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RESFEN 3.0: A PC Program for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings

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1997-12-01

*A PC Program*

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# RESFEN 3.0



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*for Calculating the Heating and Cooling Energy Use  
of Windows in Residential Buildings*

Windows and Daylighting Group  
Building Technologies Program  
Environmental Energy Technologies Division  
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## **RESFEN 3.0: Program Description**

A PC Program for Calculating the Heating and Cooling Energy Use of Windows  
in Residential Buildings

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December 1997

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## 1. INTRODUCTION

Today's energy-efficient windows can dramatically lower the heating and cooling costs associated with windows while increasing occupant comfort and minimizing window surface condensation problems. However, consumers are often confused about how to pick the most efficient window for their residence. They are typically given window properties such as U-factors or R-values, Solar Heat Gain Coefficients or Shading Coefficients, and air leakage rates. However, the relative importance of these properties depends on the site and building specific conditions. Furthermore, these properties are based on static evaluation conditions that are very different from the real situation the window will be used in. Knowing the energy and associated cost implications of different windows will help consumers and builders make the best decision for their particular application, whether it is a new home, an addition, or a window replacement.

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

RESFEN 3.0 is a major improvement over previous versions of RESFEN because it performs hourly calculations using a version of the DOE 2.1E energy analysis simulation program. RESFEN is currently being evaluated for possible use as part of an annual energy window rating system being developed by the National Fenestration Rating Council (NFRC). RESFEN supplements NFRC Heating Rating (HR) and Cooling Rating (CR) indices (still under development) which are intended to provide relative guidelines on window energy impacts (see page 12). Table 5.2 lists the input assumptions used in RESFEN versions 1.4/2.4 and 3.0. These assumptions are being reviewed and may be refined in future versions to more accurately reflect typical building configurations and operation. In addition, the user interface is being redesigned to be even more user-friendly and easy to use.

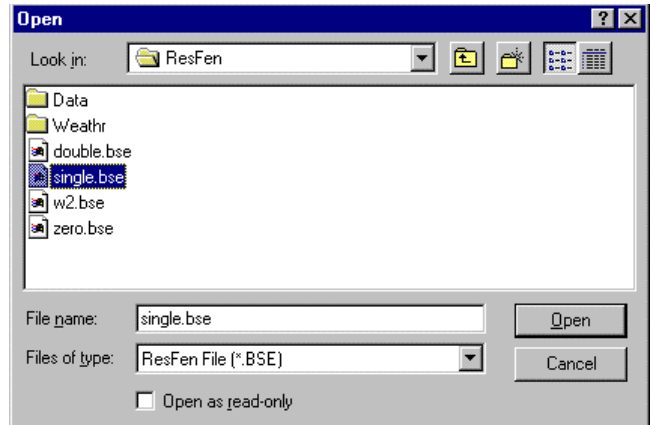
Update information, future releases and program information about RESFEN and other software tools from the Windows and Daylighting Group at LBNL (such as WINDOW 4.1 and THERM 1.0) can be found on the World Wide Web at URL: <http://windows.lbl.gov>. To obtain RESFEN 3.0, WINDOW 4.1 or THERM 1.0, fax or email your address and phone number to Pat Ross, Fax: 510 486-4089, email: [PLRoss@lbl.gov](mailto:PLRoss@lbl.gov).

## 2. QUICK START

1. Double Click on the RESFEN icon.



2. The program will ask for a RESFEN file. There are several default files on the installation disk. Pick one, such as "single.bse", which is a ranch-style house with single glazing, a slab floor, frame walls, a gas furnace and central air conditioning.



3. The program will open with the input values of that file, as well as the calculated results.

4. Change any input values that are not correct. For example, you can change the location to another city, change the HVAC system type, or input another window type. When you change an input value, the Calculate button become active and the Output Data values and graphs are reset to zero.

5. Press the Calculate button, and an hourly simulation using DOE2 will be performed. When the calculation is finished, the values in the Output Data section will be updated.

**House Data**

Run ID: single.bse

Units: IP

Location: DC Washington

Electric Cost: \$ .10/MWh

Gas Cost: \$ .65/therm

House: Ranch-Slab-Frame

AcGf: AcGf

Orientation: N,E,S,W

View: Annual Energy

**Window Data**

Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area(%FA)	3.75	3.75	3.75	3.75	15.00
Height(ft)	4.00	4.00	4.00	4.00	
Width(ft)	2.00	2.00	2.00	2.00	
U-factor	1.30	1.30	1.30	1.30	
SHGC	0.74	0.74	0.74	0.74	
Ctm/ft2	0.98	0.98	0.98	0.98	
Shading Type	None	None	None	None	

**Output Data - Energy** Compared to: windowless wall

Cooling(kWh/ft2)	3.12	5.98	6.15	6.51	5.44
Heating(k.Btu/ft2)	122.42	80.95	33.32	92.50	82.30
Cooling(kWh)	180	345	355	376	1256
Heating(k.Btu)	7070	4675	1924	5342	19011

**Energy Graphs:** Cooling(kWh/ft2), Heating(k.Btu/ft2), Cooling(kWh), Heating(k.Btu)

## 3. INSTALLATION

### 3.1. Hardware Requirements

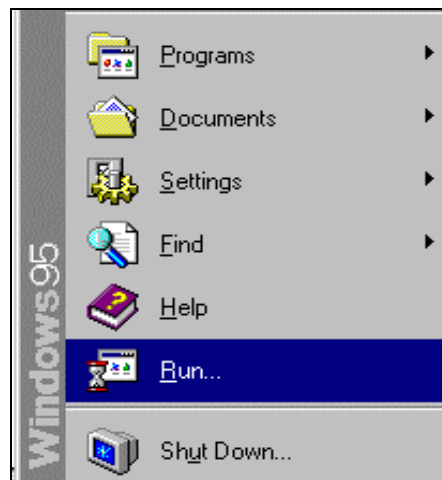
First, make sure your computer system meets these specifications:

- 100% IBM-compatible pentium or higher with a math co-processor. A 133MHz pentium computer will take about 40 seconds to perform a simulation.
- At least 16 MB of random access memory (RAM), configured as extended memory. 32 MB of RAM is preferred for optimum operation.
- Microsoft Windows<sup>(TM)</sup> 95 or Windows<sup>(TM)</sup> NT.
- Hard disk drive with at least 10 megabytes of available disk space.
- Printer supported by Microsoft Windows<sup>(TM)</sup> 95 or Windows<sup>(TM)</sup> NT (serial, parallel, or shared over a network).
- Monitor and mouse.

### 3.2. Setup

Five diskettes are provided.

1. Insert Diskette #1 into the floppy drive on your computer.
2. In Microsoft Windows 95<sup>(TM)</sup> or Windows NT<sup>(TM)</sup>, click the Start toolbar button and select Run:



*Pick Run from the Start toolbar.*

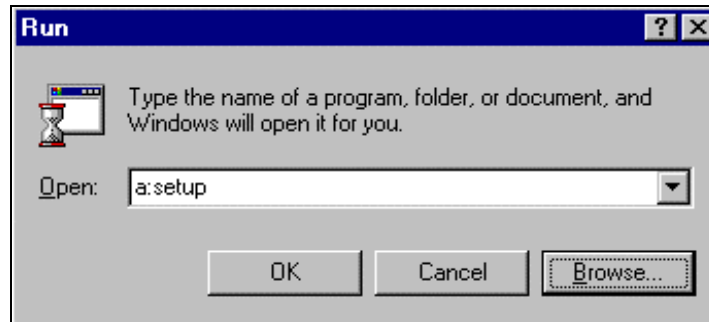
In the Run window, type

`<floppy drive>:setup.exe`

where <floppy drive> is the drive letter of the diskette drive on your machine, usually "a:" or "b:"

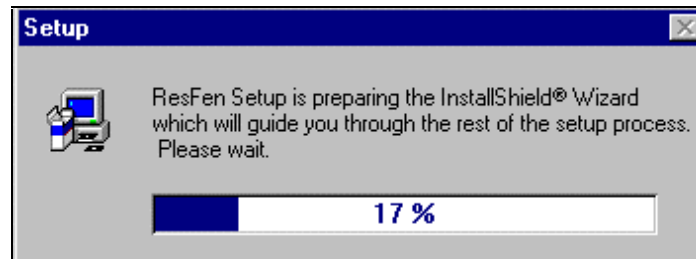
Press the OK button in the Run dialog box.





*Type <drive letter>:setup and press OK.*

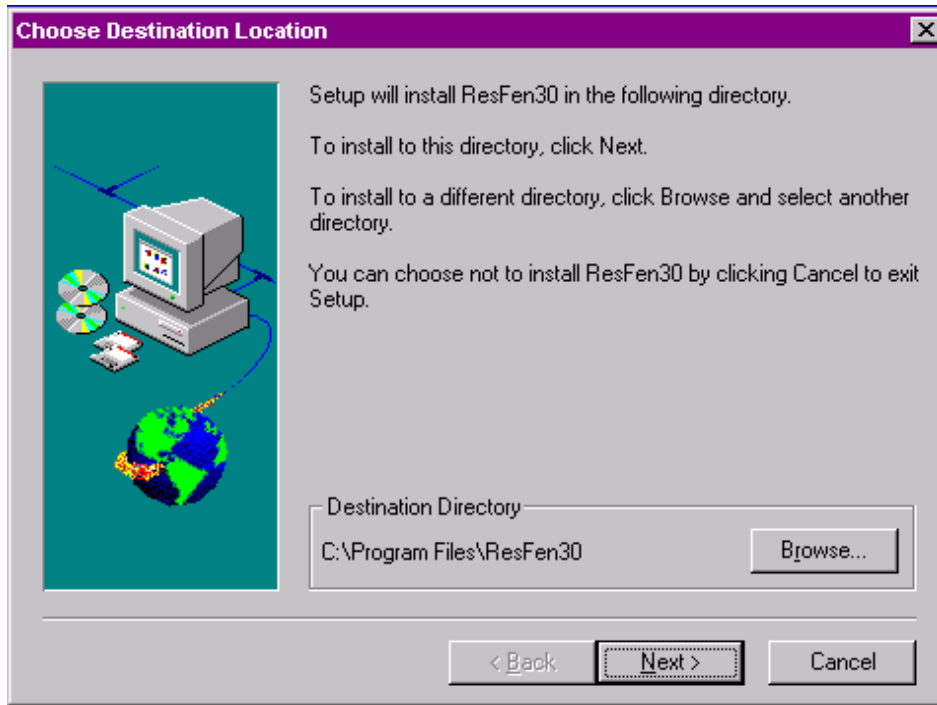
3. The initial RESFEN Setup window will appear..



*The initial RESFEN Setup window.*

4. When the initial Setup window has finished, the Choose Destination Location window will display. The default directory where the program will be installed is C:\Program File\ResFen. However, if you want to install the program in another directory on your computer, you can use the Browse button to specify the location.

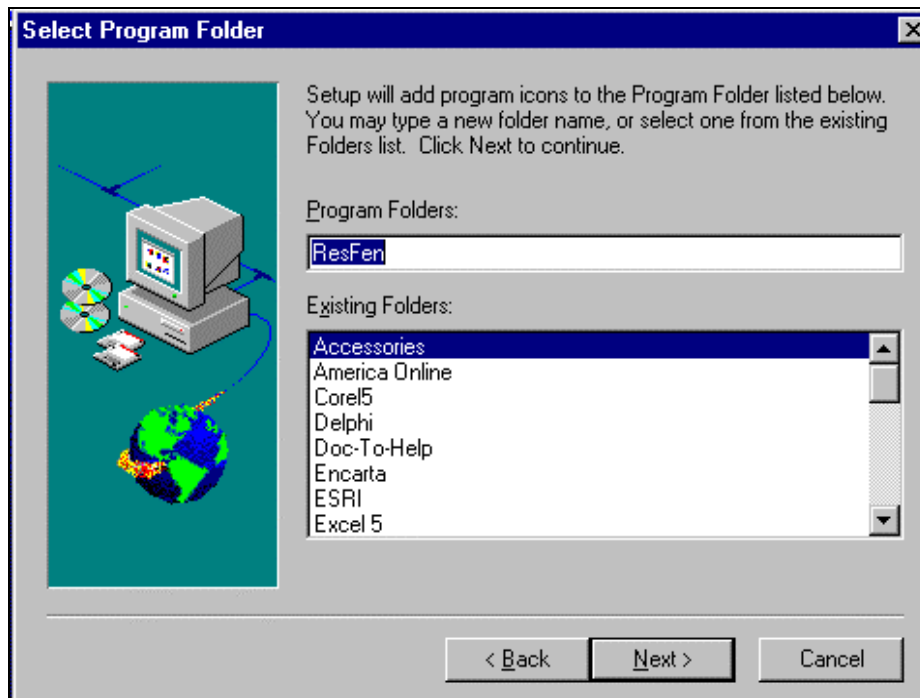
Press the Next button when you are satisfied with the Destination Directory.



*Choose Destination Location screen. A different location can be selected using the Browse button. Press Next when you are satisfied with the Destination Directory.*

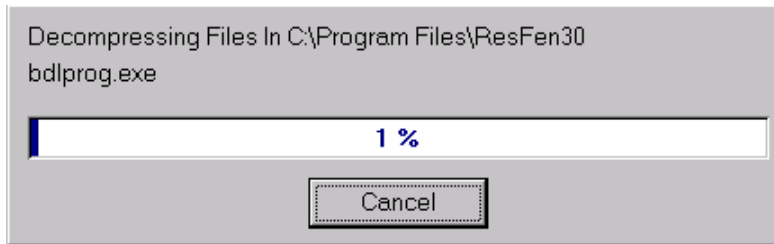
5. The next screen to display is the Select Program Folder, which specifies a default folder for the program icons, and allows you to define an alternate folder name.

Press the Next button when you are satisfied with the Program Folder name.



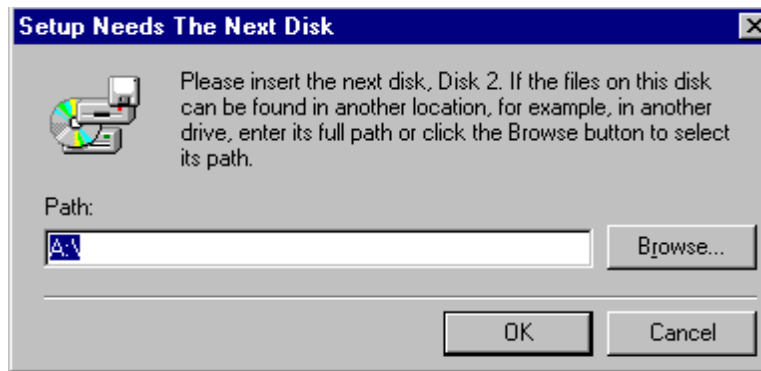
*Use the default folder name "ResFen" or specify a new folder name. Then press Next to go to the next screen.*

- Setup will automatically install RESFEN into the specified destination directory on your computer. As needed, the program will ask you to install the other diskettes.



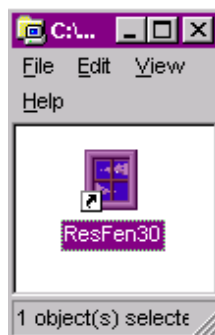
*Setup will decompress and copy the program files into the specified destination directory.*

- Setup will ask for diskettes as it progresses through the installation.



*Setup will request diskettes as the program is installed.*

- Setup will automatically make a group box called "ResFen" with the appropriate icons. The icon to run the ResFen program is shown below. Using standard Microsoft Windows 95<sup>(TM)</sup> or Windows NT<sup>(TM)</sup> methods, this icon can be copied or moved to the desktop if desired.



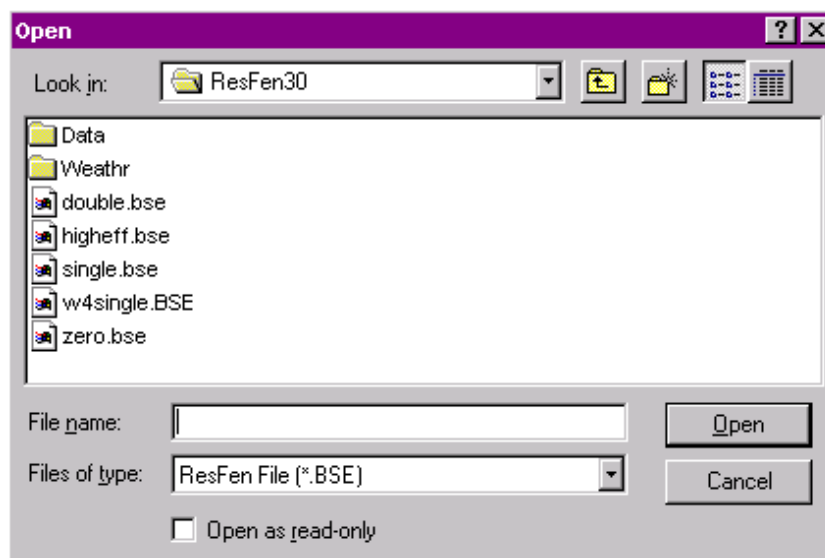
*Icon to run ResFen.*

### 3.3. Running RESFEN 3.0

To run RESFEN 3.0, double click on the RESFEN icon:



An introductory screen will be first displayed followed by a dialog box asking for the name of an input file. All ResFen files have the extension '.BSE'. Sample files are included with the installation diskettes and should be displayed automatically in the initial screen, as shown below.



*Initial screen to specify a ResFen file to run.*

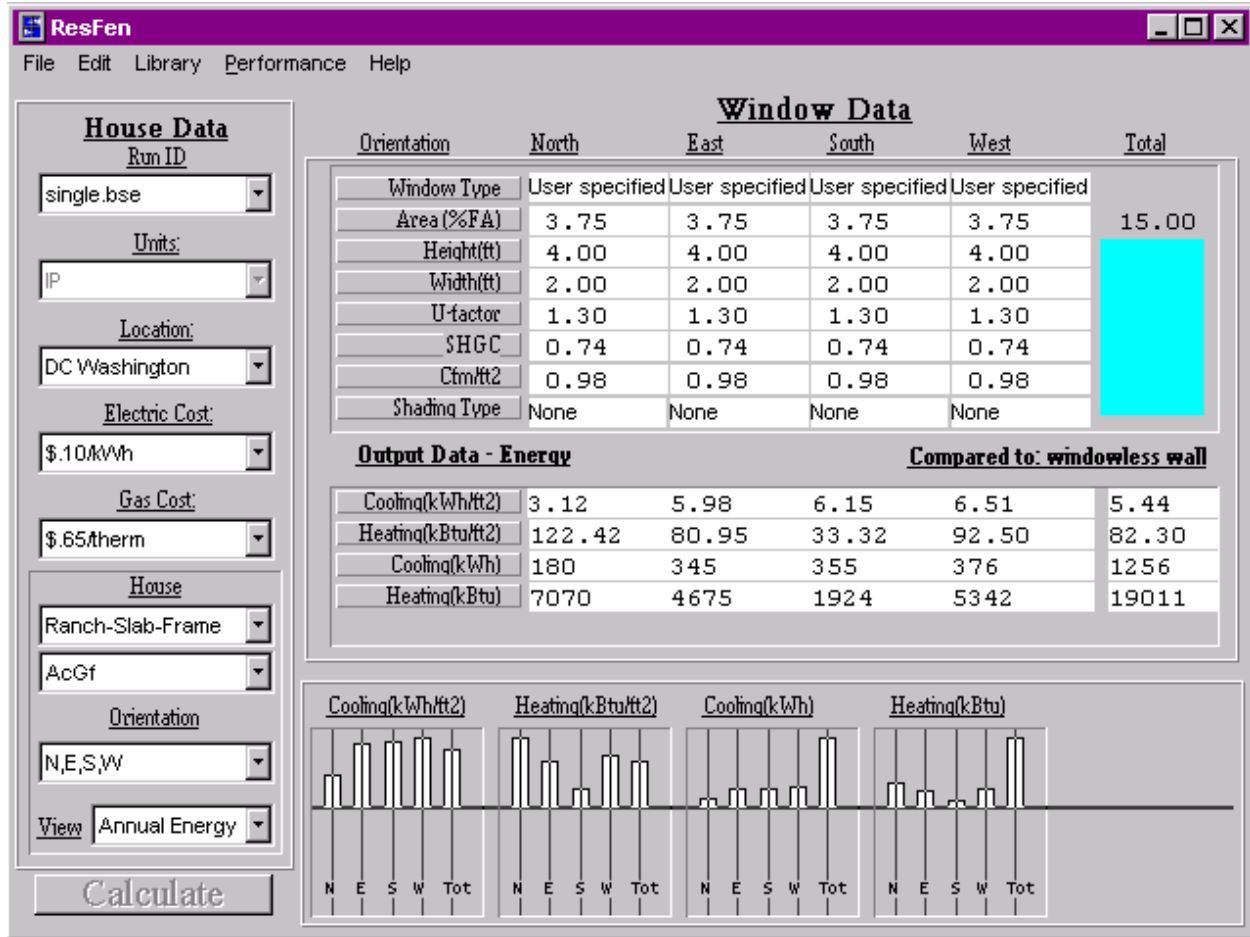
These sample files can be used as templates, modified with ResFen, and saved with other file names (see [Save](#) instruction below). When you have picked a ResFen file, the RESFEN 3.0 main screen appears, with Pull-Down Menus along the top part of the screen, House Data parameters along the left-hand side of the screen, Window Data parameters appearing on the upper half of the screen, and Output Data displayed on the bottom half of the screen.

### 3.4. Trouble Shooting

Please send E-mail to Robin Mitchell ([rdmitchell@lbl.gov](mailto:rdmitchell@lbl.gov), 510 486-4141, FAX: 510 486-4089) if you have any trouble running the program.

## 4. PROGRAM DESCRIPTION

The figure below shows the main screen of RESFEN. Information is entered about the building in the House Data section, and windows in the Window Data section. Results are shown in the Output Data and graph sections. The Calculate button allows new results to be simulated when house or window data has changed.

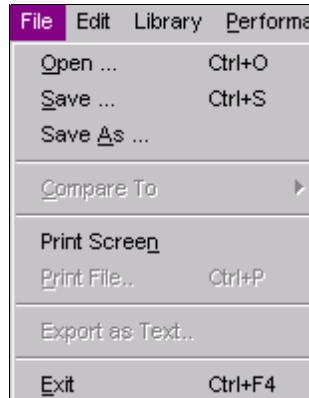


The Main Screen

## 4.1. Pull-Down Menus

Each menu can be accessed by using the mouse or by pressing ALT and then typing the first letter of the menu. To select the menu choices, you can click on the choice with your mouse, type the underlined character of each menu choice, or use the up and down arrow keys. For each list of menu choices, keyboard shortcuts are indicated to the right of the menu item.

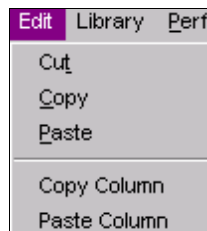
### File



*The File Menu*

<u>O</u> pen	Open a previously saved file. (Ctrl+O)
<u>S</u> ave	Save the current configuration for later access. (Ctrl+S)
<u>S</u> ave <u>A</u> s	Save the current configuration with another file name. After using Save As, if you save the file again, check the file name you are saving to (using the Save As feature again rather than Save) to make sure the file is being saved to the right name.
<u>C</u> ompare To	<i>Not currently implemented.</i>
<u>P</u> rint <u>S</u> creen	Print a copy of the current screen.
<u>P</u> rint <u>F</u> ile	<i>Not currently implemented.</i>
<u>E</u> xport as <u>T</u> ext...	<i>Not currently implemented.</i>
<u>E</u> xit	Quits the program. (Ctrl+F4)

### Edit



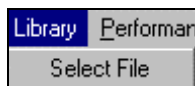
*The Edit Menu*

<u>C</u> ut	Cut selected text to the clipboard.
<u>C</u> opy	Copy selected text to the clipboard.
<u>P</u> aste	Paste text from the clipboard over selected text or to current cursor position.

- Copy Column** Copy values of the current column to the clipboard. Your cursor can be on any field in the column, and all the column field values will be copied to the clipboard.
- Paste Column** Paste column values stored in the clipboard (using Copy Column) into the current column, which will overwrite all the existing field values. The cursor can be in any field in the column and all the values will be pasted into the appropriate fields.

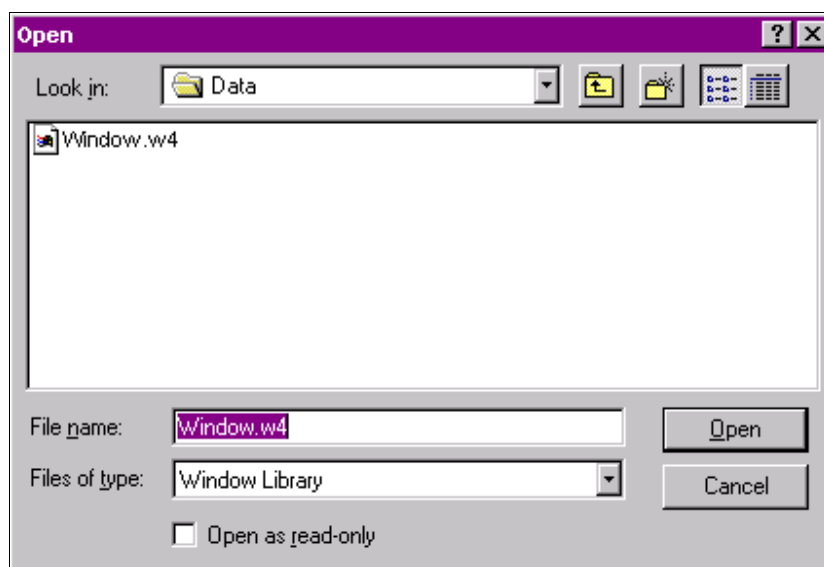
### Library

- Select File** Used to select a Window Library.



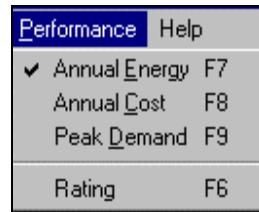
*The Library Menu*

The Select File menu choice displays the following Open window, which is used to specify the WINDOW4.1 Library file (*window.w4*) that RESFEN will use when displaying the “Window4 Lib” choices in the Window Type pulldown list. By default, RESFEN will look in the RESFEN\DATA subdirectory for the *window.w4* file distributed with the program, but libraries in other directories can be specified using this Library/Select File feature. RESFEN looks for any file with a “.w4” extension, so it is possible to rename the WINDOW4.1 library, but keep in mind that WINDOW4.1 only recognizes the name *window.w4*. (Arasteh, D.K. et. al. 1994. “WINDOW 4.1: A PC Program for Analyzing Window Thermal Performance in Accordance with Standard NFRC Procedures.” LBL Report 35298. Berkeley, CA.) For a description of WINDOW 4.1 visit our web site at <http://windows.lbl.gov>. To obtain WINDOW 4.1, fax or email your address and phone number to Pat Ross, Fax: 510 486-4089, email: PLRoss@lbl.gov.



*Window Library File Open window.*

## Performance



*The Performance Menu*

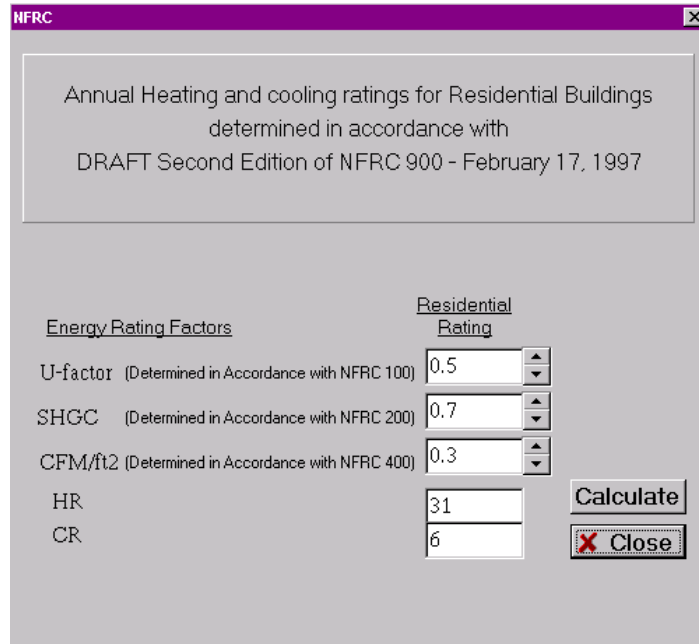
<i>Annual Energy</i>	Annual energy output data. See "Output Data" section for details about the values in this display. (F7)
<i>Annual Cost</i>	Annual energy cost output data. See "Output Data" section for details about the values in this display. (F8)
<i>Peak Demand</i>	Peak demand output data. See "Output Data" section for details about the values in this display. (F9)
<i>Rating</i>	A calculator for the Annual Heating (HR) and Cooling (CR) Rating values, calculated in accordance with the DRAFT Second Edition of NFRC 900, February 17, 1997. (F6)

The Heating Rating (HR) and the Cooling Rating (CR) are comparative heating and cooling energy ratings for windows used in any climate. Ratings range from 0 to 100, with today's best available technology at about 50. The final format of the HR and CR rating system is still under development and the values calculated in this version of RESFEN are determined in accordance with the DRAFT Second Edition of NFRC 900, February 17, 1997. Once this process is complete, HR and CR values promise to be better indicators of relative annual energy use than basic window properties such as U-factor. However, they will still be a comparative performance indicator similar to miles-per-gallon ratings for automobiles. The use of computer tools like RESFEN is required for more accurate calculation of specific annual energy use or cost savings. ("NFRC 900: Procedure for Determining the Annual Heating and Cooling Energy Ratings of Fenestration Products used in Residential Buildings", 2<sup>nd</sup> Edition: Draft #1, prepared by National Fenestration Rating Council Incorporated, February 17, 1997).

Selecting this choice presents a new screen, shown below, with the HR and CR values displayed for the current values of U-factor, SHGC, and CFM/ft<sup>2</sup>. These values are for the total fenestration product, including glass and frame. This screen is a calculator, and the HR and CR values will change when the U-factor, SHGC, and CFM/ft<sup>2</sup> are changed. *In this version of the program, the values displayed are not linked to the currently open RESFEN file.*

<i>U-factor</i>	U-factor. IP units: Btu/hr-ft <sup>2</sup> -°F.
<i>SHGC</i>	Solar heat gain coefficient. Units: dimensionless.
<i>CFM/ft<sup>2</sup></i>	Air Leakage. Units: CFM per window unit area.
<i>HR</i>	NFRC Heating rating.
<i>CR</i>	NFRC Cooling rating.





*Annual Heating (HR) and Cooling (CR) Rating values, calculated in accordance with the DRAFT Second Edition of NFRC 900, February 17, 1997. The methodology for calculating these ratings is in the process of being revised in 1998. Check the LBNL web page (<http://windows.lbl.gov>) or the NFRC web page (<http://www.nfrc.org>) for the latest information about these Rating values.*

## Help

*About*      Information about RESFEN, including the version number of the program.

## 4.2. House Data

The left side of the Main screen contains the House Data, a series of pulldown lists which allow you to specify the geographic location, utility costs, house type, HVAC type and house window orientation.

The screenshot shows a vertical form titled "House Data". It contains the following fields from top to bottom:
 

- Run ID:** A pulldown menu with "single.bse" selected.
- Units:** A pulldown menu with "IP" selected.
- Location:** A pulldown menu with "AZ Phoenix" selected.
- Electric Cost:** A pulldown menu with "\$.10/kWh" selected.
- Gas Cost:** A pulldown menu with "\$.65/therm" selected.
- House:** A section containing two pulldown menus: "Ranch-Slab-Frame" and "AcGf".
- Orientation:** A pulldown menu with "N,E,S,W" selected.
- View:** A pulldown menu with "Annual Energy" selected.
- Calculate:** A large button at the bottom of the form.

*The House Data portion of the Main Screen*

<b>Run ID</b>	Name of the file that is currently open. (Use File/Open to open another file).
<b>Units</b>	Output units designation. (Choice other than Inch-Pounds is not implemented in this version). <ul style="list-style-type: none"> <li>•IP (Inch-Pounds)</li> </ul>
<b>Location</b>	Forty-six geographic locations (see Table 1).
<b>Electric Cost</b>	Varies from \$0.02/kWh to \$0.20/kWh in increments of \$0.01/kWh.
<b>Gas Cost</b>	Varies from \$0.30/therm to \$1.00/therm in increments of \$0.05/therm.
<b>House Type</b>	Two pulldown lists. The first represents five residential building types; the second represents two HVAC types. In this version of RESFEN, the floor areas of each building type are fixed, although future versions will include floor area as an input. The one story building types assume a floor area of 1,540 ft <sup>2</sup> , and the two story building type assumes a floor area of 2,240 ft <sup>2</sup> . <p>Building types:</p> <ul style="list-style-type: none"> <li>•Ranch-Slab-Frame (one story)</li> <li>•Ranch-Slab-Masonry (one story)</li> </ul>

- Ranch-Crawl-Frame (one story)
  - Ranch-Crawl-Masonry (one story)
  - 2 Story-Slab-Frame
- HVAC types:
- AcGf (Air conditioner and Gas furnace)
  - HeatPump (Heat Pump with air conditioner)
- Orientation* Two sets of orientations with windows facing either:
- N, E, S, W
  - NE, SE, SW, NW
- View* There are three views of the output data that can be selected from this pulldown list:
- Annual Energy
  - Annual Cost
  - Peak Demand
- The values in the Output Data section (including the graphs) will change when the View is changed -- the Calculate button does not need to be pressed in order to see the results of different views.
- Calculate Button* The Calculate button is used to calculate the heating and cooling results. The Calculate button becomes active and Output Data values are reset to 0 when House or Window Data values change.

### 4.3. Window Data

The upper right-hand section of the Main screen is used to input information about the windows in the house for each of the four orientations, as shown in the figure below. Use your mouse, the Tab key or the arrow keys to move between the fields.

<b>Window Data</b>					
Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area(%FA)	3.00	2.00	5.00	2.00	12.00
Height(ft)	4.00	4.00	4.00	4.00	
Width(ft)	2.00	2.00	2.00	2.00	
U-factor	0.48	0.48	0.48	0.48	
SHGC	0.58	0.58	0.58	0.58	
Cfm/ft2	0.30	0.30	0.30	0.30	
Shading Type	None	None	None	None	

The Window Data portion of the Main Screen

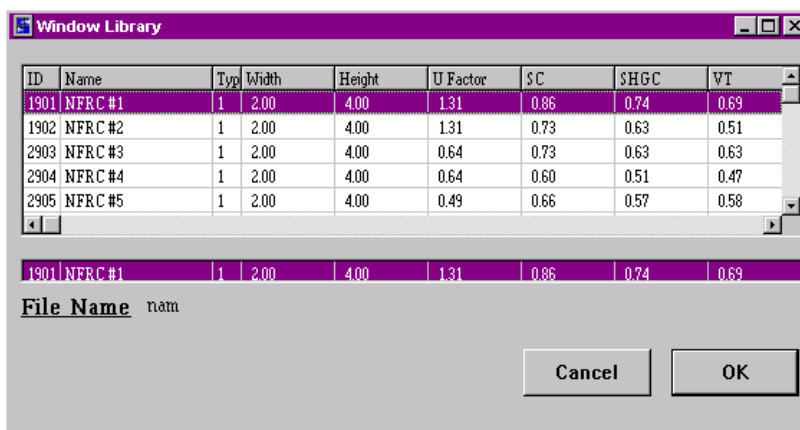
The program has the capability of varying the fenestration system parameters for each orientation: (north, east, south, west) or (northeast, southeast, southwest, northwest). The NFRC total product properties, which include the glazing and frame, should be used for the area, window height and width, U-factor, solar heat gain coefficient (SHGC), and infiltration (CFM per unit area). The *Area* parameter represents the total window area on any one facade as a percentage of the total floor area (see detailed *Area* explanation below). The *Height* and *Width* values are used for defining the size of an average window in that orientation.

**Window Type** There are two choices for Window Type, which are accessed by clicking on the Window Type field for each orientation:

<b>Window Data</b>				
Orientation	North	East	South	West
Window Type	User specified	User specified	User specified	User specified
Area(%FA)	Window4 Lib		5.00	2.00
Height(ft)	4.00	4.00	4.00	4.00
Width(ft)	2.00	2.00	2.00	2.00
U-factor	0.48	0.48	0.48	0.48
SHGC	0.58	0.58	0.58	0.58
Cfm/ft2	0.30	0.30	0.30	0.30
Shading Type	None	None	None	None

Two Window Type Choices, "User specified" or "Window4 Lib".

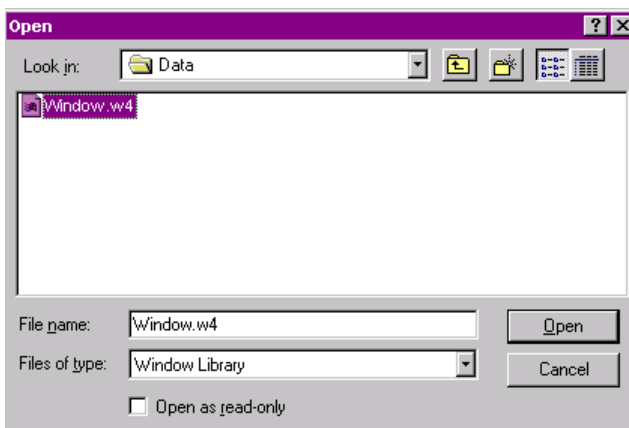
- **User specified:** The user enters all the window properties (U-factor, SHGC, infiltration CFM per unit).
- **Window4 Lib:** Values from a window library created by the WINDOW4.1 program (see the WINDOW4.1 User Manual) are used for some of the window properties. This choice displays the WINDOW4.1 Library (shown below) specified using the Library/Select menu option.



If Window Type = Window4 Lib, RESFEN displays a list of the windows in the WINDOW4.1 library, and a window can be selected.

A record from the Window Library can be selected by either double clicking on it with the mouse, or highlighting it and pressing OK. The up and down arrow keys can also be used to move between records in the library.

The Library/Select menu can be used to specify the location of the WINDOW4.1 library (shown below). The WINDOW4.1 window library file is named “**window.w4**”. You can rename this file, keeping the “.w4” extension, if you want to save different window types in different files -- RESFEN will look for any file with a “.w4” extension. Keep in mind, however, that WINDOW4.1 only reads files named “**window.w4**”.



Use the Library/Select menu to specify the location of a WINDOW4.1 library.

When the Window4 libraries are specified, RESFEN automatically uses one of two possible calculation methods, depending on what files are available – *method (b) is recommended for experienced WINDOW4.1 users only:*

- (a) *WINDOW4.1 Window Library (e.g., window.w4) only* – if only the standard WINDOW4.1 window library file (e.g., window.w4) exists RESFEN will use the U-factor and SHGC from that file. The air infiltration values must be entered by the user.
- (b) *WINDOW4.1 Window Library (e.g., window.w4) and additional WINDOW4.1 DOE-2.1E output(ASCII) file (e.g., window.dat), recommended for experienced WINDOW4.1 users only* –if both files

exist, RESFEN will use the values from these files for the window properties. RESFEN automatically determines if there is an associated DAT file for the window library (they must have the same name before the extension), and will use the additional values if they exist.

The DOE2 output files are generated using the WINDOW4.1 program, and can be generated for one window at a time, for a range of records in the window library, or for the entire window library. To create these files in WINDOW4.1, go to either the main screen (for one window at a time), or the Window Library (F2) for a range of records in the library or the entire library. From either place, use Alt-Print and select the Report Type of "DOE-2" (from the Window Library, you first have to enter the range of windows to create the report for, the default being the first through the last window record). The program will then ask you for a file name for this output file – type a name that will correspond to the name of the Window Library, and give it the extension ".dat", such as "window.dat" for the entire library, or the name of a specific subset of the library, such as "low-e.dat". The main thing to remember is that for RESFEN to connect the two files, the ".w4" file and the ".dat" file must have the same prefix. So for the "low-e.dat" file, there would have to be a corresponding "low-e.w4" WINDOW4.1 Window Library file, with the same windows as in the low-e.dat file. Also keep in mind that WINDOW4.1 will only save windows with a single glazing system to the DOE2 output file, so this technique will not work for horizontal or vertical sliders, or double doors. In this version of RESFEN, the window IDs in the ".w4" file and the ".dat" file must be identical – if the program automatically detects a ".dat" file, it cannot handle windows in the ".w4" file that are not in the ".dat" file. Call for more information if you are having trouble making this feature work. (See Section 3.4, Troubleshooting).

Default NFRC library files, named **window.w4** and **window.dat**, are distributed with RESFEN3.

<i>Area</i> (%Floor Area)	Total window area given as a percent of floor area for each of four orientations. Single-story floor area is 1,540 ft <sup>2</sup> ; two-story floor area is 2,240 ft <sup>2</sup> . For example, if you want to model three windows that are 3' x 4' on the south orientation, the total window area is 36 square feet. That is 2.3% (36/1540) for the single-story house.
	Any value between 0% and 12% can be used for each orientation, and the four orientations must not exceed 48% of the floor area. The fifth area value in the <i>Total</i> column represents the sum of the window areas of the four orientations.
<i>Height</i>	Average height of window(s) for each orientation. IP Units: feet
<i>Width</i>	Average width of window(s) for each orientation. IP units: feet.
<i>U-Factor</i>	U-factor. IP units: Btu/hr-ft <sup>2</sup> -°F. Legal values: between 0.05 and 1.30 Btu/hr-ft <sup>2</sup> -°F under standard winter conditions.
<i>SHGC</i>	Solar Heat Gain Coefficient. Legal values: between 0.05 and 0.90.
<i>CFM/Area</i>	Infiltration. IP units: CFM/ft <sup>2</sup> . Legal values: between 0.05 and 1.30 CFM/ft <sup>2</sup> .

- Shading Type*      Four shading schemes can be modeled:
- None.
  - Obstruction: 10 foot tall surface 20 feet from building, for the orientation specified. Used to model large obstructions, such as neighboring houses or other buildings.
  - Overhang: 2 foot overhang at roof line.
  - Interior Shade: drapes with a shading coefficient of 0.60 are deployed whenever the incident or transmitted solar gain (in either summer or winter) exceeds 30 Btu/ft<sup>2</sup>-hr.

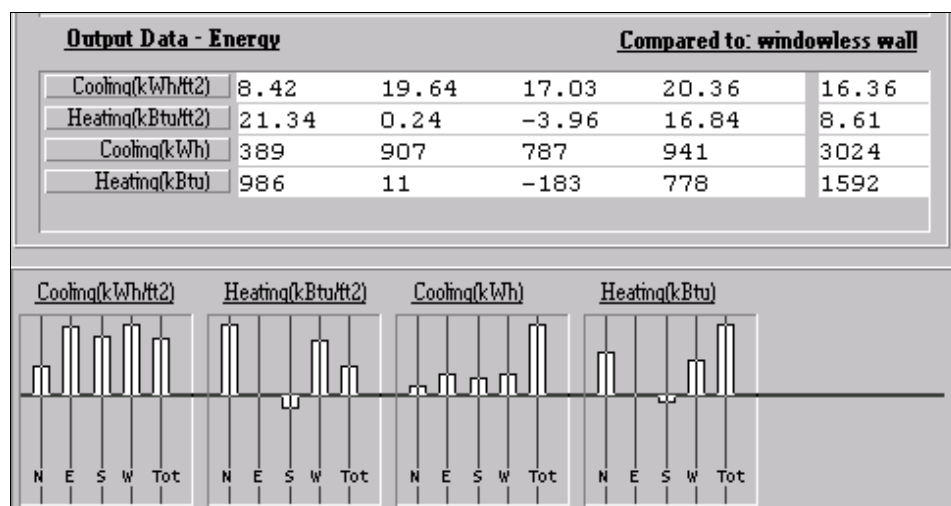
#### 4.4. Output Data

The lower portion of the screen shows the results of the calculations, in the Output Data section. The results displayed are based on the selection in the View pulldown list in the House Data section and the tabular data in the Window Data section. The results will appear as 0 whenever any changes have been made to the input values of either section. In order to obtain new results, press the Calculate button.

The results are all relative to a standard insulated windowless wall. Positive values mean that the window uses *more* energy than an insulated wall with no windows; negative values mean that the window uses *less* energy than an insulated wall with no windows. All cooling results will be positive but heating energy use can be either positive or negative. If the results are positive, the smallest value will be the most energy efficient window configuration. If the results are negative, the largest negative value will be the most energy efficient window configuration. When comparing positive and negative results, the window configurations with negative results will be the most energy efficient. It is possible for a window configuration to use less heating energy than an insulated wall (and thus have a negative result) because the solar heat gain from the window adds heat to the space, and reduces the heating requirements of the building.

#### Annual Energy

The Annual Energy view shows the difference between the annual energy consumption of a building with the window being modeled and a windowless wall. Positive values mean that the window uses *more* energy than a standard insulated wall with no windows; negative values mean that the window uses *less* energy than a standard insulated wall with no windows. The first four columns represent the four window orientations, and the fifth column is the total.



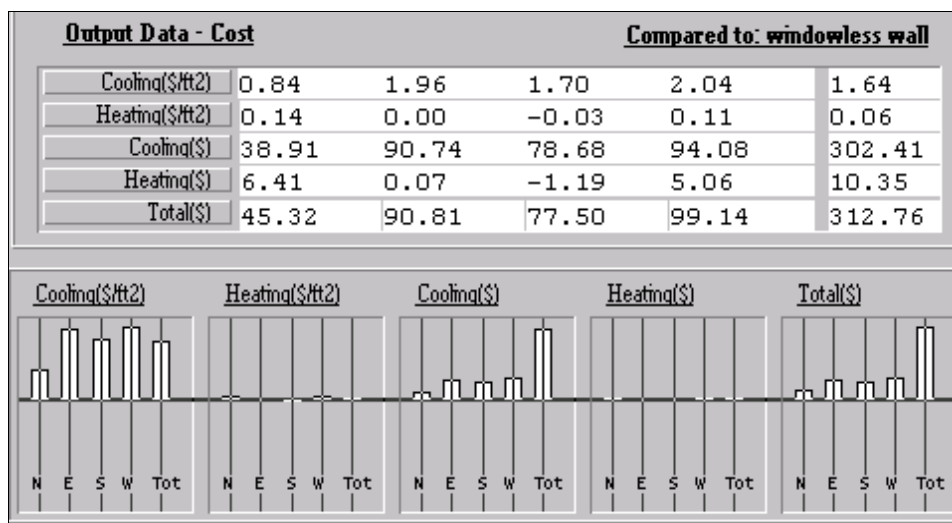
*The Output Data portion of the Main Screen for View = Annual Energy*

- Cooling/Unit Area** Cooling energy per unit window area.  
Units: IP: kWh/ft<sup>2</sup>.
- Heating/Unit Area** Heating energy per unit window area.  
Units: IP: kBtu/ft<sup>2</sup> or kWh/ft<sup>2</sup> for HeatPump.
- Cooling Energy** Cooling energy due to windows.  
Units: IP: kWh.
- Heating Energy** Heating energy due to windows.  
Units: IP: kBtu or kWh for HeatPump.



### Annual Cost

The Annual Cost view shows the difference between the annual energy cost of a building with the window being modeled and a windowless wall. The energy use values in the Annual Energy view are converted to costs using the input values for electricity and gas. Positive values mean that the window uses *more* energy than a standard insulated wall with no windows; negative values for heating mean that the window uses *less* energy than a standard insulated wall with no windows. Negative values represent economic savings that will offset other energy consuming features in the house, thus reducing the total home heating bill.



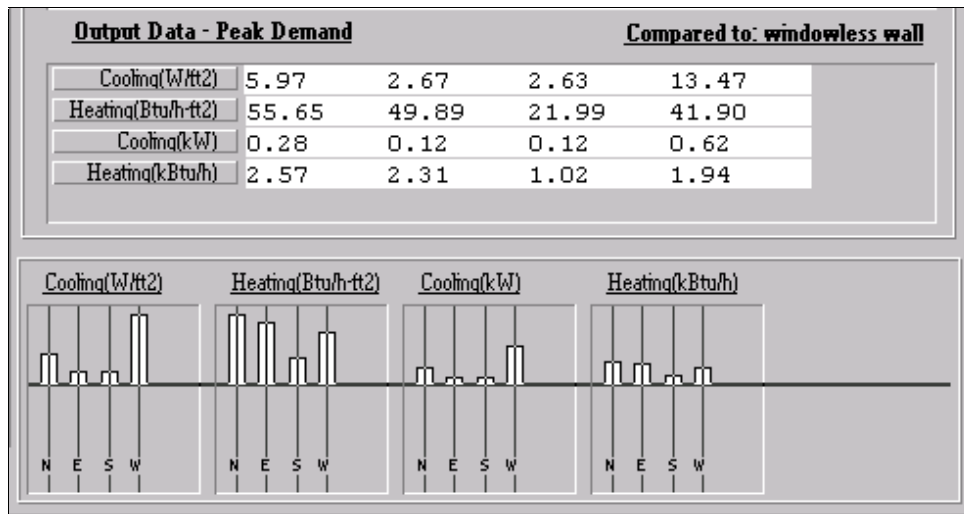
The Output Data portion of the Main Screen for View = Annual Cost

- Cool Cost/ Unit Area** Cooling energy per unit window area.  
Units: IP: \$/ft<sup>2</sup>.
- Heat Cost/ Unit Area** Heating energy per unit window area.  
Units: IP: \$/ft<sup>2</sup>.
- Cooling Cost** Cooling energy due to windows.  
Units: \$/year.
- Heating Cost** Heating energy due to windows.  
Units: \$/year.
- Total Energy Cost** Sum of the Cooling and Heating Energy Cost.  
Units: \$/year.

## Peak Demand

The Peak Demand view shows the difference between the peak energy demand of a building with the window being modeled and a windowless wall. Positive values mean that the window has a higher peak demand than a standard insulated wall with no windows; negative values mean that the window has a lower peak demand than a standard insulated wall with no windows.

Peak heating and cooling loads determine the required size of the furnace and air conditioner needed to meet the maximum thermal loads. Lower peak demand means smaller and less expensive equipment. Peak heating conditions typically occur on a cold winter night, and peak cooling conditions typically occur on a hot, sunny summer afternoon. Consult your HVAC contractor or local utility for more information.



*The Output Data portion of the Main Screen for View = Peak Demand*

<i>Cool Peak/ Unit Area</i>	Cooling peak per unit window area. Units: IP: W/ft <sup>2</sup> .
<i>Heat Peak/ Unit Area</i>	Heating peak per unit window area. Units: IP: Btu/ft <sup>2</sup> or kW for HeatPump.
<i>Cooling Peak</i>	Cooling peak due to windows. Units: IP: kW.
<i>Heating Peak</i>	Heating peak due to windows. Units: IP: kBtu/hr or kW for HeatPump.

## 5. EXAMPLES

The following examples show how RESFEN can be used to help select more energy efficient windows for a home. All single story prototypes used in these examples have a floor area of 1540 ft<sup>2</sup>. Window properties listed are standard NFRC total values which includes the glazing and frame.

### 5.1. Example 1: Window Selection in a Heating Climate, Madison, WI

Four possible window choices are compared for a typical house in Madison, Wisconsin. The house, as described on the RESFEN screen presentation below, is a ranch style home with a slab-on-grade floor and frame construction. Heating is supplied by a gas furnace and cooling by a central air conditioner. Gas utility cost for heating is \$0.60/therm and electric utility cost for cooling is \$0.08/kWh.

Input Description	Input Value
Location	WI Madison
Electric Cost	\$0.08/kWh
Gas Cost	\$0.60/therm
House	Ranch-Slab-Frame
	AcGf

*Example 1 House Data Input Values*

The four windows to be analyzed are listed on the following table. All windows have been selected to have relatively high visible transmittance (TVIS), and are assumed to be 2'x4' casements. Although the air leakage varies somewhat by frame type, units with leakage values < 0.30 cfm/ft<sup>2</sup> will have a very small effect on heating and cooling.

	U-Factor	SHGC	TVIS	Air Leakage (cfm/ft <sup>2</sup> )
A. Double glazed clear 1/8" clear, 1/2" air, 1/8" clear wood or vinyl frame	0.49	0.58	0.57	0.56
B. Double glazed low-E 1/8" clear, 1/2" argon, 1/8" low-E (0.20) wood or vinyl frame	0.33	0.55	0.52	0.15
C. Double glazed spectrally selective low-E 1/8" low-E (0.04), 1/2" argon, 1/8" clear wood or vinyl frame	0.29	0.31	0.51	0.15
D. Triple glazed low-E superwindow 1/8" low-E (0.08), 1/2" argon, 1/8" clear 1/2" argon, 1/8" low-E (0.08) insulated vinyl frame	0.15	0.37	0.48	0.08

*Example 1 Window Input Values*

Window A represents what is currently being used in the house. It is a typical clear, double-glazed unit most commonly used in cold-climates. Window B has a high-transmission low-E coating, while Window C has a spectrally selective low-E coating (a low SHGC combined with a relatively high visible transmittance). Window B is designed to reduce winter heat loss (low U-factor) and provide winter solar heat gain (high SHGC). Window C also reduces winter heat loss (low U-factor) but it reduces solar heat gain as well (low SHGC), an asset in the summer, and a detriment in the winter. Window D, with triple glazing and two low-E coatings, is representative of the most efficient window on the market today with respect to winter heat loss (very low U-factor). In addition, its low solar heat gain coefficient minimizes summer cooling.

The windows are distributed as shown on the RESFEN input screen below, from a real building design: 3% on the north, 2% on the east and west, and 5% facing south. RESFEN runs were made for each of the window types and the energy cost results are presented in the summary table below. If you are interested in studying the effect of window type by orientation or the results for a generic house, a set of RESFEN runs with an equal glazing percentage on each orientation may be useful.

**House Data**

Run ID: 1a.BSE

Units: IP

Location: WI Madison

Electric Cost: \$.08/kWh

Gas Cost: \$.60/therm

House: Ranch-Slab-Frame

AcGt: AcGt

Orientation: N,E,S,W

View: Annual Cost

**Window Data**

Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area(%FA)	3.00	2.00	5.00	2.00	12.00
Height(ft)	4.00	4.00	4.00	4.00	
Width(ft)	2.00	2.00	2.00	2.00	
U-factor	0.49	0.49	0.49	0.49	
SHGC	0.58	0.58	0.58	0.58	
Cfm/ft2	0.56	0.56	0.56	0.56	
Shading Type	None	None	None	None	

**Output Data - Cost** Compared to: windowless wall

	North	East	South	West	Total
Cooling(\$/ft2)	0.18	0.27	0.27	0.31	0.25
Heating(\$/ft2)	0.38	0.08	-0.22	0.12	0.04
Cooling(\$)	8.16	8.23	20.80	9.69	46.88
Heating(\$)	17.78	2.35	-16.68	3.61	7.06
Total(\$)	25.94	10.58	4.12	13.30	53.94

Bar chart showing Cooling and Heating costs by orientation (N, E, S, W, Tot).

Example 1 Input Screen for Glazing Type A.

Case	Window Description	Energy Cost (\$/yr)		
		Heating	Cooling	Total
1. Window A, N/S/E/W	A - Double glazed clear	7.06	46.88	53.94
2. Window B, N/S/E/W	B - Double glazed low-E	-31.58	44.55	12.98
3. Window C, N/S/E/W	C - Double glazed spectrally selective low-E	5.50	22.06	27.56
4. Window D, N/S/E/W	D - Triple glazed low-E superwindow	-41.93	29.26	-12.67
5. Window B on E & S Window C on W Window D on N	B - Double glazed low-E C - Double glazed spectrally selective low-E D - Triple glazed low-E superwindow	-33.72	36.60	2.88

Example 1 RESFEN Results

We see that there are significant savings in annual heating costs by using windows with low U-values (Cases 2 and 4, using Windows B and D) instead of double-glazed, clear units (Case 1, using Window A). The high-transmission low-E unit (Case 2, using Window B) is better than the spectrally selective low-E unit (Case 3, using Window C) in heating season performance. The benefit of reducing cooling costs in this climate from Window C must be examined in terms of whether air conditioning is installed in the house and operated full-time; however, the increased comfort of a window with a low SHGC is a factor to be considered whether or not the homeowner is paying for cooling. The triple-glazed unit (Case 4, using Window D), with its very low U-value, results in even greater heating season savings. Case 5 shows that using a combination of different windows on different orientations (double glazed low-E on the East and South, double glazed spectrally selective low-E on the West, and triple-glazed superwindow on the North) results in more energy savings than either window type B or C installed on all orientations. This may be a more cost effective option than installing Window D on all orientations.

The table below shows the breakdown of heating and cooling by window orientation, and it is clear that the larger glazing percentage on the South orientation makes a significant difference in the heating savings, particularly for the two windows with low U-factors and relatively high solar heat gain coefficients, which are Windows B and D. By studying the results by orientation, you can use RESFEN to determine the optimal glazing distribution as well as glazing type by orientation for your building.

Case	U-factor	SHGC	Heating (\$/yr)					Cooling (\$/yr)					Total (\$/yr)
			N (3%)	E (2%)	S (5%)	W (2%)	T	N (3%)	E (2%)	S (5%)	W (2%)	T	
1. Window A	0.49	0.58	17.78	2.35	-16.68	3.61	7.06	8.16	8.23	20.80	9.69	46.68	53.94
2. Window B	0.33	0.55	7.20	-4.12	-31.71	-2.95	-31.58	7.92	7.75	19.64	9.24	44.55	12.98
3. Window C	0.29	0.31	10.00	1.66	-8.53	2.37	5.50	3.85	4.12	9.91	4.19	22.06	27.56
4. Window D	0.15	0.37	-0.27	-6.08	-30.2	-5.38	-41.93	5.02	5.00	12.89	6.35	29.26	-12.67
5. Combined	--	--	-0.27	-4.12	-31.70	2.37	-33.72	5.02	7.75	19.64	4.19	36.60	2.88

*Example 1 RESFEN Results by window orientation (N=North, E=East, S=South, W=West, T=Total).*

## 5.2. Example 2: Window Selection in a Cooling Climate, Phoenix, AZ

Four possible window choices are compared for a house planned for construction in Phoenix, Arizona. The house, as seen on the RESFEN screen presentation shown below, is a ranch style home with a crawl space floor and masonry construction. Heating is supplied by a gas furnace and cooling by a central air conditioner. Gas utility cost for heating is \$0.70/therm and electric utility cost for cooling is \$0.09/kWh.

Input Description	Input Value
Location	AZ Phoenix
Electric Cost	\$0.09/kWh
Gas Cost	\$0.70/therm
House	Ranch-Crawl-Masonry
	AcGf

*Example 2 House Data Input Values*

The four windows to be analyzed are listed on the following table (all windows are assumed to be 3'x5' horizontal sliders):

	U-Factor	SHGC	TVIS	Air Leakage
A. Double glazed clear 1/8" clear, 1/2" air, 1/8" clear aluminum frame	0.83	0.72	0.63	0.56
B. Double glazed bronze 1/8" bronze, 1/2" air, 1/8" clear aluminum frame	0.83	0.61	0.48	0.56
C. Double glazed spectrally selective low-E 1/8" low-E (0.04), 1/2" argon, 1/8" clear thermally broken aluminum frame	0.46	0.39	0.56	0.15
D. Double glazed spectrally selective low-E 1/8" low-E (0.04), 1/2" argon, 1/8" clear vinyl frame	0.31	0.33	0.52	0.15

*Example 2 Window Input Values*

Window A is a typical clear, double-glazed unit with a standard aluminum frame. Window B, with bronze-tinted glass, represents a traditional approach to reducing solar heat gain (note the reduced SHGC due to the tinting). Window C is a spectrally selective low-E coating (a low SHGC combined with a high visible transmittance) and a thermally broken aluminum frame, resulting in a lower U-factor compared to the standard aluminum frames of Windows A and B. Window D is also a spectrally selective low-E coating, but has a vinyl frame, resulting in the lowest U-factor and SHGC of all the windows studied.

The windows are distributed as shown on the RESFEN input screen below: 3% on the north, 2% on the east and west, and 5% facing south. RESFEN runs were made for each of the windows and the energy cost results are presented below which have been extracted from RESFEN.

File Edit Library Performance Help

**House Data**

Run ID: 2c3x5sao BSE

Units: IP

Location: AZ Phoenix

Electric Cost: \$.09/kWh

Gas Cost: \$.70/therm

House: Ranch-Crawl-Masoni

AcGf: AcGf

Orientation: N,E,S,W

View: Annual Cost

Calculate

**Window Data**

Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area(%FA)	3.00	2.00	5.00	2.00	12.00
Height(ft)	3.00	3.00	3.00	3.00	
Width(ft)	5.00	5.00	5.00	5.00	
U-factor	0.46	0.46	0.46	0.46	
SHGC	0.39	0.39	0.39	0.39	
Cfm/ft2	0.15	0.15	0.15	0.15	
Shading Type	None	Overhang	Overhang	Overhang	

**Output Data - Cost** **Compared to: windowless wall**

	North	East	South	West	Total
Cooling(\$/ft2)	0.34	0.63	0.40	0.63	0.46
Heating(\$/ft2)	0.07	0.04	-0.02	0.06	0.03
Cooling(\$)	15.76	19.46	31.03	19.54	85.78
Heating(\$)	3.37	1.30	-1.17	1.90	5.39
Total(\$)	19.12	20.75	29.86	21.43	91.17

Example 2 Input Screen for Case 5, Window C with 2' overhangs on the East, South and West.

Case	Window Description	Energy Cost (\$/yr)		
		Heating	Cooling	Total
1. Window A, N/S/E/W	A – Double glazed clear, aluminum frame	8.37	233.16	241.53
2. Window B, N/S/E/W	B – Double glazed bronze, aluminum frame	10.37	198.83	209.20
3. Window C, N/S/E/W	C – Double glazed spectrally selective low-E, thermally broken aluminum frame	3.66	122.00	125.66
4. Window D, N/S/E/W	D – Double glazed spectrally selective low-E, vinyl frame	0.26	101.03	101.29
5. Window C, N/S/E/W 2' overhang S/E/W	C – Double glazed spectrally selective low-E, thermally broken aluminum frame	5.39	85.78	91.17
6. Window D, N/S/E/W 2' overhang S/E/W	D – Double glazed spectrally selective low-E, vinyl frame	1.88	69.67	71.55

Example 2 RESFEN Results

The cooling loads are dominant in this climate, so we see significant savings in annual cooling costs by using windows with a low solar heat gain coefficient (Window C) instead of double-glazed, clear units or traditional bronze-tinted glass (Windows A and B). Window D, which has a vinyl frame rather than a thermally-broken aluminum frame, results in the lowest heating and cooling loads of the four glazing types, due to both the low solar heat gain factor and the low U-value. Cases 5 and 6 show that the lowest energy costs result from the combination of high performance glazing (Windows C and D) and a two foot overhang on the South, East and West orientations.

### 5.3. Example 3: Window Selection in a Mixed Heating and Cooling Climate, Kansas City, MO

Four possible window choices are compared for a house planned for construction in Kansas City, MO. The house, as seen on the RESFEN screen presentation shown below, is a ranch style home with a crawl space floor and wood frame construction. Heating is supplied by a gas furnace and cooling by a central air conditioner. Gas utility cost for heating is \$0.60/therm and electric cost for cooling is \$0.08/kWh.

Input Description	Input Value
Location	MO Kansas City
Electric Cost	\$0.08/kWh
Gas Cost	\$0.60/therm
House	Ranch-Slab-Frame
	AcGf

*Example 3 House Data Input Values*

The four windows to be analyzed are listed on the following table (all windows are assumed to be 2'x4' casements):

	U-Factor	SHGC	TVIS	Air Leakage (cfm/ft <sup>2</sup> )
A. Double glazed clear 1/8" clear, 1/2" air, 1/8" clear wood or vinyl frame	0.49	0.58	0.57	0.56
B. Double glazed low-E 1/8" clear, 1/2" argon, 1/8" low-E (0.20) wood or vinyl frame	0.33	0.55	0.52	0.15
C. Double glazed spectrally selective low-E 1/8" low-E (0.04), 1/2" argon, 1/8" clear wood or vinyl frame	0.29	0.31	0.51	0.15
D. Triple glazed low-E superwindow 1/8" low-E (0.08), 1/2" argon, 1/8" clear 1/2" argon, 1/8" low-E (0.08) insulated vinyl frame	0.15	0.37	0.48	0.08

*Example 3 Window Input Values*

Window A represents what is currently being used in the house. It is a typical clear, double-glazed unit commonly used in all climates. Window B has a high-transmission low-E coating, while Window C has a spectrally selective low-E coating (a low SHGC combined with a relatively high visible transmittance). Window B is designed to reduce winter heat loss (low U-factor) and provide winter solar heat gain (high SHGC). Window C also reduces winter heat loss (low U-factor) but it reduces solar heat gain as well (low SHGC), an asset in the summer, and a detriment in the winter. Window D, with triple glazing and two low-E coatings, is representative of the most efficient window on the market today with respect to winter heat loss (very low U-factor).

The windows are distributed as shown on the RESFEN input screen below: 3% on the north, 2% on the east and west, and 5% facing south. RESFEN runs were made for each of the windows and the energy cost results are presented below which have been extracted from RESFEN.



5. EXAMPLES

**House Data**

Run ID: Sa.BSE

Units: IP

Location: MO Kansas City

Electric Cost: \$.08/kWh

Gas Cost: \$.60/therm

House: Ranch-Slab-Frame

AcGf: AcGf

Orientation: N,E,S,W

View: Annual Cost

**Window Data**

Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area (%FA)	3.00	2.00	5.00	2.00	12.00
Height (ft)	4.00	4.00	4.00	4.00	
Width (ft)	2.00	2.00	2.00	2.00	
U-factor	0.49	0.49	0.49	0.49	
SHGC	0.58	0.58	0.58	0.58	
Ctm/ft2	0.56	0.56	0.56	0.56	
Shading Type	None	None	None	None	

**Output Data - Cost** **Compared to: windowless wall**

	North	East	South	West	Total
Cooling (\$/ft2)	0.18	0.45	0.38	0.47	0.36
Heating (\$/ft2)	0.26	0.02	-0.25	0.05	-0.03
Cooling (\$)	8.54	13.83	29.25	14.57	66.19
Heating (\$)	11.81	0.61	-19.61	1.18	-5.72
Total (\$)	20.35	14.43	9.63	16.05	60.47

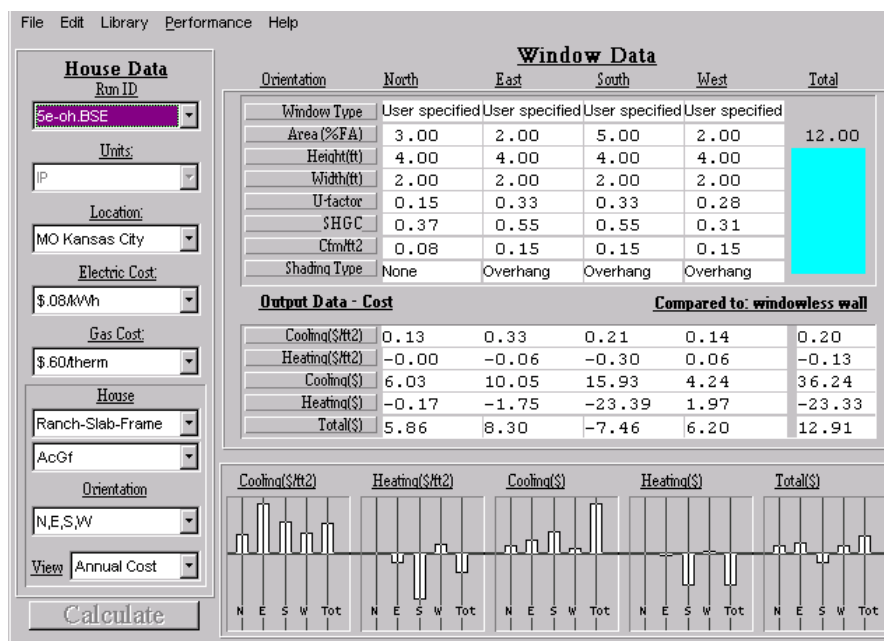
Bar chart showing monthly energy costs for Cooling (\$/ft2), Heating (\$/ft2), Cooling (\$), Heating (\$), and Total (\$).

Example 3 Input Screen for Window A.

Case	Window Description	Energy Cost (\$/yr)		
		Heating	Cooling	Total
1. Window A, N/S/E/W	A - Double glazed clear	-5.72	66.19	60.47
2. Window B, N/S/E/W	B - Double glazed low-E	-30.31	62.43	32.12
3. Window C, N/S/E/W	C - Double glazed spectrally selective low-E	-1.72	30.26	28.54
4. Window D, N/S/E/W	D - Triple glazed low-E superwindow	-34.88	40.60	5.72
5. Window B on E & S Window C on W Window D on N	B - Double glazed low-E C - Double glazed spectrally selective low-E D - Triple glazed low-E superwindow	-31.80	52.17	20.37
6. Window B on E & S Window C on West Window D on North 2' overhang, E/S/W	B - Double glazed low-E C - Double glazed spectrally selective low-E D - Triple glazed low-E superwindow	-23.33	36.24	12.91

Example 3 RESFEN Results

We see that there are significant savings in annual heating costs by using windows with low U-values (Cases 2 and 3, using Windows B and C) instead of double-glazed, clear units (Case 1, using Window A). The high-transmission low-E unit (Case 2, using Window B) is better in heating season performance than the spectrally selective low-E unit (Case 3, using Window C), but Window C is clearly better during the cooling season. The triple-glazed unit (Case 4, using Window D), with its very low U-value, results in even greater heating season savings. Case 5 shows that using a combination of different windows on different orientations (double glazed low-E on the East and South, double glazed spectrally selective low-E on the West, and triple-glazed superwindow on the North) results in more energy savings than either window type B or C installed on all orientations, which may be a more cost effective solution than using Window D on all orientations. Case 6 shows another low energy cost case that is also probably cost effective, which is the combination of high performance glazing (the same combination of windows as Case 5) and a two foot overhang on the South, East and West orientations.



Example 3 Input Screen for Case 6, a combination of high performance windows on different orientations with 2' overhangs on the East, South and West.

Another way to use RESFEN is to evaluate different building designs in terms of the glazing percentage on different orientations. For example, if you were still designing your house, and wanted to determine the energy impact of rotating it 180 degrees (because the great view was really to the north, not the south), you could do another run with RESFEN with the new glazing orientation, as shown in the next input screen – the window type in this case is double glazed, low-E, but now there is 5% glazing on the North and 3% glazing on the South. You can see that the total energy cost is greater than Case 2 – the cooling cost is reduced somewhat because there is less glazing on the south, but the increased heating cost (because there is less heat gain in the winter from the south facing windows) results in an overall increase in energy cost. At this point, you could begin analyzing this new configuration with different window and shading options, as we have done in the previous examples, in order to maximize the energy savings for this particular design.

File Edit Library Performance Help

### Window Data

**House Data**

Run ID: 5b-180.BSE

Units: IP

Location: MO Kansas City

Electric Cost: \$.08/kWh

Gas Cost: \$.60/therm

House: Ranch-Slab-Frame

AcGf: AcGf

Orientation: N,E,S,W

View: Annual Cost

**Calculate**

Orientation	North	East	South	West	Total
Window Type	User specified	User specified	User specified	User specified	
Area(%FA)	5.00	2.00	3.00	2.00	12.00
Height(ft)	4.00	4.00	4.00	4.00	
Width(ft)	2.00	2.00	2.00	2.00	
U-factor	0.33	0.33	0.33	0.33	
SHGC	0.55	0.55	0.55	0.55	
Cfm/ft2	0.15	0.15	0.15	0.15	
Shading Type	None	None	None	None	

**Output Data - Cost** **Compared to: windowless wall**

	North	East	South	West	Total
Cooling(\$/ft2)	0.20	0.42	0.35	0.45	0.31
Heating(\$/ft2)	0.11	-0.12	-0.40	-0.09	-0.09
Cooling(\$)	15.09	12.99	16.11	13.85	58.03
Heating(\$)	8.52	-3.57	-18.50	-2.78	-16.33
Total(\$)	23.61	9.42	-2.39	11.06	41.70

Cooling(\$/ft2)

Heating(\$/ft2)

Cooling(\$)

Heating(\$)

Total(\$)

Example 3 Input Screen for Case 2, but with the North glass area = 5% and the South glass area = 3%.

## 6. TABLES

### 6.1. US Cities Available for Analysis with RESFEN 3.0

AK	Juneau	NM	Albuquerque
AL	Birmingham	NV	Las Vegas
AZ	Phoenix	NV	Reno
CA	Fresno	NY	Buffalo
CA	Los Angeles	NY	New York
CA	San Diego	OH	Cincinnati
CA	San Francisco	OK	Oklahoma City
CO	Denver	OR	Medford
DC	Washington	OR	Portland
FL	Jacksonville	PA	Philadelphia
FL	Miami	PA	Pittsburgh
GA	Atlanta	SC	Charleston
HI	Honolulu	TN	Memphis
ID	Boise	TN	Nashville
IL	Chicago	TX	Brownsville
LA	Lake Charles	TX	El Paso
MA	Boston	TX	Forth Worth
ME	Portland	TX	San Antonio
MN	Minneapolis	UT	Salt Lake City
MO	Kansas City	VT	Burlington
MT	Great Falls	WA	Seattle
ND	Bismarck	WI	Madison
NE	Omaha	WY	Cheyenne

## 6.2. RESFEN Modeling Assumptions

The following table contains the input value assumptions used for the DOE2 simulations in RESFEN. The input assumptions were the same for RESFEN versions 1.4 and 2.4, but some values changed in RESFEN version 3.0, as the table below indicates. These assumptions are under review and may be updated in the next version of RESFEN.

PARAMETER	RESFEN Ver 1.4/2.4	RESFEN Ver. 3.0
FLOOR AREA (ft <sup>2</sup> & dimensions)	1540 39.24 x 39.24 x 8	1540 <sup>(a)</sup> 41.5 x 41.5 x 8
FOUNDATION	Slab	Slab, Crawl Space <sup>(b)</sup>
INSULATION	Wall: R19 Roof: R30	Wall: R19 <sup>(c)</sup> Roof: R30
INFILTRATION	ELA=0.77 ft <sup>2</sup> (0.58 ACH)	ELA=0.77 ft <sup>2</sup> (0.58 ACH)
STRUCTURAL MASS (lb/ft <sup>2</sup> )	> 3.5	1088 ft <sup>2</sup> walls <sup>(a)</sup> (≅ 4.3)
INTERNAL MASS Furniture (lb/ft <sup>2</sup> )	3.3	5.5 <sup>(d)</sup>
WINDOW AREA (% Floor Area)	15.6%	Variable
WINDOW TYPE	Variable	Variable
WINDOW DISTRIBUTION	Variable	Variable
EXTERIOR SHADING	None, 2' Overhangs, or Obstructions ( $\tau=0.50$ ) 20'	None, 2' Overhangs, or Obstructions <sup>(j)</sup> ( $\tau=0.0$ ) 20'
INTERIOR SHADING	None, or Shades SC multiplier of 0.60 when solar gain > 30 BTU/ft <sup>2</sup>	None, or Shades SC multiplier of 0.60 when solar gain > 30 BTU/ft <sup>2</sup> . <sup>(j)</sup>
HVAC SYSTEM	Furnace & A/C	Furnace & A/C, Heat Pump
HVAC EFFICIENCY	Heating: 0.74 Cooling: 2.80	Heating: 0.70 Cooling: 2.70 <sup>(e)</sup>
PART-LOAD PERFORMANCE	Default DOE-2 heating, cooling PLRs	Default DOE-2 heating, cooling PLRs <sup>(i)</sup>
THERMOSTAT SETTINGS	Heating: 70°F Cooling: 78°F	Heating: 70°F Cooling: 78°F
NIGHT HEATING SETBACK	60°F 11 PM – 6 AM <sup>(g)</sup>	60°F 11 PM – 6 AM <sup>(g)</sup>
INTERNAL LOADS (kBtu/day)	54 Sensible 12.2 Latent	56.1 Sensible 12.2 Latent
NATURAL VENTILATION	Enthalpic 10 ACH 78°F Winter, 72°F Summer	Enthalpic - SG 78°F / 72°F based on 4 days history <sup>(h)</sup>
WEATHER DATA TYPE	WYEC	13 TMY2, 33 WYEC2 <sup>(i)</sup>
NUMBER OF LOCATIONS	11	46
CALCULATION TOOL	DOE-2.1D	DOE-2.1E

**Footnotes:**

- (a) All versions of RESFEN model two building types – a 1540 ft<sup>2</sup> single-story ranch house, and a 2240 ft<sup>2</sup> two-story house. The table shows the dimensions, interior wall area, and internal loads levels for the one-story house only.
- (b) Future versions of RESFEN may vary the building foundation by location based on most prevalent type as indicated by the U.S. Bureau of the Census. (Ref: “Assessment of the Energy Savings Potential of Building Foundations Research”, Sterling, Labs, et al., University of Minnesota, Minneapolis 1985).
- (c) Future versions of RESFEN may vary the R-values for walls and ceilings for new buildings based on ASHRAE 90.2 requirements. (Ref: *Energy-Efficient Design of New Low-Rise Residential Buildings, ASHRAE Standard 90.2-1993*, American Society of Heating, Refrigerating, and Air-conditioning Engineers, Atlanta GA 1993, 1995).
- (d) RESFEN 3.0 assumes a furniture weight of 5.5 lbs/ft<sup>2</sup> of floor area based on information from a moving company (Ref: “Analysis of Climatic Conditions and Preliminary Assessment of Alternative Cooling Strategies for Houses in California Transition Climate Zones”, Y.J. Huang and H. Zhang, LBL-36320, Lawrence Berkeley National Laboratory, Berkeley, CA, 1995).
- (e) RESFEN 3.0 models a net heating system efficiency of 0.70, equating to a 78% efficient furnace with a 10% duct loss factor, and a net cooling system COP of 2.70, equating to a SEER 10.0 air-conditioner with a 20% duct loss factor. Future versions of RESFEN may model the average efficiency of furnaces and air-conditioners currently being shipped based on information from LBNL’s Appliance Standards Group, plus average duct loss factors from studies by LBNL and FSEC (Florida Solar Energy Center).
- (f) RESFEN 3.0 uses the default Part-Load Curves in the DOE-2.1E program. Future versions of RESFEN may model the most representative part-load performance from current residential equipment. (Ref: Winkelmann, F., Birdsall, B., Buhl, F., Ellington, K., Erdem, E., Hirsch, J., and Gates, S. 1993. “DOE-2 Supplement, Version 2.1E”, LBL-34947, Lawrence Berkeley National Laboratory, Berkeley CA, 94720.)
- (g) RESFEN 1.4 and 3.0 assume a 6-hour night setback to 60°F. Future versions of RESFEN may model a moderate setback of 65° F in recognition that all houses may not use night setbacks. Recent studies of residential indoor conditions have shown that nighttime temperatures are significantly lower than those during the day in the heating season (Ref: “Occupancy Patterns and Energy Consumption in New California Houses,” Berkeley Solar Group for the California Energy Commission, 1990).
- (h) RESFEN 3.0 use a feature in DOE-2 that allows the ventilation temperature to switch between a higher heating (or winter) and a lower cooling (or summer) temperature based on the cooling load over the previous four days.
- (i) RESFEN 3.0 uses a mix of TMY2 weather tapes from the National Renewable Energy Laboratory and WYEC2 weather tapes from ASHRAE. There are 239 TMY2 locations with average weather data compiled from 30+ years of historical weather data. (Ref: *TMY2 User’s Manual*, National Renewable Energy Laboratory, Golden, CO, 1995), but only 55 WYEC2 locations (Ref: *WYEC2 User’s Manual*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, CA, 1997). The two weather data sets are of comparable reliability, but in the future we propose for internal consistency to use only TMY2 weather tapes.
- (j) Future versions of RESFEN will allow combinations of interior and exterior shading devices to represent typical conditions.

## 7. ACKNOWLEDGEMENTS

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