SOFTWARE DESCRIPTION FOR ENER-WIN: A VISUAL INTERFACE MODEL FOR HOURLY ENERGY SIMULATION IN BUILDINGS

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ABSTRACT

Using the Visual Basic development tool kit, the authors have developed a highly interactive graphical interfáce to an hourly energy simulation model for estimating annual energy consumption in buildings. The software, named ENER-WIN, features an interfáce program that calls and controls the execution of the energy simulation model and the weather data processor. The software will run on PCcompatible microcomputers under the Windows operating system.

Intended users of the software are architects, building designers, engineers, energy code officials, and utility company personnel. The program can be utilized for new building designs, retrofit designs, or energy code compliance checking; and will perform HVAC equipment sizing, monthly utility bill estimates, annual, energy budgets, peak load demand charges, and a present worth life-cycle cost analysis for the building fácility. Designers using the program. will find it useful for checking alternative energy conservation proposals during the design process.

INTRODUCTION

Energy efficiency of a proposed or existing building facility is one of the most important criteria that will determine a building's overall cost burden to the owners (Clarke 1989; Degelman 1990). It is a generally accepted fact that large amounts of energy and operating cost savings can be derived from proper design of building's external envelope and mechanical equipment. It has been shown by some researchers that little or no cost penalty is incurred in building most energy-efficient buildings when compared to inefficient buildings. However, in some cases, there are significant extra costs required to make a building energy-efficient.

To justify extra expense for achieving energy efficiency, the building designer must be able to accurately simulate annual energy performance while the building is undergoing major design decisions early in the process. It is necessary, therefore, to incorporate effective energy analysis tools into the decision making process. Later, the energy results may still need to be verified; therefore, energy simulation tools should also be applicable for evaluation and verification in the later stages.

Using the Visual Basic development tool kit under Windows(R), the authors have developed a visual interface for software that performs hourly calculations of the annual energy consumption in buildings. The software, named ENER-WIN, features an interactive user interface that will allow the user to easily explore alternative design proposals (Degelman and Soebarto 1994). This interface program calls and controls the execution of the energy simulation model and the weather data processor either during the design process, verification stage, or in post-occupancy retrofit.

The front-end interface of ENER-WIN was programmed using Visual Basic 3.0 while the simulation model was compiled in the FORTRAN-77 Language. The sketching program was written in C and the weather filer and retriever was written in Quick Basic.

OBJECTIVES

The general objective of this software is to encourage energy design considerations as standard operating practice for building designers. Specific objectives are to provide:

(1) a rapid feedback tool that will enhance the designing and rechecking of building energy strategies,
(2) a visualization capability that helps designers to better explore alternative design proposals during the early stages of design,
(3) an easy-to-use drawing module for sketching building features related to energy analyses,
(4) fast access to default data bases, including weather data, building envelope properties, occupancy and operating schedules, HVAC equipment properties, and life-cycle cost parameters, and

(5) an energy design/evaluation tool under the Windows environment.

SOFTWARE CAPABILITIES

The capabilities of ENER-WIN include the followings:

(1) *Estimation of the annual energy performance of buildings:*
ENER-WIN estimates the annual energy performance of buildings by reporting total annual energy consumption and the overall energy utilization factor (EUF), in terms of Btus per square foot per year. This quantity can be compared to the Building Energy Performance Standards (BEPS).

(2) *Identification of targets of opportunity for energy reductions:*
ENER-WIN facilitates the examination of building configurations and thermal properties which may help to reduce annual cost and conserve energy. It does this by providing percentage breakdowns for heating and cooling energy expenditures for a number of building components. Peak demand charges as well as energy cost are also shown so the user can devise cost saving strategies, such as peak load shaving by use of thermal storage or equipment load diversification. Alternative strategies can easily be tested and compared by simply changing the values in the input file.

(3) *Estimation of the peak design loads:*
Peak loads are produced for heating and cooling for the entire building central plant as well as for each zone of the building.

(4) *Calculation of floating space temperatures for passive designs:*
The program calculates "discomfort degree-hours" for the internal occupied environment of non air-conditioned (passively heated and cooled) buildings. In this mode, the software permits the space to float through an unrestricted range throughout the whole year. This feature permits a detailed study of the effects of thermal mass, window placement, and thermal envelope properties.

TECHNICAL BASIS

Analytical components of ENER-WIN are organized into 9 categories. They are: (1) weather data generation, (2) envelope material cataloging, (3) user profile cataloging, (4) zone processing, (5) building geometry processing, (6) load calculations, (7) system simulations, (8) energy summations, and (9) life-cycle cost predictions. These are further described below:

(1) *Weather data generation:*
Weather data generation is done hour-by-hour, producing hourly values for dry-bulb temperature, dewpoint temperature, wind speed, sun angles, cloud cover fraction, and direct and diffuse insolation. A more detailed description of the weather simulation model has been published in previous papers (Degelman 1990, 1991). Luminous values are derived from the thermal radiation by use of a luminous efficacy algorithm (Gillette and Treado 1985). The weather model permits the user to specify any of the 270 cities in the database as well as the period of the desired simulation each month -- 1, 2, 3, or 4 weeks per month. Figure 1 shows the ENER-WIN's weather data screen.

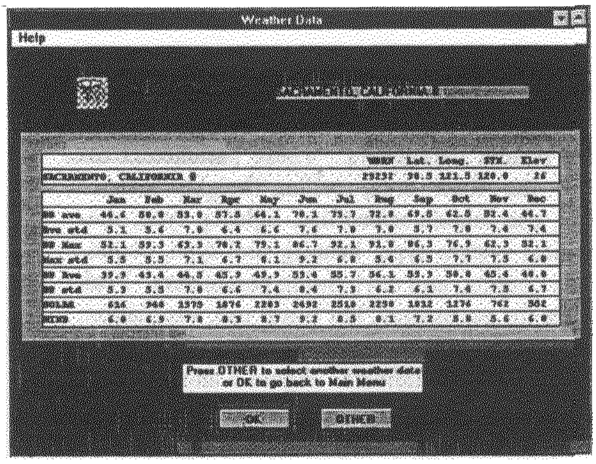

Fig. 1. Weather Data Screen in ENER-WIN

(2) *Envelope material cataloging:*
The envelope material cataloging permits any wall, woof, or glazing assembly to be specified and entered in a simple, numbered catalog. The material specifications require the assembly's thermal conductance, thermal capacitance (time lag), and the absorptivity of the outside surface to solar radiation. Glazing assemblies require input of overall thermal conductance, thermal radiation transmissivity, emissivity, and luminous transmissivity. Cost data are also permitted if the life cycle costing is desired. ENER-WIN allows up to 20 each of wall and window types, and these can be applied to up to 400 wall surfaces in one simulation run. Figure 2 shows the window material catalog.

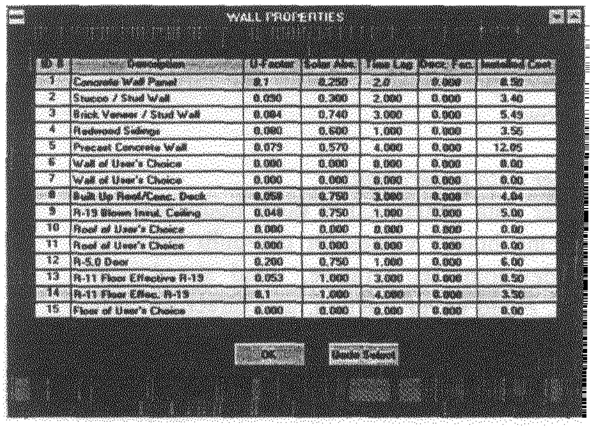

Fig. 2. Window material catalog

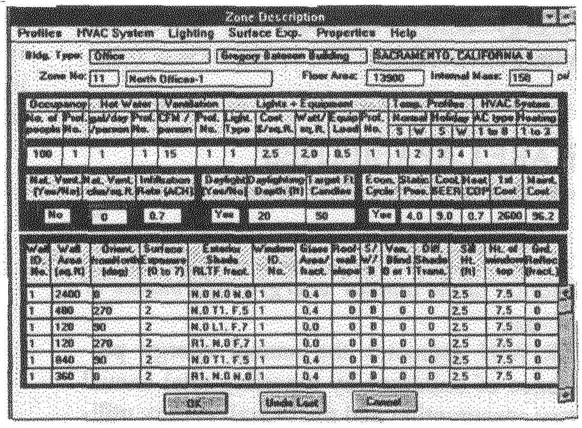

Fig. 3. Zone Description screen

(3) *User profile cataloging:*
The user profile cataloging permits the user to specify up to 50 different profiles of hourly patterns of occupancy, hot water usage, lighting, electric loads, ventilation rates, normal summer and winter temperature settings, and holiday summer and winter setbacks.

(4) *Zone processing:*
The zone processing involves linking the zones to the profile numbers and specifying the other zone related parameters. These parameters include the floor area, ceiling height, interior mass, use schedules/profiles, lighting type, mechanical system type, heating fuel type, economizer cooling, and daylighting parameters. Peak values for occupancy, hot water use, ventilation, lighting, and equipment are also linked to the respective profile numbers. Figure 3 shows an example ENER-WIN screen for describing a zone.

(5) *Building geometry processing:*
This processing is conducted in a set of routines which link the previously defined envelop catalog to the walls and roofs of each building zone. The geometry routines also manipulate the envelope's areas, orientations, slope, shading, and exposure to the specified ground cover. Shade types include diffuse screens, venetian blinds, overhangs, adjacent building, and trees. Ground surface exposures include selection from both natural and paved materials.

(6) *Load calculations:*
Loads calculations, system simulations, and energy summations are performed simultaneously for each of the 8760 hours in a year beginning at 1:00 a.m. on January 1 and are based on the generated exterior weather conditions and the interior temperature profiles and loads (Degelman 1990).

The simulation's transient modeling is based on sol-air temperature, time lag, decrement factor and the Total Equivalent Temperature Differential concept and Time Averaging techniques (TETD/TA). The zone temperature response is based on ASHRAE-type weighting factors that differentiate between the radiated and convected gain components. The fractions used are shown in TABLE 1.

TABLE 1. Radiant and Convective Percentages of Total Gains

Heat Gain Source	Radiative %	Convective %
Window solar, no inside shade	100	0
Window solar, with inside shade	58	42
Fluorescent lights	50	50
Incandescent lights	80	20
People	33	67
Transmission, roofs and walls	60	40
Infiltration and ventilation	0	100
Machinery & Appliances	20-80	80-20

The convective portions are transferred directly to loads, and the radiative portions are assumed to be absorbed by the interior mass of the building using an interior capacitance of 0.21 Btu/lb.F. This absorbed radiative portion later becomes load as it is convected into the air volume at a rate dictated by typical surface convective heat transfer coefficients and the temperature difference between the wall/ceiling surfaces and the zone air.

After deriving the interior surface temperatures, the program is also able to compute an interior "operative temperature" based on the MRT's to assess human comfort. Daylighting contributions are also computed, based on a modified Daylight Factor (DF) methodology. These results are used to estimate energy reductions through use of photocell-controlled light dimmers.

(7) *System simulations:*
The system is initially sized for the hottest day in July, but may be resized numerous times, if necessary, when a new peak load is encountered. The energy calculations are based on embedded system efficiencies typical of the system chosen.

(8) *Energy summations:*
The program outputs a monthly summary of the various categories of energy use, as well as peak demands and utility bills. At the end of the simulation cycle, the site line and source energy utilization factor (EUF's) are printed. Peak load breakdowns and dates of occurrence for heating and cooling are also tabulated.

(9) *Life-cycle cost predictions:*
As the final step, ENER-WIN processes the life-cycle cost projection. First costs of the building are computed based on the unit cost of walls, windows, and roofs; the floor construction cost; lighting system cost; and mechanical system cost. ENER-WIN then performs a present worth analysis to include the future recurring costs of fuel, electric, and maintenance cost.

PROGRAM INPUT PROCESS

Because the user needs a rapid feedback from the energy simulation program to enhance the designing and rechecking of energy design strategies, inputs to ENER-WIN are kept to be minimal. In general the program only requires three main inputs: the building type, the building location, and the building geometry with certain envelope materials.

The building type can be selected from the Project Information screen of the program. By selecting from a list of 15 building types, the program will automatically install default values for the building type selected. These default values are used as energy parameters that control the annual simulation. The default values can be modified at any later time.

Defining the building location means selecting the weather conditions for that particular location. The building geometry is then described by using the sketching routine that will allow the user to draw the building HVAC zones, assign the room height, building orientation, and number of floor in the building. Figure 4 shows the sketching routine of ENER-WIN.

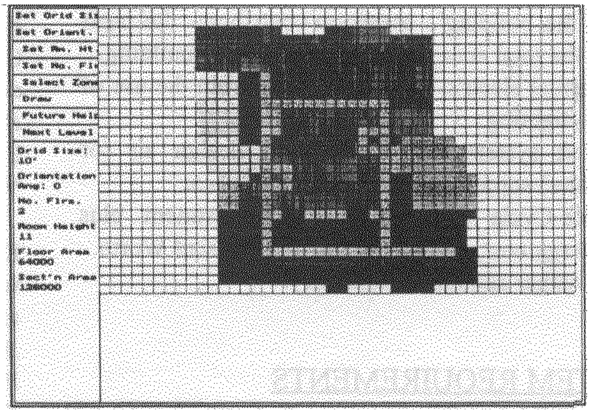

Fig. 4. Sketching the floor plan with HVAC zones

After the sketching process is complete, a drawing processor is executed to analyze the geometric conditions of the walls, roofs and floors of each zone -- including how these are shaded by adjoining walls and outside structures. The user then specifies additional (non-geometric) design parameters such as HVAC systems, lighting power density, and ventilation profiles.

When the input process is done, the user can execute the simulation program. The user can also specify the number of weeks in a month and the number of months in a year to be simulated. When a quick analysis is more desirable (as in the preliminary design stage), a one-week per month simulation will be adequate. However, to obtain a more detailed answer (as in the case when sizing the HVAC equipment or determining the peak load), it is suggested that the user conduct a full-month simulation. The longer simulation will obviously require more simulation time; however, running the simulation in ENER-WIN generally will only require less than 3 minutes on Intel 486's and Pentiums.

OUTPUT REPORTS

First, ENER-WIN reports the weather data statistics from the input data base. Then it presents the wall/roof and window/skylight catalogs; 24-hour occupancy, use, and temperature profiles; and the zone information showing thermal envelope properties and other parameters.

The simulation output is presented in the followings:

(1) Monthly energy use and charges, broken-down into space heating, space cooling, fan motors. Water heating, lighting and equipment.
(2) Annual energy and cost breakdowns for various components. This breakdown gives a valuable information to the user as to which component

of the building's envelope contributes the most to the total energy consumption in the building.

(3) Annual electric and cost savings from the use of daylighting.
(4) Peak system and zone loads, design air (or water) supply quantities and duct sizes.
(5) Life-Cycle cost analysis of investment plus energy cost, in terms of the total Present Worth.
(6) Weather simulation summary.

SYSTEM REQUIREMENTS

ENER-WIN is a Windows-based energy simulation program. Therefore, the program requires the followings:

(1) A personal computer with Intel 386 or above with total RAM of 4 MB or greater although ENER-WIN will only require 500-Kbytes of RAM when executing.
(2) Microsoft Windows, version 3.1 or later.
(3) An IBM-compatible Video Graphic Array (VGA) controller and monitor.
(4) A Microsoft-compatible mouse and mouse driver software installed independent of Windows.
(5) A printer to print the tabular results.

ACKNOWLEDGMENTS

ENER-WIN uses the ENERCALC simulation engine, which was originally developed under a subcontract from the Woodlands Development Corporation under a DOE grant to study energy conserving method in 220 commercial buildings in Woodlands Metro Center. Subsequent updates have been made possible through support from the Center of Energy and Mineral Resources (CEMR), William Wayne Caudill Research Fellowship, and the Department of Architecture, all at Texas A&M University.

The ENERCALC and the Weather Simulation models were developed by Larry Degelman. The ENER-WIN interface and Windows adaptation were developed by Veronica Soebarto. The sketching matrix software was developed by Tao-Kuang Huang. All of them are from the Department of Architecture, Texas A&M University.

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