



Teaching Architecture + Energy

Hosted by Washington University in St. Louis



Welcome to the Teaching Architecture + Energy project at Washington University. This site is part of a collaborative network of energy technology teachers in architecture schools, sponsored in part by the U.S. Dept. of Education. Our goal is to make it easier for architecture students to understand energy concepts and to design energy efficient buildings. The curricula developed here and at other universities is centered around Energy Scheming, a energy simulation tool that helps the student think about energy as an integral part of building design.

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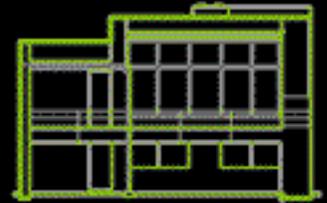
[Students](#)



Climate:
context for design



Exercises:
"recycling with energy scheming"



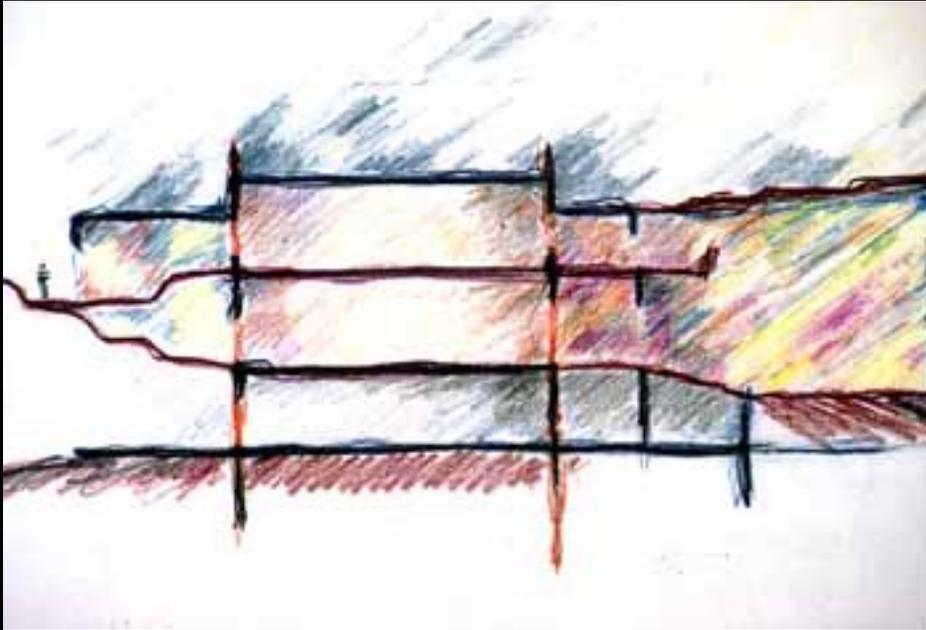
Example:
shanley building



Student Work

Legal Disclaimer

RECYCLING WITH ENERGY SCHEMING: Schematic Design & Performance



TERRAIN MAP: outline of exercise



A. DOCUMENTING: input your building



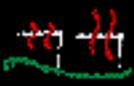
B. DEFINING: take-offs and specifications



C. ANALYZING: understanding energy patterns



D. RE-DESIGNING: 'generate and test' cycles



E. EVALUATING: energy codes as indicators

RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance

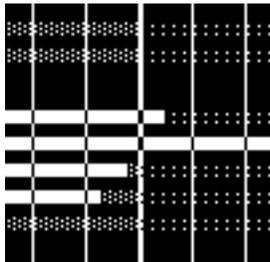
D. RE-DESIGNING: 'generate and test' cycles



In Part D of this exercise, you creatively re-design your schematic design and evaluate it using Energy Scheming until it meets your performance goals.

Before You Start Part D

Make a copy of your Part C file as an archive. Rename the file you will be using for Part D. You may want to use the "before" (part C) file later to compare your performance with your new design. It is also good insurance to have the back up.



1) [Re-Design to Meet Your Window Performance Targets](#)

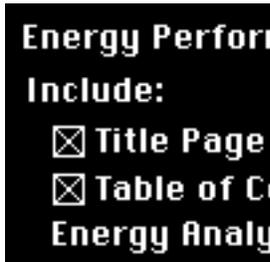
Work back and forth between the design of your elevations and the bars shown in the Rule-of-Thumb Window Sizing Aid until you have as many performance factors near 100% of your target as possible.



2) [Re-Design to Reduce Net Flows and Peak Loads](#)

Use graphic reports to help you re-design to:

- Reduce the building's net daily heat flow.
- Reduce the magnitude of gains and losses.
- Minimize the peak loads.



3) [Print the "Energy Performance Report"](#)

The Energy Performance report allows you to examine energy flows in tabular format, review the energy strategies and schedules used, and check the definition of all of your elements (building data).



4) [Document Design Changes](#)

Make a NEW set of Schematic Design Drawings that show changes made to improve energy and lighting design.

[Part D Grading Criteria](#)

Discussion

Energy Scheming helps you to understand the relationship between architectural design decisions and the energy use of the building being designed. You can propose a design and then see how it performs. After you have used it for a while, you will also develop an intuition for the complex relationships between energy use and form, such that you can also use energy ideas to help generate form.

You can make design changes to affect energy use by both "Strategic" and "Tactical" means. Energy loads are most affected by larger form decisions that set the context for smaller decisions. In general, the designer needs to get the strategic moves right BEFORE fine tuning with tactical moves. This avoids the problem of an elegant part in a dysfunctional whole. For instance, a building with a very long west facing facade is a missed

strategic level opportunity and will set up a difficult problem for the designer to solve with the tactical strategy of shading elements at the envelope. In the end, it is the interaction of all the elements and decisions in the design, taken together, that determine the building's energy use patterns. However, keep in mind that problems can be solved at more than one scale and that there are often several ways to solve the same issue. Consider for any particular issue, whether one of the following approaches makes the most sense.

- **Strategic Choices**

- *Making major form decisions*
(such as design of the section, roof shape, organization of rooms, orientation, massing, floor area, size, etc.),
- *Compositional changes that keep the major forms the same*
(such as shading devices, mass placement, and window size and location),

- **Tactical Choices**

- *Component choices*
(such as insulation thickness, electric lighting selection, and color).
 - *Working with schedules*
(occupancy, internal temperature, etc.)
-



RECYCLING WITH ENERGY SCHEMING



TERRAIN MAP



DOCUMENTING



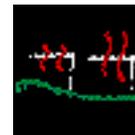
DEFINING



ANALYZING



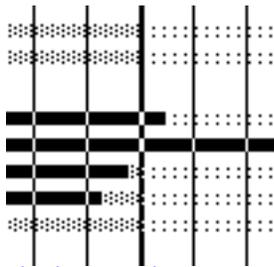
RE-DESIGNING



EVALUATING

RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance
D. RE-DESIGNING: 'generate and test' cycles

re-designing for performance targets



[shanley example.](#)

1) Re-Design to Meet Your Window Performance Targets.

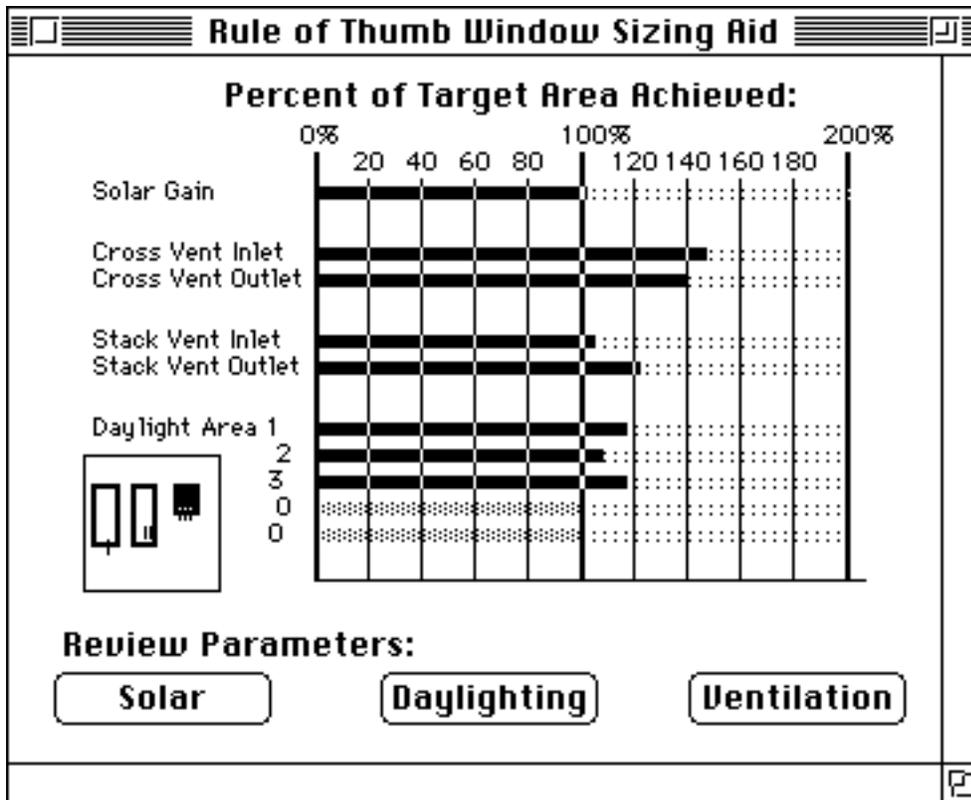
Work back and forth between the design of your elevations and the bars shown in the Rule-of-Thumb Window Sizing Aid until you have as many performance factors near 100% of your target as possible.

As you probably know, windows have a larger influence over energy use, both gains and losses, than any other building element. Getting the window size and placement in the right ballpark early in the design is important.

Work back and forth between the design of your elevations and the bars shown in the Rule-of-Thumb Window Sizing Aid until you have as many performance factors near 100% of your target as possible. Depending on your climate, site context, and building type, one of the variables (heating, cooling, or lighting) may govern window sizing.

- Solar heating performance is increased by more south facing glazing.
- Cross ventilation performance is increased by larger windows facing the breeze and by outlets at least as large as inlets. Remember, since ES is using airport wind data, it is fine to oversize cross ventilation by as much as 90% if your building is in a dense urban area, or 40% in a suburban area.
- Stack ventilation performance is increased by larger inlets and outlets or by increasing the height between them.
- Daylighting is increased by larger windows in the appropriate zone.

Lowering your performance targets (parameters) is NOT the best solution.



Turn in

- A record of the "Percentages of Target Area Achieved" AFTER your re-designs. Bring BOTH the initial performance AND the revised performance figures or graphs.

For a guide, see the [shanley example](#).

Jump to the next section: [Net Flows and Peak Loads](#)

RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance

D. RE-DESIGNING: 'generate and test' cycles

net flows and peak loads



2) Re-Design to Reduce Net Flows and Peak Loads.

Use graphic reports to help you re-design to:

- Reduce the building's net daily heat flow.
- Reduce the magnitude of gains and losses
- Minimize the peak loads

Energy Scheming gives you several types of graphic feedback that help you to reduce the building's energy use through good design. See the *ES Manual, Chapter 6*, for more information.

There are three basic energy goals that *Energy Scheming* can help you to move towards:

- **Reducing the building's net daily heat flow**

Net heat flow is the difference between heat loss and heat gain for a given hour. The net heat flow during each hour determines whether a building will need to be heated, cooled, or is in thermal balance. The sum of all net heat gain hours during a particular day represents the additional energy that will have to be met by a mechanical cooling system. The sum of all net heat loss hours during a particular day represents the additional energy that will have to be met by a mechanical heating system. The sum of all heat net gains over the course of the cooling season determines the annual cooling energy use, and thus the operating cost for cooling. The same holds for the sum of all heating season net losses. Therefore, reducing the building's net heat flows will reduce energy use, environmental impact, and operating costs.

Your goal should be to reduce the building's net heat flow to zero during all months. By examining the graphic report, you can determine which months have the greatest net loads and focus your attention there first. Try to get the building to flat line in the "Total Net Flow" graphic report.

- **Reducing the magnitude of gains and losses**

Heat gains and heat losses can be used to offset each other. Ideally, heat loss and heat gain equal each other and the building is in thermal balance each hour of the day. Because internal gains vary with the occupancy schedule, because solar gains vary with the sun's seasonal and daily path, and because the outside temperature fluctuates daily and seasonally, gains and losses do not often balance unless heat storage or passive cooling is employed. When a building has low net loads, this may be the result of either a combination of low losses offsetting low gains, or high losses offsetting high gains.

Your goal should be to reduce the magnitude of gains and losses, even if large gains are balanced by large losses. Try to reduce the height to the hourly bars in the "Total-Gain and Loss" graph.

For instance, a building may be designed for passive heating using large heat gains from large amounts of south facing glass to offset large heat losses from poorly insulated walls and roof. The building could be in balance, but improving the insulation levels would allow less expensive windows and thermal mass, while improving acoustics and dampening internal temperature swings. Alternatively, a commercial building may appear to be thermally balanced in winter, using large heat gains from low efficiency lights to offset envelope losses. More efficient lights would lower the internal heat gains and might shift the building to a need for more heating, thus the solar collection area could be increased. This would have the double advantage of reducing summer cooling loads and reducing overall energy costs, since auxiliary cooling Btu's from electricity often cost five times as much as auxiliary heating Btu's from gas.

- **Minimize the peak loads**

Peak loads are the largest hourly heat gain and the largest hourly loss during any hour of the year. These hourly peaks determine the size of heating and cooling equipment. The peak energy demand for commercial buildings also often sets the building's electric rate or demand charges. Higher peak demands equal higher cost per kWh (for electricity).

To determine the peak heating load and the peak cooling load, look at the "Total Net Flow" graphic report. If you hold down the cursor on the largest hour, you can see the loads contributed by each element.

Your goal should be to minimize the peak loads by flattening the curves in the graph.

Redesign your building for the above goals.

Keep working between the graphic report (several formats) and the building design and specifications. In this process, explore the impact of at least one from each of the following categories:

- Strategic Choices
 - Making major form decisions

- *Compositional changes that keep the major forms the same*
- Tactical Choices
 - *Component choices*
 - *Working with schedules , settings, and parameters.*

Turn in

- *Annotated graphic reports*
Show "Before" AND "After" performance. These will indicate how your understanding of energy design allowed you to improve the building's performance.
- *A minimum 500 word explanation of your process.*
List changes you have made in response to your initial run and intermediate cycles of design and evaluation. Document the success or failure of your changes using *Energy Scheming* runs. Comment on any remaining thermal issues and suggest how they might be resolved.

Be prepared to discuss these in class.

For a guide, see the [Shanley Example](#).

Jump to the next section: [Energy Performance Report](#)

RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance

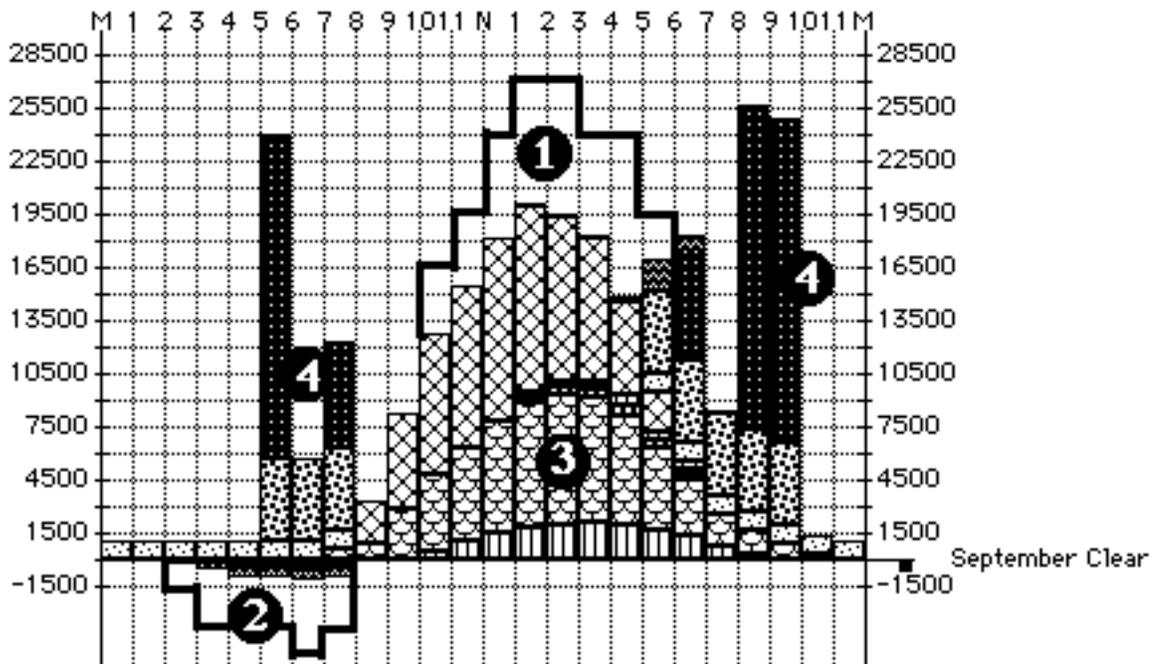
Suggestions for how to explain your work.

Below are some suggestions for a possible format used to annotate screen captures or prints of graphs. You may document and explain your work in any way you choose. A recommended method is to capture screens from ES, cropping and labeling in an image processor, such as Photoshop or Canvas; then import the image into a page layout program like PageMaker or a word processor like MSWord to annotate and write up your work.

1. Annotate the graphs

- Highlight the hours on the graphs when certain phenomena are taking place and key them to your explanations.
- Draw the outline of your "old" graph on top of your "new" graph and highlight the differences. Key the highlights to your explanations.

An example:



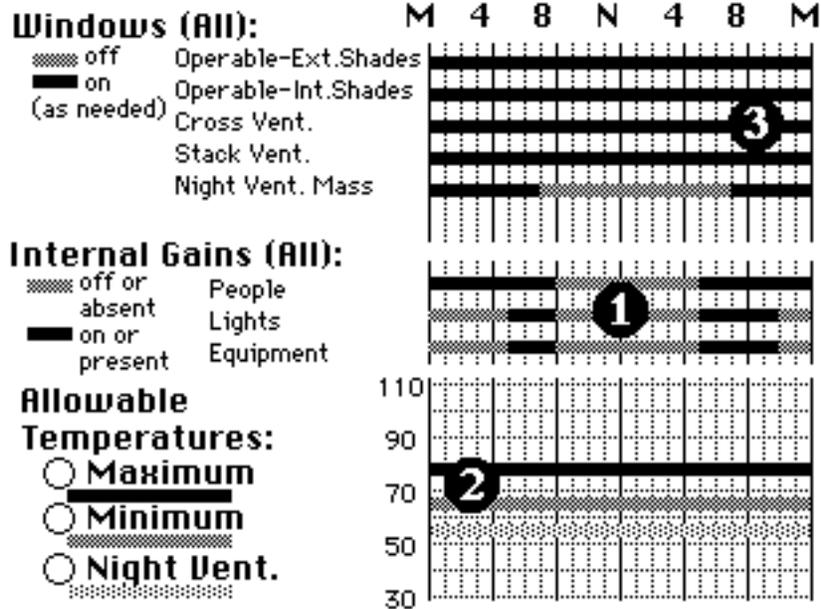
1. The dark line shows the profile of the previous graphic output. Reduction in solar gain by shading was effective in lowering the peak load.
2. Reduction in infiltration was effective in reducing loss.
3. The roof gain is still high. It may be able to be reduced by making the shingles light in color.
4. Electric lighting cannot be reduced because there is insufficient light available for daylighting.

2. Annotate the schedules

The performance of a building is often greatly influenced by when people are present, when lights and equipment are on or when shading is allowed. There are also important interactions between the climate and schedules. Annotating the schedules will sometimes help you explain why the building is performing the way it is.

For example:

September Clear



1. There is no heat gain from people in the middle of the day because the people are gone and the lights and equipment are turned off.
2. Heat gain could be reduced by having a higher thermostat set-point at mid-day when the building is unoccupied.
3. Cross ventilation is "on" all the time and there is wind, therefore there must not be any windows facing in the correct direction to ventilate because ventilation is not shown in the load graph.

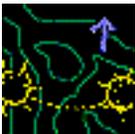


Jump to other Sections of: **B. DEFINING: take-offs and specifications**

- 1) [Tuning Settings to Fit Your Building.](#)
- 2) [Define Your Daylight Zone Icon](#)
- 3) [Set Performance Goals](#)
- 4) [Create Plan Specifications.](#)
- 5) [Create Elevation Specifications.](#)
- 6) [Use the Rule-of-Thumb Window Sizer](#)
- 7) [View the Graphic Report](#)
- 8) [Interpret and Assess Performance.](#)



RECYCLING WITH ENERGY SCHEMING



TERRAIN MAP



DOCUMENTING



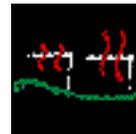
DEFINING



ANALYZING



RE-DESIGNING



EVALUATING

D. RE-DESIGNING: 'generate and test' cycles

energy performance report

Energy Perform

Include:

- Title Page
- Table of C
- Energy Analy

3) Print the "Energy Performance Report"

The Energy Performance report allows you to examine energy flows in tabular format, review the energy strategies and schedules used, and check the definition of all of your elements (building data). The report will also provide information that your instructor will use to track down the causes of any remaining problems with your building's performance as shown on the graphic reports

[shanley example.](#)

-
- From the FILE menu, select "Print Energy Performance Report"
 - Check the boxes for:
 - Title Page
 - Table of Contents
 - General Building Information and Building Drawing
 - Total Net Flow
 - Total; Gain and Loss
 - By Element Group
 - Energy Strategies
 - Building Schedules
 - Building Data
 - Annual Summary
 - Sec Summary

Energy Performance Report Format

Include:

Title Page Unmark All Report Items

Table of Contents

Energy Analysis:

General Building Info. & Building Drawing

Energy Summary Graphs:

Total Net Flow

Total - Gain & Loss

By Element Group

Energy Strategies

Building Schedule

Climate Data

Building Data

Annual Summary

Hourly Data

Spec Summary

Turn in

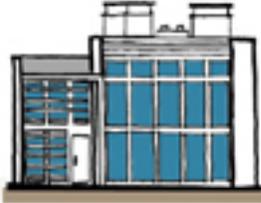
- *A copy of the Energy Performance Report.*
The report should represent your final scheme.

For a guide, see the [Shanley Example](#).

Jump to the next section: [Document Design Changes](#)

D. RE-DESIGNING: 'generate and test' cycles

documenting changes



4) Document Design Changes

Make a NEW set of Schematic Design Drawings that show changes made to improve energy and lighting design that you made as a result of using *Energy Scheming*.

[shanley example.](#)

Turn in

- *Annotated Drawings*

Make drawings at 11 x 17, showing your final design. **Indicate on the drawings** the most important design changes you made from your initial schematic design. Bring the following drawings to lab. They will be used as the basis for your final design + energy review.

| | HEATING | COOLING | LIGHTING |
|-----------------|---|---------------------------------------|---------------------------------------|
| SITE SCALE | 1) only required if changes were made | 2) only required if changes were made | 3) only required if changes were made |
| BUILDING SCALE | 4) floor plan & section | 5) floor plan & section | 6) floor plan & section |
| COMPONENT SCALE | 7) typical sections for wall, roof, floor | 8) shading elements | 9) lighting distribution |

For a guide, see the [Shanley Example.](#)

EXAMPLE PROJECT

shanley dental building, clayton, mo



harris armstrong, architect, 1936

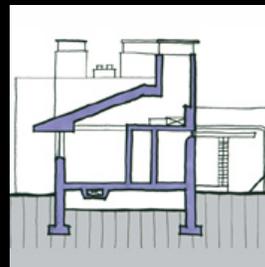


Worked Example

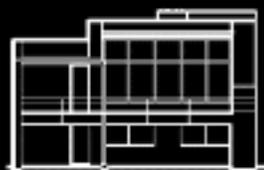
Re-Cycling with *Energy Scheming* exercise



Model



Final Drawings



Drawings



Site Photos

EXAMPLE PROJECT: example exercise

outline of example problem pages



exercise

A. DOCUMENTING: input your building (example)

1. [Assemble Schematic Plans and Elevations of Your Design](#)
2. [Identify the Building's Construction Type\(s\)](#)
3. [Diagram the Solar Concept](#)
4. [Determine Your Simulation Strategy](#)
5. [Diagram the Daylighting Zones](#)
6. [Get the Drawings into the Computer](#)
7. [Create a New Climate](#), if necessary



exercise

B. DEFINING: take-offs and specifications (example)

1. [Tune Settings to Fit Your Building](#)
2. [Define Your Daylight Zone Icon](#)
3. [Set Performance Goals for Lighting and Heating](#)
4. [Create Plan Specifications](#)
5. [Create Elevation Specifications](#)



exercise

C. ANALYZING: understanding energy patterns (example)

1. [Use the Rule-of-Thumb Window Sizer](#)
2. [View the Graphic Report](#)
3. [Interpret and Assess the Building's Performance](#)



exercise

D. RE-DESIGNING: generate and test cycles (example)

1. [Re-Design to Meet Your Window Performance Targets](#)
2. [Re-Design to Reduce Net Flows and Peak Loads](#)
3. [Print the "Energy Performance Report"](#)
4. [Document Design Changes](#)



exercise

E. EVALUATING: comparing with energy codes (example)

1. [Set an Energy Budget](#)
2. [Choose Reference Criteria](#)
3. [Model Your Reference Case Building](#)
4. [Compare the Performance of the Two Designs](#)



[Download the PDF version of the exercise](#)

D. RE-DESIGNING : generate and test cycles.

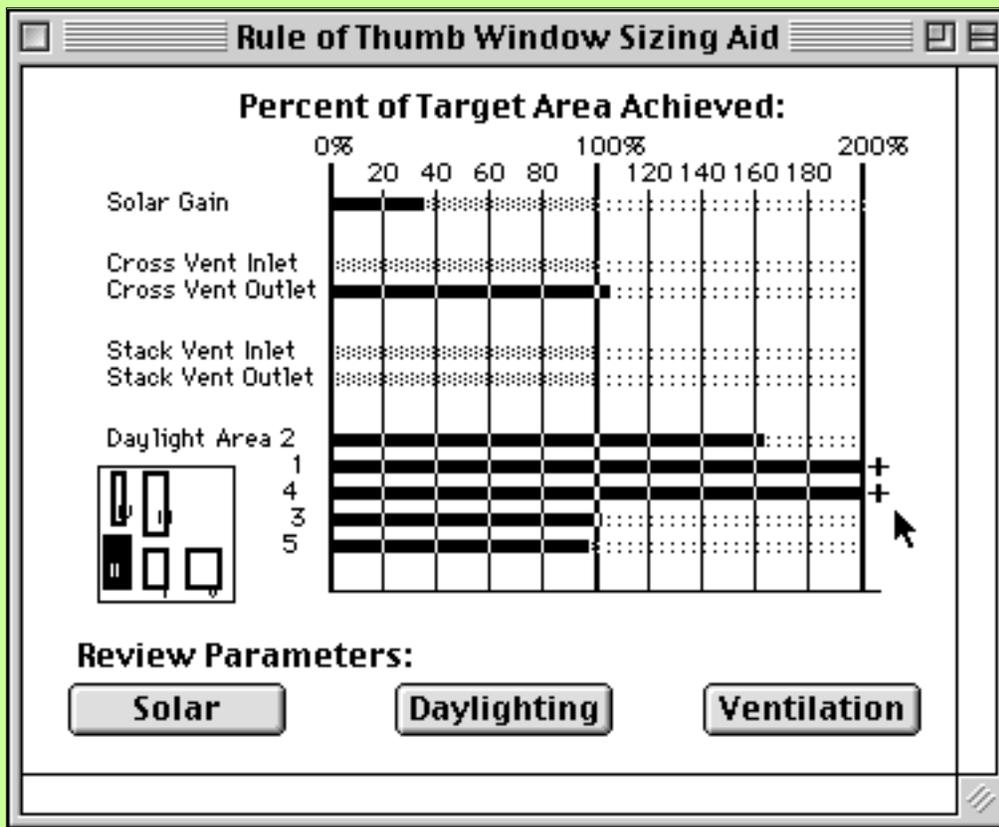
window performance targets



1. Re-design to Meet Your Window Performance Targets

[exercise](#)

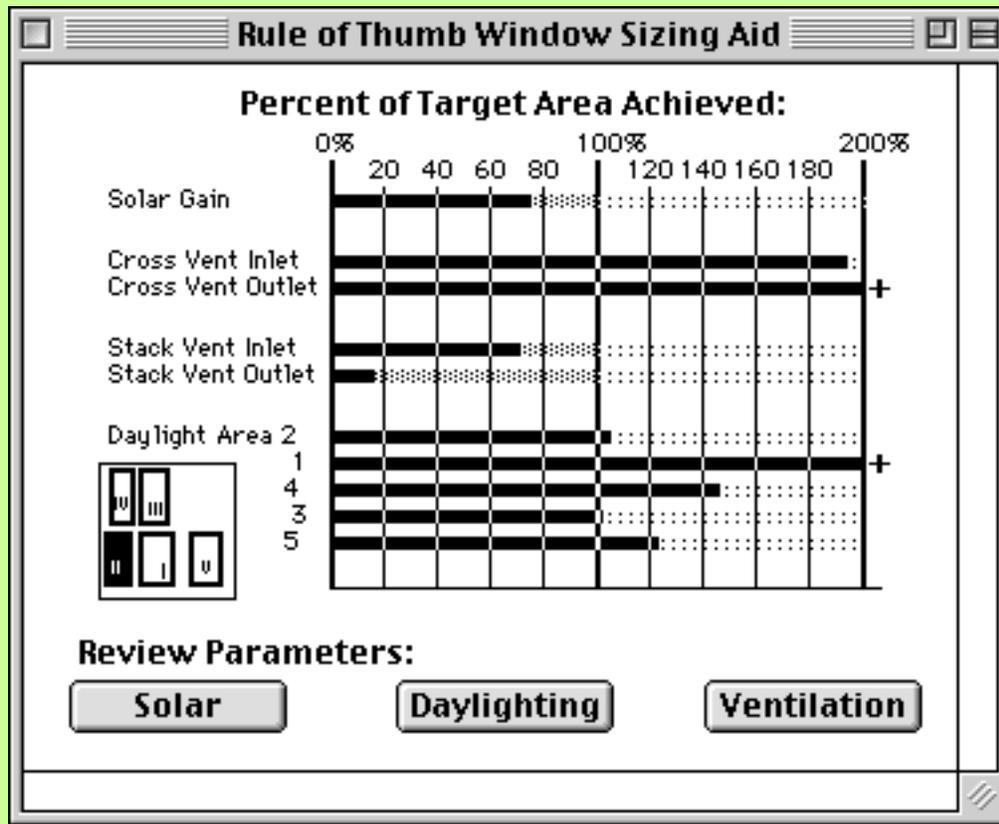
Performance Targets "BEFORE"



Click on one of the sizing bars in the graph to learn more about it. Click on any of the parameters buttons to review the design targets.

Performance Targets "INTERMEDIATE" first re-design

Performance Targets "INTERMEDIATE" first re-design



Solar Gain

Our re-design added a sunspace in two sections across the narrow south facade, linked by a fan-driven loop to the north side rooms. Our performance after this initial re-design increased from about 35% to about 75% of our target. Any additional south glass would have to be added to the roof of the north wing.

Cross Ventilation

Previously, we had lots of cross ventilation outlet, but no inlets. We made operable some of the windows on the south, north and west sides of the building. South windows are the only inlets possible, since the wind comes from that direction in summer. Even though the overall performance for cross ventilation now exceeds what is necessary, according to the rule-of-thumb, we know that the north side offices can not be effectively cooled with cross ventilation.

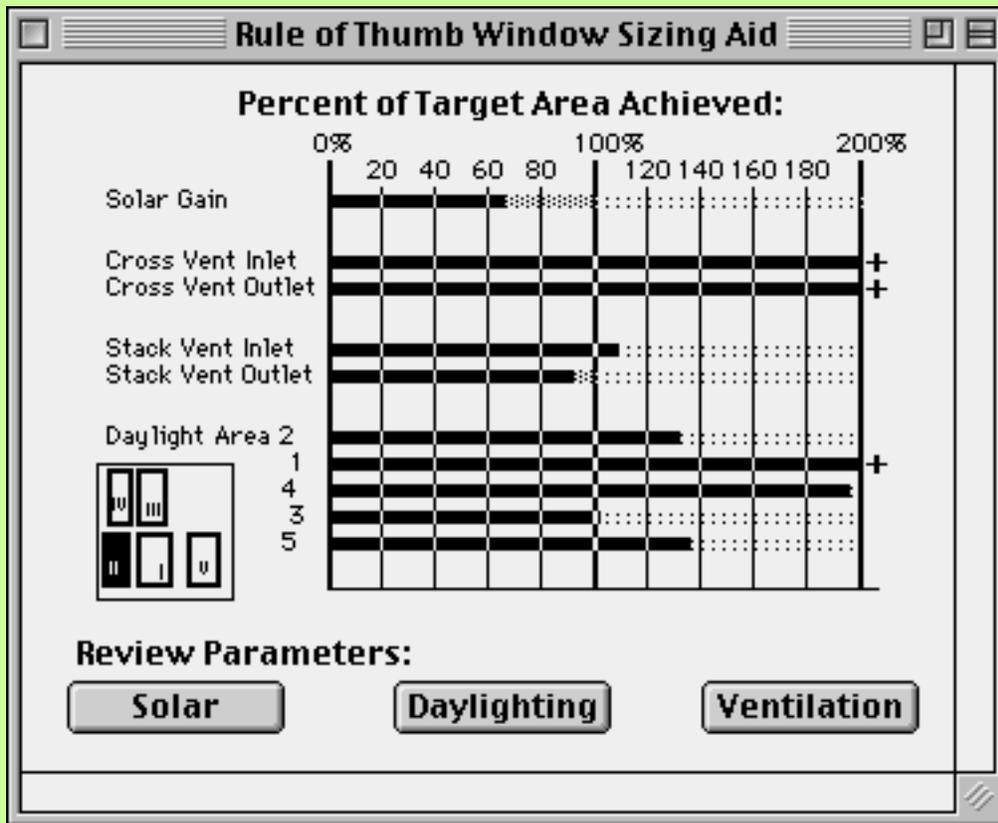
Stack Ventilation

In the re-design, there is now stack outlet at the back of the waiting room and over the corridor to serve the offices. Inlets are provided via the south sunspace, which open up completely in summer, and through the operable portion of the east office windows. As one can see, the stack inlets are only about 70% of what is required, and the outlets are a miserable 18%. To solve this, we will change the double-hung east and windows to casements (inlets) and make the stack towers much larger by increasing them in the E/W dimension.

Daylighting

In the initial design, zones I, II, and IV showed excessively high levels, with two zones over 200%. In our redesign, we added a sunspace. It will obviously have very high levels of daylight. We re-ordered the daylight zones, assigning zone 1 to the sun space and combining the previous zones I (waiting) and II (reception) into a single new zone II. Windows in the back wall of the sunspace are now a part of zone II, reducing the light in the waiting area to a more reasonable level. All sunspace windows now go with zone I, so we don't care if it overshoots the daylighting target. Zones II and II are now right at 100%. Given the shading and double glazing, we might consider adding more window area later. Otherwise, we are doing good.

Performance Targets "AFTER" first re-design



Stack Ventilation

In the final design, we have substantially increased the size of the stack ventilation towers; we also made the windows at the top of the sunspace operable. The stack outlet is now up to 92% of the target. Since our graphic reports show that we have no net cooling loads on the typical summer day, we believe that our target is achieved. Although, more ventilation will likely help on the extreme days.

Jump to the next EXAMPLE section: [Re-design to Reduce Net Flows and Peak Loads](#)

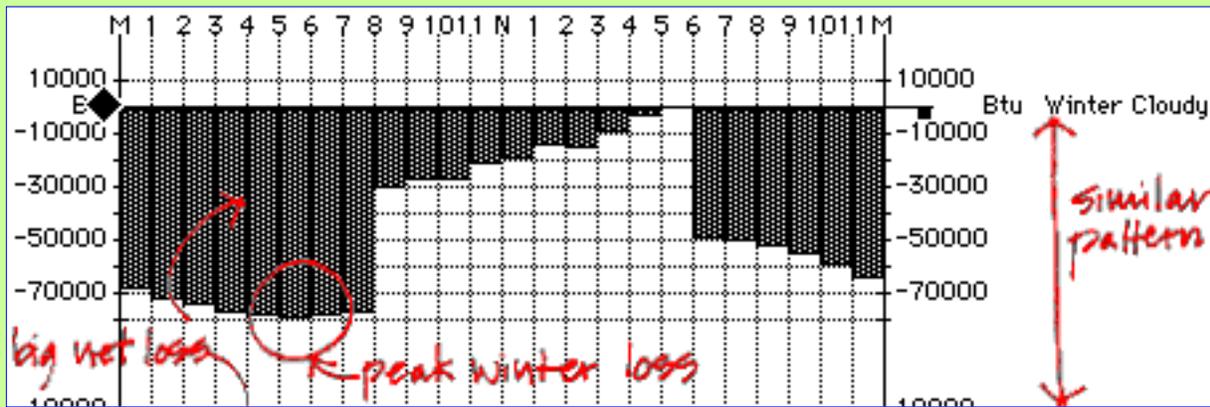
D. RE-DESIGNING : generate and test cycles.

net flows and peak loads

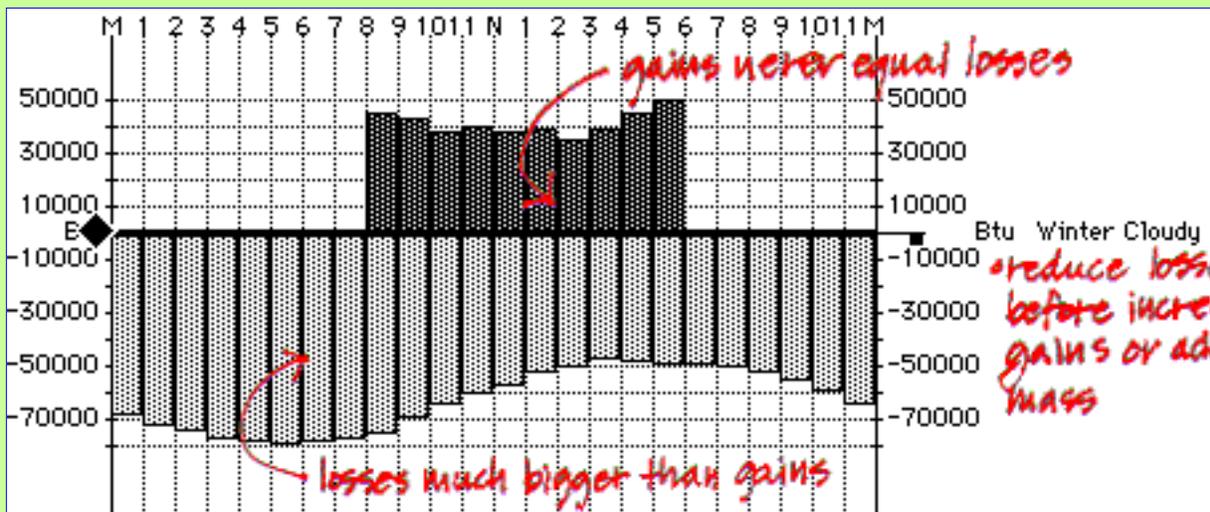


2.Re-Design to Reduce Net Flows and Peak Loads

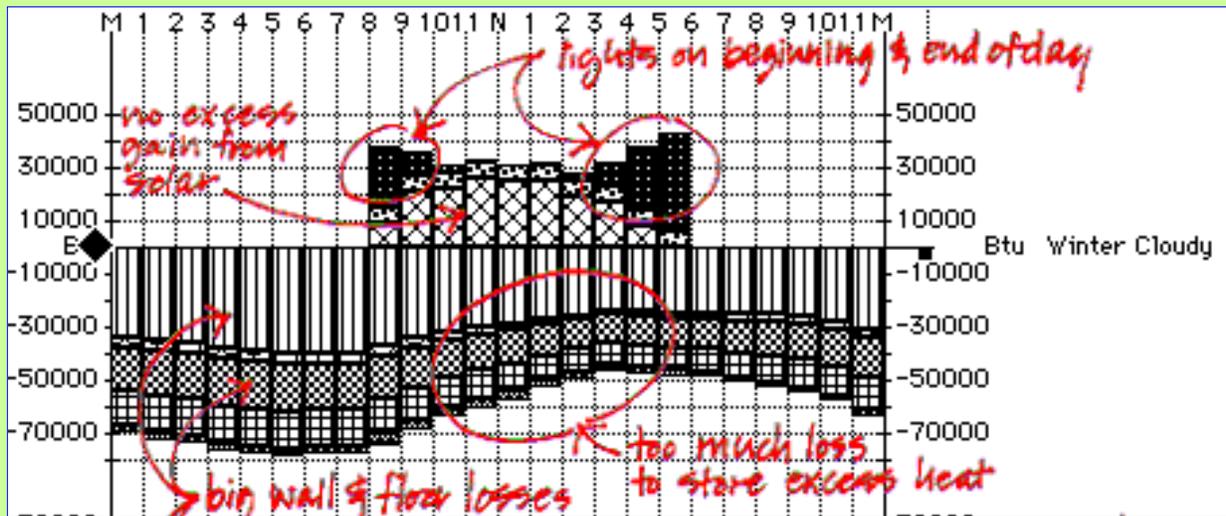
[exercise](#)



Annotated "[Net Flow](#)" graphic report for the Shanley Building.



Annotated "[Total Gain and Loss](#)" graphic report for the Shanley Building.



Annotated "[By Element Group](#)," graphic report for the Shanley Building.

ANALYSIS

- Reducing the building's net daily heat flow.
- Reducing the magnitude of gains and losses
- Minimize the peak loads

Jump to the next **EXAMPLE** section: [Print the "Energy Performance Report"](#)

RECYCLING WITH "ENERGY SCHEMING": Worked Example

D. RE-DESIGNING : generate and test cycles.

energy performance report



3.Print the "Energy Performance Report"

[exercise](#)

We printed as instructed.

Jump to the next **EXAMPLE** section: [Document Design Changes](#)

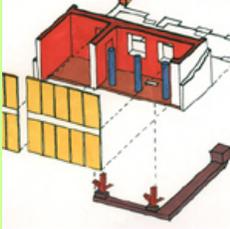
D. RE-DESIGNING : generate and test cycles.

design changes

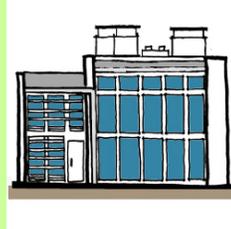


4. Document Design Changes

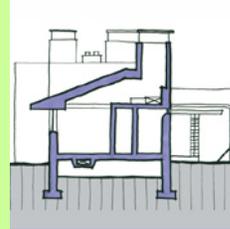
[exercise](#)



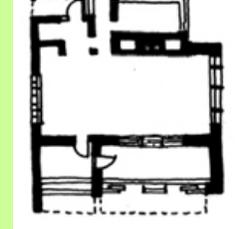
[Solar Concept](#)



[New Elevations](#)



[New Sections](#)



[New Plans](#)

INTERMEDIATE SCHEME

The following design changes were made in the initial re-design cycle (the Intermediate Scheme):

Strategic Changes

- Changed roof form over offices to promote flow to stack outlets, increasing its slope.
- Created a series of new ventilation stacks on west side of offices and on north side of waiting room.
- Added a Sun Space on south elevation for solar heating, allowing a large increase in collection area.

Tactical Changes

- Added wall insulation to uninsulated walls.
- Added floor insulation to uninsulated floor over crawl space.
- Increased ceiling insulation.
- Made windows operable on south side for inlets.
- Changed some windows to operable types, creating a ventilation path from inlets to outlets for each space.
- Changed windows to double glazed, low-e type to improve their R-value.
- Added shading on all sides, except north

FINAL SCHEME

The following design changes were made in the final re-design cycle (the Final Scheme):

Strategic Changes

- Made stacks much bigger, expanding them to the width of the corridor.

Tactical Changes

- Added additional thermal storage in the Sun Space, in the form of water.
- Changed block mass in exterior walls from "Hollow" to "Solid" mass, by filling with high sand content grout.
- Changed South windows in Sun Space to clear glazed to increase solar transmission.
- Added Night Insulation to all windows: R-5 for most windows, R-9 for Sun Space.
- Added rigid insulation to walls below grade.
- Added insulation to floor of Sun Space and to Sun Space slab edge.
- Changed electric lights from incandescent general diffuse type to the more efficient fluorescent indirect type.

RECYCLING WITH ENERGY SCHEMING: Download Exercise and Example



Download the exercise and example

The following links download a PDF version of the exercise and the example.

- to download the files mouse click once on the links below
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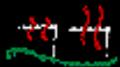
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