Building Energy Simulation

User News

For Users of DOE-2, SPARK, BLAST and their Derivatives

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What's New?

❁ **Changes ahead for the *User News***

In the next issue of the Building Energy Simulation *User News* we will present an updated and expanded Directory of DOE-2 Program Related Software and Services. In November, 1997, we sent each vendor of a commercial version of DOE-2, or of a utility program used with DOE-2, a survey. Information received from the vendors will serve to standardize the program descriptions in the Directory. Also, the front page of the newsletter will undergo a facelift.

❁ **Green Building Challenge '98**

According to the Royal Architectural Institute of Canada's *Advanced Buildings Newsletter (see Vol. 1, No. 19 December 1997),* DOE-2.1E was selected as the program of choice for the Green Building Challenge '98 (GBC '98) assessment. Three buildings were chosen for detailed assessment using the GBC '98 assessment framework. The design team for each building will now begin to collect data and then carry out energy simulations. Each national team will carry out the assessment using the computerized system developed for GBC '98. Results will be reported at the GBC '98 conference in Vancouver in late October 1998. To subscribe to the newsletter, contact Nils Larsson via fax at (613) 232-7018.

What's New? Is continued on p. 11

What's Inside?

The *Building Energy Simulation User News* is published by the Simulation Research Group at LBNL with cooperation from the BLAST Support Office at the University of Illinois. Direct comments or submissions to Kathy Ellington, Editor, MS: 90-3147, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, or e-mail kathy@srge.lbl.gov or fax us at (510) 486-4089. Direct BLAST inquiries to the BLAST Support Office, phone (217) 333-3977, support@blast.bso.uiuc.edu

EnergyPlus

*The Merger of BLAST and DOE-2**

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Introduction

The Federal Government, as the largest owner and operator of buildings in the United States, has long been aware of the importance of energy conscious building design and operation. Energy conscious engineering has the potential to save building owners and tenants millions of dollars and contribute to the conservation of vital natural resources. In an effort to promote energy efficiency, both DOD and DOE have separately funded the development of building energy analysis tools since the 1970s.

At the outset, both research efforts charted separate courses toward the same goal: a robust and comprehensive building energy analysis program. There was no way of knowing *a priori* which path would achieve the goal; therefore, it was prudent to fund multiple development efforts toward the same end. As it turned out, both research projects succeeded in producing useful energy analysis tools. The DOD effort produced the Building Loads Analysis and System Thermodynamics (BLAST) program that has its origins in the NBSLD program developed at the US National Bureau of Standards (now NIST). The DOE effort produced the DOE-2 program that has its origins in the Post Office program written for the US Post Office. The two programs are comprised of hundreds of subroutines each designed to solve a specific problem in achieving the overall goal. In some cases, the subroutines developed by the DOE-2 team were more accurate. In other cases, the subroutines developed by the BLAST team were more accurate.

The research initiative outlined in this paper describes the current efforts to consolidate the research and development gains of the last two decades. The name chosen for the new program is EnergyPlus. The goal is to take the best features and capabilities of BLAST and DOE-2 and combine them in a new program. Many new building technologies that cannot be evaluated by either BLAST or DOE-2 will be accessible with the new tool. In addition, a number of building simulation models that today can only be used by researchers will be included in the new program.

* For the complete text of this paper, please refer to the proceedings of IBPSA's Building Simulation '97, held September 8-10, 1997, in Prague, Czech Republic.

The Structure of EnergyPlus

Overall Program Structure

EnergyPlus will be structured using a free-format input file that contains a complete object-based description of the building and HVAC systems. This input file will be of a form that can be produced from the DOE-2 Building Description Language (BDL) file, the BLAST input file, or using preprocessing agents which may be developed in the future.

The building simulation will be based on the heat balance engine from IBLAST, a research version of BLAST with HVAC systems integrated into the building simulation. In order to provide maximum flexibility, an HVAC engine will be developed to handle the communication between the heat balance engine and the various HVAC modules, including DOE-2 and BLAST template systems, SPARK and HVACSIM+ systems, and other systems that may be developed in the future. The HVAC manager will also manage data communication between the HVAC modules and the input and output data structures.

The calculation engine will write results into an output data structure accessible to output post-processing agents. The output data structure will be simple yet complete so that interface developers can easily access the results of the simulation without modifying the calculation engine. The overall program structure is summarized in Fig. 1.

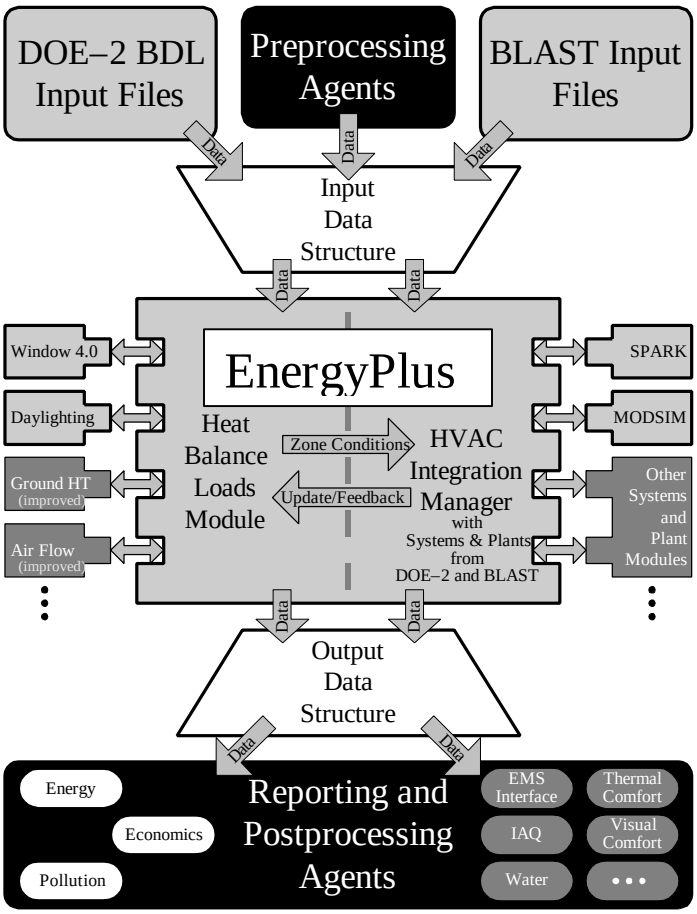

Figure 1: Simulation Overview

Solution Technique: Integrated Simulation

There is strong consensus in the design community that a tool with additional capabilities is needed. Recent user surveys by both DOE and DOD indicated strong support for the project. This is in large part due to the inclusion of integrated simulation capabilities in the new program. EnergyPlus will utilize the IBLAST integrated solution technique to correct the most serious deficiency of the BLAST and DOE-2 sequential simulations — the inaccurate prediction of space temperatures. Accurate prediction of space temperatures is crucial to energy efficient system engineering. System sizes, plant sizes, occupant comfort and occupant health are all dependent on space temperatures.

Integrated simulation allows engineers and architects to evaluate a number of energy saving measures that cannot be simulated adequately with either DOE-2 or BLAST. These include:

- "Free cooling" using outside air
- Realistic system controls
- Moisture adsorption and desorption in building elements
- Radiant heating and cooling systems

Program Elements to be Included

In addition to providing users the capability of using either BLAST or DOE-2 input formats, EnergyPlus will incorporate features from both programs into the calculation engine, as shown in the following table

Source of EnergyPlus Program Elements

Concepts to be taken from IBLAST		
Simultaneous Solution Technique	Heat Balance Engine	Coil Models
Combined Heat and Mass Transfer	Interior Convection	Internal Mass
Radiant Heating and Cooling	MODSIM Connection	Thermal Comfort
System and Plant Models		
Concepts to be taken from DOE-2		
Daylighting	SPARK Connection	Advanced Fenestration
System and Plant Models	Switchable Glazing	Sky Models
Input Function Capability		
New Features		
HVAC Water and Air Loops	Interzone Airflow	
Implied New Programming for Infrastructure		
New Reporting Mechanism		

Simulation Management

At the outermost program level, a Simulation Manager Module (shown schematically in Fig. 2) controls the entire loop structure of the simulation. This includes all of the simulation loops from the sub-hour level up through the complete simulation period, which may be a season or a year or several years. The actions of the individual simulation modules are directed through simulation status flags. These flags tell the simulations to take certain actions such as initialization, reporting or record keeping.

The Heat and Mass Balance Engine

The EnergyPlus program will incorporate a heat balance model for building thermal zone simulations. Several fundamental assumptions are implied in the formulation. The most fundamental of these is that the air in the thermal zone can be modeled as well-stirred. This

means it has a uniform temperature throughout the zone because it mixes by motion within itself. There is ongoing research into more complex models lying somewhere between the well stirred model and a full CFD calculation. The EnergyPlus modular structure will allow these models to be included into an energy simulation so their overall effect on can be evaluated from different viewpoints.

The other major assumption in the current heat balance model is that the surfaces of the room (walls, windows, floor, etc.) can be treated as entities having:

uniform surface temperatures,
uniform long and short wave irradiation,
diffuse radiating surfaces, and
one-dimensional heat conduction.

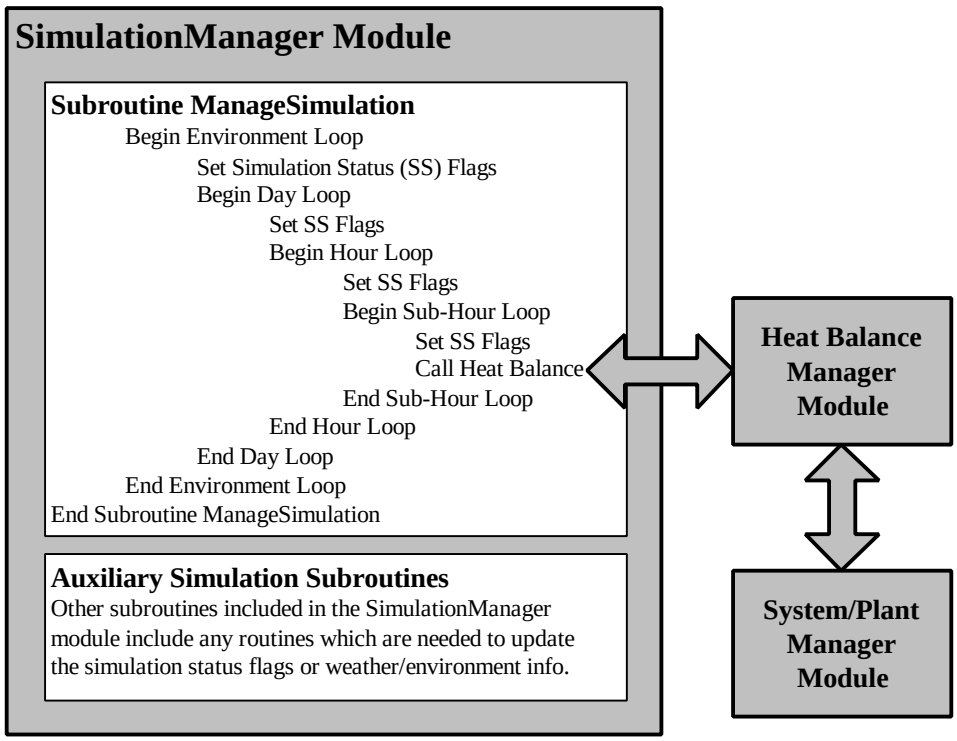

Figure 2: Simulation Manager

Within the framework of these assumptions, the current heat balance model can be constructed out of four distinct processes:

The outside face heat balance.
The wall conduction process.
The inside face heat balance.
The air heat balance.

The air heat balance also implies an air mass balance which takes into account various mass streams (exhaust air, infiltration, etc.). The relationships between the four fundamental processes are shown schematically in Fig. 3. Each of the fundamental processes is shown in a rounded box in the figure. The energy flow is indicated with arrows. If an energy exchange is taking place, the arrows point in both directions.

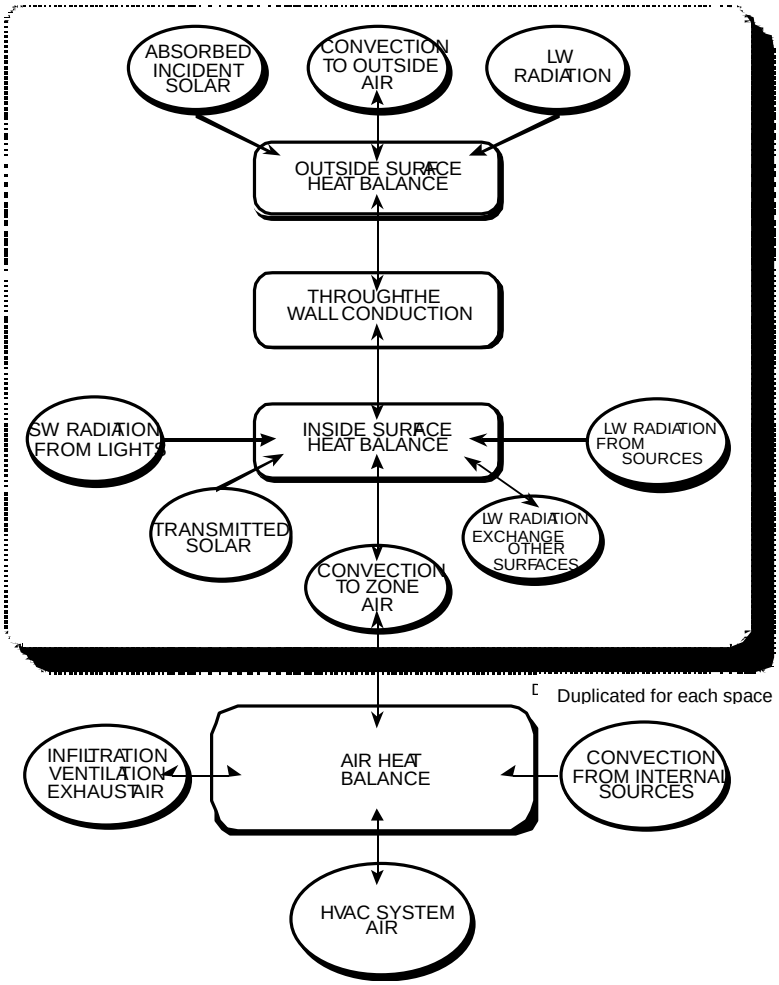

Figure 3: Heat Balance Solution Technique

The processes depicted in Fig. 3 are for an opaque surface. A transparent surface would be similar except the absorbed solar energy would be split into an inward and an outward flowing fraction. These, in turn, would participate in the corresponding surface heat balances. Except for the air heat balance, the processes shown are repeated for each surface in the space.

The HVAC Engine

The sequential simulation of building, air distribution system and central plant found in DOE-2 and BLAST imposes rigid boundaries on the program structures. The simultaneous solution technique used in EnergyPlus allows for the redrawing of those boundaries.

The schematic in Fig. 4 visualizes a typical system in the context of the EnergyPlus simulation. The HVAC systems have been divided into three blocks on the basis of information flow. The goal was to minimize the information flow paths between blocks so that data could be localized to the greatest extent possible. The heat extraction block represents the interaction with the heat balance engine. This is indicated by the squares labeled "zones". The schematic shows only two zones per system type, and two system types, but these numbers can be increased arbitrarily. The information that is passed between the interface block and the heat extraction

block consists of airflow rates, enthalpies, and temperatures. This is the information needed by the air balance part of the heat balance engine.

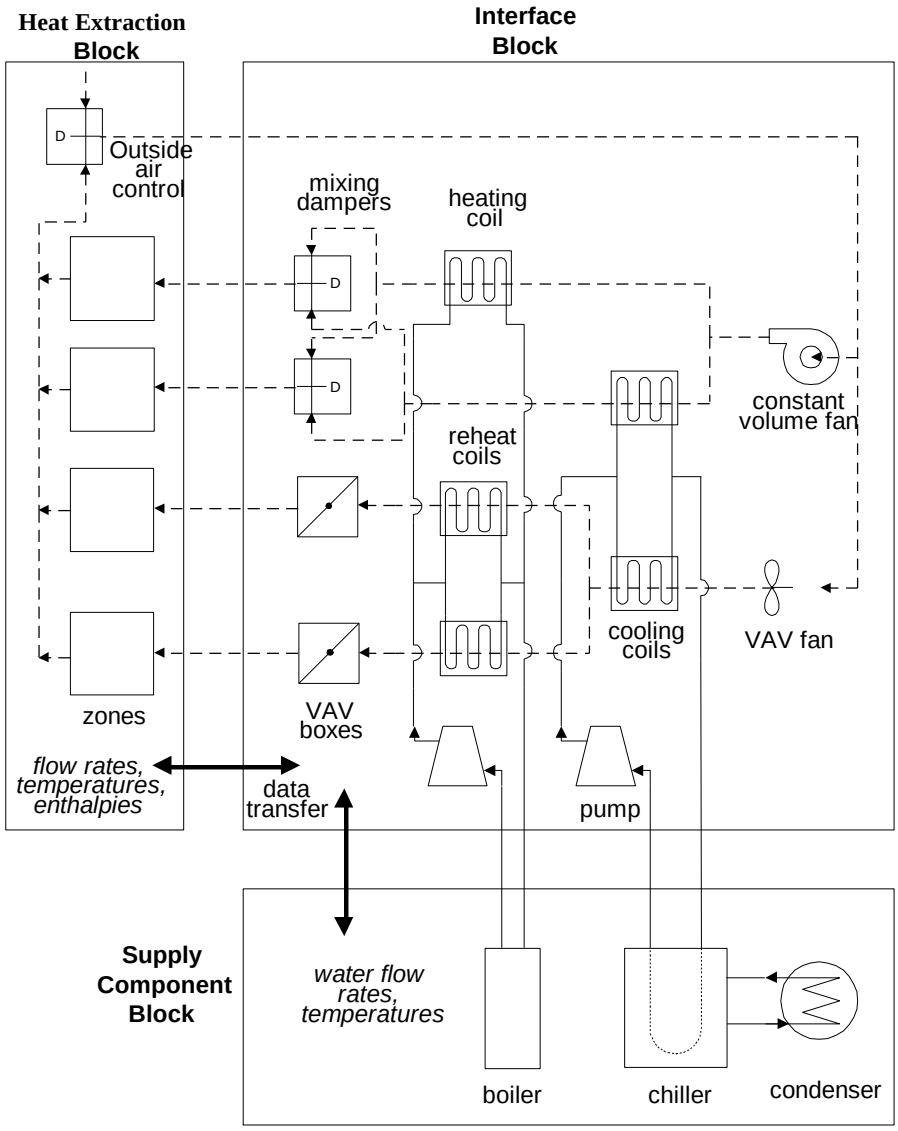

Figure 4: Schematic of Representative HVAC Simulation

The supply component block contains the code to simulate the primary energy components such as boilers and chillers. Again, the information passed to the interface block consists of flow rates and temperatures of a fluid which could be water, brine, refrigerant or other heat transfer medium.

The interface block contains the routines necessary to simulate the pumps, fans, coils, and airflow control devices. Of these, the coil simulation is the most difficult, and a modular structure within the block allows alternative coil models to be substituted easily.

The EnergyPlus HVAC simulation will be based on “water distribution loops” and “air distribution loops” rather than equipment types. This structure results in a blurring of the traditional boundaries between the building, the air distribution system and the central plant.

Software Development Plan

Programming Goals

FORTRAN90 (F90) was selected as the programming language for EnergyPlus for two reasons:

- Both BLAST and DOE-2 were written in previous versions of FORTRAN. Thus the code can move by evolution to the new language.
- F90 allows movement toward an object-based simulation by providing a modular structure.

In the context of this development, F90 refers to the full American National Standard FORTRAN 90 language as defined in the American National Standard Programming Language FORTRAN 90, ANSI X3.198-1992 and International Standards Organization Programming Language FORTRAN, ISO/IEC 1539:1991(E). Two subclasses of code will be allowed in the program:

FORTRAN90 Strict	Code that adheres to at least the FORTRAN77 standard and includes all new features of FORTRAN90.
FORTRAN90 Pure	Code that does not contain any of the features which have been ruled obsolete by the FORTRAN90 standard.

Three types of code may coexist in any particular version of the program at one time:

Legacy Code	Program code from IBLAST and DOE-2 that will be rewritten, but without algorithm changes, for reasons of time constraints, testing considerations, etc.
Reengineered Code	Concepts that have been reengineered based on first principles and then modified to fit the proposed guidelines agreed upon by the team members. The starting point for reengineered code is capabilities from either IBLAST or DOE-2.
New Code	

However, while these types of code will coexist in the EnergyPlus source, different expectations on the relative “purity” of the code will be enforced. All legacy code that is included in EnergyPlus must be at least F90 strict. Mildly reengineered code (near legacy) which has not undergone any algorithm changes (only inclusion in a module, renaming of variables, etc.) will be allowed as long as it conforms to the F90 strict test. Reengineered code that has been modified significantly and all new code will be required to conform to the F90 pure standard.

Modularization of the Code

In order to make it easy to extend the basic capabilities of EnergyPlus, the developers are following a modularization process that results in a more object-oriented structure. Three types of modules are being used: modules that contain data only, modules that contain both data and procedures, and some modules that only contain procedures. The data-only modules are used to make global data available to modules throughout the code. The data-plus-procedure modules are the workhorses of the simulation, and the procedure-only modules supply utility functions. In order to make the modularization possible it is necessary to incorporate a series of manager modules whose function it is to control the overall execution of the program. One of these modules, the simulation manager was described previously.

The Reengineering Process

The modularization described in the previous section involves a major restructuring of the code contained in either DOE-2 or BLAST. Such a restructuring could result in major rewrites involving a long development time period, and very extensive testing to ensure the new code performs as intended. However, because the development team has chosen Fortran90 as the language with Fortran77 as a subset, the development can proceed using a process which we call Evolutionary Reengineering (ER). This is a newly-developed process that incrementally moves from old unstructured legacy code to new modular code by incorporating the new code with the old. The existing code retains its capability to interface with the user input data, and is extended to generate parameters needed by the new code modules. In this way the new modules can be verified without having to completely replace the entire functional capability of the old program with new code before any verification can take place. As the process proceeds, the parameters being supplied by old routines can be supplanted by those available from new routines and new data structures. This makes the transition evolutionary, and permits a smooth transition with a greater capability for verification testing.

The process is shown schematically in Fig. 5 as a series of four stages. The first stage is the starting point with legacy code and traditional input and output. The second stage, which could consist of several sub-stages, incorporates new structured code with the legacy code. This new code receives all needed inputs from the legacy code, and produces only developers' verification output. This stage is considered complete when it includes the fundamental initial modules, and has defined interfaces for new plug-in modules. In the third stage the new input data structure is included to supply input to the structured code modules, which have been algorithmically verified. In the fourth stage, the new output data structure is incorporated, and the transition is complete.

Simulation Input file Concepts

While both DOE-2 and IBLAST have structured input file definitions that have grown over time, EnergyPlus has been designed as a product for the "future". In order to maintain the possibility of accepting simulation inputs from many sources, such as CADD systems, programs which also do other functions, and similar pre-processors that have been written for BLAST and DOE-2, we have chosen to keep the actual input file very simple. It is not intended as the main interface for the end-user. We are encouraging the private sector to create a variety of user-friendly interfaces for EnergyPlus. The actual input file, while readable, will be cryptic and definitely not "user-friendly".

The input file will have words that denote "objects" of the building simulation, such as WALL, MATERIAL, LIGHTING, SYSTEM, HEATING COIL, etc. Following each object will be a list of values that describes to EnergyPlus the intentions for that item in the simulation. By working with outside interface developers, we intend to keep this file easy to produce from most programs that building designers will use. In addition, with the very loose structure (which will

be more rigorously depicted in a Data Dictionary), we intend that new module developers will find it easy to add capabilities to EnergyPlus.

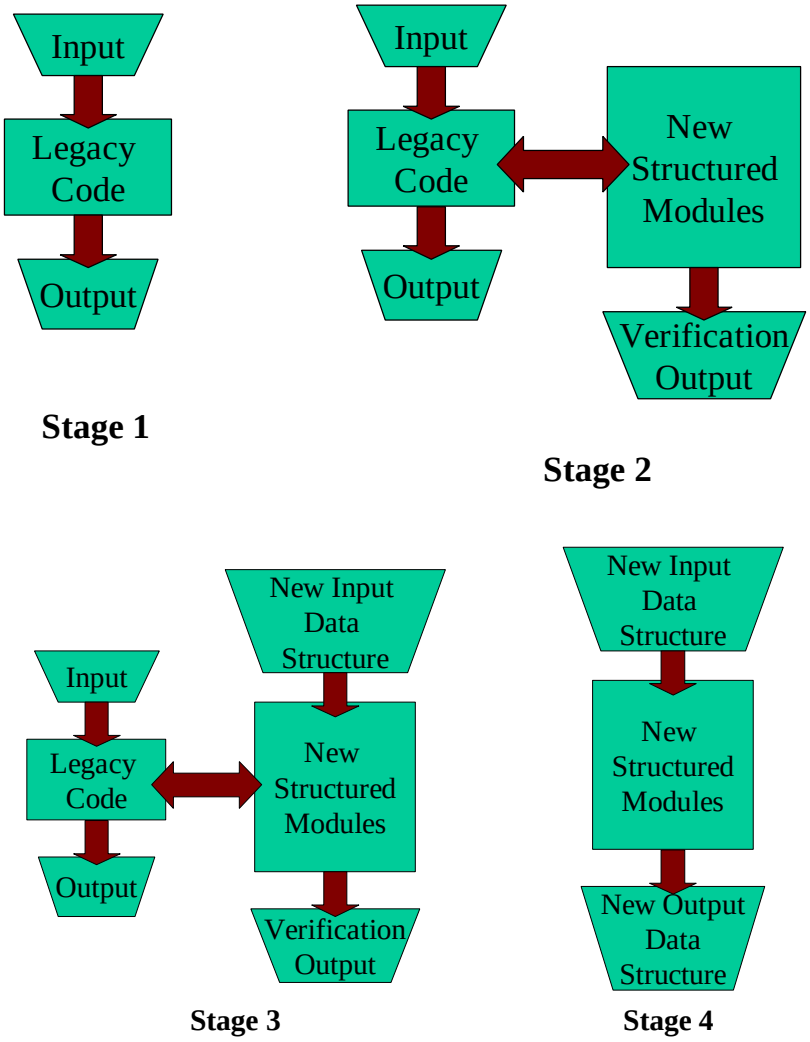

Figure 5: Evolutionary Reengineering Process

Conclusion

The EnergyPlus project not only combines the best features of the BLAST and DOE-2 programs, but also represents a significant step towards next-generation building simulation programs both in terms of computational techniques and program structures. Connectivity and extensibility are overriding constraints in the design process. This will ensure broad participation in program enhancement and facilitate third-party interface development.

Every effort has been made to maintain continuity between the existing BLAST and DOE-2 programs and EnergyPlus. The BLAST and DOE-2 development teams were merged into a single team for the EnergyPlus project, and a high priority has been placed on an input format and program structure that facilitates transition to the new program.

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What's New? (continued)

❁ **Introducing the newest DOE-2 consultants:**

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❁ **New Phone Number at ESTSC**

There are new area codes for Oak Ridge, TN. The new phone number for the Energy Science and Technology Software Center, which distributes the public version of DOE-2, is now (423) 576-2606, fax (423) 576-2865.

3-D Space Modelling With DOE-2

The RIUSKA Energy Simulation Tool

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Insinööritoimisto Olof Granlund Oy (IOGO) is one of the largest independent building services consulting firms in Finland. The company's development efforts focus on information management during the life cycle of the whole building, from early design to the facilities management phase. IOGO has developed several building applications that are used both in-house and commercially by facilities management organizations. Among these tools (Fig. 1) are:

SMOG	the Granlund 3-D Space Modeller
RETU	a Life-Cycle Cost Analyzing Tool
RIUSKA	an Energy Simulation Tool that uses DOE-2.1E as the calculation engine, and
RYHTI	the Facilities Management Tool

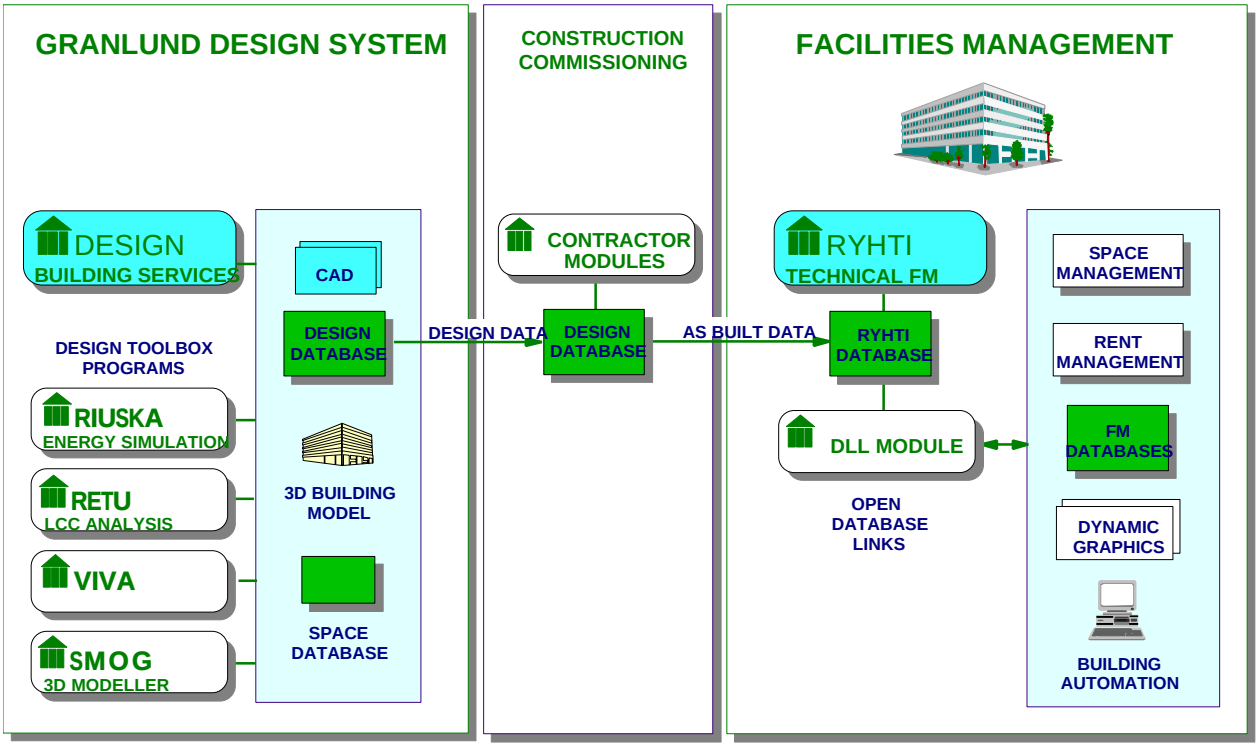

Figure 1: The information management system of Olof Granlund Oy.

As part of their design system, IOGO developed RIUSKA, an integrated simulation system meant to be used by designers in their everyday work. The simulation system covers the thermal simulation needs of the whole building life cycle from preliminary design to retrofit.

In the summer of 1997, IOGO and Lawrence Berkeley National Laboratory (LBNL) agreed to work cooperatively to integrate a cooled beam system simulation into DOE-2. The cooled beam system, popular in Scandanavian countries, is necessary to the design work at IOGO. IOGO will write the calculation routines and module code while LBNL will link the module to DOE-2.

SMOG: Granlund's 3-D Space Modeller

One of the main components of the IOGO's design system is SMOG, the Granlund 3-D Space Modeller, an add-on tool for AutoCAD R14. The application has drawing features that allow a designer to produce a 3-D model of the building. Building objects may be linked to any kind of data so that the model may be reused for several different purposes (simulations, visualization, and heat loss calculations).

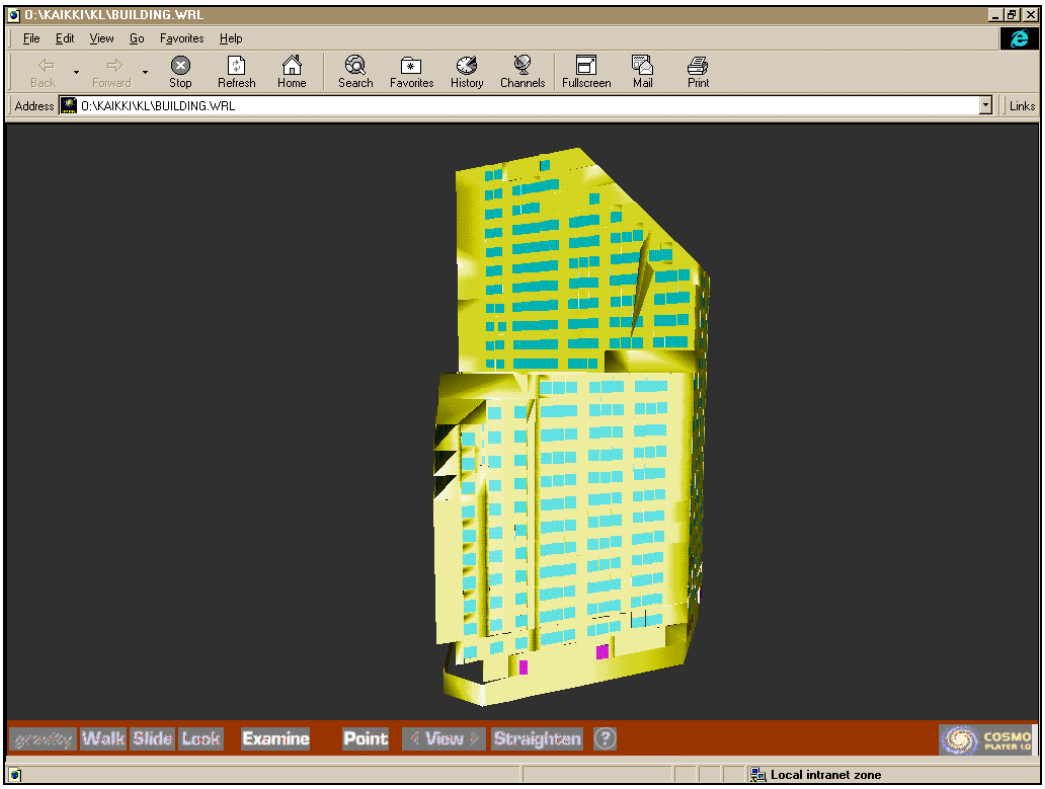

Figure 2: VRML -file used for visualization produced using the 3-D Space Modeller.

The program is fast; it is possible to accurately model whole buildings in a couple of days by draftsmen familiar with AutoCAD. Drawing objects with the 3-D modeller is easy; creating spaces is done by drawing walls around the space. To draw a building you start by drawing external walls making up the facades. The walls may be drawn with any angle of tilt. When the layout of the facades is finished, the building may be divided into smaller zones or spaces.

SMOG provides an algorithm making it possible to query the drawing for zone area and volume information as soon as you have drawn the constructions making up your zone. It calculates user defined areas (of arbitrary shapes) with an area calculation algorithm. The user can select the method of how to calculate gross and net areas.

Other drawing objects are windows and doors. Data related to the different drawing objects can be viewed and changed just by selecting the object from the drawing. A feature recognized by people involved in managing zones and zone equipment is the possibility to link query routines to external databases, thus giving access to any kind of zone information through the graphical interface.

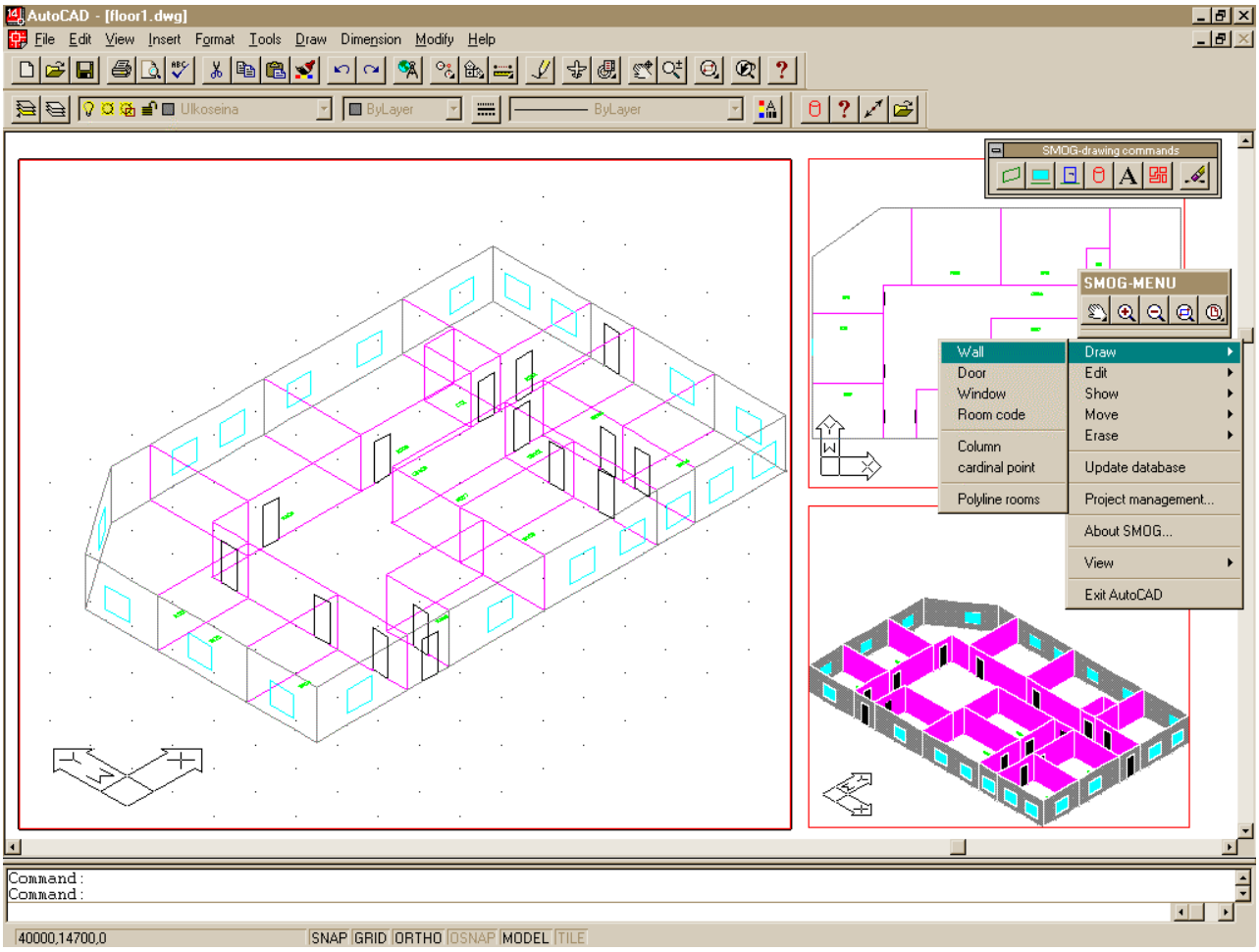

Figure 3: View of the geometry modeller.

SMOG keeps track of separating walls, meaning that it is enough to draw a separating wall once and still have links from both zones around the wall. The modeller automatically creates connections (i.e., nodes) between both wall objects and zone objects. One special feature is the ability to move single walls or wall lines just by dragging.

SMOG creates an external building geometry database used for data transfer to different applications. One of these applications is RIUSKA. SMOG's Dynamic Link Library module (DLL) makes the implementation of data transfer easy and makes the tool open to any application needing a simple 3-D building model.

Also, SMOG is intended for international use and includes a language module that enables rapid translations to new languages.

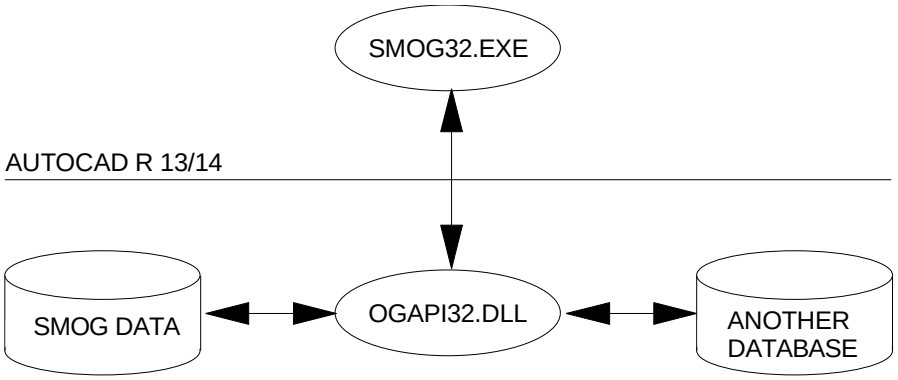

Figure 4: The API interface structure.

The RIUSKA Simulation System

The core of RIUSKA is the simulation database. The database includes information needed for the building thermal simulation. It also includes results from the simulations so that they may be reviewed anytime to-gether with the input values.

The simulation database is linked to other design databases and design programs to avoid redundant data. The same data can be used by the HVAC designer for the calculation of the cooling loads and by the electrical designer for the dimensioning of the electricity distribution system.

RIUSKA uses links to external library databases within the company. The library databases contains data about wall construction and window properties, space types, indoor air target values and load types with related usage schedule types. The simulation database will be part of the company project documenting system.

RIUSKA has different user interfaces for different purposes. The functions behind the user interfaces include default value generation routines. If some input data is missing, default values for the missing data are generated according to rules based on statistical data and know-how.

Data is exported to DOE-2 for simulation. After the simulation, data is transferred back to RIUSKA for further analysis.

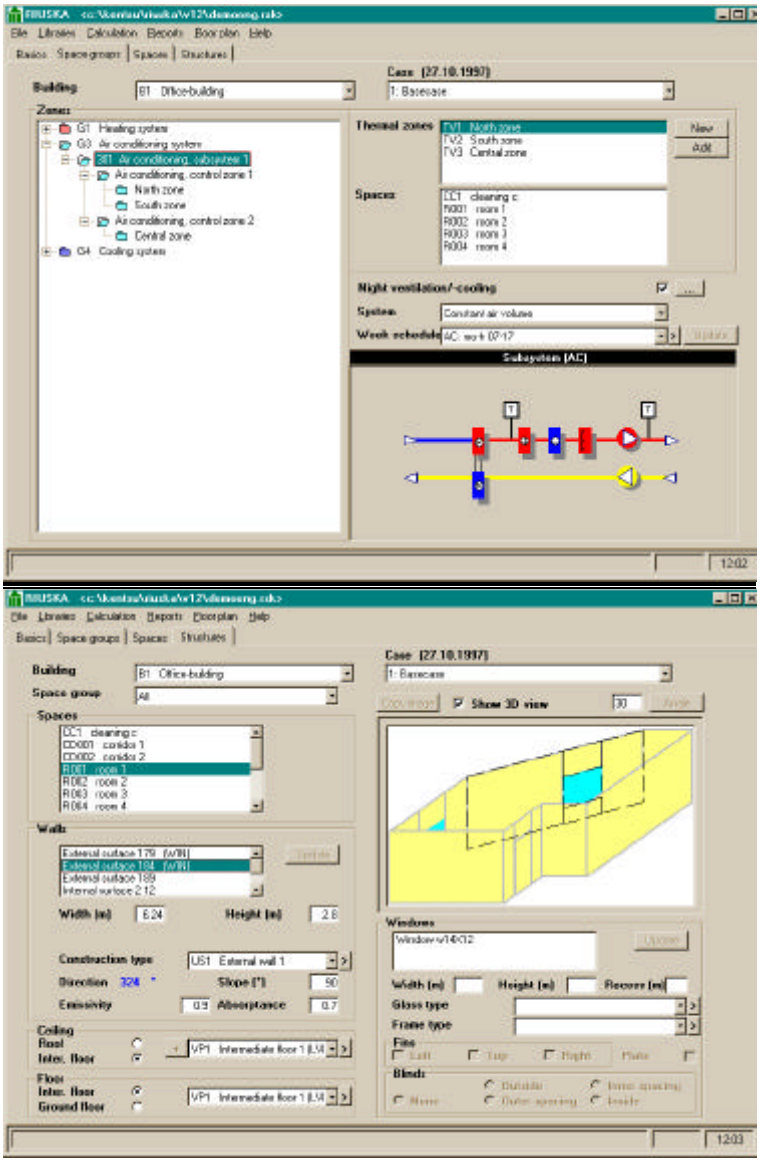

Figure 5: Views of the RIUSKA user interface

"Building Loads Analysis and System Thermodynamics"

blastnews

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The **Building Loads Analysis and System Thermodynamics (BLAST)** system is a comprehensive set of programs for predicting energy consumption and energy system performance and cost in buildings. The BLAST system was developed by the U.S. Army Construction Engineering Research Laboratory (USACERL) under the sponsorship of the Department of the Air Force, Air Force Engineering and Services Center (AFESC), and the Department of the Army, Office of the Chief of Engineers (OCE). After the original release of BLAST in December 1977, the program was extended and improved under the sponsorship of the General Services Administration, Office of Professional Services; BLAST Version 2.0 was released in June 1979. Under the sponsorship of the Department of the Air Force, Aeronautical System Division, and the Department of Energy, Conservation and Solar Energy Office, the program was further extended; BLAST Version 3.0 was completed in September 1980. Since 1983, the BLAST system has been supported and maintained by the BLAST Support Office at the University of Illinois at Urbana-Champaign.

BLAST can be used to investigate the energy performance of new or retrofit building design options of almost any type and size. In addition to performing peak load (design day) calculations necessary for mechanical equipment design, BLAST also estimates the annual energy performance of the facility, which is essential for the design of solar and total energy (cogeneration) systems and for determining compliance with design energy budgets. Repeated use of BLAST is inexpensive; it can be used to evaluate, modify, and re-evaluate alternate designs on the basis of annual energy consumption and cost.

The BLAST analysis program contains three major subprograms:

- The Space Load Prediction subprogram computes hourly space loads in a building based on weather data and user inputs detailing the building construction and operation.
- The Air Distribution System Simulation sub-program uses the computed space loads, weather data, and user inputs describing the building air- handling system to calculate hot water, steam, gas, chilled water, and electric demands of the building and air-handling system.
- The Central Plant Simulation subprogram uses weather data, results of the air distribution system simulation, and user inputs describing the central plant to simulate boilers, chillers, on-site power generating equipment and solar energy systems; it 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. HBLC allows the user to visualize the building model as it is developed and modify previously created input files. Within HBLC, each story of the building is represented as a floor plan which may contain several separate zones. Numerous other building details may be investigated and accessed through simple mouse operations. On-line helps provide valuable on-the-spot assistance that will benefit both new and experienced users. HBLC is an excellent tool which will make the process of developing BLAST input files more intuitive and efficient. You can download a demo version of HBLC (for MS Windows) from the BLAST website (User manual included!).
A FREE UPGRADE IS AVAILABLE to registered users, as of July 11. To obtain a password and instructions for downloading, e-mail to: support@blast.bso.uiuc.edu, or call (217) 333-3977. This upgrade may also be obtained by post for a nominal fee.

WINLCCID 97
LCCID (Life Cycle Cost in Design) has been a standard in the DoD community since its initial release in 1986. LCCID was developed to perform Life Cycle Cost Analyses (LCCA) for the Department of Defense and their contractors, yet it goes far beyond being just a DoD study tool by providing many features of a general purpose life cycle costing tool. With LCCID, it's easy to carry out "what-if" analyses based on variables such as present and future costs and/or maintenance and repair costs. LCCID allows an analysis based on standard DoD procedures and annually updated escalation factors as well as Energy Conservation Investment Program (ECIP) LCCA. You can download a demo version of WINLCCID 97 (for MS Windows) from the BLAST website. [See *User News* Vol. 16, No. 4, p. 5].

To order BLAST-related programs, contact Kavon Pontius at the BLAST Support Office

BLAST Order Information

Program Name	Order Number	Price Each
PC BLAST Package The standard PC BLAST Package includes the following programs: 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. A soft copy of the BLAST manual will be included as help files with the software. Executable version of BLAST Software Package for an IBM 386/486/Pentium.	3B386E3-0695	$950.00
PORTABLE BLAST (on DOS Formatted Disks) PC BLAST package plus FORTRAN source code	3BPORA3-0695	$1500.00
WINLCCID 97: executable version for 386/486/Pentium	3LCC3-0797	$295.00
WINLCCID 97: update from WINLCCID 96	4LCC3-0797	$195.00
BLAST 3.0 Documentation Set (Enter Quantity)		
Printed version in a 3-ring binder	1001-0695	$250.00
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.		

DOE-2 DIRECTORY

Program Related Software and Services

Contact the vendors for prices and ordering information

Mainframe and Workstation Versions of DOE-2

DOE-2.1D and 2.1E (Source code, executable code and documentation) For 2.1E DEC-VAX, Order #000158-DOVAX-02 For 2.1E SUN-4, Order #000158-SUN-0000 For 2.1D DEC-VAX, Order #000158-D6220-01 For a complete listing of the software available from ESTSC order their "Software Listing" catalog ESTSC-2. [See *User News* Vol. 16, No. 3, p. 21]	Energy Science Technology Software Center (ESTSC) P.O. Box 1020 Oak Ridge, TN 37831-1020 Phone: (423) 576-2606 Fax: (423) 576-2865 ESTSC@ADONIS.OSTI.GOV www.doe.gov/html/osti/
FTI-DOEv2.1E (Source code and documentation) Source code for both the ESTSC distribution and FTI/DOE. The ESTSC version is the combined SUN and VAX versions. FTI/DOE is fully portable and ready to compile. This is the source code distribution only. No executables are included with the package. Executables for most platforms are available. [See *User News* Vol. 12, No. 4, p. 16]	Finite Technologies, Inc 3763 Image Drive Anchorage, AK 99504 Contact: Scott Henderson Phone: (907) 333-8933 Fax: (907) 333-4482 info@finite-tech.com www.finite- tech.com/

PC Versions of DOE-2

ADM-DOE-2 ADM-DOE-2 (DOE-2.1E) is compiled for use on 386/486 PCs with a math co-processor and 4MB of RAM. It runs in a DOS or Windows environment and is a highly reliable and tested version of DOE-2 which contains all of the 1994/95 enhancements to the program. The package contains everything needed to run the program: program files, utilities, sample input files, and weather files. More than 300 weather files are available (TMY, TRY, WYEC, CTZ formats) for the U.S. and Canada. [See *User News* Vol. 7, No. 2, p. 6]	ADM Associates, Inc. 3239 Ramos Circle Sacramento, CA 95827 Contact: Marla Sullivan, Sales Phone: (916) 363-8383 Fax: (916) 363-1788
CECDOEDC (Version 1.0A) A microcomputer version of DOE-2.1D with a pre- and post-processor designed strictly for compliance use within the State of California. It generates some of the standard compliance forms as output. Order P40091009 for the CECDOEDC Program with Manuals. Order P40091010 for the DOE-2.1 California Compliance Manual. [See *User News* Vol. 12, No. 4, p. 13]	MS: 13 – Publication Office California Energy Commission P.O. Box 944295 Sacramento, CA 94244-2950 Phone: (916) 654-5106
EnergyPro (Win/DOE) A new Windows-based building energy analysis program designed to run on WindowsNT and Windows95. EnergyPro provides a next-generation interface for fast inputting and analyzing; including drag-and-drop, cut/copy/paste, and full graphic printout. Nonresidential modules include heating and cooling loads, California Title 24 Prescriptive Method compliance calculations, and tailored lighting calculations. A version of DOE-2 is available for use outside California. [See *User News* Vol. 18, No. 2, p. 2-8, Vol. 18, No. 4, p. 21]	Gabel-Dodd / EnergySoft, LLC 100 Galli Drive, Suite 1 Novato, CA 94949 Contact: Demian VonderKuhlen Phone: (415) 883-5900 Fax: (415) 883-5790 Martyn@energysoft.com www.energysoft.com

Caveat : We list third-party DOE-2-related products and services for the convenience of program users, with the understanding that the Simulation Research Group does not have the resources to check the DOE-2 program adaptations and utilities for accuracy or reliability.

PC Versions of DOE-2 (continued)

DOE-Plus DOE-Plus, a complete implementation of DOE-2.1D, is used to interactively input a building description, run DOE-2, and plot graphs of simulation results. Interactive error checking, context-sensitive help for all DOE-2 keywords, a 3-D view of the building that can be rotated, and several useful utilities. Also from ITEM Systems: **Demand Analyzer,** uses templates of building types and vintages to simplify DOE-2 input requirements. Online help feature. **Prep,** a batch preprocessor, ideal for parametric studies, that enables conditional text substitution, expression evaluation, and spawning of other programs. [See *User News* Vol. 11, No. 4, p. 4 and Vol. 13, No. 2, p. 54, and Vol. 16, No. 1, p. 28-32	ITEM Systems 321 High School Road NE, #344 Bainbridge Isl., WA 98110 Contact: Steve Byrne Phone: (206) 855-9540 Fax: (206) 855-9541 byrne@item.com
EZDOE EZDOE is an easy-to-use PC version of DOE-2.1D. It provides full screen, fill in the blank data entry, dynamic error checking, context-sensitive help, mouse support, graphic reports, a 750-page user manual, extensive weather data, and comprehensive customer support. EZDOE integrates the full calculation modules of DOE-2 into a powerful, full implementation of DOE-2 on DOS-based 386 and higher computers. [See *User News* Vol. 14, No. 2, p. 10 and No. 4, p. 8-14]	Elite Software, Inc. P.O. Drawer 1194 Bryan, TX 77806 Contact: Bill Smith Phone: (409) 846-2340 Fax: (409) 846-4367 76070.621@compuserve.com
FTI-DOEv2.1E Highly optimized version of DOE-2.1E software, available for most computing systems. Current support: MSDOS and Windows 3.x, Windows NT, (AIX), NeXT, and SUN. Call for platforms not listed. Documentation and weather files are available. [See *User News* Vol. 12, No. 4, p. 16]	Finite Technologies, Inc 821 N Street, #102 Anchorage, AK 99501 Contact: Scott Henderson Phone: (907) 333-8933 Fax: (907) 333-4482 Info@finite-tech.com www.finite-tech.com/fti/
MICRO-DOE-2ä MICRO-DOE-2 (2.1E), running in a DOS or Windows environment, is a widely used, reliable, and tested PC version of DOE-2.1E. It includes automatic weather processing, batch file creation, and a User's Guide with instructions on how to set up a RAM drive. System requirements: 386/486 PC with 4 MB of RAM and math co-processor. Also from ACROSOFT/CAER Engineers: **NETPath**, a network edition of MICRO-DOE-2 for up to five users, allows you to store and run DOE-2 application files on one machine using input files from another machine. The result is improved space usage and project file management. **POWERPath**, for single machines, allows you to keep MICRO-DOE-2 application files in one directory and submit input from any other directory. **BDL Builder** is a user-friendly Windows-implemented pre-processor for DOE-2.1E that allows the description of specific building and HVAC characteristics with numeric input by preparing databases, or building blocks, and then selecting records from the databases to assemble a complete input. **E2BB** translates existing DOE-2.1E text input to BDL Builder. **Weather Files** for most U.S., Canadian, and European cities are available in various formats, including TRY, TMY, CTZ, and WYEC. [See *User News* Vol. 7, No. 4, p. 2; Vol. 11, No. 1, p. 2; Vol. 15, No. 1, p. 8; Vol. 15, No. 3, p. 4; Vol. 16, No. 2, p. 1,7; Vol. 16, No. 4, p. 7-8]	ACROSOFT / CAER Engineers 1204-1/2 Washington Avenue Golden, CO 80401 Contact: Don Croy Phone: (303) 279-8136 Fax: (303) 279-0506 102447.2611@COMPUSERVE.COM

PC Versions of DOE-2 (continued)

PRC-DOE-2 A fast, robust and up-to-date PC version of DOE-2.1E. Runs in extended memory, is compatible with any VCPI compliant memory manager and includes its own disk caching. 377 weather data files available (TMY, TRY, WYEC, CTZ) for the U.S. and Canada **PRC-TOOLS** is a set of PC programs that aids in extracting, analyzing and formatting hourly DOE-2 output. Determines energy use, demand, and cost for any number of end-uses and periods. Automatically creates 36-day load shapes. Custom programs also available.	Partnership for Resource Conservation 140 South 34th Street Boulder, CO 80303 Contact: Paul Reeves Phone: (303) 499-8611 Fax: (303) 554-1370 paulreeves@aol.com
VisualDOE 2.5 for Windows ™ VisualDOE 2.5, which uses DOE-2.1E as the calculation engine, enables architects and engineers to quickly evaluate the energy savings of HVAC and other building design options. Program is supported by a graphical interface and on-line help. Program includes climate data for the 16 California weather zones. A demo can be downloaded from www.eley.com. [See *User News* Vol. 15, No. 2, p. 10; Vol. 16, No. 4, p. 9-16; Vol. 17, No. 4, p. 8-13]	Eley & Associates 142 Minna Street San Francisco, CA 94105 Charles Eley or John Kennedy Phone: (415) 957-1977 / Fax: -1381 celey@eley.com www.eley.com

Pre- and Post-Processors for DOE-2

DrawBDL DrawBDL, Version 2.02, is a graphic debugging and drawing tool for DOE-2 building geometry; it runs on PCs under Microsoft Windows. DrawBDL reads your BDL input and makes a rotatable 3-D drawing of your building with walls, windows, and building shades shown in different colors for easy identification. [See *User News*, Vol. 14, No. 1, p. 5-7, Vol. 14, No. 4, p. 16-17, and Vol. 16, No. 1, p.37]	Joe Huang & Associates 6720 Potrero Avenue El Cerrito, CA 91364 Contact: Joe Huang Phone/Fax: (510) 236-9238
Visualize-IT Visual Data Analysis Tools The ***Energy Information Tool*** is a Microsoft Windows 3.1 program for looking at and understanding metered or DOE-2.1E hourly input data. It provides the unprecedented ability to see all 8760 (or 35040) data points for a year's worth of data. You get an overview of the data with an EnergyPrint and can then explore the data with a variety of tools including load shapes, load duration curves, etc. This program requires a 486 computer and SVGA graphics capabilities. The ***Calibration Tool*** is a Microsoft Windows 3.1 program for comparing DOE-2.1E hourly output data to total load and/or end-use metered data. Options include monthly demand and load 2D graphs, maximum and seasonal load shapes, average load profiles, end use residuals, monthly average week and weekend days, and dynamic comparison load shapes. This program requires a 486 computer and SVGA graphics capabilities. [See *User News* Vol. 17, No. 2, p. 2-6]	RLW Analytics, Inc. 1055 Broadway, Suite G Sonoma, CA 95476 Contact: Jim McCray Pat Bailey Jedd L. Parker Phone: (707) 939-8823 Fax: (707) 939-9218 info@rlw.com www.rlw.com
Graphs for DOE-2 2-D, 3-D, hourly, daily, and psychrometric plots [See *User News* Vol. 13, No. 1, p. 5]	Energy Systems Laboratory Texas A&M University College Station, TX 77843 Contact: Jeff Haberl Phone: (409) 845-6065 Fax: (409) 862-2762

TOOLS AND TRAINING

User News **(a quarterly newsletter)** Sent without charge, the newsletter prints documentation updates and changes, bug fixes, inside tips on using the programs more effectively, and articles of special interest to users of DOE-2, BLAST, SPARK and their derivatives. The winter issue features an index of articles printed in all the back issues. Also available electronically at http://eande.lbl.gov/BTP/SRG/UNEWS	Simulation Research Group Bldg. 90, Room 3147 Lawrence Berkeley National Laboratory Berkeley, CA 94720 Contact: Kathy Ellington Fax: (510) 486-4089 kathy@srge.lbl.gov
Help Desk Bruce Birdsall Call or fax Bruce Birdsall if you have a question about using DOE-2. If you need to fax an example of your problem to Bruce, please be sure to telephone him prior to sending the fax. This is a free service provided by the Simulation Research Group at Lawrence Berkeley National Laboratory.	Bruce Birdsall Phone/Fax: (510) 829-8459 Monday through Friday 10 a.m. to 3 p.m. Pacific Time
Training DOE-2 courses for beginning and advanced users.	Marlin Addison Phone: (602) 968-2040
Instructional DOE-2 Video and Manual Takes you step-by-step in DOE-2.1D input preparation and output interpretation.	Dr. Michael Brandemuehl, Director JCEM/U. Colorado CEAE Dept CB 428 Boulder, CO 80309-0428 Phone: (303) 492-3915, fax 492-7317

DOE-2.1E Bug Fixes via FTP

If you have Internet access you can obtain the latest bug fixes to the LBNL version of DOE-2.1E by anonymous ftp. Here's how…

ftp to either gundog@lbl.gov or to 128.3.254.10
login: *type* anonymous
passwd: *type in your e-mail address*

After logging on, go to directory pub/21e-mods ; bug fixes are in files that end with **.mod** . A description of the fixes is in file **VERSIONS.txt** in directory **pub** . Each fix has its own version number, ***nnn*** , which is printed out as DOE-2.1E- *nnn* on the DOE-2.1E banner page and output reports when the program is recompiled with the fix. You may direct questions about accessing or incorporating the bug fixes to Ender Erdem (ender@gundog.lbl.gov).

Congratulations!

According to a November 5, 1997, notice from the California Energy Commission, EnergyPro (Version 1.0) has been approved as an alternative calculation method for demonstrating compliance with the California state building energy efficiency standards. EnergyPro, from Gabel-Dodd/ EnergySoft of Novato, CA, is a Windows 95 and NT based energy analysis pro-gram that uses DOE-2.1E as the calculation engine.

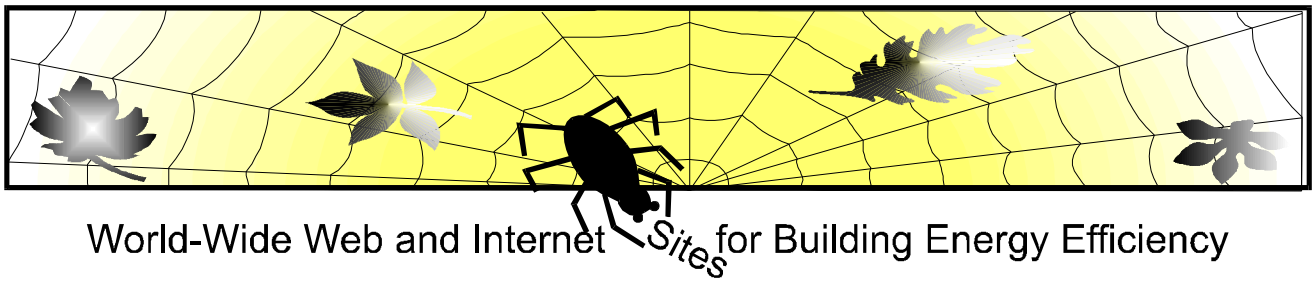
(see User News, Vol. 18, No. 2, Summer 1997)

WEATHER RESOURCES

TMY2 weather data for DOE-2. ENERGOS will provide TMY2 data for 239 cities converted for use with DOE-2 for PC versions of the program (DOE-2.1C through DOE-2.1E).	Kurmit Rockwell ENERGOS 1705-14th Street, #401 Boulder, CO; 80302 Phone: (303) 499-7907 / Fax: (303) 449-7605
Comprehensive collection of **TRY**, **TMY** and **CTZ** weather file libraries, from NCDC, which can be used on all PC versions of DOE-2. Includes original source data and pre-formatted packed versions on a single IBM format CD. Individual sites available.	Jenny Lathum or Martyn Dodd Gabel Dodd / EnergySoft, LLC 100 Galli Drive, Suite 1 Novato, CA 94949 Phone: (800) 467-4738 Fax: (415) 883-5970
European Weather Files	Andre Dewint Alpha Pi, s.a. rue de Livourne 103/12 B-1050 BRUXELLES, Belgium Phone: 32-2-649-8359 / Fax: 32-2-649-9437
TMY data sets - download from the World Wide Web **TMY2** data sets and **TMY2 User Manual** - download from the World Wide Web [See *User News* Vol. 18, no. 2, p. 17]	TMY: http//oipea-www.rutgers.edu/html_docs/TMY/tmy.html TMY2: http://rredc.nrel.gov/solar/
TMY (Typical Meteorological Year) **TRY** (Test Reference Year)	National Climatic Data Center 151 Patton Avenue, #120 Asheville, NC 28801 Phone: (704) 271-4871 order / Fax 271-4876
CTZ (California Thermal Climate Zones)	California Energy Commission Bruce Maeda, MS-25 1516-9th Street Sacramento, CA 95814-5512 1-800-772-3300 Energy Hotline
WYEC (Weather Year for Energy Calculation)	ASHRAE 1791 Tullie Circle N.E. Atlanta, GA 30329 Phone: (404)636-8400 / Fax: (404)321-5478
Canadian Weather Files in WYEC2 Format [Note: the original long-term data sets, up to 40 years of data, from which the CWEC files were derived can also be obtained directly from Environment Canada. Contact Mr. Robert Morris at (416) 739-4361.]	Dr. Didier Thevenard Watsun Simulation Lab University of Waterloo Waterloo, Ont., N2L-3G1 Canada Phone: (519) 888-4904 / Fax: (519) 888-6197 watsun@helix.watstar.uwaterloo.ca

DOE-2 ENERGY CONSULTANTS

Arizona				
Sarat Kanaka	EcoGroup, Inc., Suite 301	2085 E. Technology Circle	Tempe, AZ 85284	(602) 777-3000
Chuck Sherman	Energy Simulation Specialists	64 East Broadway, #230	Tempe, AZ 85282	(602) 784-4500
California				
George Marton	1129 Keith Avenue		Berkeley, CA 94708	(510) 841-8083
Jeff Hirsch	James J. Hirsch Associates	12185 Presilla Road	Camarillo, CA 93012	(805) 532-1045
Leo Rainer	Davis Energy Group, Inc.	123 C Street	Davis, CA 95616	(916) 753-1100
L. Heshong, D. Mahone	The Heshong Mahone Group	11622 Fair Oaks Blvd, #111	Fair Oaks, CA 95628	(916) 962-7001
Steven D. Gates, P.E.	11608 Sandy Bar Court		Gold River, CA 95670	(916) 638-7540
David J. Schwed	Romero Management Assoc	1805 West Avenue K	Lancaster, CA 93534	(805) 940-0540
Robert E. Gibeault	A-TEC	5515 River Avenue, # 301	Newport Beach, CA 92663	(714) 548-6836
Martyn C. Dodd	Gabel Dodd/EnergySoft, LLC	100 Galli Drive, # 1	Novato, CA 94949	(415) 883-5900
Robert Mowris, P.E.	10 Ridge Road		Orinda, CA 94563	(510) 254-9770
Greg Cunningham	EnerSys Solutions LLC	114 Sansome St., #1201	San Francisco, CA 94104	(415) 296-9760
Charles Eley	Eley Associates	142 Minna Street	San Francisco, CA 94105	(415) 957-1977
Chandra Shinde, P.E.	ENVIRODESIGN GROUP	385 S. Lemon Ave., E-266	Walnut, CA 91789	(909) 598-1980
Colorado				
David A. Cohen	Architectural Energy Corp	2540 Frontier Ave, #201	Boulder, CO 80301	(303) 444-4149
Kurmit Rockwell	Rocky Mtn Energy Services	1705 14th Street, # 401	Boulder, CO 80302	(303) 499-7907
Paul Reeves	PRC	140 South 34th Street	Boulder, CO 80303	(303) 499-8611
Ellen Franconi	P.O. Box 1284		Boulder, CO 80306	(303) 786-7319
Charles Fountain	Burns & McDonnell	8055 E. Tufts Avenue, #330	Denver, CO 80230	(303) 721-9292
Susan Reilly	Enermodal Engineering	1554 Emerson Street	Denver, CO 80218	(303) 861-2070
Donald E. Croy	Acrosoft/CAER Engineers	814 Eleventh Street	Golden, CO 80401	(303) 279-8136
Joel Neymark, P.E.	2140 Ellis Street		Golden, CO 80401	(303) 384-3672
Norm Weaver	Interweaver Consulting	P.O. Box 775444	Steamboat Spgs, CO 80477	(970) 870-1710
Connecticut				
Adrian Tuluca	Steven Winter Associates	50 Washington Street	Norwalk, CT 06854	(203) 852-0110
Florida				
Philip Wemhoff	1512 South McDuff Avenue		Jacksonville, FL 32205	(904) 632-7393
Dr. Paul Hutchins PE,CEM	Reynolds Smith & Hills, Inc.	4651 Salisbury Road	Jacksonville, FL 32256	(904) 279-2277
Georgia				
Lung-Sing Wong	Building Performance Engrs.	1351 Oakbrook Dr., #100	Norcross, GA 30093	(770) 409-0400
Illinois				
Michael P. Doerr	Skidmore Owings Merrill	224 S Michigan Ave # 1000	Chicago, IL 60604	(312) 360-4623
Gary H. Michaels, P.E.	G.H. Michaels Associates	1512 Crain Street	Evanston, IL 60202	(847) 869-5859
Prem N. Mehrotra	General Energy Corp.	230 Madison Street	Oak Park, IL 60302	(708) 386-6000
Robert Henninger, P.E.	GARD Analytics, Inc.	1028 Busse Highway	Park Ridge, IL 60068-1802	(847) 698-5686
Kansas				
Dr. Brian A. Rock, P.E.	A/E Dept, Marvin Hall	University of Kansas	Lawrence, KS 66045-2222	(785) 864-3603
Missouri				
Mike Roberts	Roberts Engineering Co.	11946 Pennsylvania	Kansas City, MO 64145	(816) 942-8121
Bruce A. Leavitt, P.E.	Wm. Tao & Associates Inc.	2357-59th Street	St. Louis, MO 63110	(314) 644-1400
Montana				
Michael W Harrison, P.E.	Harrison Engineering	139 Bluebird Lane	Whitehall, Montana 59759	(406) 287-5370
New York				
J. Fireovid, K. Yousef	SAIC Energy Solutions Div.	1 Marcus Boulevard	Albany, NY 12205	(518) 458-2249
Hugh I. Henderson, P.E. and Steve Carlson, P.E.	CDH Energy Corporation	P.O. Box 641	Cazenovia, NY 13035	(315)-655-1063
North Carolina				
Hank Jackson, P.E.	P.O. Box 675		Weaverville, NC 28787-0675	(704) 658-0298
Oregon				
J. Karasaki PE, R. Ogle PE	CBG Consulting Engineers	6650 SW Redwood Lane, #355	Portland, OR 97224	(503) 620-3232
Texas				
Jeff S. Haberl	Energy Systems Laboratory	Texas A&M University	College Stn., TX 77843-3123	(409) 845-6065
Washington				
Steve Byrne	ITEM Systems, suite 344	321 High School Road NE	Bainbridge Isl, WA 98110	(206) 855-9540
Gregory Banken, P.E.	Q-Metrics, Inc.	P.O. Box 3016	Woodinville, WA 98072	(205) 915-8590



The first two listings are newsgroups, not websites	
(net) sci.engr.heat-vent-ac	**HVAC** discussion group.
(net) sci.engr.lighting	**Lighting** discussion group.
These URLs, on the World-Wide Web, start with http://	
www.eren.doe.gov/buildings/ tools_directory/	**Building Energy Tools Directory** from the U.S. Department of Energy. An electronic directory of software programs under four headings: Whole-Building Analysis, Codes and Standards, Materials/Components/Equipment/Systems, and Other Applications. See *User News*, Vol. 17, No. 4, p. 35.
www.bso.uiuc.edu	**BLAST** Support Office
www.energy.ca.gov/energy/cectext/ ETEC.html	**California Energy Commission's Energy Technology and Education Center**. See *User News* , Vol. 16, No. 1, p. 42.
www.hike.te.chiba-u.ac.jp/ikeda/ CIE/publ/110-94.html	**The International Commission on Illumination – CIE** See *User News* , Vol. 16, No. 1, p. 44.
www.eren.doe.gov/	**EREN**: Energy Efficiency and Renewable Energy Network of the U.S. Department of Energy . See *User News* , Vol. 16, No. 1, p. 44.
www.doe.gov/	**U.S. Department of Energy** . See *User News* , Vol. 15, No. 4, p. 1.
www.whitehouse.gov/	**The White House** home page contains an Interactive Citizens Handbook that lists U.S. Government servers by agency. Use this site as a jumping-off point to explore other Federal agencies. See *User News* , Vol. 15, No. 4, p. 1.
www.fedworld.gov/	**FedWorld** is the U.S. Government's Federal Information Network home page. It lists web servers, ftp, gopher, and telnet sites and is organized by subject categories. See *User News*, Vol. 16, No. 2, p. 22.
www.fedworld.gov/ntis/ntishome.html	**National Technical Information Service** NTIS gathers and markets scientific, technical and business-related information.
www.caddet-ee.org	**Center for the Analysis and Dissemination of Demonstrated Energy Technologies** An IEA program for collecting and disseminating information on, energy-efficient and renewable energy technologies. See *User News* , Vol. 16, No. 2, p. 23.
crest.org/aceee	**American Council for an Energy-Efficient Economy** A non-profit organization for the advancement of energy efficiency. See *User News* , Vol. 16, No. 2, p. 23.
www.ashrae.org	**American Society of Heating, Refrigeration and Air-Conditioning** An international membership organization for HVAC professionals. *User News* , Vol. 16, No. 3, p. 31.
www.cisti.nrc.ca/irc/irccontents.html	**[Canadian] Institute for Research in Construction** IRC is part of the NRC, Canada's premier science and technology agency. See *User News* , Vol. 16, No. 3, p. 31.
next1.mae.okstate.edu/ibpsa/	**International Building Performance Simulation Association** An international society of building performance simulation professionals. See *User News*, Vol. 16, No. 4, p. 35.
www.fsec.ucf.edu/	**Florida Solar Energy Center** State of Florida's energy institute specializing in energy research and education in partnership with private and public organizations. See *User News*, Vol. 17, No. 1, p. 29.

eande.lbl.gov/BTP/WDG/ /RESFEN/resfen.html **/SUPERLITE/superlite2.html /WDG.html**	**Download Fenestration software from LBNL** See *User News*, Vol. 17, No. 1, p. 14. **RESFEN-2.4** – calculates residential fenestration heating and cooling energy use/costs **SUPERLITE-2.0** – calculates daylight illuminance distributions for room geometries **WINDOW-4.1** – thermal analysis program to characterize window product performance
www.energy.ca.gov/reports/ title24/index.html	**State of California's Title 24 Building Energy Standards** See *User News*, Vol. 17., No. 2, p. 25.
fcn.state.fl.us/fdi/fdi-home.htm	**State of Florida's Design Initiative (FDI)** See *User News*, Vol. 17, No. 2, p. 25.
fcn.state.fl.us/fdi/edesign/online/ edo.htm	***e-design,*** the online newsletter for Florida's Design Initiative See *User News*, Vol. 17, No. 2, p. 25.
www.energy.wsu.edu/ep/ wsu.edu/ep/eic/ wsu.edu/ep/eic/eicsoft.htm wsu.edu/ep/eic/eicfiles.htm	The **Energy Program (EP)** of Washington State U. *User News*, Vol. 17, No. 3, p.26. **Energy Ideas Clearinghouse**, 925 Plum St S.E., Olympia, WA 98504-3171 (360) 956-2237 Software and files from the Energy Ideas Clearinhouse More download-able energy software from the Energy Ideas Clearinhouse
eande.lbl.gov/CBS/VH/advisor.html	The **Virtual Home Energy Advisor** from LBNL's Center for Building science. Run a quick heating-cooling model (DOE-2.1E) and see how much homes in your region can save. See *User News*, Vol. 17, No. 3, p.26.
www.pge.com/customer_services/ other/pec/homepage/pec.html	Pacific Gas & Electric's **Energy Center** located in San Francisco, CA. See *User News*, Vol. 17, No. 4, p. 35
dial.uwaterloo.ca/~watsun/home.htm	**Watsun Simulation Laboratory** was established with the support of the National Research Council of Canada. Its mission is to develop general purpose simulation software for solar energy system simulation performance. See *User News*, Vol. 17, No. 4, p. 35.
WWW.CSEMAG.COM/	An online version of **Consulting-Specifying Engineer Magazine** See *User News*, Vol. 17, No. 4, p. 35.
www.homeenergy.org	**Home Energy Magazine** An impartial source to aid in making informed decisions on residential energy conservation measures. See the *User News*, Vol. 17, No. 1, p. 29 Vol. 17, No. 4, p.1.
eande.lbl.gov/BTP/BDA/BDA.html	The **Building Design Advisor** (BDA) is a software environment that supports the integrated use of multiple analysis and visualization tools throughout the building design process, from the initial, schematic design phases to the detailed specification of building components and systems. See the *User News*, Vol. 18, No. 4, p. 26
http://sabu.weea.org	The **World Energy Efficiency Association** (WEEA) was founded in June 1993 as a private, non-profit organization composed of developed and developing country institutions and individuals charged with increasing energy efficiency. . See the *User News*, Vol. 18, No. 4, p. 26

* * * Featured Sites This Issue * * *

World-Wide Web Sites for Building Energy Efficiency

Building Design Advisor
http://eande.lbl.gov/BTP/BDA/BDA.html

The Building Design Advisor (BDA) is a software environment that supports the integrated use of multiple analysis and visualization tools throughout the building design process, from the initial, schematic design phases to the detailed specification of building components and systems. Based on a comprehensive design theory, the BDA uses an object-oriented representation of the building and its context, and acts as a data manager and process controller to allow building designers to benefit from the capabilities of multiple tools.

The BDA is implemented as a Windows-based application for PCs. Its initial version is linked to a Schematic Graphic Editor (SGE) that allows designers to quickly and easily specify the geometric characteristics of building components and systems.

For more information, please contact:
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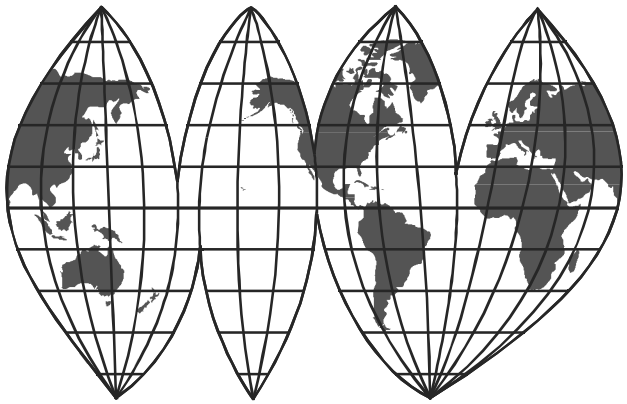
World Energy Efficiency Association
http://sabu.weea.org

The World Energy Efficiency Association (WEEA) was founded in June 1993 as a private, non-profit organization composed of developed and developing country institutions and individuals charged with increasing energy efficiency.

WEEA was formed to: (1) to assist developing countries in accessing information on energy efficiency, (2) serve as a clearinghouse for information on energy efficiency programs, technologies and measures, (3) disseminate this information worldwide, and (4) publicize international cooperation efforts in energy efficiency.



For more information, please contact:
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Washington, D.C. 20006 U.S.A.

Ph: (202) 778-4961
Fx: (202) 463-0017
E-mail: info@weea.org

DOE-2 RESOURCE CENTERS

The people listed here have agreed to be primary contacts for DOE-2 program users in their respective countries. Each resource center has the latest program documentation, all back issues of the User News, and recent LBNL reports pertaining to DOE-2. These resource centers will receive copies of all new reports and documentation. Program users can then make arrangements to get photocopies of the new material for a nominal cost. We hope to establish resource centers in other countries; please contact us if you are interested in establishing a center in your area.

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Stephane Bilodeau, P.E., M.Appl.Sc. Groupe Enerstat, Inc. 79, Wellington N. #202 Sherbrooke (Quebec) J1H 5A9, Canada Phone (819) 562-8040/Fax (819) 562-5578 bill@aramis.gme.usherb.ca	

Index to the User News

Vol. 1, No. 1 (August 1980) through Vol. 18, No. 4 (Winter 1997)

KEY: The Index lists User News volumes, issues, and page numbers as follows: Title of the article, program version that was current when article appeared, Volume, Number (No. 1 = Spring, No. 2 = Sum- mer, No. 3 = Fall, No. 4 = Winter), and page number. For example, the entry "Advanced Simulation (2.1C)...7:4,4-8" (when applicable) means that the article was entitled "Advanced Simulation" and it was printed when DOE-2.1C was the current version of the DOE-2 program; the article was printed in Volume 7:Number 4, on pages 4 through 8.

Pollutant Production Calculation in DOE-2.2

by
Fred Buhl
Simulation Research Group
Lawrence Berkeley National Laboratory

Introduction

A new feature in the upcoming DOE-2.2 program is the capability to calculate the pollutant production associated with the combustion of various type of fuel, both on and off-site. Calculations are performed for six different pollutants: CO_2, SO_2, NO_X, CO, hydrocarbons (HC) and particulate matter (PM). Results are presented in two reports: ES-G, the monthly and annual quantities of pollutant produced; and ES-H, the pollutant production by time-of-use period. The pollutant calculation is triggered by entering the new POLLUTANT-COEFFS command.

This feature is very similar to the one described by Rich Liesen in "Atmospheric Pollution Prediction in the BLAST Energy Simulation Program" (see the *User News*, Vol 18, No. 3, Fall 1997). The method and the data for the defaults of the DOE-2.2 pollutant production calculation are based on Rich's work.

Pollutant Coefficients

The calculation is based upon pollutant coefficients. A pollutant coefficient is defined as the pounds of pollutant produced per MBtu of fuel consumed (kg/MWh for metric input). For this calculation, pollutant coefficients are assumed to depend on pollutant type, fuel type, and whether the fuel is consumed on-site, or off-site for the generation of electricity.

Keywords for the POLLUTANT-COEFFS command

The user can input any or all of the pollutant coefficients, or allow them to default. The default SO_2 pollutant coefficients are regionally based. In addition to pollutant coefficients, the calculation needs the fraction of off-site electricity produced by the different fuel types (coal, oil, natural gas, etc.). The defaults for these keywords are based on figures for each state. For a large state like California, these defaults may not reflect the resource mix of a local power provider.

LOCATION (required)
The abbreviation of the name of a state. The abbreviations used are the familiar ZIP code abbreviations (IL is Illinois, CA is California, etc.). PR for Puerto Rico and DC for District of Columbia are also accepted. The location is used to choose correct default values for the pollutant coefficients. This keyword is REQUIRED.

ON-SITE-GAS Defaults (English): (115, 0.00059, 0.137, 0.034, 0.00058, 0.003)
(metric): (178, 0.00091, 0.212, 0.053, 0.00090, 0.0046)
List of six pollutant coefficients for on-site gas usage. Here, and in the following keyword examples, the pollutants are (in order of occurrence in the input list): carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM).

ON-SITE-RES-OIL Defaults (English): (170, 1.04667, 0.36667, 0.03333, 0.008533, 0.08667)
(metric): (263, 1.62035, 0.56764, 0.05160, 0.013210, 0.13417)
List of six pollutant coefficients for on-site residual oil usage.

ON-SITE-DIST-OIL Defaults (English): (170, 0.552817, 0.140845, 0.035211, 0.000408, 0.014085)
(metric): (263, 0.855816, 0.218042, 0.054510, 0.000632, 0.021805)
List of six pollutant coefficients for on-site residual oil usage.

ON-SITE-COAL Defaults (English): (200, 2.9444, 0.584, 0.20856, 0.00417, 0.03)
(metric): (310, 4.5582, 0.904, 0.32287, 0.00646, 0.046)
List of six pollutant coefficients for on-site residual oil usage.

ELEC-FROM-GAS Defaults (English): (115, by region, 0.2, 0.039078, 0.001661, 0.00293)
(metric): (178, by region, 0.31, 0.060497, 0.002571, 0.00454)
List of six pollutant coefficients for on-site residual oil usage.

ELEC-FROM-OIL Defaults (English): (170, by region, 0.3, 0.033175, 0.0069, 0.1)
(metric): (263, by region, 0.46, 0.051358, 0.0107, 0.15)
List of six pollutant coefficients for on-site residual oil usage.

ELEC-FROM-COAL Defaults (English): (200, by region, 0.7, 0.02886, 0.00481, 0.1)
(metric): (310, by region, 1.1, 0.04468, 0.00745, 0.15)
List of six pollutant coefficients for on-site residual oil usage.

ELEC-FRAC-GAS (default: by state)
Fraction of off-site electricity produced using gas.

ELEC-FRAC-OIL (default: by state)
Fraction of off-site electricity produced using oil.

ELEC-FRAC-COAL (default: by state)

Fraction of off-site electricity produced using coal.

UTILITY-RATE (required)
The U-name of a UTILITY-RATE command. The program uses the time-of-use block charges in this utility rate to create a report ES-H which shows pollutant production broken down by time-of-use period.

Example
The following example input shows an electric utility rate defined with a seasonal and time-of-day rate structure. The POLLUTANT-COEFFS command triggers the pollutant production calculation. The input for this command is the minimum, using all defaults. The time-of-use structure defined in the utility rate is reflected in the output report ES-H.

A. Example Input

```
              ECONOMICS-REPORT  SUMMARY=(ES-D,ES-E,ES-F,ES-G,ES-H)
                                ..

       $ THE FLAGS USED IN THE BLOCK-CHARGES AND SCHEDULE BELOW

       $                        WINTER    SUMMER
       $           OFF-PEAK      1.1       2.1
       $           SHOULDER      1.2       2.2
       $           ON-PEAK       1.3       2.3

SEASONS-SCH  SCHEDULE  TYPE=FLAG
                       THRU MAY 15 (WD)  (1,8)(1.1) (9,12)(1.2) (13,17)(1.3)
                                         (18,22)(1.2) (23,24)(1.1)
                                   (WEH) (1,8)(1.1)  (9,24)(1.2)
                       THRU SEP 15 (WD)  (1,8)(2.1) (9,12)(2.2) (13,18)(2.3)
                                         (19,24)(2.2)
                                   (WEH) (1,8)(2.1) (9,24)(2.2)
                       THRU DEC 31 (WD)  (1,8)(1.1) (9,12)(1.2) (13,17)(1.3)
                                         (18,22)(1.2) (23,24)(1.1)
                                   (WEH) (1,8)(1.1)  (9,24)(1.2)   ..

WINTER-OFF-PK = BLOCK-CHARGE BLOCK-SCH = SEASONS-SCH
                             SCH-FLAG  = 1.1
                             BLOCK1-TYPE = KWH/KW
                             BLOCKS-1 = (200,800)
                             COSTS-1  = (.04,.05)
                             LIMITS-1 = (0,0)  ..

WINTER-SHLDR = BLOCK-CHARGE  BLOCK-SCH =SEASONS-SCH
                             SCH-FLAG  = 1.2
                             BLOCK1-TYPE = KWH/KW
                             BLOCKS-1 = (200,800)
                             COSTS-1  = (.045,.055)
                             LIMITS-1 = (0,0)  ..

WINTER-ON-PK = BLOCK-CHARGE  BLOCK-SCH = SEASONS-SCH
                             SCH-FLAG  = 1.3
                             BLOCK1-TYPE = KWH/KW
                             BLOCKS-1 = (200,800)
                             COSTS-1  = (.05,.06)
                             LIMITS-1 = (0,0)  ..

WINTER-DEMAND = BLOCK-CHARGE BLOCK-SCH = SEASONS-SCH
                             SCH-FLAG  = 1.3
                             TOU-SEASON-LINKS = (SUMMER-DEMAND)
                             BLOCK1-TYPE = DEMAND
                             BLOCKS-1 = (1)
                             COSTS-1  = (5.0)  ..


SUMMER-OFF-PK = BLOCK-CHARGE BLOCK-SCH = SEASONS-SCH
                             SCH-FLAG  = 2.1
```

```
                              BLOCK1-TYPE = KWH/KW
                              BLOCKS-1 = (175,800)
                              COSTS-1  = (.045,.055)
                              LIMITS-1 = (0,0)  ..

SUMMER-SHLDR = BLOCK-CHARGE   BLOCK-SCH = SEASONS-SCH
                              SCH-FLAG  = 2.2
                              BLOCK1-TYPE = KWH/KW
                              BLOCKS-1 = (175,800)
                              COSTS-1  = (.055,.065)
                              LIMITS-1 = (0,0)  ..
SUMMER-ON-PK = BLOCK-CHARGE   BLOCK-SCH = SEASONS-SCH
                              SCH-FLAG  = 2.3
                              BLOCK1-TYPE = KWH/KW
                              BLOCKS-1 = (175,800)
                              COSTS-1  = (.065,.075)
                              LIMITS-1 = (0,0)  ..

SUMMER-DEMAND = BLOCK-CHARGE BLOCK-SCH = SEASONS-SCH
                              SCH-FLAG  = 2.3
                              TOU-SEASON-LINKS = (WINTER-DEMAND)
                              BLOCK1-TYPE = DEMAND
                              BLOCKS-1 = (1)
                              COSTS-1  = (6.00)  ..

GAS-RATE = UTILITY-RATE     TYPE=NATURAL-GAS
                            FUEL-METERS = FLM1
                            ENERGY-CHG = .60  ..

ELEC-RATE = UTILITY-RATE    TYPE = ELECTRICITY
                            BLOCK-CHARGES = (WINTER-OFF-PK,WINTER-SHLDR,
                                             WINTER-ON-PK,SUMMER-OFF-PK,
                                             SUMMER-SHLDR,SUMMER-ON-PK
                                             WINTER-DEMAND,SUMMER-DEMAND)  ..

$ Pollutant Production Calculation

$ The pollutant calculation is requested with the command POLLUTANT-COEFFS.
$ Required input is a LOCATION (a US state specified with post office
$ abbreviation) and a UTILITY-RATE.  The pollutant production report ES-H
$ reports the pollution production according to the time of use blocks
$ specified in the utility rate.

POLLUTANT-COEFFS            LOCATION=IL
                            UTILITY-RATE=ELEC-RATE  ..
```

B. Example Output

```
SIMPLE STRUCTURE RUN 3A, CHICAGO        INCREASED ROOF INSULATION               DOE-2.2b-027
Fri Jan  9 13:55:16 1998 BDL RUN  1

 REPORT- ES-G Summary of Pollutant Production                  WEATHER FILE- Chicago IL TMY2

            CARBON      SULPHUR     NITROGEN       CARBON       HYDRO-  PARTICULATE
           DIOXIDE      DIOXIDE       OXIDES     MONOXIDE     CARBONS       MATTER
 MONTH       (LB)         (LB)         (LB)         (LB)        (LB)         (LB)
 -----    --------     --------     --------     --------     --------     --------

  JAN       8378.1     78.62238     17.64021      1.97866      0.10554      1.78545

  FEB       6199.2     67.59749     13.97099      1.40433      0.08568      1.50900

  MAR       5618.3     74.11236     13.91426      1.19124      0.08800      1.62381

  APR       3899.3     78.81496     12.32568      0.65315      0.08313      1.67291

  MAY       4346.2    101.85219     15.10340      0.63920      0.10394      2.14390
```

JUN	5082.1	119.09686	17.66057	0.74743	0.12153	2.50688
JUL	6153.1	144.19458	21.38225	0.90494	0.14714	3.03516
AUG	5737.2	134.44791	19.93694	0.84377	0.13720	2.83001
SEP	4632.5	108.56061	16.09818	0.68131	0.11078	2.28510
OCT	3836.9	88.25845	13.17182	0.57480	0.09042	1.85960
NOV	4750.3	68.15607	12.30003	0.97235	0.07883	1.48248
DEC	7006.5	74.58499	15.61343	1.59872	0.09538	1.66931
TOTAL	65638.3	1138.26819	189.11319	12.18972	1.24755	24.40296

SIMPLE STRUCTURE RUN 3A,
CHICAGO INCREASED ROOF INSULATION DOE-2.2b-027 Fri Jan 9 13:55:16 1998BDL RUN 1

REPORT- ES-H Pollutant Production by Block-Charge WEATHER FILE- Chicago IL TMY2

UTILITY-RATE: ELEC-RATE

POLLUTANT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
BLOCK: WINTER-OFF-PK						USE: TIME-OF-USE							
CO2 (LB):	1797.8	1224.4	871.0	313.6	94.2	0.0	0.0	0.0	123.1	219.7	695.9	1151.9	6491.6
SO2 (LB):	6.829	5.688	5.535	4.581	2.207	0.000	0.000	0.000	2.885	4.695	5.359	6.036	43.815
NOx (LB):	2.806	2.012	1.577	0.820	0.327	0.000	0.000	0.000	0.428	0.719	1.351	1.960	12.001
CO (LB):	0.488	0.326	0.222	0.064	0.014	0.000	0.000	0.000	0.018	0.035	0.172	0.302	1.642
HC (LB):	0.015	0.011	0.009	0.005	0.002	0.000	0.000	0.000	0.003	0.005	0.008	0.011	0.068
PM (LB):	0.183	0.145	0.133	0.099	0.046	0.000	0.000	0.000	0.061	0.099	0.125	0.150	1.042
BLOCK: WINTER-SHLDR						USE: TIME-OF-USE							
CO2 (LB):	4068.1	2945.6	2805.0	2116.9	978.0	0.0	0.0	0.0	1140.4	1974.9	2389.9	3433.8	21852.4
SO2 (LB):	41.379	35.644	39.375	41.740	22.919	0.000	0.000	0.000	26.724	45.375	36.533	39.516	329.202
NOx (LB):	8.878	6.982	7.178	6.589	3.399	0.000	0.000	0.000	3.963	6.775	6.407	7.941	58.110
CO (LB):	0.940	0.645	0.580	0.361	0.144	0.000	0.000	0.000	0.168	0.296	0.475	0.765	4.374
HC (LB):	0.054	0.044	0.046	0.044	0.023	0.000	0.000	0.000	0.027	0.046	0.041	0.049	0.375
PM (LB):	0.931	0.787	0.858	0.887	0.482	0.000	0.000	0.000	0.563	0.956	0.791	0.877	7.132

```
     BLOCK: WINTER-ON-PK                        USE: TIME-OF-USE

 CO2 (LB):      2512.2   2029.1   1942.3   1468.8    850.7      0.0      0.0      0.0   1045.7
1642.3   1664.4   2420.9  15576.4
 SO2 (LB):      30.414   26.266   29.203   32.494   19.935    0.000    0.000    0.000   24.505
38.188   26.264   29.032  256.302
 NOx (LB):       5.956    4.977    5.159    4.916    2.956    0.000    0.000    0.000    3.634
5.678    4.542    5.713   43.531
 CO  (LB):       0.550    0.433    0.389    0.228    0.125    0.000    0.000    0.000    0.154
0.243    0.326    0.532    2.980
 HC  (LB):       0.037    0.031    0.033    0.034    0.020    0.000    0.000    0.000    0.025
0.039    0.030    0.036    0.285
 PM  (LB):       0.672    0.576    0.633    0.686    0.420    0.000    0.000    0.000    0.516
0.804    0.567    0.642    5.515

     BLOCK: SUMMER-OFF-PK                       USE: TIME-OF-USE

 CO2 (LB):         0.0      0.0      0.0      0.0    116.6    318.9    435.4    377.1    144.8
0.0      0.0      0.0   1392.8
 SO2 (LB):       0.000    0.000    0.000    0.000    2.731    7.472   10.203    8.837    3.394
0.000    0.000    0.000   32.639
 NOx (LB):       0.000    0.000    0.000    0.000    0.405    1.108    1.513    1.310    0.503
0.000    0.000    0.000    4.840
 CO  (LB):       0.000    0.000    0.000    0.000    0.017    0.047    0.064    0.055    0.021
0.000    0.000    0.000    0.205
 HC  (LB):       0.000    0.000    0.000    0.000    0.003    0.008    0.010    0.009    0.003
0.000    0.000    0.000    0.033
 PM  (LB):       0.000    0.000    0.000    0.000    0.057    0.157    0.215    0.186    0.071
0.000    0.000    0.000    0.687

     BLOCK: SUMMER-SHLDR                        USE: TIME-OF-USE

 CO2 (LB):         0.0      0.0      0.0      0.0   1046.1   2139.0   2514.2   2378.3    979.9
0.0      0.0      0.0   9057.5
 SO2 (LB):       0.000    0.000    0.000    0.000   24.516   50.128   58.920   55.733   22.963
0.000    0.000    0.000  212.258
 NOx (LB):       0.000    0.000    0.000    0.000    3.635    7.433    8.737    8.265    3.405
0.000    0.000    0.000   31.475
 CO  (LB):       0.000    0.000    0.000    0.000    0.154    0.315    0.370    0.350    0.144
0.000    0.000    0.000    1.332
 HC  (LB):       0.000    0.000    0.000    0.000    0.025    0.051    0.060    0.057    0.023
0.000    0.000    0.000    0.217
 PM  (LB):       0.000    0.000    0.000    0.000    0.516    1.055    1.240    1.173    0.483
0.000    0.000    0.000    4.468
SIMPLE STRUCTURE RUN 3A, CHICAGO        INCREASED ROOF INSULATION              DOE-2.2b-027
Fri Jan  9 13:55:16 1998BDL RUN  1

 REPORT- ES-H Pollutant Production by Block-Charge
WEATHER FILE- Chicago IL TMY2

     BLOCK: SUMMER-ON-PK                        USE: TIME-OF-USE

 CO2 (LB):         0.0      0.0      0.0      0.0   1260.7   2624.2   3203.4   2981.8   1198.6
0.0      0.0      0.0  11268.8
 SO2 (LB):       0.000    0.000    0.000    0.000   29.543   61.497   75.071   69.877   28.089
0.000    0.000    0.000  264.078
 NOx (LB):       0.000    0.000    0.000    0.000    4.381    9.119   11.132   10.362    4.165
0.000    0.000    0.000   39.159
 CO  (LB):       0.000    0.000    0.000    0.000    0.185    0.386    0.471    0.439    0.176
0.000    0.000    0.000    1.657
 HC  (LB):       0.000    0.000    0.000    0.000    0.030    0.063    0.077    0.071    0.029
0.000    0.000    0.000    0.269
```

```
 PM  (LB):       0.000    0.000    0.000    0.000    0.622    1.294    1.580    1.471    0.591
0.000    0.000    0.000    5.559

     BLOCK: WINTER-DEMAND                    USE: TIME-OF-USE

 CO2 (LB):      2512.2   2029.1   1942.3   1468.8    850.7      0.0      0.0      0.0   1045.7
1642.3   1664.4   2420.9  15576.4
 SO2 (LB):      30.414   26.266   29.203   32.494   19.935    0.000    0.000    0.000   24.505
38.188   26.264   29.032  256.302
 NOx (LB):       5.956    4.977    5.159    4.916    2.956    0.000    0.000    0.000    3.634
5.678    4.542    5.713   43.531
 CO  (LB):       0.550    0.433    0.389    0.228    0.125    0.000    0.000    0.000    0.154
0.243    0.326    0.532    2.980
 HC  (LB):       0.037    0.031    0.033    0.034    0.020    0.000    0.000    0.000    0.025
0.039    0.030    0.036    0.285
 PM  (LB):       0.672    0.576    0.633    0.686    0.420    0.000    0.000    0.000    0.516
0.804    0.567    0.642    5.515

     BLOCK: SUMMER-DEMAND                    USE: TIME-OF-USE

 CO2 (LB):         0.0      0.0      0.0      0.0   1260.7   2624.2   3203.4   2981.8   1198.6
0.0      0.0      0.0  11268.8
 SO2 (LB):       0.000    0.000    0.000    0.000   29.543   61.497   75.071   69.877   28.089
0.000    0.000    0.000  264.078
 NOx (LB):       0.000    0.000    0.000    0.000    4.381    9.119   11.132   10.362    4.165
0.000    0.000    0.000   39.159
 CO  (LB):       0.000    0.000    0.000    0.000    0.185    0.386    0.471    0.439    0.176
0.000    0.000    0.000    1.657
 HC  (LB):       0.000    0.000    0.000    0.000    0.030    0.063    0.077    0.071    0.029
0.000    0.000    0.000    0.269
 PM  (LB):       0.000    0.000    0.000    0.000    0.622    1.294    1.580    1.471    0.591
0.000    0.000    0.000    5.559

     TOTAL

 CO2 (LB):      8378.1   6199.2   5618.3   3899.3   4346.2   5082.1   6153.1   5737.2   4632.5
3836.9   4750.3   7006.5  65638.3
 SO2 (LB):      78.622   67.597   74.112   78.815  101.852  119.097  144.195  134.448  108.561
88.258   68.156   74.585 1138.268
 NOx (LB):      17.640   13.971   13.914   12.326   15.103   17.661   21.382   19.937   16.098
13.172   12.300   15.613  189.113
 CO  (LB):       1.979    1.404    1.191    0.653    0.639    0.747    0.905    0.844    0.681
0.575    0.972    1.599   12.190
 HC  (LB):       0.106    0.086    0.088    0.083    0.104    0.122    0.147    0.137    0.111
0.090    0.079    0.095    1.248
 PM  (LB):       1.785    1.509    1.624    1.673    2.144    2.507    3.035    2.830    2.285
1.860    1.482    1.669   24.403
```

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