DOE-2.2 and *PowerDOE*®
THE NEW GENERATION IN DOE-2 BUILDING ENERGY ANALYSIS

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INTRODUCTION

DOE-2.2, the much awaited and newest generation of the DOE-2 building energy analysis software program, is ready for public release. At the same time, PowerDOE®, a Windows™-based graphical application that incorporates DOE-2.2, is also now available for commercial distribution. DOE-2.2 adds significant new modeling capabilities to DOE-2.1E and facilitates use in interactive products, while PowerDOE presents the first interactive and graphical environment for DOE-2.2 that is both user-friendly and comprehensive. The DOE-2.2 project is a collaboration between Lawrence Berkeley National Laboratory (LBNL), primarily under funding from the U.S. Department of Energy, and James J. Hirsch and Associates, under funding from the Electric Power Research Institute (EPRI) as well as other gas and electric utility industry organizations. The major support for PowerDOE development has come from EPRI, Southern California Edison, Pacific Gas and Electric, Southern Company, and the Bonneville Power Administration.

PROJECT DEVELOPMENT

DOE-2.2 and PowerDOE development was initiated in 1992 as a collaboration between the U.S. Department of Energy and the Electric Power Research Institute. The project's initial concept was to update and enhance DOE-2 to allow direct and close integration with a comprehensive graphical user interface. The objective was to make DOE-2 easier to learn and less expensive to use, thus extending DOE-2's detailed modeling capabilities to building designers rather than being limited to use by energy analyst specialists. However, as the project proceeded, two issues slowed its completion. First, the benefit and need for significant enhancements to the DOE-2 simulation engine became more and more evident; this has produced a significant new "standard" version of DOE-2, i.e., DOE-2.2. Secondly, the changing nature of the utility and government funding "landscape" resulted in two tools, rather than one tool, i.e., DOE-2.2 (machine independent, batch execution) and PowerDOE (Windows-based, interactive execution). Both tools are open (source and executable licensing through a wide range of vendors), inexpensive (a few hundred dollars), well documented and supported, and share a common "simulation engine" core.

This article provides an overview of the DOE-2.2 simulation enhancements and the PowerDOE version 1 user interface. Additional features for future releases of DOE-2 and PowerDOE version 2 are briefly described. Machine requirements and availability are also described. *PowerDOE is a registered trademark of the Electric Power Research Institute.*

DOE-2.2 ENHANCEMENTS

Space constraints permit only brief description of only the most important DOE-2.2 enhancements over DOE-2.1E.

Circulation loops — DOE-2.2 now uses an integrated air-side/water-side HVAC simulator, thus the DOE2.1E SYSTEM and PLANT programs are replaced with a combined HVAC simulation program. One benefit from this change is improved connectivity between the loads incurred by secondary HVAC system components such as air handler coils and reheat coils and the primary HVAC equipment such as boilers and chillers. Primary equipment, terminal units and coils are now attached to specific circulation loops. Currently, three levels of circulation loops are provided: "dedicated" equipment loops which serve specific pieces of primary equipment, "primary" loops and, "secondary" loops. Each level of loop may have associated constant-flow or variable-flow pumps. Different coils in the same system or zone such as preheat coils, re-heat coils and baseboards, can be supplied flow by different loops. Additionally, valves and pumps are explicitly modeled including flow, pressure drop, and pressure control.

Central plant equipment — Major new equipment selections include:

- ground loop heat exchanges (GLHX) for use with water source heat pumps;
- heat rejection equipment including enhanced cooling tower and fluid cooler models with or without heat exchangers;
- greatly improved control modeling including hot and chilled water reset,
- expanded equipment assignment to meet loop loads and many "load management" modes to control overall plant operation.

Additionally, each chiller, boiler, pump, etc., is now modeled separately, thus each piece of equipment can now have unique size and performance characteristics.

Air handling equipment — A Dual Fan option has been added to the Dual Duct, Multi-Zone, and Packaged Multi-Zone systems. The return fan can be located either in the return or relief air stream. Exhaust fans can be scheduled separately from supply/return fans. All coils can be independently assigned to fluid loops.

Expressions — Expressions are general multi-line equation-like entries used to calculate input values. Expressions can be simple or complex, arithmetic or logical, and can reference one or more other building parameters. Expressions differ from input macro's (still supported) in that they operate on actual keyword values rather than simply manipulate text. Using expressions, building models can be made to be easily "adjustable". See Figures 3 and 4 below.

Shapes and geometry — all opaque heat transfer surfaces, floors and spaces can now be described as arbitrary polygons (up to thirty sides). Using polygon input for floors and spaces can greatly decrease the time required for describing complex geometry of architectural features.

Windows — windows can now be "built up" in a layer-by-layer manner, combining multiple glass layers, gaps and/or blinds.

Lighting systems — lighting systems can now be described on a luminaire-by-luminaire basis or the user can describe a target illuminance and DOE-2.2 will calculate the required number of luminaires.

Multiple lighting and equipment profiles — previously, only one lighting and one equipment description could be input per space (i.e., one power density with one associated schedule). DOE-2.2 now permits up to five lighting and five equipment descriptions per space.

Scheduling and design days — Design days can be specified in a more common format using familiar values from ASHRAE and other sources. Schedules have been enhanced to allow separate specification of profiles to use for heating and cooling design days and enhanced to include many new types with support for metric specifications. Reset schedules can also include day/night alternate values.

Meters — Three levels of electric meters can be defined (site, building, and sub-building) with up to 100 total meters being allowed in an arbitrary tree structure. Any energy consuming equipment can be individually assigned to a meter. All meters have separate and combined summary and hourly report capabilities. All electric meters can include a transformer model that allows the accounting of stand-by losses and performance as a function of load. Also, 15-, 30-, and 60-minute demand intervals (either fixed or floating windows) are supported for the most important HVAC electric equipment; these demand intervals are also accounted for in the utility rate calculation. Multiple fuel, chilled water and steam meters can also be defined (up to 15 each).

Libraries — DOE-2.2 now uses a more general library feature that permits a user to store and retrieve a much broader variety of building components including: windows, walls, lighting fixtures, spaces, schedules, air handlers and central plant equipment. The standard library includes: extensive schedules for common building types as well as space and equipment usage; extensive (with user over-ride capabilities) primary/secondary equipment performance curves.

Documentation — Documentation for DOE-2.2 has been completely revised. The *DOE-2.2 Basics Manual* (an extension of the *DOE2.1E Basics Manual*) is an introduction to DOE-2 for new users. The old *DOE-2.1A Reference Manual*, *DOE-2.1E Supplement* and *DOE-2.1E BDL Summary* have been combined (at last!) into the *DOE-2.2 Command/Keyword Dictionary* which defines all of the commands and keywords in the DOE-2.2 input language. The *DOE-2.2 Topics Manual* provides discussion and example input for "topics" that are broader than a single command or keyword, e.g., daylighting or circulation loops.

POWERDOE USER INTERFACE

PowerDOE's user interface provides important visual feedback that greatly reduces the time required to prepare an accurate building description. For example, the Building View screen (Figure 1) which displays a three-dimensional view of all building and shading surfaces, allows the user to quickly catch gross building and external shading geometry errors. The user may easily shift the position of the viewer and can suppress the display of any selected type of surface. From the 3-D view, the user may also select any building surface to be edited by simply clicking on it.

PowerDOE is organized into four main modules: LOCATE SITE (e.g., select weather location), DESCRIBE BUILDING (architectural, HVAC, building operations and utility services input screens), RUN CALCULATIONS (specify simulation periods and select standard or hourly reporting) and REVIEW RESULTS (graphical reports summarizing simulation results).

LOCATE SITE

PowerDOE provides an extensive library of average year weather data. Users can easily select from over 650 standard weather files for North America including, TMY, TMY2, CTMY, WYEC, WYEC2, CTZ, and TRY. (Figure 2). Other site-related data may be specified, including design day data.

Figure 1: 3-D Building View provides graphical feedback on the overall building envelope. The user may easily tilt or rotate the view, and can suppress the display of any selected type of surface. The user may also select any building element to be edited simply by clicking on it.
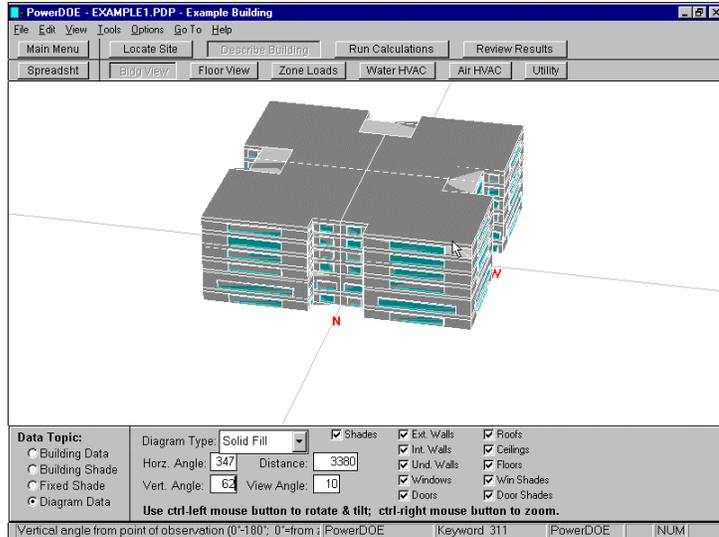
Figure 2: Locate Site
Users may zoom, point and click to select from over 650 average year weather files available for North American locations (e.g., TMY, WYEC, etc.). Actual year weather files (e.g., airport weather data obtained directly from the National Climatic Data Center) may also be used.
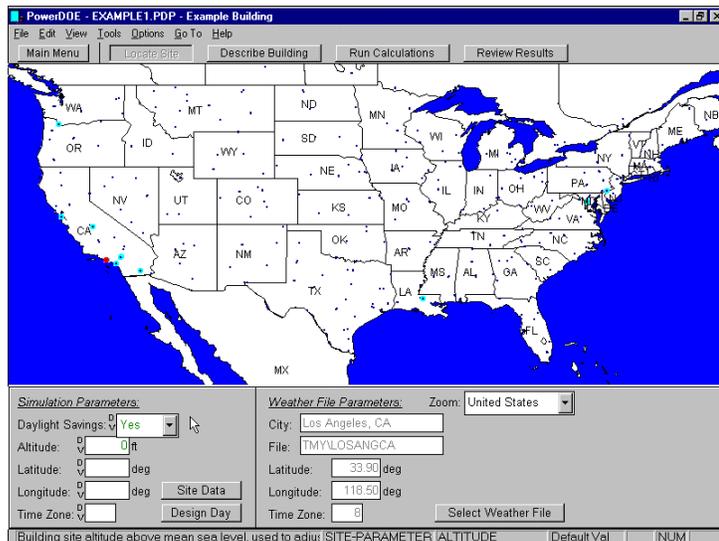
Figure 3: Floor View
The Floor View screen provides building designers with a familiar plan view of each floor within the building. Clicking on any building component (e.g., space, wall, window, etc.) displays data for the selected component at the bottom of the screen (the southwest space is selected at right).
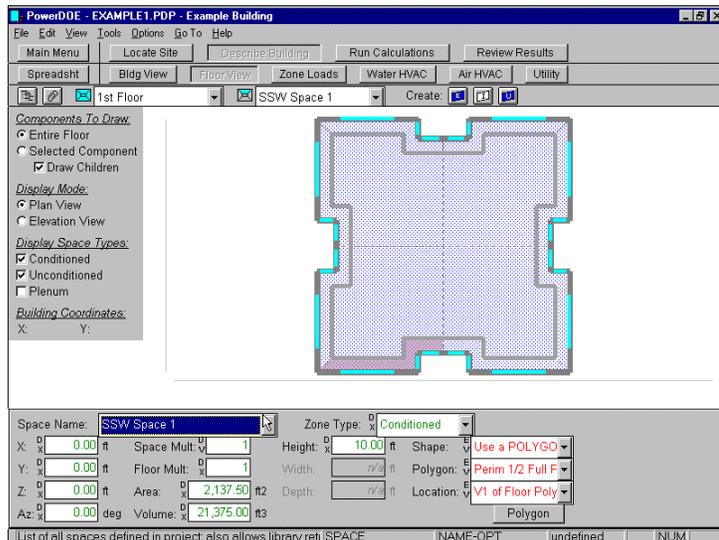
DESCRIBE BUILDING

PowerDOE organizes architectural and HVAC building components in a hierarchy that is intuitive and familiar to designers and analysts. Building areas are grouped into floor plans (Figures 3 and 4) while HVAC equipment is grouped by air flow and water flow paths that supply building HVAC requirements (Figures 5 and 6).

Using the new "expressions" capability of DOE-2.2, building models can be created that are more flexible than ever. For example, using expressions to describe the layout of the example floor plan illustrated in Figure 3, the floor footprint and zone depth are easily modified into the floor plan illustrated in Figure 4 by changing only four user-defined input parameters (overall building length, facade "notch" width and depth, and perimeter zone depth).

Air-side and water-side screens (Figures 5 and 6) help the user readily identify the equipment installed on each air-side and water-side circuit. For example, on the air-side equipment screen shown in Figure 7, "installed" system options are illustrated by colored icons. "Uninstalled" system options are shown as dotted gray outlines. Users double click on uninstalled pieces of

equipment to install them. On the chilled water loop screen shown in Figure 6, installed suppliers (i.e., chillers) are shown on the top leg of the loop. Demanders (i.e., chilled water coils) are shown on the bottom leg of the loop.

Most of PowerDOE's input screens are organized to visually illustrate the selected building component while simultaneously displaying only the most important data pertaining to the selected building component. For example, in Figure 7, the lower portion of the screen is used to display the most important data describing the system. More detailed inputs and component descriptions are accessible if desired (Figure 8), either by clicking on the "More" button in the lower right hand corner of the screen or by double clicking on any icon for a selected system option (e.g., double clicking on the DX cooling coil). Similarly, by double clicking on primary equipment icons in Figure 6, more detailed information is presented for the selected piece of primary equipment (Figure 9).

"Zoning" a selected building floor into separate spaces can now be done graphically in PowerDOE (Figure 10) by simply pointing and clicking on the floor footprint

Figure 4: "Flexible" Geometry Using equation-like input "expressions" to describe the layout of the example floor plan in Figure 3, the floor footprint and zone depth are easily modified into the floor plan illustrated at right by changing only four user-defined parameters (building length, facade "notch" width and depth, and perimeter zone depth, compare Fig. 3)
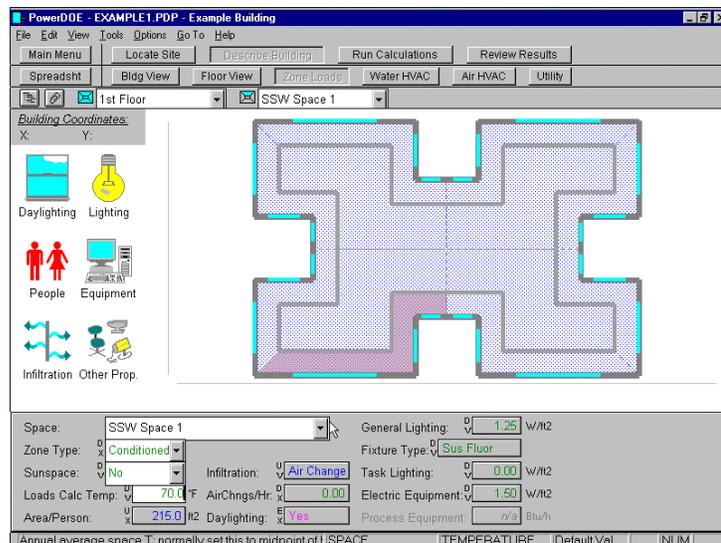
Figure 5: Air-Side HVAC
The Air-Side HVAC System
screen provides building
designers with a schematic
view of each air-side system.
Clicking on any system
component (e.g., fan, coil, etc.)
displays data for the selected
component at the bottom of the
screen.
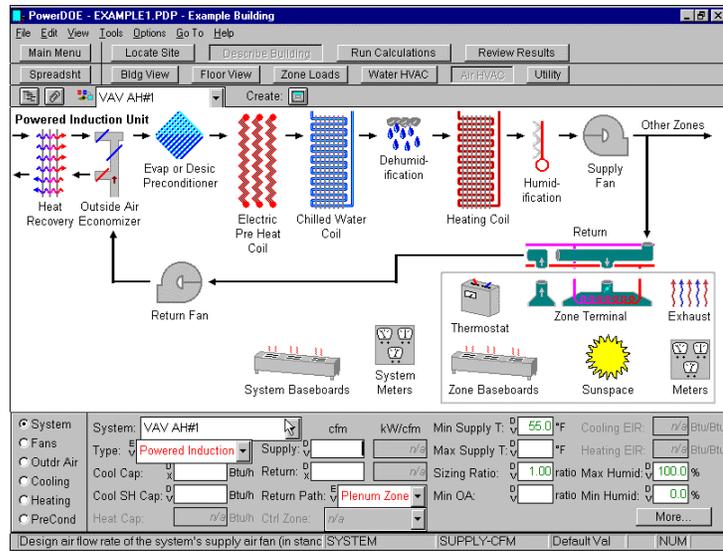
Figure 6: Water-Side HVAC
The Water-Side HVAC Loop
screen provides a schematic
view of each water-side loop
within the building. On the
chilled water loop screen
shown at right, suppliers (i.e.,
chillers) are shown on the top
leg of the loop. Demanders
(i.e., chilled water coils) are
shown on the bottom leg of the
loop.
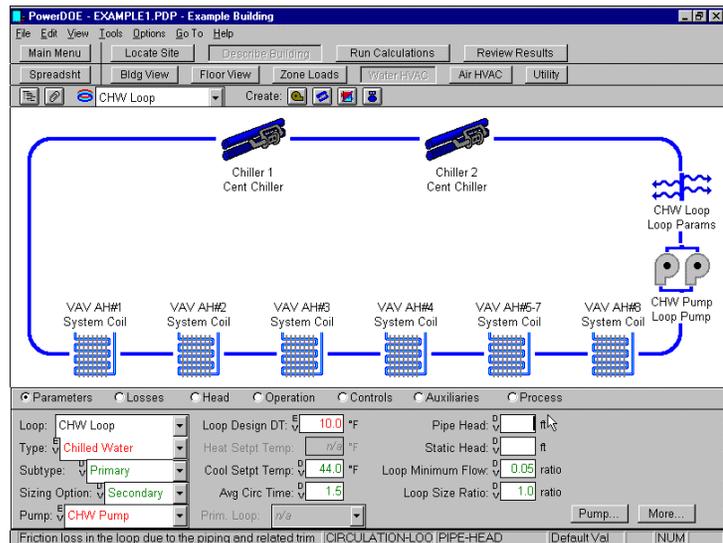
Figure 7: Uninstalled Options
On the Air-Side HVAC
System screen at right,
"installed" system options are
illustrated by colored icons.
"Uninstalled" system options
are shown as dotted outlines.
Double click on these
uninstalled components to
install them.
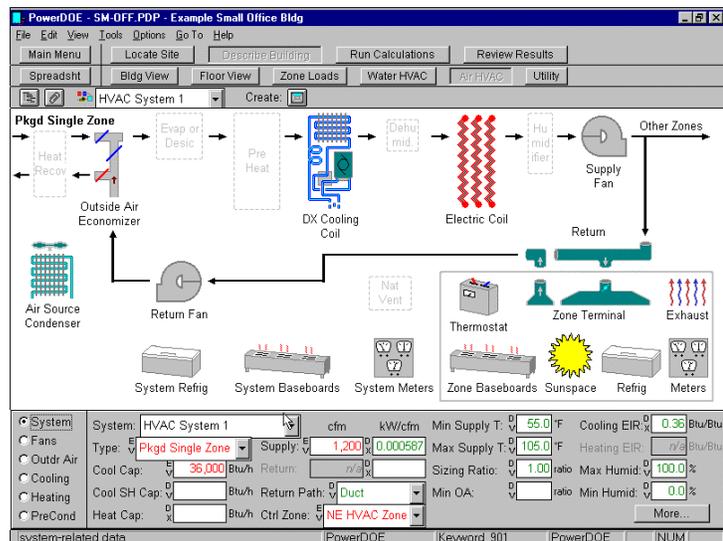
Figure 8: Air-Side Details
Detailed air-side component descriptions are displayed on a "pop-up" tabbed dialog (shown at right), by clicking on the "More" button in the lower right hand corner of the screen or by double clicking on any selected system component icon (e.g., double clicking on the DX cooling coil).
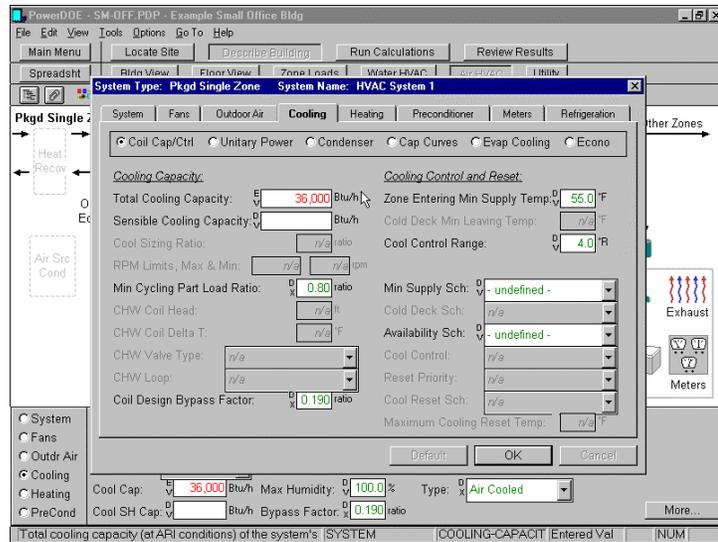
Figure 9: Primary Equipment
Double clicking on primary equipment icons (e.g., in Figure 6) displays the primary equipment screen shown at right. A "pop-up" tabbed dialog (not shown) can be displayed by clicking on the "More" button in the lower right hand corner of the screen.
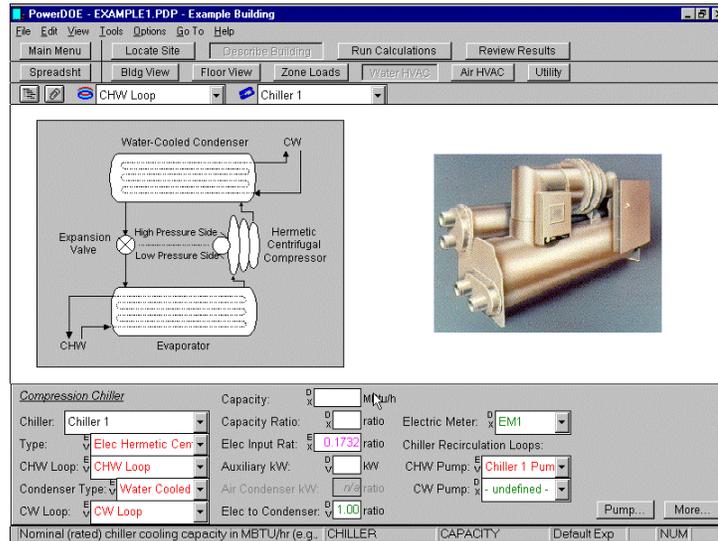
Figure 10: Polygon dialog
"Zoning" a selected building floor into separate spaces can now be done graphically in PowerDOE by simply pointing and clicking on the floor footprint to outline the desired zone (i.e., "space") boundaries.
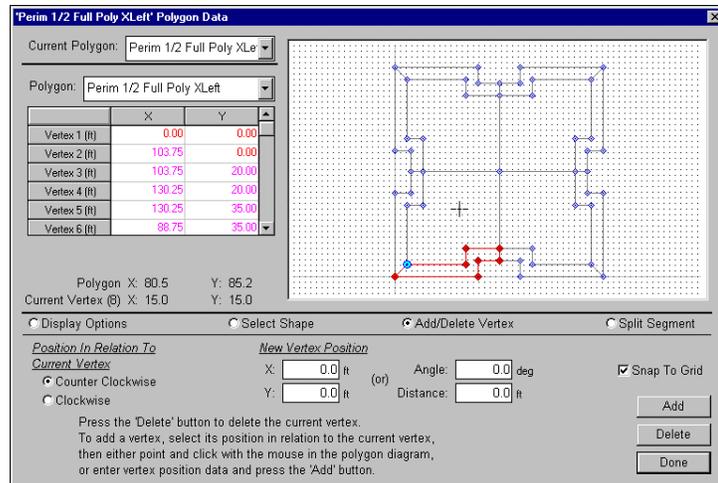
to outline the desired zone (i.e., "space") boundaries. This method of defining spaces uses polygons to define the space shape, which later greatly speeds the placement of the walls, ceilings and floors that surround spaces.

On all PowerDOE screens, only those controls (i.e., input fields) that are applicable to the current building description or selected component are active. Inactive controls are grayed back and marked "*n/a*" (Figure 8).

Pop-up "tabbed dialog boxes", such as the one shown in Figure 8, allow a user to quickly review all relevant inputs pertaining to a currently selected building component. Alternatively, PowerDOE also provides a global summary worksheet in a spreadsheet-like format containing data for all building elements (Figure 11). This spreadsheet mode of displaying data is especially useful for reviewing a specific input (e.g., window glass type) across all components to which it applies (i.e., across all windows in the building). Using the building data spreadsheet, users can efficiently review or directly edit any building data from this central "database".

Space internal loads (people, lighting, daylighting, equipment and infiltration) are input using the Zone Loads screen (shown in Figure 12 with the zone loads detailed data tabbed dialog displayed).

Schedules may be reviewed or edited from anywhere in the interface via a right mouse click. Schedules allow all building and HVAC schedule profiles to be entered graphically, numerically, or as expressions (Figure 13). For easily comparing various schedules, PowerDOE can display multiple weekly schedules side-by-side, as shown in Figure 14. An extensive schedule library, combined with the ability to easily copy, modify and save user-defined schedules, make using schedules in PowerDOE much less tedious than before.

REVIEW RESULTS

Results are reviewed in a separate application called DOE-2REV that enables preparation and display of customized reports (Figure 15). When running PowerDOE, DOE-2REV is seamlessly integrated, with full navigation functionality between the two applications as if they were one. DOE-2REV can also be executed separately for post-processing DOE-2.2 results.

Figure 11: Bldg Spreadsheet PowerDOE provides a global summary worksheet in a spreadsheet-like format containing data for all building elements. Users can efficiently review or directly edit any building data from this central "database".

Figure 12: Zone Loads
Space internal loads are input using the Zone Loads screen (shown at right with the zone loads detailed data tabbed dialog displayed). Only those controls (i.e., input fields) that are applicable to the current building description or selected component are active. Inactive controls are grayed back and marked "*n/a*".
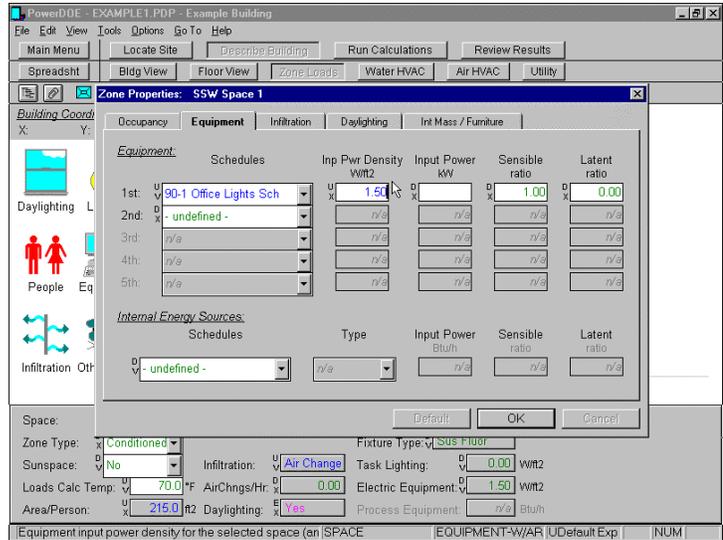
Figure 13: Day Schedule
Schedules may be reviewed or edited from anywhere in the interface via a right mouse click. An extensive schedule library, combined with the ability to easily copy, graphically modify and save user-defined schedules, make using schedules in PowerDOE much less tedious than before.
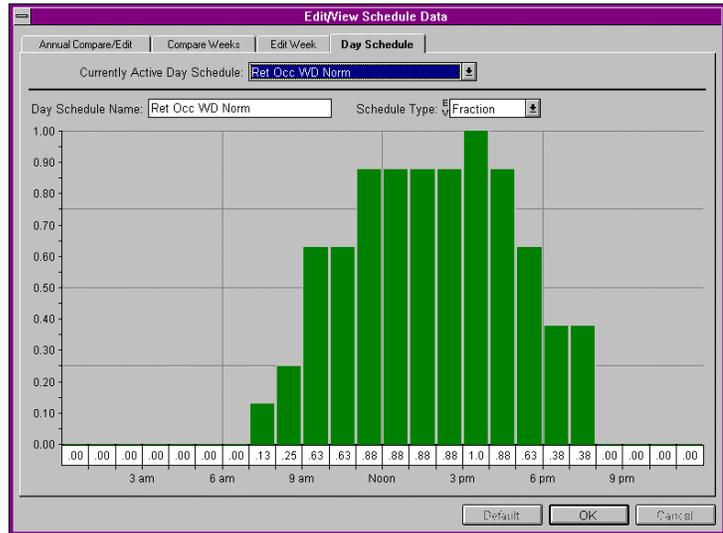
Figure 14: Compare Weeks
For easily comparing various schedules, PowerDOE can display multiple weekly schedules side-by-side.
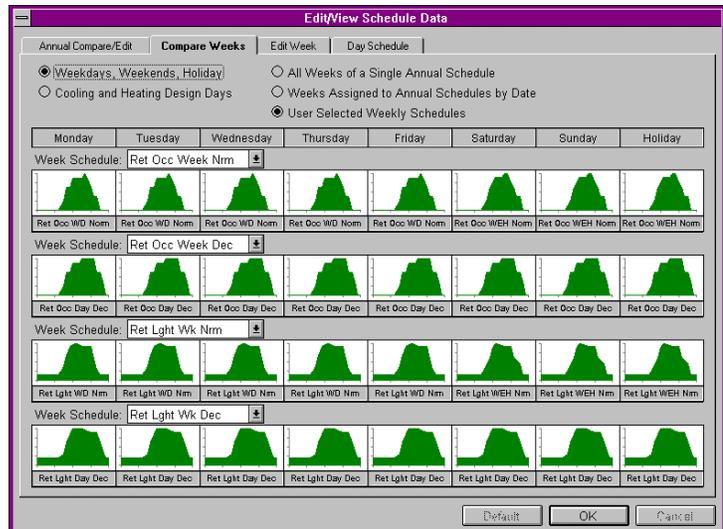
Figure 15: Review Results
The Review Results module provides predefined and user-defined graphical reports. A predefined utility report is shown at right, showing peak day electrical profiles for January through June.
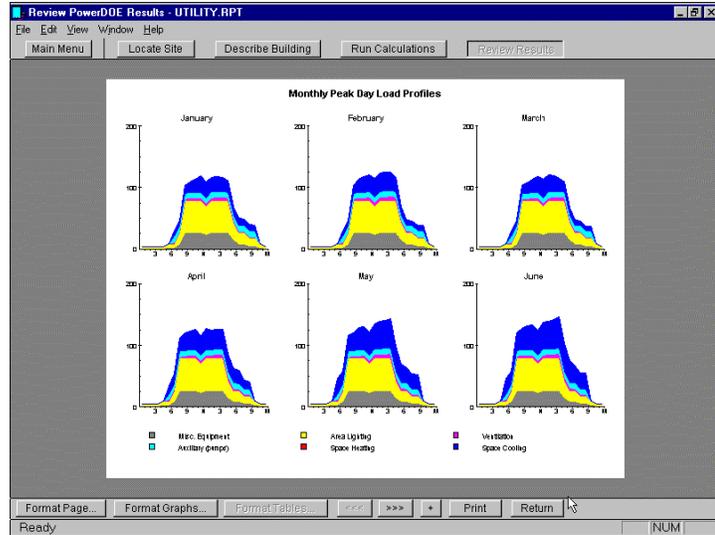
Input Data Sources

PowerDOE inputs can either be user-input values (directly input by the user), DOE-2.2 defaults (program default values used in the absence of user inputs), user defaults (defaults established by the user), DOE-2.2 library data (data retrieved from the DOE-2.2 library), or formula-like "expressions". PowerDOE labels each of these data sources (small labels to the left of the input controls, see Figures 3 through 9) and displays them in different font colors, permitting the user to easily recognize the source of the data.

Online HELP

PowerDOE includes a comprehensive online help system. Context-sensitive help is available for every data entry field, as well as for every program screen. When the user points to a data field and clicks the right mouse button, PowerDOE displays a drop down "Quick Menu" beside that field. The user can then select Field Help for the particular field, or Topic Help for information on the current screen. Help is also available from the main menu bar or by pressing the F1 key, and includes standard Windows Help components such as Contents and a Search Keywords dialog box. In addition, the online help system contains extensive hypertext links that provide quick access to related topics.

POWERDOE STRUCTURE and the DOE-2.2 SIMULATION ENGINE

PowerDOE has a modular structure that allows sections of the program to be externally accessed or to be connected with other analysis tools. The modular structure of PowerDOE also enables third-party developers to use PowerDOE's interface modules and the DOE-2.2 simulation engine in their applications.

Due to reduced file access and improved memory management, the simulation speed of DOE-2.2 is approximately 25% faster than DOE-2.1E. Simulations can also be performed in the background while the user performs other tasks on the computer.

MACHINE REQUREMENTS

DOE-2.2 versions will be available for DOS, Microsoft Windows (EXE and DLL format), Unix, VAX, and other common operating systems; hardware requirements vary, but generally 32 megabytes of RAM memory and 200 megabytes of hard disk space is required. The minimum PowerDOE computer requirements are: Pentium™ PC, color VGA monitor, 32 megabytes of RAM

memory, 200 megabytes of free hard drive space. <u>Recommended</u> specifications include: a Super-VGA monitor (800x600 resolution) is suggested for improved display of graphics, 64 megabytes of RAM, and a 200 MHz or faster Pentium (for larger projects). Microsoft Windows™ 3.1 is the <u>minimum</u> operating environment; Windows95™ is recommended and Windows NT™ is also supported. Although no conflicts are anticipated, use of PowerDOE under Windows98 is still being evaluated.

FUTURE ENHANCEMENTS

Subsequent releases of both DOE-2.2 and PowerDOE are planned that will incorporate additional features; details of these features will be the subjects of future articles. Features that are funded and under development include:

- *Process Refrigeration* — A module for modeling commercial (supermarkets, food service) and industrial (warehouses, food processing) facilities with complex refrigeration systems including refrigerant piping networks, compressor racks and chillers with alternative refrigerants, controls, air-units, display cases, condensers, and heat reclaim for HVAC and DHW;

- *Process Equipment* — the ability to model process equipment loads and characteristics with much greater detail, including libraries of specialized equipment specifications. The first use of this enhanced modeling capability is a food service kitchen equipment module designed for a "vertical" range of users from equipment manufactures' representatives and utility professionals to design engineers. Later modules could include industrial and laboratory applications.

- *Rule processor* — a general rule processor used to automate selected modeling processes. The first use of the rules processor will be a module for showing compliance with building energy standards. Using rules from any energy code (e.g., ASHRAE 90.1 or California Title24) a "code compliant" version of an as-designed building model can be automatically generated.

- *Automated Design* — using the rule processor capability described above, design "agents" will be developed to assist in the selection of better energy and cost performing design alternatives – initial agents are being developed for glazing and HVAC system selection;

- Wizards for guiding the user step-by-step through the process of describing a building and creating building components plus a library of prototype building models — the user would customize a prototype by specifying building type (i.e.: office, hospital, etc.), size (i.e.: large, medium, small), vintage (i.e.: pre 1970's, 1970's, 1980's, etc.), and location;

- Building type specific modeling applications designed to allow rapid analysis of specific building types – initial applications for food service, supermarkets, central plants, and refrigerated warehouses.

AVAILABILITY

Both DOE-2.2 and PowerDOE are expected to be available for commercial distribution beginning in July of 1998. Visit http://www.doe2.com to obtain the latest details, list of distributors, costs, licensing information, free evaluation copies, tutorial and training information.