

On the right side, under Weather Data, click on one of the following links: USA, California, Canada or International.

We recommend that you also download the weather utility RPT file for each location. The RPT file includes design data where available, statistics for the weather file, including typical and extreme periods (hottest summer week, coldest winter week, typical spring week, etc), Koppen climate classification, heating and cooling degree days, monthly average minimum and maximum dry bulb and dew point temperatures, undisturbed ground temperatures, direct and diffuse solar radiation, relative humidity, and wind speed and direction.

Energy Professionals Training Videos

The Consumer Energy Center of the California Energy Commission has created training videos for building energy professionals. The videos take the form of informal discussions between two professionals, demystifying and explaining the subject matter. The current titles include these: Beyond the Code, Cool Roofs, CHEERS, Exhaust Ventilation Systems, Fenestration (glazing), HVAC, Housewrap, Cellulose Insulation, Fiberglass Insulation, Spray Foam Insulation, Inspections, Radiant Barriers, Structural Insulated Panels and Water Heaters. There is a separate series for the Collaborative for High Performance Schools Project.

California Energy Commission http://cec.ishow.com/

You are invited to test **DoeRayMe**, a new DOE-2.1E screening tool application currently being developed by Jason Glazer, P. E., of GARD Analytics, Inc. **DoeRayMe** is a simple and flexible interface that uses a specially developed DOE-2 input file (template) that contains special codes describing the parameters available to be changed in the user interface. This allows new screening tools to be developed by any DOE-2 user. Please visit the **DoeRayMe** web site at http://www.gard.com/DoeRayMe.

Join the EnergyPlus User Group

The developers of EnergyPlus have formed a support group to foster discussion and maintain an archive of information for program Users. We invite questions about program usage and suggestions for improvement to the code. Go to groups.yahoo.com/group/EnergyPlus_Support/

Interoperability—Making Building Software Talk to Each Other

Drury B Crawley[1]
US Department of Energy
Washington, DC

Vladimir Bazjanac[2] and Robert Hitchcock[3]
Lawrence Berkeley National Laboratory
Berkeley, CA

Introduction

Increasingly, today's building professionals must use computer-based tools to do their daily jobs. Whether it's computer-aided design (CAD) for building design and layout, cost estimating, HVAC calculations, or energy performance, it's all computer-based. For energy professionals, these software tools have long been the chief and best means of analyzing and improving the potential energy performance of buildings. These tools have helped their users quantify and save billions of dollars in new and existing buildings over the last 25 years.

But using any computer-based tool has a price and building energy performance tools are no exception. Entering building geometry and other thermophysical data accounts for much of the cost. To make it worse, this often duplicates essentially the same information entered in other programs such as CAD and cost-estimating tools. Re-entering data often leads to errors, omissions and inconsistent definitions across different tools, potentially leading to wrong decisions.

Interoperability

Many experts (including the authors) believe the solution to the problem lies in interoperable software—seamless data sharing among building software tools. An underlying foundation for interoperable software is a general object-oriented data model of buildings—geometry, thermophysical properties, components, equipment, systems—for the building industry. The International Alliance for Interoperability (IAI), a group of building software developers and users, has constructed such a data model known as Industry Foundation Classes (IFC). After several years of development the IFC object data model now offers a common, computer-based method to define and exchange information about buildings.

Building models instead of drawing lines

Traditional 2-D CAD drawings comprise series of lines and textual information that must be interpreted *together as a group* to comprehend not only building geometry but all the other building properties. Often different interpretations lead to inconsistencies, omissions and mistakes.

In a building data model such as the IFC, building parts are defined as objects, with attributes and relationships to other building objects. A 3-D building model can contain all the pertinent information within itself: geometry in 3-D, associated definitions of materials and constructions, performance characteristics and specifications, cost, monitoring and life-cycle information, etc. Different software tools that use data from this building model obtain identical data from the same source. The figure on the next page shows a schematic of the IFC data model.

How will interoperable software help the design professional?

Interoperable software promises more productive work at the same cost. Instead of spending resources on (manual) data entry and debugging, building professionals can instead spend time using the tools. This facilitates earlier, well-

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1 Drury B Crawley is a program manager at the US Department of Energy working on building energy software tools and high performance commercial buildings.

2 Vladimir Bazjanac, PhD, is a Staff Scientist at the Lawrence Berkeley National Laboratory working on data modeling, and the development and deployment of interoperable software in the building industry.

3 Robert Hitchcock, PhD is a Staff Research Associate at the Lawrence Berkeley National Laboratory working on the development of interoperable software for the building industry.

informed decision making, which may eventually result in earlier building occupancy. Since it dramatically reduces the initial expenditure necessary to operate the tool, interoperable software is also more affordable to use.

As data are imported directly and seamlessly from the same source, they are consistent in each tool, thus the opportunity for omission or error in entry is significantly reduced. This prevents misunderstandings and mistakes that result from different data set interpretation, and eventually results in fewer construction errors and change orders. A properly maintained building model also provides a decision-making record that can minimize the urge to litigate.

Schematic of the IFC Model

What interoperable software is available today?

Software tools that use the IFCs (IFC-compatible) can now directly exchange building geometry for many building objects such as spaces and related walls, windows, and doors. Building energy simulation tools, like EnergyPlus, and cost estimating software, like Timberline's Precision Estimating (PECAD), can import this building geometry from 3-D building models that have been generated by IFC-compatible CAD programs. This eliminates the need to enter building geometry manually in these tools, dramatically reduces the cost of their use, expedites the work on the project, and eliminates errors and omissions usually resulting from multiple manual data entry.

Autodesk's Architectural Desktop (ADT), Bentley's Microstation, Graphisoft's ArchiCAD and Microsoft's Visio are examples of CAD software with interfaces to the IFC data model. With the latest versions of the data model (IFC 2.0 and 2x), compliant tools can also exchange information on building materials, as well as some cost and facilities management data. However, this capability is still under development in many of the programs. It must also be noted that the exchange of geometric data between existing IFC-compatible tools is still being tested and verified.

Current developments

Extending the IFC model to support exchange of additional building information is in progress. An HVAC extension will support exchange of non-geometric information needed for building energy performance simulation tools. HVAC, structural and facilities management extensions will be completed this calendar year and software tools that implement these extensions should be available within the next year. Pilot projects are in progress in several countries. These are "real life" projects that use IFC-compatible interoperable software tools in daily professional work and decision-making. The projects range from federal laboratory and commercial office buildings to large public auditoria and sports arenas. They are providing valuable lessons on how to effectively use interoperable software, including energy simulation tools, in daily professional work and are offering clear illustrations of benefits the industry can gain from software interoperability.

For more information on software interoperability, go to www.iai-international.org, and www.blis-project.org. See also back issues of the *Building Energy Simulation User News* -- Vol. 22, No. 4 (July/August 2001), "*EnergyPlus Interoperability: Acquisition of Building Geometry from IFC-Compatible CAD Tools.*" Also Vol. 21, No. 5 (September/October 2000), *"The Bild-IT Project: Acquiring Geometry from CAD for EnergyPlus Through the Use of Industry Foundation Classes"* and *"The BSPro COM-Server: Interoperability Among Software Tools Using Industry Foundation Classes."*

Improving The Building Design And Operation Of A Thai Buddhist Temple Using Coupled DOE-2/CFD Simulations

Atch Sreshthaputra[1], Jeff S. Haberl[2], Malcolm J. Andrews[3]
Texas A&M University, USA

In hot-humid climates, particularly in developing countries, the use of air-conditioning is becoming common in residential and commercial buildings. However, there are buildings (e.g., Thai Buddhist temples) that do not use air-conditioning systems for various reasons, including economic hardship and religious constraints. Therefore, the buildings must rely on passive cooling by means of natural ventilation to obtain comfort conditions, even though it is difficult to accomplish because of high levels of moisture in the air, which causes occupant discomfort.

Currently, the authors have been studying the thermal comfort and calculated airflow of a 100-year-old Buddhist temple located in Bangkok (Fig. 1; see Fig. 2 for the ground floor plan of the temple). The goal of this research is to improve comfort conditions inside the building by means of new design strategies and improved operating procedures. Both DOE-2.1E and a computational fluid dynamics (CFD) program, called HEATX, were extensively used in this investigation. In order to validate the simulation models, local measurements of the indoor and outdoor environmental conditions were obtained during 1999. Then, the heat transfer characteristics of this traditionally-designed temple were reviewed and compared with modern, measured designs. During the course of this study, it was found that the old temple designs maintain indoor temperatures well above acceptable comfort ranges for most parts of the year, due in part to its high-mass construction. Humidity is also a major problem that causes not only human discomfort, but also physical damages to the precious interior decorations due to mold and mildew. Unfortunately, these conditions have been made worse for the new temple design, which was constructed without proper insulation or shading (Sreshthaputra, 2002).

Figure 1: Front entrance of the case-study temple.

To simulate this, DOE-2 was used to study the ventilation effect by specifying two adjacent unconditioned spaces which include the temple space and an attic. Figure 3 shows a DRAWBDL plot of the case study temple (Huang 1994). The estimated ventilation/infiltration rates supplied to these spaces were calculated by HEATX, which was developed by one of the authors (Andrews and Prithiviraj 1997).

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[1] Ph.D. Candidate, Department of Architecture
[2] Associate Professor, Department of Architecture
[3] Associate Professor, Department of Mechanical Engineering

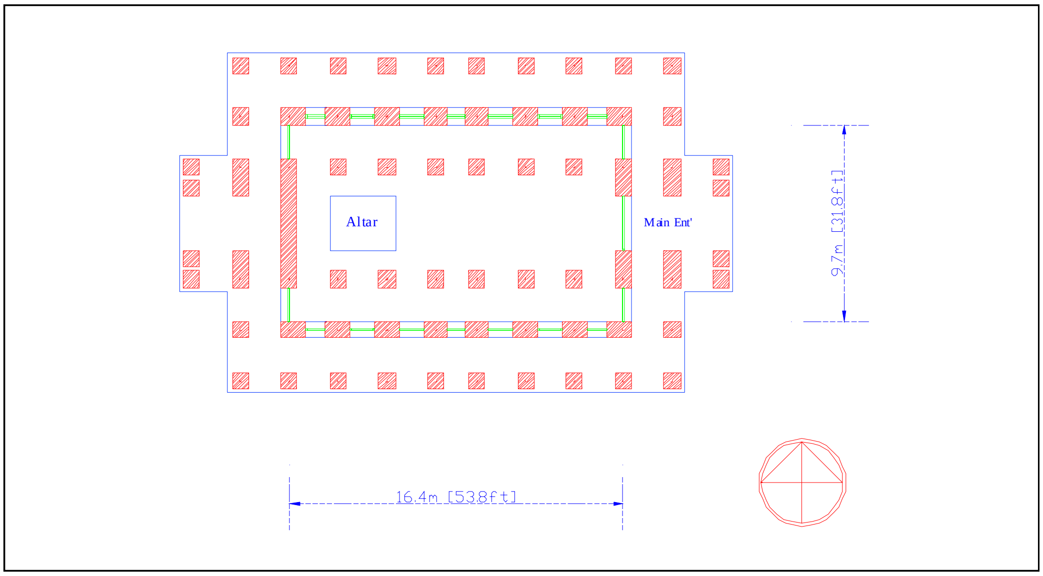

Figure 2: Ground floor plan of the case-study temple.

The HEATX code employs a modified two-equation k-ε turbulence model with source terms for turbulence generation and dissipation due to buoyancy. The formulation involves solving equations for pressure, three components of velocity, temperature, turbulence kinetic energy, and its dissipation rate, both for steady and transient problems. The total number of computational cells is 313,000, which is considered a high number of computational cells by current CFD standards. For the temperature calculations presented in Figure 5, a typical steady state computation takes two days of CPU time on a Pentium III PC computer, dedicated solely to this task.

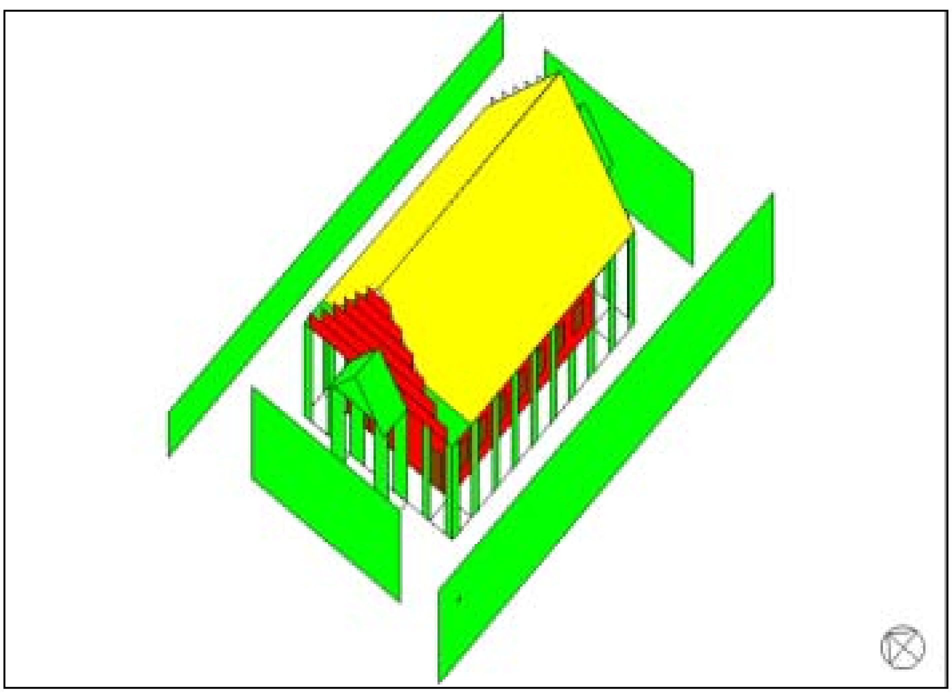

Figure 3: DRAWBDL plot of the case-study temple showing adjacent buildings.

The flowchart diagram in Figure 4 outlines the process by which DOE-2 and HEATX were combined to simulate the indoor air temperature of the case-study temple for 24-hour periods on a summer and a winter day. The whole process started with creating input files of both programs from the same building description data, measured data, and weather data. Two important variables were fed back and forth between the two programs during the calibration process. One was the amount of outside air infiltrating into the building, which was specified by the term “Air Exchange Rate (AIR-CHANGES/HR)” in DOE-2, and the other was the interior surface convection coefficient, which was called “Inside Surface Film Resistance (INSIDE-FILM-RES).”

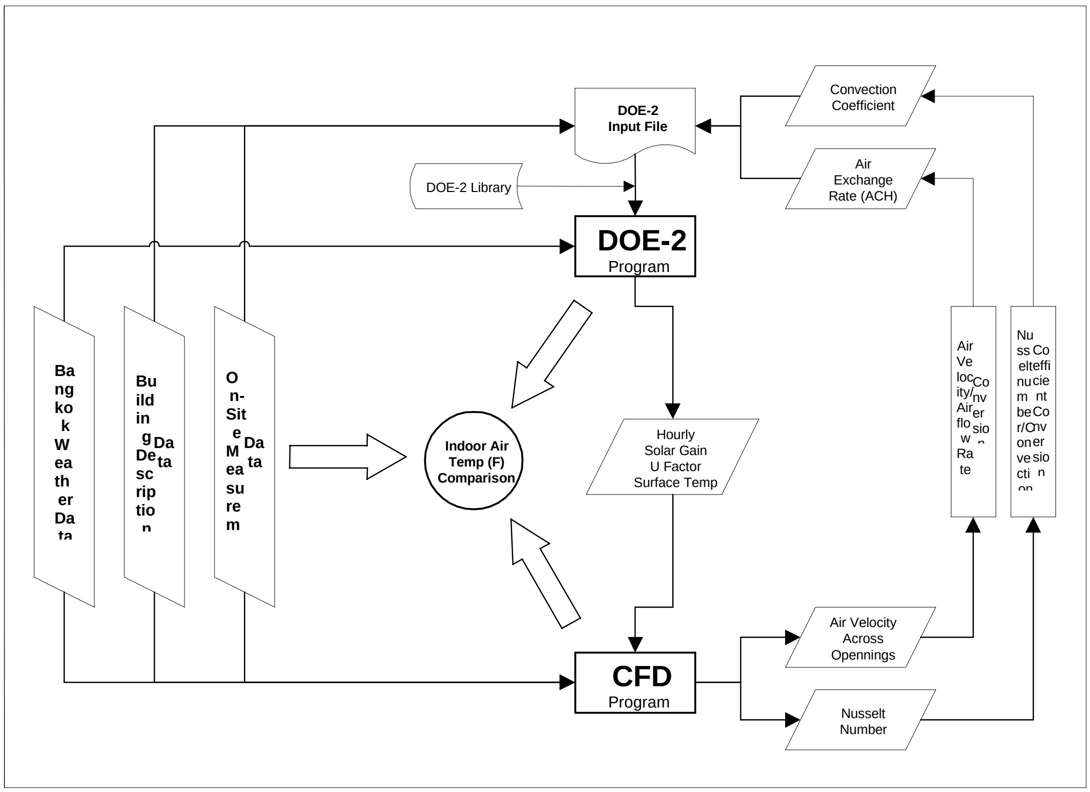

Figure 4:   Flowchart showing combined DOE-2/CFD simulations for a 25-hour period.

For the first run, the initial values of these variables were assigned based on ASHRAE recommendations. By supplying DOE-2 with these initial values, the U-factor, the hourly solar gain to walls and roofs, and the hourly surface temperature were calculated. These output variables were used for setting boundary conditions in HEATX, which then calculated the velocity of air flowing through all openings along with an average Nusselt number at each surface. Later, air velocity and Nusselt numbers calculated by HEATX were then used to calculate the airflow rate and surface convection coefficients for DOE-2, respectively. The calibration loop went on until the indoor temperature calculated by both programs agreed with the measured data.

Nonetheless, since it was impossible for this research to perform the coupled DOE-2/CFD hourly simulations for one full year (i.e., 8,760 hours) with updated values of airflow rates and convection coefficients for every time-step (i.e., every hour as wind speed and direction change), this research adopted the method that average values of air exchange rates and corresponding convection coefficients, which were obtained by the coupled DOE-2/CFD simulations, could be used by DOE-2 for the hourly calculations. Combined DOE-2/CFD simulations were performed only for two average days in summer and winter, then the average maximum air exchange rate was supplied to DOE-2 in order to perform one-year hourly simulations.

With the DOE-2 capability of generating the hourly output for one year, the simulated indoor temperatures were compared with the measured data. Once the simulated values matched well with measured data on the average, the simulation model was then declared a calibrated model and was used for further investigation in terms of different design options.

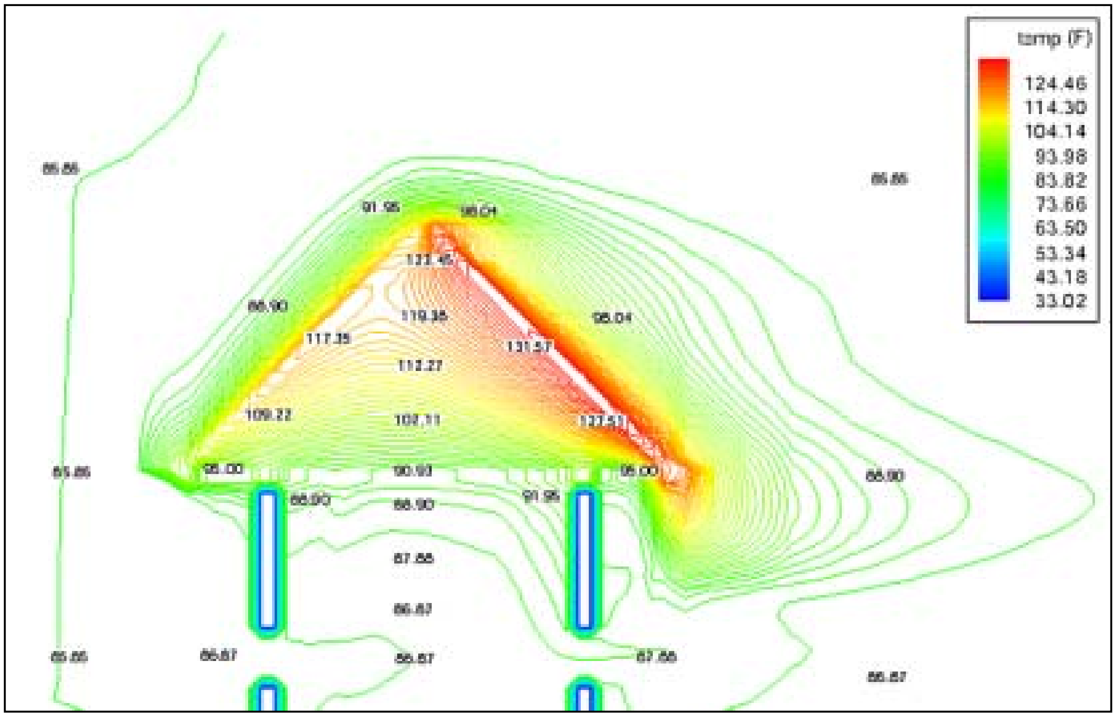

Figure 5: ***HEATX simulation results showing a temperature distribution plot of the solar heated attic of the temple.***

By comparing the calibrated DOE-2 and CFD simulations with local measurements, the overall thermal performance of the case-study temple is presented in Figure 6. It indicates that the effort to combine DOE-2 and CFD to simulate the case-study temple was successful since the simulated hourly indoor temperatures have good agreement with measured data throughout the year. The coefficient of variation in terms of root mean squared error (CV-RMSE) was used as a measurement of error between the simulated and measured values. The CV-RMSE of the simulation model is 1.83%. However, there is a systematic difference between the amplitude of the diurnal temperature swings of the measured and DOE-2 simulated indoor temperatures. This results from a number of factors. First, an average maximum air infiltration rate, calculated by a steady-state CFD simulation using the average maximum outdoor wind speed, may be slightly too high for a one-year of hourly DOE-2 simulations. This caused the DOE-2 simulated indoor temperatures to follow the outdoor temperatures and the result was more fluctuation than what really occurred inside the temple.

Second, even though the infiltration rate assigned in DOE-2 might be appropriate, variations of daily ventilation schedules of the temple may be causing this error. The ventilation schedule assigned in DOE-2 was obtained from a discussion with maintenance personnel. However, from several site visits to collect the data, it was found that sometimes the temple was closed without reason during the afternoon. This caused the indoor temperatures to have less fluctuation when compared with the DOE-2 results.

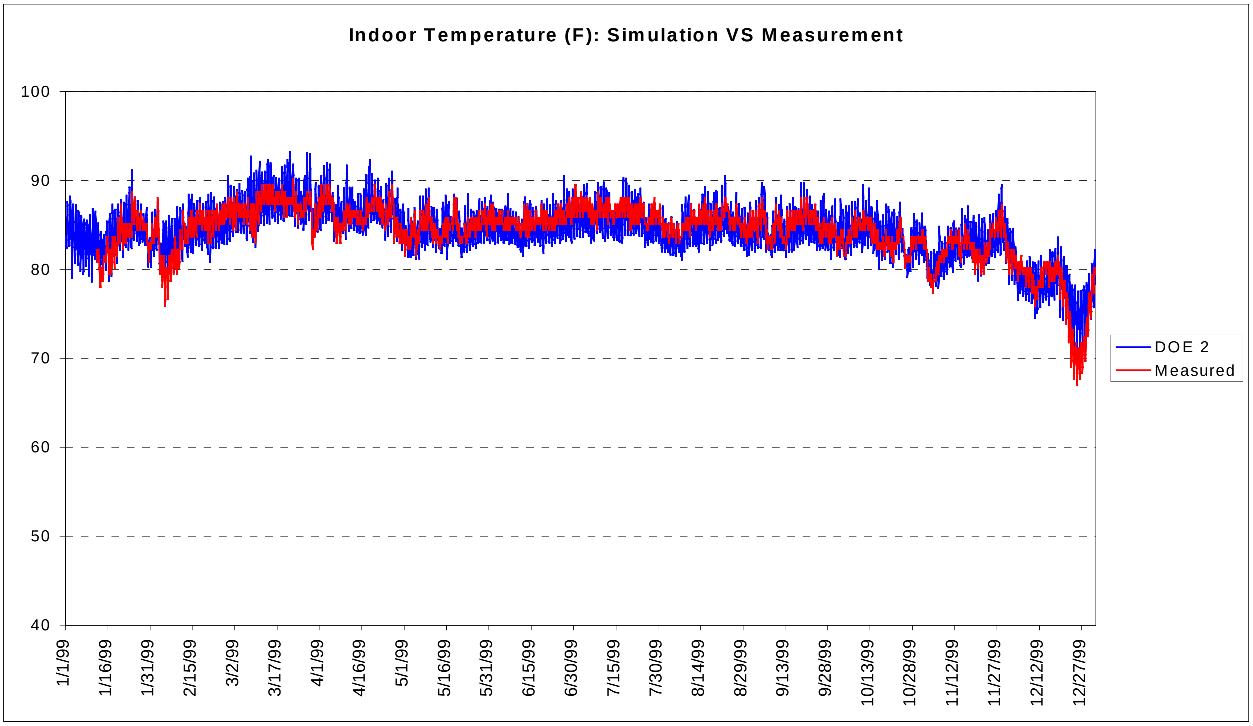

Figure 6: ***Comparison of hourly-simulated and measured space temperatures for a one-year period.***

Once a calibrated simulation model was developed, it was then used to obtain a better understanding of how the building performed thermally, including new design strategies and changes to operational modes. The effects of each design and operation strategies were then simulated with measured weather data during the same period (Royal Thai Meteorological Department 2000), and compared with the original design as presented in Figure 7.

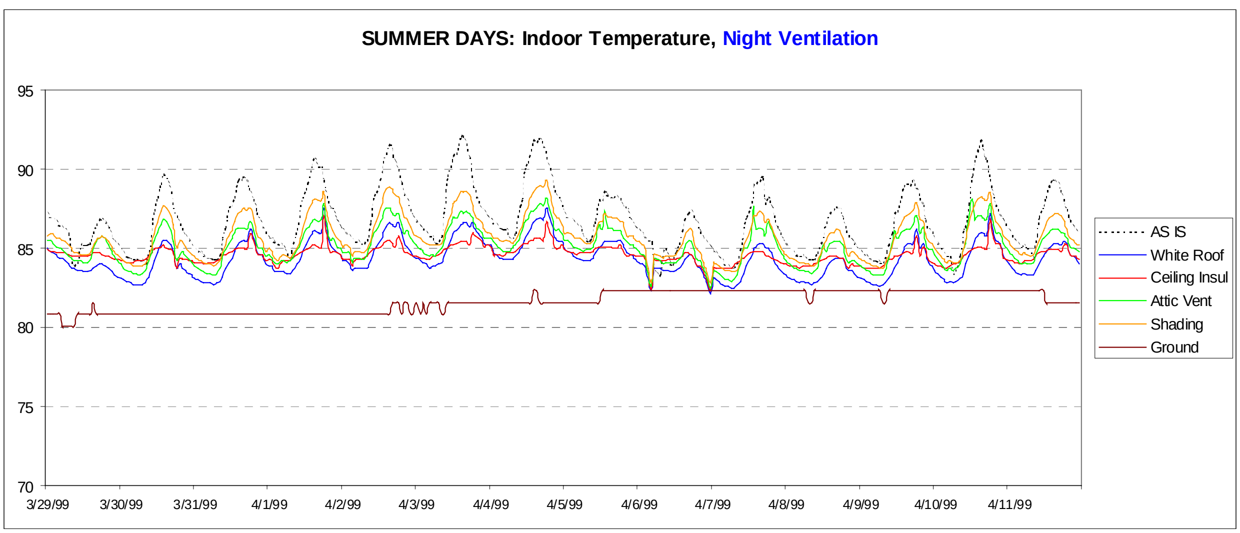

Figure 7: ***The effects of new design and operation strategies as compared with the original design. This figure shows preliminary results of the DOE-2/CFD simulations including the results of several new design strategies and the measured floor temperatures of the temple.***

Preliminary results indicated that the comfort conditions can be improved with several design and operation strategies, including: a low-absorptivity roof surface, ceiling insulation, solar shading, attic ventilation, and night ventilation of the temple space. Two prototype buildings were proposed; one constructed with high mass walls, the other with highly insulated lightweight materials. Both had white roofs, R-30 ceiling insulation, solar shadings, and daytime attic ventilation. Nighttime space ventilation with daytime vents shut was recommended for both prototypes.

Figure 8 shows the DOE-2 simulated indoor temperatures of both prototypes as compared with the original design (i.e., AS-IS). It was found that both prototypes performed a lot better than did the original design. Peak summer indoor temperatures dropped by 5-8°F. The highly insulated lightweight prototype performed better than did the high mass prototype. This investigation can lead to both an improvement of new design for future temples and, eventually, guidelines for renovating existing temples which were built more than a hundred years ago.

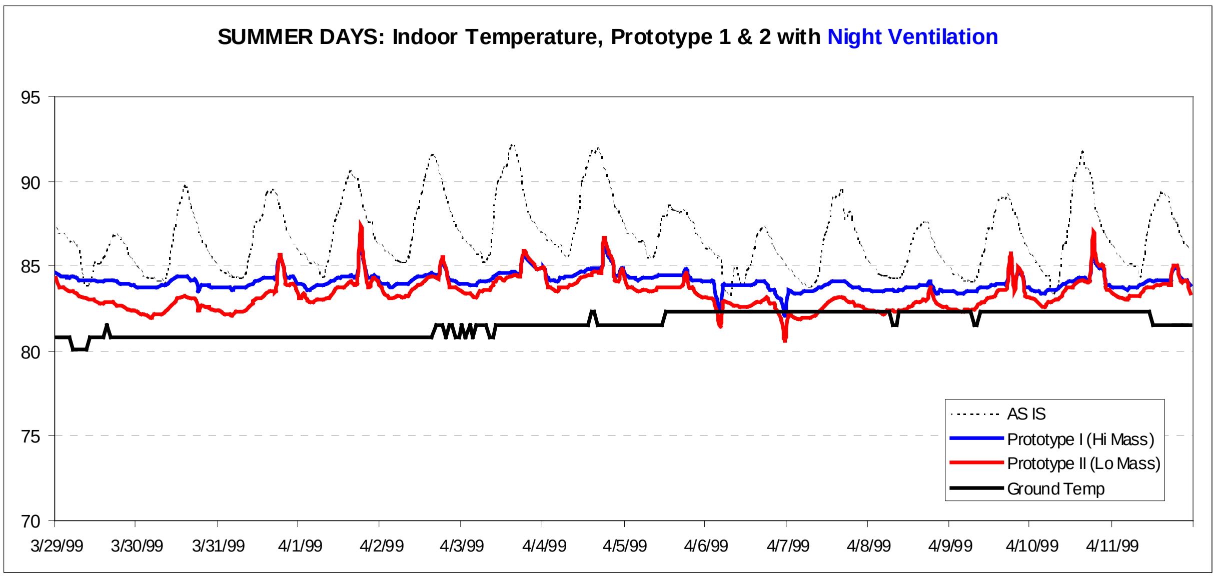

Figure 8: ***The effects of two prototype building designs as compared with the original design. This figure shows the simulated indoor temperatures of two prototypes including the measured ground temperatures of the temple.***

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This research was supported by the Royal Thai Government and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) through the Grant-In-Aid scholarship for graduate students. The computer software and instrument used for simulations and measurements were supported by the Department of Architecture and the Department of Mechanical Engineering, Texas A&M University.

Recent LBNL Reports

These reports are available from Pat Ross of the LBNL Building Technologies Program. Please fax your request to Pat at (510) 486-4089; be sure to include the LBNL number.

LBNL-50677

A Computer Simulation Appraisal of Non Residential Low Energy Cooling Systems in California

by

Norman Bourassa, Philip Haves, and Joe Huang
Building Technologies Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720-0001

Abstract

An appraisal of the potential performance of different Low Energy Cooling (LEC) systems in nonresidential buildings in California is being conducted using computer simulation. The paper presents results from the first phase of the study, which addressed the systems that can be modeled, with the DOE-2.1E simulation program.

The following LEC technologies were simulated as variants of a conventional variable-air-volume system with vapor compression cooling and mixing ventilation in the occupied spaces:

- Air-side indirect and indirect/direct evaporative pre-cooling
- Cool beams
- Displacement ventilation

Results are presented for four populous climates, represented by Oakland, Sacramento, Pasadena and San Diego. The greatest energy savings are obtained from a combination of displacement ventilation and air-side indirect/direct evaporative pre-cooling. Cool beam systems have the lowest peak demand but do not reduce energy consumption significantly because the reduction in fan energy is offset by a reduction in air-side free cooling. Overall, the results indicate significant opportunities for LEC technologies to reduce energy consumption and demand in nonresidential new construction and retrofit.

LBNL-50515

Barriers in Developing and Using Simulation-Based Decision-Support Software

by

Konstantinos Papamichael, Ph.D and Vineeta Pal, Ph.D
Building Technologies Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720-0001

Abstract

The need for proper consideration of energy-related performance aspects during building design has been identified since the energy crises of the 1970s. However, energy performance is still considered in a very small fraction of building projects, mainly because proper consideration is very expensive. It requires the use of computational software tools, which are not easy to learn and are time-consuming to use.

Several attempts have been made to facilitate the use of energy simulation tools, but none has brought a significant increase in the consideration of energy performance. Energy related performance criteria are still considered only in a small fraction of buildings and, in most cases, after most of the building design is complete.

This paper is focused on the main barriers in properly considering energy-related performance aspects in building decisions, which range from sociopolitical, to technical. The paper includes consideration of issues related to the general interest of the building industry in energy performance and environmental impact, current practice trends, modeling capabilities and performance of tools, compatibility of computational models and availability of data.

Finally, a strategy for government-industry collaboration towards removing the barriers is presented, along with the main issues that need to be resolved towards potential implementation.

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LBNL-50612

A Computational Tool for Interactive, Integrated Consideration of Energy and Lighting Performance Criteria

by

Vineeta Pal and Konstantinos Papamichael
Building Technologies Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720-0001

Abstract

One of the major impediments to the widespread use of existing simulation tools for analyzing building performance is the time and effort involved in preparing the input files and interpreting the vast quantities of output data. Furthermore, most simulation tools can only address specific areas of building performance and therefore cannot address the interactions among different aspects of building performance.

In this display presentation we will demonstrate the Building Design Advisor (BDA), an interactive computational tool that supports integrated consideration of multiple aspects of energy and lighting performance, including the energy performance of daylight-responsive lighting control systems. The user interacts with this tool through a simple graphical editor for specifying the geometry and placement of spaces, windows, shading, external obstructions, lighting fixtures, control sensors, etc. Non-geometric parameters are automatically assigned default values based on standards and codes, and may be modified by the user at any time. BDA automatically activates the relevant simulation tools when the user selects performance parameters to be computed and provides the results in a graphical form, allowing comparison of multiple design options with respect to multiple performance criteria.

This functionality and ease of use is made possible by the system architecture of the BDA that includes an object-based representation of the building components and systems, an extensible palette of simulation tools, and a process control mechanism that automatically handles the activation of multiple simulation tools and the data exchange between them. The functionality provided by these mechanisms and structure will be demonstrated through examples.

LBNL-51134

The Integration of Engineering and Architecture: A Perspective on Natural Ventilation for the new San Francisco Federal Building

by

Erin McConahey, Arup
901 Market Street, Suite 260
San Francisco, CA 94103

Phil Haves
Building Technologies Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory
Berkeley, CA 94720-0001

Tim Christ, Morphosis, Santa Monica, CA

Abstract

A description of the in-progress design of a new Federal Office Building for San Francisco is used to illustrate a number of issues arising in the design of large, naturally ventilated office buildings. These issues include the need for an integrated approach to design involving the architects, mechanical and structural engineers, lighting designers and specialist simulation modelers. In particular, the use of natural ventilation, and the avoidance of air-conditioning, depends on the high degree of exposed thermal mass made possible by the structural scheme and by the minimization of solar heat gains while maintaining the good daylighting that results from optimization of the façade. Another issue was the need for a radical change in interior space planning in order to enhance the natural ventilation; all the individual enclosed offices are located along the central spine of each floorplate rather than at the perimeter. The role of integration in deterring the undermining of the design through value engineering is discussed. The comfort criteria for the building were established based on the recent extension to the ASHRAE comfort standard based on the adaptive model for naturally ventilated buildings. The building energy simulation program EnergyPlus was used to compare the performance of different natural ventilation strategies. The results indicate that, in the San Francisco climate, wind-driven ventilation provides sufficient nocturnal cooling to maintain comfortable conditions and that external chimneys do not provide significant additional ventilation at times when it when it would be beneficial.

DOE-2

DOE-2.1E (version 119) 1,000-Zone version for Windows from ESTSC; other vendors of DOE-2 based programs are listed on our website: http://SimulationResearch.lbl.gov > DOE-2

Cost is as follows:

$ 300	U.S. Government, non-profit Educational
$ 575	U.S., Mexico, Canada
$ 1268	Japan only
$ 1075	All Other Non-U.S.

DOE-2 Documentation on a CD from ESTSC - Cost US$100

What is included on the CD?

- DOE-2 Reference Manual (Part 1)
- DOE-2 Reference Manual (Part 2)
- DOE-2 BDL Summary (2.1E)
- DOE-2 Engineers Manual (2.1A)
- DOE-2 Supplement to the Reference Manual (2.1E)

Order Software and ESTSC Documentation

Ed Kidd
NCI Information Systems, Inc.
Energy Science and Technology Software Center (ESTSC)
P.O. Box 1020
Oak Ridge, TN 37831

Phone: 865/576-1037
Fax: 865/576-6436
Email: estsc@adonis.osti.gov

Free DOE-2 Documentation (http://SimulationResearch.lbl.gov > DOE-2 > Documentation)

- DOE-2 Basics (2.1E)
- Update Package #1:
  DOE-2.1E Basics, the Supplement and BDL Summary
- Update Package #2: (Version 107, DOE-2.1E) BDL Summary and Supplement.
- Update Package #3:
  Appendix A of the Supplement.
- Update Package #4: (1000-zone DOE-2.1E) BDL Summary.
- DOE-2 Modeling Tips (pdf)

DOE-2 Basics Manual and Update Packages 1, 2, 3 and 4, not included on the ESTSC CD, consist of scanned pdf files and may be downloaded from our web site. You may also request the same information on a CD by sending email to klellington@lbl.gov.

The files need to be printed and the update pages inserted into the existing DOE-2 manuals.

Note that Update Packages are **not** cumulative and each one contains different information. You have to download all four packages to update the DOE-2 documentation completely.

DOE-2 Modeling Tips a compilation of all the "how to" articles from the *Building Energy Simulation User News* (through 2001).

DOE-2 listings are continued on the next page

Purchase DOE-2 Documentation

DOE-2 Sample Run Book (2.1E) -- The Sample Run book is the only remaining DOE-2 manual not available electronically. It must be purchased separately from NTIS; information is at http://SimulationResearch.lbl.gov > DOE-2 > Documentation

DOE-2 Training

Private or group DOE-2 courses for beginning and advanced users:

Contact Marlin Addison at (602) 968-2040, or send email to marlin.addison@doe2.com

DOE-2 Help Desk

Email, phone or fax the Simulation Research Group with your questions (klellington@lbl.gov).
Phone: (510) 486-5711, Fax: (510) 486-4089

There is no cosmetic for beauty like happiness

Building Design Advisor 3.0

Decision making through the integrated use of multiple simulation tools and databases

The **Building Design Advisor (BDA)** is a Windows® program that addresses the needs of building decision-makers from the initial, schematic phases of building design through the detailed specification of building components and systems. The BDA is built around an object-oriented representation of the building and its context, which is mapped onto the corresponding representations of multiple tools and databases. It then acts as a ***data manager*** and ***process controller***, automatically preparing input to simulation tools and integrating their output in ways that support multi-criterion decision-making. BDA 3.0 includes links to **SGE** (a grapical editor for schematic design), **DElight** (a daylighting simulation tool), **ECM** (a simplified electric lighting simulation tool) and the **DOE-2.1E** building energy simulation program.

ECM, an **electric lighting simulation tool**, is integrated through BDA with DOE-2. BDA's Schematic Graphic Editor (**SGE**) allows placement of electric lighting luminaires and specification of reference points for daylight-based electric lighting controls. Moreover, BDA has the capability of **running DOE-2 parametrically** to generate a plot that shows the relationship between effective aperture and energy requirements. There is also the added functionality of working with either **English units or Metric units**.

Current development efforts are focused on the completion of BDA 3.1, which includes computation of operating energy costs.

The BDA source code is available for licensing; if interested, please contact Dr. Papamichael at K_Papamichael@lbl.gov. To download a copy of the latest version, go to **http://gaia.lbl.gov/BDA/index.html**

For Beta Testing of BDA 3.1, contact Kosta Papamichael at k_papamichael@lbl.gov.

RELEASE OF ENERGY-10, VERSION 1.5

ENERGY-10 is a design tool for smaller residential or commercial buildings that are less than 10,000 ft^2 or buildings that can be treated as 1- or 2-zone increments. It performs whole-building energy analysis for 8760 hours/year, including dynamic thermal and daylighting calculations. ENERGY-10 was specifically designed to facilitate the evaluation of energy-efficient building features in the very early stages of the design process.

Version 1.5 Upgrades

Life Cycle Costs

A whole new capability is included to evaluate life-cycle costs. The year-by-year cash flow of the building is determined and discounted to the present value. The difference between Bldg-1 and Bldg-2 is determined in terms of net present value, NPV (the difference in life-cycle costs), internal rate of return, benefit-to cost ratio, or simple payback.

Up-to-date compiler

The entire program has been ported to 32-bit and (with the exception of the CNE thermal simulation engine) programmed in Visual C++ 6.0, the current Microsoft compiler. One benefit that users will appreciate is that it is no longer necessary to close ENERGY-10 before starting a new project.

More Wall Layers

In previous versions, you were restricted to 6 layers in a wall construction. This has now been expanded by 3, giving you the opportunity to define a 7-layer wall plus two air films.

New Graphs

Graphs are programmed in a new and powerful graphing package (Olectra).

New Reports

A Cost Summary report tabulates the results of the life cycle cost evaluation. An HVAC and EES Cost report details the components of HVAC cost and each of the EES costs. A Peak Loads report identifies the peak loads and corresponding HVAC rated capacities for the AutoSize calculations and also the peak loads and consumptions during the annual simulation showing when the peaks occurred.

Douglas K. Schroeder
1331 H Street N.W., #1000
Washington, DC 20004

Tel: 202.628.7400 ext 210
Fax: 202.383.5043
www.sbicouncil.org

Sustainable Buildings Industry Council (SBIC)

ENERGY-10 User Group at http://www.sbicouncil.org/forum

SBIC Bookstore at http://www.sbicouncil.org/store/resources.php#pubs

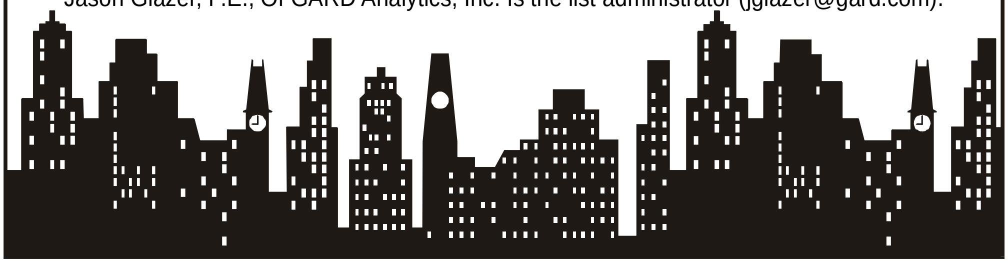
The *Green Building Guidelines* is SBIC's second generation of sustainable residential design guidelines created in cooperation with the National Association of Home Builders. Written in plain language with complementary illustrations, case studies, and check lists, the *Guidelines* is a valuable resource for builders and even buyers interested in producing or purchasing energy- and resource-efficient homes. Cost is $50; to order, go to www.sbicouncil.org.

Join the BLDG-SIM Mailing List

BLDG-SIM is a mailing list for users of building energy simulation programs like EnergyPlus, DOE-2, Trace-600, HAP, BLAST, ESP, SERIRES, TRNSYS, TASE, ENERGY-10 and others. Because building simulation professionals are located worldwide, the BLDG-SIM list is an attempt to foster the development of a community of those users. Users of all levels of expertise are welcome and are encouraged to share their questions and insights about these programs.

The web page for BLDG-SIM is http://www.gard.com/bldg-sim.htm

Jason Glazer, P.E., Of GARD Analytics, Inc. Is the list administrator (jglazer@gard.com).



The Building Energy Simulation User News is published bi-monthly and distributed electronically by the Simulation Research Group at Lawrence Berkeley National Laboratory. Direct comments or submissions to Kathy Ellington (KLEllington@lbl.gov). Direct BLAST-related inquiries to the Building Systems Laboratory (support@blast.bso.uiuc.edu).

 This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of the Building Technologies Program, State and Community Programs, Office of Building Systems of the U.S. Dept. of Energy, under Contract No. DE-AC03-76SF00098

GenOpt 1.1.2

Generic Optimization Program

GenOpt *is a multi-parameter optimization program; it automatically finds the values of user-selected design parameters that minimize a cost function, such as annual energy use, calculated by an external simulation program like EnergyPlus, SPARK, DOE-2, BLAST, TRACE, TRNSYS, etc.*

GenOpt *can be used with any simulation program that has text-based input and output. It also offers an interface for adding custom optimization algorithms to its library.*

Release of GenOpt 1.1.2

GenOpt 1.1.2 fixes problems in reading simulation output files where the objective function value is followed by a comma. Such output strings can be found, for example, in some EnergyPlus outputs.

Also, a method called 'postProcessObjectiveFunction(int, double[] f)' has been added to the file named 'Optimizer.java'. You can modify this function to easily implement post-processing of the objective function value, such as adding two outputs to seek the minimum of the sum of the two outputs.

Example files have been added to the ***GenOpt*** web page (http://SimulationResearch.lbl.gov > GenOpt) to help users set up the program to optimize EnergyPlus simulations. ***GenOpt*** input files still have the same syntax as in version 1.1.1. Therefore, your ***GenOpt*** input files are compatible with the new version.

GenOpt 1.1.2 **(with user manual) may be downloaded free of charge from**

http://SimulationResearch.lbl.gov > GenOpt

DOE-2 Bug/Change List

The entire, up-to-date bug fix and additions list for DOE-2.1E is available as a text file on our website. It's at http://SimulationResearch.lbl.gov under "DOE-2" in the left menu

The Lowdown on Downloads from Lawrence Berkeley National Laboratory

Free Downloads

BDA 2.0 (Building Design Advisor) *A beta version of 3.0 is available from vpal@lbl.gov*	**gaia.lbl.gov/BDA**
COMIS (multi-zone air flow and contaminant transport model)	**www-epb.lbl.gov/comis**
***EnergyPlus* 1.0.1** (new-generation whole-building energy analysis program, based on BLAST and DOE-2)	**www.energyplus.gov** --or-- **SimulationResearch.lbl.gov > EnergyPlus**
***GenOpt*®1.1.2** (generic optimization program)	**SimulationResearch.lbl.gov > GenOpt**
RADIANCE (analysis and visualization of lighting in design)	**radsite.lbl.gov/radiance/**
Desktop Radiance (integrates the Radiance Synthetic Imaging System with AutoCAD Release 14)	**radsite.lbl.gov/deskrad/**
RESEM (Retrofit Energy Savings Estimation Model) (calculates long-term energy savings directly from actual utility data)	**eetd.lbl.gov/btp/resem.htm**
SUPERLITE (calculates illuminance distribution for room geometries)	**eetd.lbl.gov/btp/superlite2.html**
THERM 2.1a (models two-dimensional heat-transfer effects in building components where thermal bridges are of concern)	**windows.lbl.gov/software/therm/therm.html**
VisualSPARK 1.0.1 (Simulation Problem Analysis and Research Kernel) (connect component models to simulate innovative building envelope and HVAC systems)	**SimulationResearch.lbl.gov > VisualSPARK**
WINDOW 5 (thermal analysis of window products)	**windows.lbl.gov/software/window/window.html**

Free Software / Request by Fax from 510.486.4089

RESFEN 3.1 (choose energy-efficient, cost-effective windows for a given residential application)	**windows.lbl.gov/software/resfen/resfen.html**

Web Based

Home Energy Saver (quickly computes home energy use) and ***Home Improvement Tool*** (simplified Home Energy Saver)	**hes.lbl.gov** and **hit.lbl.gov**

Purchase

ADELINE 2.0 (daylighting performance in complex spaces)	**radsite.lbl.gov/adeline/**

BLAST*news*

www.bso.uiuc.edu

Building Systems Laboratory, 30 Mech Eng Bldg.
University of Illinois, 1206 West Green Street
Urbana, IL 61801
Tel: (217) 333-3977 - Fax: (217) 244-6534
support@blast.bso.uiuc.edu

The **Building Loads Analysis and System Thermodynamics (BLAST** program predicts energy consumption, energy system performance and cost for new or existing (pre-retrofit) buildings.

BLAST contains three major sub-programs:

- **Space Load Prediction** computes hourly space loads in a building based on weather data and user inputs detailing the building construction and operation.
- **Air Distribution System Simulation** uses the computed space loads, weather data, and user inputs.
- **Central Plant Simulation** computes monthly and annual fuel and electrical power consumption.

Heat Balance Loads Calculator (HBLC)
The BLAST graphical interface (HBLC) is a Windows-based interactive program for producing BLAST input files. You can download a demo version of HBLC (for MS Windows) from the BLAST web site (User manual included).

HBLC/BLAST Training Courses
Experience with the HBLC and the BLAST family of programs has shown that new users can benefit from a session of structured training with the software. The Building Systems Laboratory offers such training courses on an as needed basis typically at our offices in Urbana, Illinois.

WINLCCID 98
LCCID (Life Cycle Cost in Design) was developed to perform Life Cycle Cost Analyses (LCCA) for the Department of Defense and their contractors.

To order BLAST-related products, contact the Building Systems Laboratory at the address above.

Program Name	Order Number	Price
PC BLAST Includes: BLAST, HBLC, BTEXT, WIFE, CHILLER, Report Writer, Report Writer File Generator, Comfort Report program, Weather File Reporting Program, Control Profile Macros for Lotus or Symphony, and the Design Week Program. The package is on a single CD-ROM and includes soft copies of the BLAST Manual, 65 technical articles and theses related to BLAST, nearly 400 processed weather files with a browsing engine, and complete source code for BLAST, HBLC, etc. Requires an IBM PC 486/Pentium II or compatible running MS Windows 95/98/NT.	3B486E3-0898	$1500
PC BLAST Package Upgrade from level 295+	4B486E3-0898	$450
WINLCCID 98: executable version for 386/486/Pentium	3LCC3-0898	$295
WINLCCID 98: update from WINLCCID 97	4LCC3-0898	$195

The last four digits of the catalog number indicate the month and year the item was released or published. This will enable you to see if you have the most recent version. All software will be shipped on 3.5" high density floppy disks unless noted otherwise.

FREE Membership in 2002!!!

International Building Performance Simulation Association USA Affiliate

The IBPSA-USA Board of Directors has waived the annual membership fee for 2002 so joining our organization is easier than ever. If you want to become a member, send an email with your name, company, mailing and email address, and phone and fax numbers to Rick Strand (r-strand@uiuc.edu). You will receive a confirmation email to indicate that you have been accepted for membership.

www.ibpsa.org

SPARK is an equation-based simulation environment that allows you to build customized models of complex physical processes by connecting calculation objects that represent system components like walls, fans, heat exchangers, chillers, ducts, mixing boxes, controls, etc. It is aimed at the simulation of innovative and/or complex building systems that are beyond the scope of whole-building programs like DOE-2 and EnergyPlus. VisualSPARK adds a graphical user interface to SPARK to simplify use of the program.

New features in VisualSPARK 1.0.2

Default preferences in setupcpp

Added support for default values for the component preferences specified in a file called default.prf and residing in the working directory. The default values are used to populate the template preference file associated with the solutio sequence generated by *setupcpp* for the problem. If the file exists upon calling *setupcpp*, the values in the file are used in place of the hard-coded default preference settings. If no such file exists, then *setupcpp* will generate a template file with the hard-coded default preferences for possible future modification by the user.

Absolute tolerance property for each problem variable

- A new variable property, `ATOL`, was added to the *SPARK* language on the `PROBE`, `PORT` and `LINK` statements in order to specify the absolute tolerance for each problem variable. The `ATOL` property should be set to the absolute value at which the variable in question is essentially insignificant.
- In *solver*, added support to load the `ATOL` property for each problem variable, thus replacing the `AbsTolerance` keyword previously specified in the problem.prf file at the component level.
- Improved the input handler to allow it to read in properties of problem variables along with the variable values at the specified time stamps. The syntax to specify the property `ATOL` of the variable `X` is the qualified name `X:ATOL`. The input handler can read in values for any variable properties, namely `MIN`, `MAX`, `ATOL` and `INIT`.

Sparse linear solution technique

- Added sparse linear solution method based on the C library *umfpack* (http://www.cise.ufl.edu/research/sparse/umfpack) v3.2 by Tim Davis. This new solution method is selected by specifying the value 4 for the key `MatrixSolvingMethod` in the problem.prf file. It does not rely on vendor-specific BLAS routines but instead on vanilla C code, thus ensuring portability of the *SPARK* program.
- Drastic gains in calculation speed by many orders of magnitude have been observed on large problems for which the Jacobian matrix is typically more than 90% sparse.

Full affine invariant scaling scheme

Replaced previous scaling schemes with a single scaling scheme that achieves fully affine invariant scaling in both the variable space and residual space. This makes *solver* less sensitive to changes in the variable units and to formulations where the variables show very different orders of magnitude. If convergence difficulties are encountered with a particular problem, the full scaling scheme should be selected in the problem.prf file to improve the numerical behavior of *solver*.

Automatic Jacobian refresh strategy

- Added value 0 as a possible choice for the `TrueJacobianEvalStep` key in the problem.prf file. The value 0 indicates that the Jacobian matrix will be refreshed automatically by the solver code whenever it is needed to ensure robust and fast convergence. The refresh strategy is based on the convergence behavior of weighted residual and increment norms between successive iterations.
- For values larger than zero, the key `TrueJacobianEvalStep` still specifies the iteration frequency at which the Jacobian should be reevaluated.

Statistics log file

At the end of the simulation, *solver* generates a log file with performance statistics about the solver operation. In particular, you can find information on :

- the preference settings used for the simulation for each strong component;
- the average sparsity of the Jacobian matrix and the number of times it has been refreshed; and
- the operation of both the linear solver and the nonlinear solver with average calculation times.

This information can be used to compare the computational efficiency of solving models with different formulations or different preference settings.

Problem driver API

The problem driver application programming interface (API) added to *VisualSPARK* 1.0.2 allows an advanced user to:

- customize the sequence of operations to re-solve the same problem,
- manage and solve multiple problems,
- retrieve solution values and specify new inputs for a new simulation of the same problem, and
- change runtime parameters (e.g., to perform sensitivity analysis).

We have also modified the main.cpp file that implements the main *SPARK* driver function to use the new set of API. Comprehensive documentation on how to write such a problem driver function is available at http://simulationresearch.lbl.gov.

Changes

Documentation

- Merged glossary of terms between the *SPARK Reference Manual* and the *VisualSPARK Users Guide*.
- Enforced text conventions throughout the documentation to better distinguish the different elements of the *SPARK* language.

Parser

Discontinued usage of the keyword `UPDATE_FROM_LINK` in `LINK`, `PORT` and `PROBE` statements and replaced it with the keyword `INPUT_FROM_LINK` that better reflects its behavior

Solver

Improved convergence strategy

In order to ensure that badly-scaled systems are solved with satisfactorily precision, we now force the convergence check in the non-linear solver to occur in the variable space, i.e. solely based on the increments value, after the first iteration. This represents a change from *VisualSPARK* 1.0.1 where a successful residual check carried out even after the first iteration was a sufficient condition to stop the iteration. The convergence test is stricter and more robust, especially for problems with variables with very different order of magnitudes.

Variable scales based on individual absolute tolerances

The introduction of the `ATOL` property in the *SPARK* language allows to consider an individual absolute tolerance for each problem variable, as opposed to for each strong component as in *VisualSPARK* 1.0.1. The convergence check in the nonlinear solver and the computation of the cost function used with the backtracking Newton schemes have been updated to support the new absolute tolerance mechanism.

Graphical User Interface

- Changed default wall clock settings to year 2002
- Changed title of button from "MODIFY" to "MODIFY CLASS PATH"
- Added support for new solver features in the component preferences editor
- The absolute tolerance entry has been removed from the component preferences editor because it is now specified on a
- variable-by variable basis.
- Added the sparse LU matrix solving method.
- Reduced scaling types to "None" and "Full" in place of the former scaling options in *VisualSPARK* 1.0.1.

Bug Fixes

Documentation

Corrected typo in description of the macro links where the single quote ′ used to prefix an object name in a hierarchy of objects was replaced with the single quote ` as prescribed by the *SPARK* syntax.

```
obj1’obj2’obj3~linkname
```

has been replaced with

```
obj1`obj2`obj3~linkname
```

Parser

- Keyword `PARAMETER` did not work when there were more than one `PARAMETER` statement in one class.
- Fixed infinite loop bug caused by aliased variables. Aliased variables are created in `LINK` statements that do NOT contain obj.port connections.

Setupcpp

Write out error message showing the calling syntax if *setupcpp* is executed with no argument at the command-line instead of crashing.

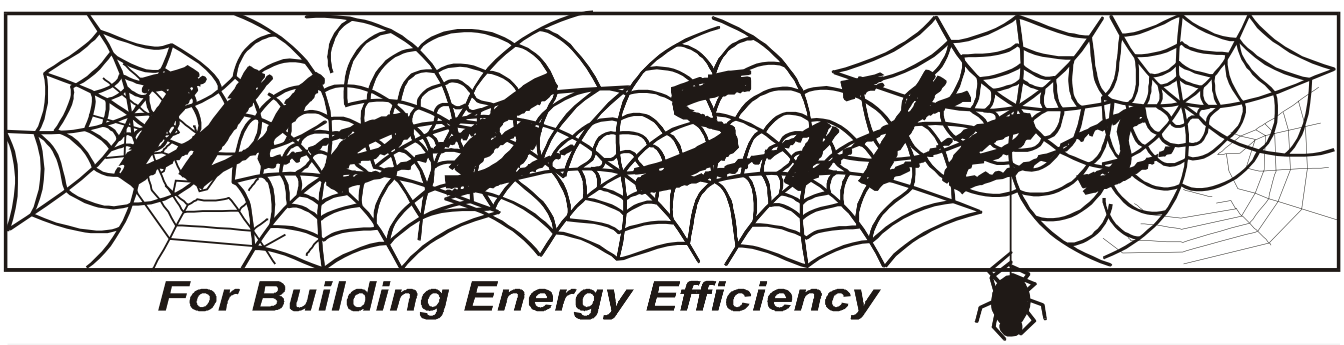
Solver

Fixed bug in *sparksym* for the *mathomatic* symbolic solver that limited to 14 the number of variables allowed in the equation to be processed.

Download VisualSPARK 1.0.1 from

http://SimulationResearch.lbl.gov > VisualSPARK 1.0.1

VisualSPARK 1.0.2 is expected to be available September/October 2002



http://www.coe.berkeley.edu/calview/ | **Distance Learning (E-Classes) in Engineering**

If you need to finish your degree or stay abreast of emerging technologies while still working full time, consider distance learning or “E-classes.” The University of California at Berkeley (UCB) offers E-classes through its Cal VIEW program. Go to the Cal VIEW home page for more information and to follow the links to other participating institutions and employers.

PG&E Fall 2002 Programs

Pacific Gas and Electric Company™
WE DELIVER ENERGY.℠

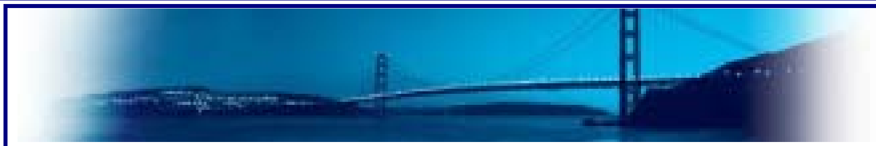
To register call the Pacific Energy Center (at least one week in advance) 415.973.7268 or go to www.pge.com/pec

HVAC

September 12	**Chilled Water Plant Retrofits** ◘ This program includes techniques for the identification and evaluation of retrofit measures for existing chilled water plants, including pumps, chillers, towers, and controls.
September 13	**Simulation of Chilled Water Plants** ◘ This follow-up session to the Chilled Water Plant Retrofits class held on Thursday, September 12, is a high-level program for software developers and those with advanced simulation skills. It covers simulation techniques used to evaluate chilled water plants, including pumps, chillers, towers, and controls. The instructors will address two subject areas: fundamental equipment models (pumps, towers, and chillers) and the application of these models in whole-plant simulations.
October 9	**Energy Efficient Design of Cleanroom Facilities** ◘ A recent study by Lawrence Berkeley National Laboratory found that cleanroom HVAC energy alone accounts for roughly 1,200 MW of load in California. cleanroom facilities have energy intensities of 75 to 150 W/sf, a load well over 10 times the energy intensity of an office building. HVAC energy typically represents between 30% and 50% of all energy used in a cleanroom facility. Lawrence Berkeley National Laboratory (LBNL) estimates the maximum efficiency potential of HVAC improvements in cleanrooms to be 85%.
October 22	**Underfloor Air Systems** ◘ HVAC systems using Underfloor Air Distribution (UFAD) are increasingly being designed into both market-rate and green building projects.
October 24	**HVAC for Architects: a Primer and Update** ◘ This class begins with the fundamentals of heat transfer through building systems (e.g., glazing and insulation), a review of load calculations, psychrometrics, and the dynamics of thermal comfort. We will discuss applications of a variety of HVAC equipment, system types, and controls, both conventional and non-conventional, including the challenge of balancing owner's needs and system efficiencies. We will tour a working HVAC system. We will also cover an HVAC perspective of sustainability, LEEDS certification, code issues, and systems commissioning.

WHOLE-BUILDING PERFORMANCE

October 23	**Benchmarking and CAL-ARCH** ◘ This seminar will address the concept of benchmarking and issues concerning building-to-building energy use comparisons. The discussion will include two benchmarking tools: EPA/DOE's nationally based tool and Lawrence Berkeley National Lab's California-based CAL-ARCH.
November 7	**Preliminary Energy Audits** ◘ This introduction to energy audits will cover billing data analysis, strategies for identifying energy conservation opportunities, and cost and payback calculations. During the afternoon part of this program, students will conduct a "mock audit." This class is geared toward facility personnel interested in conducting "walk-through" audits.
November 19	**Life Cycle Cost Analysis** ◘ This class covers the full environmental life cycle cost analysis: the balancing of environmental, social, and economic factors while understanding and acknowledging building and system efficiency, longevity, and durability.



PG&E Fall 2002 Programs

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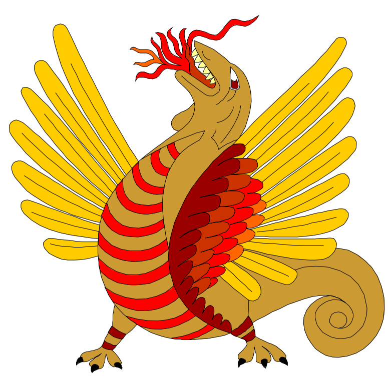
To register call the Pacific Energy Center (at least one week in advance) 415.973.7268 or go to www.pge.com/pec

ARCHITECTURE

October 24	**HVAC for Architects: a Primer and Update** (See description under HVAC)
October 30	**Solar Geometry** ◾ Fundamental principles used to locate the sun in the sky at different times of day and year and explain why sun location is essential to climate responsive design;solar azimuth, altitude, and profile angles; declination angle and its effect on seasonal change; atmospheric effects; the difference between solar time and clock time; the impact of a site's longitude and latitude; and how to interpret a sun path diagram.
October 30	**Designing Shading Devices** ◾ Learn how to design a shading device and know precisely when it will and will not block direct sunlight. Solar Geometry (October 30) is a prerequisite.
October 31	**Advanced Daylighting in Practice** ◾ This program will address advanced issues and methodologies in daylighting design and evaluation. Daylighting fundamentals will NOT be reviewed in this advanced program.

LIGHTING

September 17 **October 15**	**Lighting Fundamentals** ◾ Basic concepts, terminology, light and color theory, electric light sources, luminaire design, controls, calculations, and economics.
September 24	**Lamp and Ballast Performance** ◾ Discussion of the performance characteristics of lamps and ballasts operating in different luminaires and control systems. This is an advanced technical presentation geared toward senior specifiers, engineers, and agents doing commercial lighting work
October 10	**Task and Ambient Lighting** ◾ Task lighting has the potential of not only saving energy but providing higher quality lighted environments. This class covers options for luminaire selection, illuminance, and luminance levels, control systems, and strategies for doing integrated design based on recent local demonstration projects.



Run for safety, foolish pedestrians!