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.

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
How Low is Low Energy Use?
When working with Energy Scheming, the question often arises, “How do I know when I have reduced my energy use enough?” The problem is not unlike the difficulty designers often have in determining when to “stop designing.” The short answer to the question is that the goal is to achieve “Zero Net Energy Use,” to flat line the building’s net flow graphs for all seasons. In practice, determining how much to focus on reducing energy use depends on many factors, such as the project’s life cycle energy costs, the use of the building, and the values of the designer and clients. While reducing the net flows on typical days for each season to zero may be achievable and even economically beneficial, using passive means to achieve zero net energy on extreme design days is rarely feasible.

One way to get a sense of how your building is performing is to compare it to a similarly designed building that uses standards found in energy codes. Energy codes vary widely from state to state. Some states have no energy code other than the requirements found in “basic” building codes, the same codes that cover issues such as life safety. Other states have adopted energy codes based on the Model Energy Code or on the standard developed by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, the ASHRAE / IES Standard 90.1-1989 requirements. Still other states, such as California, and some municipalities, go beyond these model codes to develop their own more stringent requirements.

1. Setting an Energy Budget: a range of values
One of the designer’s first decisions is to set an energy use goal for the building. This is a programming level design choice that will effect both the process of how the building is designed and the final design product.

2. Choosing Reference Criteria
After setting your energy use goal, you must find the prescriptive standards for your building type and climate.

3. Model Your Reference Case Building
Using the prescriptive values for your building type and climate, model your building in Energy Scheming.
4. **Compare the Performance of the Two Designs**

After changing settings and takeoffs for the reference building, calculate the energy performance. Compare the following graphs:

- net flow graphs for the Code Reference
- net flow graphs for your Initial Run Building (as is with no design changes)
- net flow graphs for your Final Run Building (after all design changes to improve performance)
E. EVALUATING: energy codes as indicators

setting an energy budget

1. Setting an Energy Budget: a range of values

One of the designer's first decisions is to set an energy use goal for the building. This is a programming level design choice that will effect both the process of how the building is designed and the final design product.

Although it requires lots of "embodied intelligence," it is possible to design buildings that use little or no net energy. The following examples show a range of different goals for saving energy in buildings. Some, like the Model Energy Code, are targeted at governments; others, like the Energy Star and Canadian 2000 programs, are designed to use market-based approaches that go beyond the codes. Comprehensive environmental standards like BEPAC support drastically reduced energy use within a credit system that integrates many criteria, for voluntary use by designers and owners. These BEPAC scores are then used to market the building to highly educated workers and to corporations seeking a green image. Zero net energy buildings that produce at least as much energy as they consume are technically feasible and at present are mostly represented by educational facilities and research or demonstration projects.

Choose an Energy Use Goal

Use the examples on the Energy Budgets page to choose an energy use goal in relation to Model Energy Code standards. A modest goal would be 20% less than code (the Energy Smart standard). A challenging goal would be 70% less than code (the BEPAC maximum credit standard).

- Barely Legal

The AIA membership, back in 1995, passed a resolution that all buildings should meet the ASHRAE 90.1 standard. This standard, along with the MEC standards for residential buildings, should be taken as the MINIMUM standards for energy conserving buildings. Indeed, in many places, the represent the worst energy use allowed by law.

Multiple Pathways

Requirement of energy codes can usually be met by at least two paths, a Prescriptive approach and a Performance Approach. Under the Prescriptive Approach, the designer has only to verify that a standard set of requirements, such as minimum envelope R-values and maximum window U-values are met. Under the performance method, the building's energy use is calculated using computer software. Two runs are usually required, one using the prescriptive values for the building's design and construction, and one for the building as designed. The performance approach allows the design to break some rules as long as the overall energy use is lower than that of the prescriptive path reference building.

Energy Star Buildings: 30% less

The U.S. Environmental Protection Agency and the U.S. Department of Energy are sponsoring a joint program called ENERGY STAR Homes and ENERGY STAR Buildings. These buildings are designed to use a minimum of 30% less energy than code designed buildings, while reducing an equivalent amount of associated pollution. So, this would be a modest, conservative, achievable, and economically feasible goal.
"ENERGY STAR Homes" use at least 30% less energy than required by the national Model Energy Code while maintaining or improving indoor air quality. A more efficient ENERGY STAR Home simply COSTS LESS to own and operate.

"EPA's ENERGY STAR Buildings" program is a voluntary energy-efficiency program for U.S. commercial buildings. The ENERGY STAR Buildings program focuses on profitable investment opportunities available in most buildings using proven technologies. A central component of the program is the five stage implementation strategy that takes advantage of building system interactions, enabling building owners to achieve additional energy savings while lowering capital expenditures. Through these actions, Partners can expect to reduce total building energy consumption by 30% on average.

Canadian Standards: even less
Wouldn't you know it, the Canadians at the Canadian Centre for Mineral and Energy Technology have a more ambitious program than EPA.

C-2000 Buildings: 50% less
The requirements cover a broad range of performance criteria, including the need to demonstrate annual energy consumption of less than 50% of that required by ASHRAE 90.1. Other performance requirements have been established to assure minimal environmental impact, a high quality indoor environment, as well as adaptable and long-lived building components.

R-2000 Homes: 40% less
R-2000 Homes are some of the most energy efficient and comfortable homes being built commercially today and, following the introduction of new technical requirements in 1994, are the most environmentally friendly and provide a healthier indoor environment.

Advanced Houses Program: 80% less
This is a program/project sponsored by Natural Resources Canada (NRCan, formerly Energy Mines and Resources -- EMR). It's goal is to push the R2000 standard even further. These houses would at minimum be twice as energy-efficient as current R-2000 homes.

Environmental Performance Criteria: 70% less
The Building Environmental Performance Assessment Criteria (BEPAC) is the first comprehensive method for evaluating the environmental performance of both new and existing office buildings in Canada. BEPAC evaluates the environmental merits of office buildings and is incentive oriented to guide and encourage the market to value more environmentally responsible practices and higher performance standards. It is voluntary in its application and offers a certificate of design and management performance for office buildings and their tenancies. BEPAC has several standards related to energy use; maximum credit awards are give to buildings reducing energy use by at least 70% in comparison to a datum building.
Zero Emissions Buildings: achieving the sustainable ideal

Several houses have been built that use renewable technologies such as active solar systems and photovoltaics to supplement what passive design and the building fabric alone can not achieve. They all depend on very low net loads from heating, cooling and lighting. Here are two examples you can see on the web:

- **Oberlin’s Environmental Studies Center**
  “Booming student interest prompted David Orr, professor of environmental studies, to propose that the college build “a highly visible model of ecological design in a zero-emissions building.” [Press release](#). The project is being designed by [William McDonough + Partners](#).

- **Zero Energy House in Woubrugge**
  A Dutch energy consultant has developed and demonstrated a house designed to produce as much energy as it consumes.

Jump to the next section: **Choosing Reference Criteria**
E. EVALUATING: energy codes as indicators

2. Choosing Reference Criteria

After setting your energy use goal, you must find the prescriptive standards for your building type and climate.

For purposes of this exercise, we will use the model energy code (residential) and the Commercial Energy Code (based on ASHRAE 90.1). The designer can then use Energy Scheming to model the building with these prescriptive values in one run and compare the graphs generated to those of the building as designed.

Model energy codes (MEC) in the USA are divided into residential and commercial codes. The Residential MEC is further divided into Single Family and Multi Family standards. For more information on model energy codes, see the United States Department of Energy Building Standards & Guidelines Program (BSGP), a program run by Pacific Northwest National Labs.

Find Your Prescriptive Standards
Use the following help pages to find heat transfer values for your building’s envelope.

- Prescriptive Standards for Residential Buildings
- Prescriptive Standards for Commercial Buildings
- California’s Title XXIV
  Tips on how to compare your building to a code building in California.

Jump to the next section: Model Your Reference Case Building
RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance

E. EVALUATING: energy codes as indicators

MEC prescriptive standards: residential

RESIDENTIAL BUILDINGS

Model Energy Code for Residential Buildings

The Model Energy Code (MEC) is published by the Council of American Building Officials (CABO) and is updated annually by the CABO Code Changes Committee.

The prescriptive approach, the simplest of the three approaches, allows builders or designers to select from various combinations of energy conservation measures based on "climate zone" location. Each combination or "package" specifies insulation levels, glazing areas, glazing U-values (thermal performance), and sometimes heating and cooling equipment efficiency. By locating the correct climate zone and looking up the appropriate table of packages, one can ensure the project meets one of the packages listed for that zone.

To determine if your proposed design complies with the climate-specific requirements:

1. Determine the climate zone for your proposed building's location from the appropriate state map.

The state maps are divided into climate zones that fall along county boundaries. Based on the county in which your building is located, find your zone from the appropriate state map. The zones are shown graphically on each map along with their corresponding zone numbers.

2. Find the prescriptive package table for your building's climate zone.

Once you know the number of your climate zone, you can go to the prescriptive package table for that zone. The tables of prescriptive packages correspond to the climate zones depicted on the state maps. Each climate zone has a one-page table of prescriptive packages from which you can select one package. If your building meets the insulation R-value, glazing, and (sometimes) heating and/or cooling equipment efficiency requirements specified for the package you select, then the building complies with the MEC.

Your table will look something like the excerpt from climate Zone 10 (St. Louis, MO city and county) below:
The MEC check Prescriptive Packages were developed to demonstrate compliance with the insulation and window requirements of the Council of American Building Officials (CABO) Model Energy Code (MEC). This version of the prescriptive packages demonstrates compliance with the 1995 edition of the MEC.

### Status of Energy Codes

- **Status of Energy Codes in Missouri**
- **Status of Energy Codes in Illinois**

### 3. Select a Prescriptive Package from Those Possible in Your Climate Zone

To select the correct package from the table for your building:

- **Make an Assumption about HVAC Equipment**
  
  Decide whether the building will have either 1) "Normal" efficiency systems; 2) "High Heating" efficiency systems; or 3) "High Heating AND High Cooling" efficiency systems. This determines what block of packages are available to you. Note that the envelope requirements are more stringent for less efficient HVAC systems. *Energy Scheming* calculates loads only, and does not address HVAC systems.

- **Calculate the Proposed Glazing Area Percentage**
  
  Check the "Building Data" and "Spec Summary" sections of your ES Energy Performance Report to find the total takeoff areas of windows and walls. You can print just these sections of the report by checking their boxes in the "Print Energy Performance Report" dialog box.

  - **Calculate the Glazing Area**
    
    Calculate the total area (ft²) of all glazing assemblies (windows, sliding glass doors, skylights, etc.) located in the building envelope. The nominal area or rough opening is acceptable for windows. The area of windows in the exterior walls of conditioned basements should be included. Windows in unconditioned basements are NOT included.

  - **Calculate the Gross Wall Area**
    
    The gross wall area includes the following:
    - all above-grade walls enclosing conditioned spaces (including attic knee walls and skylight shafts)
    - the peripheral edges of floors (the area of the band joist and subfloor between floors)
    - walls of conditioned basements with an average depth less than 50% below grade (include the entire wall area even the below-grade portions).
    - all windows and doors (including windows and doors in conditioned basements).

  - Divide the glazing area by the gross wall area and multiply by 100 to determine the *Proposed Glazing Area Percentage*.

- **Select the package that fits best with your combination of assumed HVAC efficiency and calculated Glazing Area Percentage.**
Find the corresponding requirements for glazing, ceiling, wall, roof, floors, slabs, and below-grade walls. Input them Into Energy Scheming

Here are a few notes from the prescriptive guide to remember:

- **General Notes**
  - The insulation R-values listed for each package are the minimum allowed for that package. R-value requirements refer to the R-value of the insulation only.
  - Wall and ceiling insulation R-values refer to the sum of the stud cavity insulation plus insulating sheathing (if used). For example, an R-16 wall requirement can be met with R-13 cavity insulation and R-3 sheathing.
  - It is important to select a package consistent with the proposed framing used in the building. For example, it would be impossible to comply with a package specifying R-38 ceiling insulation (approximately 12 in. thick) if the building plans include a cathedral ceiling with 2x8 framing (approximately 7.5 in. thick).

- **Glazing**
  - The glazing U-value and the glazing area percentage listed for each package are the maximum allowed for that package. To input the window U-value into ES, first convert the U-values to R-values. Then input the window R-values in the detailed window spec layer for "Window Plane."

- **Ceiling**
  - Proposed R-values for ceilings represent the sum of the cavity insulation plus insulating sheathing (if used). For ventilated ceilings, insulating sheathing must be placed between the conditioned space and the ventilated portion of the roof (typically applied to the trusses or rafters immediately behind the drywall or other ceiling finish material).

  The ceiling R-value requirements do not assume a raised or oversized truss construction. If the insulation achieves the full insulation thickness over the exterior walls, R-30 insulation may be used to meet an R-38 insulation requirement and R-38 insulation may be used to meet an R-49 insulation requirement.

  Input the R-value for ceilings into the detailed section of the roof spec, similar to the wall spec illustrated below.

- **Walls**
  - Since you will probably have already defined the wall materials of your base building, ES selects and calculates a variety of factors about the wall section for you. Input R-values from the prescriptive standards into the detailed wall spec. Leave all other values the same as those chosen by ES.
Roofs
Input the R-value into the detailed section of the roof spec, similar to the wall spec illustrated above.

Floor
Floors over unconditioned space include floors over unconditioned crawl spaces, basements, and garages. Floors over outside air include floor cantilevers, the floor of an elevated building, and floors of overhangs (such as the floor above a recessed entryway or open carport). Floors over outside air must meet the ceiling R-value requirement. Input the R-value into the detailed section of the floor spec.

Basement
Basement walls that enclose conditioned spaces must be insulated from the top of the basement wall to 10 ft below ground level or to the basement floor, whichever is less. Any individual wall of a conditioned basement with an average depth 50% or more below grade is considered a basement wall; a wall over 50% above grade is considered an above-grade wall and must meet the wall R-value requirement for the package.

Take off basement walls like regular walls. Include the area below grade. Begin with R-values given in the code and add to that value, the R-value of the earth. To estimate the R-value of the earth surrounding a below grade wall, use Sun, Wind, and Light, strategy 30, pp. 86-7.

Slab R-Value
The prescriptive package slab R-value requirements are for unheated slabs. Add an additional R-2 for heated slabs, except in Zone 1 which does not require slab insulation. For packages with a slab insulation requirement, the insulation must extend a total linear distance of at least 24 inches in Zones 2-12 and 48 inches in Zones 13-19. A heated slab is a slab with ducts or hydronic heating elements in or under the slab.
Crawl Space

Crawl space wall R-value requirements are for walls of unventilated crawl spaces (i.e., not directly vented to the outside). Ignore crawl space insulation requirements, because this uncommon construction type can not be evaluated effectively in Energy Scheming.
MEC prescriptive standards: commercial

COMMERCIAL BUILDINGS

Requirements for All Buildings
To meet the MEC, all buildings must comply with requirements for limiting air leakage through the building envelope and installing vapor retarders. For commercial buildings modeled in ES, these requirements do not have a significant effect. For non-residential buildings, ES models ventilation according to ASHRAE requirements for ventilation, based on occupancy type.

Climate-Specific Requirements
The COMcheck-EZ prescriptive package tables contain climate-specific envelope requirements for walls, windows, skylights, roofs, floors, and below-grade walls. Included are required insulation levels, glazing areas, and glazing U-factors.

There are several packages for each climate zone, based on the window-wall ratio (WWR), which is the gross window area divided by the gross wall area. The gross wall area includes:

- the opaque area of all above-grade walls enclosing conditioned spaces (excluding doors and windows)
- the area of the band joist and subfloor between floors
- the area of all doors and windows.

The gross window area includes the rough-opening area of the window, not just the transparent-glass area.

To determine if your proposed design complies with the climate-specific requirements

Calculate the WWR for your design.
As described above. Check the "Building Data" and "Spec Summary" sections of your ES Energy Performance Report to find the total takeoff areas of windows and walls. You can print just these sections of the report by checking their boxes in the "Print Energy Performance Report" dialog box.

Determine the climate zone for your proposed building’s location from the appropriate state map.

Map of Missouri Climate Zones.
Click to enlarge and see climate legend.

To find climate zones by county from a map for any US state, you can download the following file:
Maps of All States (1.5 MB Adobe Acrobat file)

Find the prescriptive package table for your building’s climate zone.
Once you know the number of your climate zone, you can go to the prescriptive package table for that zone. These standards apply to most commercial and high-rise residential buildings three stories or more above grade. A building designed and constructed to meet the COMcheck-EZ requirements generally meets or exceeds the energy efficiency of a similar building constructed to meet ASHRAE/IES Standard 90.1-1989 requirements.

Your table will look something like the excerpt from climate Zone 10b (St. Louis, MO city and county) below:
### Table of St. Louis City and County Commercial Prescriptive Standards (Zone 10b)
Click on the chart or text above to view the whole chart.

Click here to download specific State Maps and Prescriptive Packages in Adobe Acrobat format from DOE's web server

- **Map of Missouri with Prescriptive Packages** (85 K Adobe Acrobat file)
- **Prescriptive Packages for All States** (119 K Adobe Acrobat file)

**MEC Envelope Compliance Guide**
This guide offers more details about code compliance related to the envelope. It is not necessary that you refer to it for schematic design with ES, but you might find it interesting.

#### Select the package from the table that best fits your design’s construction characteristics based on WWR.
There are three categories (columns) of WWR:
- 0 to 10 % Window - Wall Ratio
- 10 to 25 % Window - Wall Ratio
- 25 to 40 % Window - Wall Ratio

Within each WWF category, select values based on your construction characteristics.

#### Find the corresponding requirements for walls, windows, skylights, roof, floor, and below-grade walls. Input them Into Energy Scheming.

- **Walls**
  Since you will probably have already defined the wall materials of your base building, ES selects and calculates a variety of factors about the wall section for you. Input R-values from the prescriptive standards into the detailed wall spec. Leave all other values the same as those chosen by ES.
Windows

Natural Ventilation
The codes typically require that a free opening of at least 4% of the floor area be available for natural ventilation. Make sure that you define 4% of your windows as operable cross ventilation openings. This will allow you to compare the code minimum against your actual design, which in some cases may have more than 4%

In most cases, the WWR will affect the window requirement.
To input the window U-value into ES, first convert the U-values to R-values. Then input the window R-values in the detailed window spec layer for "Window Plane."

Solar Heat Gain Coefficient
Your (base case) design must also have a Solar Heat Gain Coefficient (SHGC) less than or equal to that in the prescriptive package. In ES, input values of SHGC in the "Window Plane" spec layer of the Detailed Window Spec.
Projection Factor

The SHGC required by the prescriptive standards is affected by the projection factor (PF) of qualifying overhangs. The projection factor is based on the ratio of the overhang depth to the overhang height above the window sill. Based on the characteristics of your building's overhangs (if any), choose the correct SHGC and window U-factor.

- Skylights
  Skylights are limited in area by code, usually to 3% of floor area. Check the limits for your climate zone. If your building has more skylights than allowed by code, reduce your skylight area for the code building ES run to the maximum allowed.

  To input the prescriptive skylight U-value into ES, first convert the U-values to R-values. Then input the window R-values in the detailed window spec layer for "Window Plane." Horizontal skylights are taken off in plan. Sloped skylights are taken off in the elevation drawings.

- Roofs
  First find the roof construction that most closely matches your building. Then, for each construction type, the prescriptive standards give two options for roofs, one for continuous insulation, such as rigid insulation over a concrete deck, and one for cavity insulation such as between rafters. Input the R-value into the detailed section of the roof spec.

- Floors
  First find the floor construction that most closely matches your building. Then, for each construction type, the prescriptive standards give two options for floors, one for continuous insulation, such as rigid insulation under joists, and one for cavity insulation such as batt insulation between joists. Input the R-value into the detailed section of the floor spec. These conditions apply only for floors over unheated basements, crawl spaces, and exposed outdoor conditions. They do not apply to slabs on grade.

- Slab Edge and Below-grade walls
  The required minimum slab edge and basement insulation is given as R-values.

  - For slabs on grade
    ES uses an arcane $F_2$ value, which has to be calculated by an ASHRAE method. To simplify, assume that slab insulation
is rigid insulation with an R-value of 4 per inch. Determine how many inches of rigid insulation would be required to meet the code. Then select the closest insulation thickness in inches from the table view (by clicking on "Select Floor Components") in the floor spec.

For Basement Walls
Take off basement walls like regular walls. Include the area below grade. Begin with R-values given in the code and add to that value, the R-value of the earth. To estimate the R-value of the earth surrounding a below grade wall, use Sun, Wind, and Light, strategy 30, pp. 86-7.

* All images not taken from Energy Scheming are from the ComCheck EZ Envelope Guide
RECYCLING WITH "ENERGY SCHEMING": Schematic Design Performance

E. EVALUATING: energy codes as indicators

California Title XXIV prescriptive standards

WHAT CAN BE COMPARED
The California code covers envelope loads, lighting, HVAC, and water heating. Since Energy Scheming only calculates heating and cooling loads, we can compare the heating and cooling loads of your design against those of the minimum (worst) building allowed by code. This analysis will include the envelope loads and internal loads, including the heat gain effects of lighting. We can not, using this tool, compare HVAC performance, total lighting system energy use, or hot water energy. General Overview of CA Title XXIV code

HOW TO FIND TITLE XXIV PRESCRIPTIVE STANDARDS

Title 24 on-line
● Administrative Regulations -- California Code of Regulations
● SubChapter 1 -- All Occupancies -- General Provisions
● SubChapter 2 -- All Occupancies -- Mandatory Requirements for the Manufacture, Construction, and Installation of Systems, Equipment, and Building Components
● SubChapter 3 -- Nonresidential High-Rise Residential, and Hotel/Motel Occupancies -- Mandatory Requirements for Space Conditioning and Service Water Heating Systems and Equipment
● SubChapter 4 -- Nonresidential High-Rise Residential, and Hotel/Motel Occupancies -- Mandatory Requirements for Lighting Systems and Equipment
● SubChapter 5 -- Nonresidential, High-Rise Residential, and Hotel/Motel Occupancies -- Performance and Prescriptive Compliance Approaches for Achieving Energy Efficiency
● SubChapter 6 -- Nonresidential High-Rise, and Hotel/Motel Occupancies -- Additions, Alterations, and Repairs
● SubChapter 7 -- Low-Rise Residential Buildings -- Mandatory Features and Devices
● SubChapter 8 -- Low-Rise Residential Buildings -- Performance and Prescriptive Compliance Approaches
● SubChapter 9 -- Low-Rise Residential Buildings -- Additions and Alternations in Existing Low-Rise Residential Buildings
● APPENDIX 1-A -- Standards Referenced In Energy Efficiency Regulations

Tips on modeling a TITLE XXIV CODE BUILDING in Energy Scheming

NATURAL VENTILATION
● Use 5% of floor area for the total of inlets and outlets. Make sure that all your windows are fixed, except for the 5% of floor area required.
● Turn off all stack ventilation, since the configuration of ventilation is not specified by code.

WINDOWS
Total area of windows:
● Use the lesser of
  ○ a) the proposed building design, OR
  ○ b) 40% of the wall area
● For U-values and Shading Coefficients, see: TABLE NO. 1-I.
  For the shading coefficient of the reference building, use the values listed in the table for "Relative Solar Heat Gain." The RSHG is equal to the shading coefficient (SC) of the window multiplied by the shading coefficient of the exterior shading. For the reference building, interior shades are ignored. Since the glazing itself will likely have some shading effect (relative to single clear glass, for which SC = 1.0), find the required maximum SC for the exterior shading by:
  ○ SC_{exterior} = RSHG ÷ SC_{glass}
  ○ SC_{glass} can be found by selecting the glass type in the ES window spec and then clicking on the button for "detailed window specs." Assume that "Transmission" is equal to SC plus 0.10, for the window. So: SC_{wind} = T_{wind} + 0.1. Default values for T can also be found in the ES Manual Appendix.
SKYLIGHTS
- Use the lesser of
  - a) the proposed building design, OR
  - b) 5% of the wall area
- For U-values and Shading Coefficients, see: TABLE NO. 1-I.

WALLS AND ROOFS
- Configuration, orientation, and areas are the same as the proposed building design.
- For R-values, see: TABLE NO. 1-I.
- Change your wall and roof construction to a metal framed wall with no mass. Use the detailed spec to set R-value to tabled value for metal framing.
- Set exterior color to "medium" and turn mass off by setting to "none."

FLOORS
- Configuration, orientation, and areas are the same as the proposed building design.
- For R-values, see: TABLE NO. 1-I. These value apply to exposed floor areas only, NOT to slabs on grade.
- For slabs, set insulation to "none." Turn mass off in floor.
Set exterior color to "medium" and turn mass off by setting to "none"

DOORS
There are no R-value or area requirements for doors. Treat them the same in the reference building as in your design.

MASS
The code does not account for mass in the prescriptive requirements. Eliminate all mass takeoffs from the code reference building, that is, anything taken off in the mass icon, either in plan or in elevation.

PEOPLE and EQUIPMENT
Since these are not architectural design variables, use the same takeoffs and specs as you did for your design.

VENTILATION and INFILTRATION
Mechanical ventilation is not required for spaces with natural ventilation. The code allows for "demand controlled" ventilation during occupied hours. This fits well with the ES method of calculating energy from ventilation. Model the code reference building in the same way as your design.

LIGHTING
Title XXIV sets maximum Lighting Power Densities (LPD) by building or space occupancy type:

<table>
<thead>
<tr>
<th>Occupancy Type</th>
<th>Lighting Power Density (Watts / ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools, average of all spaces</td>
<td>1.8</td>
</tr>
<tr>
<td>Classrooms</td>
<td>2.0</td>
</tr>
<tr>
<td>Corridors, restrooms, support spaces</td>
<td>0.8</td>
</tr>
<tr>
<td>Offices</td>
<td>1.6</td>
</tr>
</tbody>
</table>

To spec lights in ES using these rates, you must use the "Detailed Lighting Design" method from the window spec. Energy Scheming requires two inputs for each lighting type:
- The Efficiency (E) of the lighting system in Btu per hour per square foot per footcandle (Btuh/h, ft², fc)
- The Illumination level (I) required in the space, in footcandles (fc)

To spec lighting in ES that meets these LPD requirements ES, do the following:
1. Convert the units: LPD (W/ft²) ÷ 0.2928 (Btuh/W) = E (I)
2. Divide EI by the required Illumination in fc to get the maximum E allowed.
3. Input the value for E in the Detailed Lighting Design Spec.

The Lighting Types table from ES 3.0 is included here for reference.
Example:

- Classroom LPD, from the above table is 2.0 W/sf maximum

- Since LPD (W/ft²) ÷ 0.2928 (Btuh/W) = EI, 
  2.0 ÷ 0.2928 = EI = 6.83

- 6.83 ÷ 30 fc = 0.228 Btuh/h, ft², fc

- From the above schedule of lighting types, it is clear that incandescent, halogen and general diffuse fluorescent lighting will not meet the code. For the code reference building, input a value of 0.228 as the least efficient system allowed.

Accounting for Daylight Controls

Energy Scheming assumes continuous dimming using daylight sensors and variable lighting controls. When there is enough daylight to meet the required illumination level (fc), no lights are used. When daylight is insufficient (or when it is blocked by opaque shades), electric light is used during occupied hours to make up the difference. Since Title XXIV does not require automatic daylight sensitive controls, you can add the full value of the electric lighting load back to the graphic reports of your code reference building, thus making your design look outstanding! To do this:

- Set your occupancy schedule for the code building to include some night time hours. Run the ES calculation.
- Copy the graphic report to Photoshop.
- Cut out an hourly bar for electric lights during a night hour (all lights on).
- Reset your occupancy schedule to the correct times. Recalculate your graph.
- Copy the graphic report to a new Photoshop file. Cut and paste the electric lighting bar into the new graph for each hour of occupancy.
- You can do the same for the net flow with a little creative Photoshop work.

Obviously, this should be the LAST thing that you do.
E. EVALUATING: energy codes as indicators

3. Model Your Reference Case Building
Using the prescriptive values for your building type and climate, model your building in *Energy Scheming*.

*shanley example.*

Use the same geometry and takeoffs as you do for the actual building design. You may begin with either case first. After finishing your first case, make a copy of the file to use as the beginning point for your comparative case.

When modeling your reference case building:

- Keep the floor, wall, and roof area takeoffs the same as in your design.
- Change R-values in the floor, wall, and roof specifications to match the prescriptive standards. Use the detailed specs to input exact R-values from the prescriptive standards.
- Do not specify stack ventilation.
- Do not specify any shading other than that specifically allowed in the prescriptive standards.
- For Residential Buildings, do not specify cross ventilation.
- For Commercial Buildings, limit operable cross ventilation openings (inlets plus outlets) to 4% of floor area.
- Do not add additional thermal mass or south facing glass.

Keep internal temperature settings the same.

Jump to the next section: Compare the Performance of the Two Designs
4. Compare the Performance of the Two Designs

After changing settings and takeoffs for the reference building, calculate the energy performance. Compare the following graphs:

- net flow graphs for the Code Reference
- net flow graphs for your Initial Run Building (as is with no design changes)
- net flow graphs for your Final Run Building (after all design changes to improve performance)

For each set of graphs, estimate the following factors and compare for the three runs:

<table>
<thead>
<tr>
<th>Month</th>
<th>Peak Load</th>
<th>Total Net Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>the lowest hourly loss in winter</td>
<td>sum of all hourly net losses for winter day</td>
</tr>
<tr>
<td>Summer</td>
<td>the highest hourly gain in summer</td>
<td>sum of all hourly net gains for summer day</td>
</tr>
</tbody>
</table>

To find the sum of hourly loads for a daily graph, printout the "Annual Summary" part of the "Energy Report". Choose ONLY the "Annual Summary". If you don't then you will get more information than you want, about 75 pages.
Compare the peak loads for your initial and final runs to the Code Reference Building.

- **Compare the Peak Loads for each season**
  What percentage improvement (% load reduction) do your Initial and Final Run show, relative to the Code Reference Building?
  To find out:
  
  \[ 100 \cdot \left( \frac{\text{Run Z Peak}}{\text{Reference Bldg. Peak}} \times 100\% \right) \]

- **Compare the Total Net Loads for each season**
  What percentage improvement (% load reduction) do your Initial and Final Run show, relative to the Code Reference Building?
  To find out:
  
  \[ 100 \cdot \left( \frac{\text{Run Z Total Daily Net}}{\text{Reference Bldg. Total Daily Net}} \times 100\% \right) \]

**Evaluate how your final design performed relative to your Energy Use Goal**
Did your initial run pass code? Did you meet your target of reducing code minimum performance by the percentage of your goal? If not, what changes could you make to improve performance further?
EXAMPLE PROJECT
shanley dental building, clayton, mo

Worked Example
Re-Cycling with *Energy Scheming* exercise
EXAMPLE PROJECT: example exercise

outline of example problem pages

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

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

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

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

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
When upgrading an older existing building with poor insulation, such as the Shanley Building, bringing the building up to the standard of the Model Energy Code can be a challenge in itself. However, the MEC sets a standard that can basically be met by addressing conservation to reduce loads.

It does not require passive approaches to reducing the remaining loads. But since using *Energy Scheming* helps us to make buildings that "sail" on available site-based energy forces, we will go beyond the MEC. Ideally, we would like to make a building with zero heating and cooling loads, but being constrained by our existing site, with less than optimum orientation and building massing (the short south side), our goal for the Shanley Building re-design will be to improve the the building as much as possible while keeping the original design intentions of the architect. We choose a modest goal of 50% less than MEC.
E. EVALUATING: comparing with energy codes

2. Choose Reference Criteria

To compare our redesign to the building required by code, we established the MEC criteria by beginning with the original building as designed, and then upgrading its elements, while holding fixed such existing conditions as the shading design and building form. Our climate zone for St. Louis City and County is Zone 10b for commercial buildings. The following criteria are based on the prescriptions for zone 10b (see table below).

1. The Shanley building has 761 sq. ft. of windows and 2732 sq. ft. of wall area. So, that puts the building in the “High Fenestration Area” (25-40% of wall area). Our total “window wall- ratio” for the entire building is 27% (716 / 2732 = 0.27).

2. The walls are masonry with no framing. From the table for the combination of masonry walls and high fenestration with no framing, we select the Minimum R value = 5.

Window U-value requirement is based on the WWR, while the Solar Heat Gain Coefficients (SHGC) requirements are based on the shading of the window as measured by a simple projection ratio, with lower SHGC required for poorer shading. There are several conditions for shading of windows in the original Shanley building. We selected U-values and SHGC’s for each window, depending on its conditions.

The section illustrates the calculation of two projection ratios for the south facade.

- The main floor is shaded by a large overhang with proportions: 2.5 / 12 = 0.20. Therefore, from table below,
  - Max SHGC = 0.4
  - Max U-value = 0.5. Taking the reciprocal, the minimum R-value = 2. Use the R-value to input to ES.

- The lower windows are shaded by a balcony with proportions: 10 / 3.5 = 2.8. Therefore, from table below,
  - Max SHGC = 0.6
  - Max U-value = 0.5. Taking the reciprocal, the minimum R-value = 2. Use the R-value to input to ES.

3. This is a office window on the east side

- The office windows have projection = 2.5 / 4.
  - Max SHGC = 0.6
  - Max U-value = 0.5, so min. R-value = 2
This is the bathroom window on the north side

- Windows that are glass block have no projection
  - Max SHGC = 0.4
  - Max U-value = 0.5, so min. R-value = 2

4. There are no sky lights.

5. The roof system is all-wood joists with insulation in the roof cavity, so use R-25 min.

6. The floor system is all-wood joists with insulation in the floor cavity, so use R-19 min.

7. No insulation is required for the slab.
### COMcheck-EZ™ Prescriptive Packages

#### Envelope Component

<table>
<thead>
<tr>
<th>Walls (a)</th>
<th>Framing</th>
<th>Minimum R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMU, 8&quot; or greater with Integral Insulation (b)</td>
<td>Minimum R-value</td>
<td></td>
</tr>
<tr>
<td>All Other Masonry Walls</td>
<td>Minimum R-value</td>
<td></td>
</tr>
</tbody>
</table>

#### High Fenestration Area (25%-40% Window-Wall Ratio)

<table>
<thead>
<tr>
<th>No Framing</th>
<th>Metal Framing 25%</th>
<th>Wood Framing 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

#### Windows

<table>
<thead>
<tr>
<th>Maximum Solar Heat Gain Coefficient</th>
<th>Maximum U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

#### Skylight (Limit 3% of Roof Area)

<table>
<thead>
<tr>
<th>Maximum U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
</tr>
</tbody>
</table>

#### Roof

<table>
<thead>
<tr>
<th>Continuous Insulation</th>
<th>Roof Cavity Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-Wood Joist/Truss</td>
<td>19</td>
</tr>
<tr>
<td>Nonwood Joist/Truss</td>
<td>20</td>
</tr>
<tr>
<td>Concrete Slab or Deck</td>
<td>19</td>
</tr>
<tr>
<td>Metal Purlin with Thermal Break</td>
<td>20</td>
</tr>
<tr>
<td>Metal Purlin without Thermal Break</td>
<td>20</td>
</tr>
</tbody>
</table>

#### Floor

<table>
<thead>
<tr>
<th>Continuous Insulation</th>
<th>Floor Cavity Insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-Wood Joist/Truss</td>
<td>12</td>
</tr>
<tr>
<td>Nonwood Joist/Truss</td>
<td>13</td>
</tr>
<tr>
<td>Concrete Slab or Deck</td>
<td>13</td>
</tr>
</tbody>
</table>

#### Slab Edge or Basement Walls

<table>
<thead>
<tr>
<th>Minimum R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

### Notes:

- For walls next to unconditioned spaces, use the Low Fenestration Area wall requirements.
- Integral insulation in concrete masonry units may be perlite, vermiculite, or other insulating material.

- "NA" indicates the category is not applicable.
- A minimum R-value of zero indicates no insulation is required.
- "Any" indicates any available product will comply.
- "X" indicates no complying option exists in the prescriptive packages.

Note: this is an excerpt from the full table for Zone 10b, showing only the values for high WWR.

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Jump to the next EXAMPLE section: 3. Model Your Reference Case Building
EVALUATING: comparing with energy codes

3. Model Your Reference Case Building

Methods
To set your buildings specifications for the MEC, you should work from an ES file that has the elements already defined. Then, go into the detailed specification windows and change the settings to match the MEC requirements.

Mass
Since MEC has no requirements for mass, you have a choice:

- Model your building with mass characteristics as originally designed, in which case ES will use mass for heat storage.
- Model the "worst building allowed by code" by turning OFF all the mass in the specs. This will generally decrease your overall performance and show a bigger difference between the code building and your design, if you have used mass in your design.

We used the first option, assuming that the basic characteristics of the original design, with its exposed mass surfaces, would be preserved while the insulation upgrades and window retrofits were carried out. So, the MEC building for our study INCLUDES the effect of all of the original mass. This means that we are assuming that wall insulation is added to the outside of the masonry and the building is re-stuccoed. If insulation were added to the inside, we would turn the mass off, since it would no longer be thermally coupled to the interior air.

Natural Ventilation.
Remember to reduce the operable window areas to the minimum. The codes typically require that a free opening of at least 4% of the floor area be available for natural ventilation. Make sure that you define 4% of your windows as operable cross ventilation openings. This will allow you to compare the code minimum against your actual design, which in some cases may have more than 4%.

1. Windows.
   In the Detail Window Specs, we changed all the windows to an R-value of 2 and a SHGC of either 0.6 or 0.4, depending on their shading projection.
2. **Walls.**
   In the Detail Wall Specs, we changed all the walls to have an R-value of 5, keeping their previously defined masonry characteristics.
3. In the Detail Floor Specs, we changed all the floors to have an R-value of 19.

4. Floors
   In the Detail Roof Specs, we change all the Roofs to have an R-value of 25 (note: change the loss and gain R-values to the same R-value)
### 4. Compare the Performance of the Two Designs

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Roof Type 2</td>
</tr>
<tr>
<td>Total R-Value (gain)</td>
<td>25.00°F, h, sf/Btu</td>
</tr>
<tr>
<td>Total R-Value (loss)</td>
<td>25.00°F, h, sf/Btu</td>
</tr>
<tr>
<td>Lag in Hours</td>
<td>2</td>
</tr>
<tr>
<td>Decrement Factor</td>
<td>0.82</td>
</tr>
<tr>
<td>Absorptivity/Conductance</td>
<td>0.15</td>
</tr>
<tr>
<td>Pitch</td>
<td>1:12</td>
</tr>
</tbody>
</table>
E. EVALUATING: comparing with energy codes

4. Compare the Performance of the Two Designs

NET FLOW PERFORMANCE REPORT

The following graphs show overlaid net flow graphs for three designs for two days, an average seasonal day and an extreme design day, in each of two seasons. The three designs shown are:

- The **Original Building** from 1936, as designed by Harris Armstrong
- The MEC **Code Building**, with minimum envelope requirements as specified by code.
- Our **Final Re-Design**

*Overlaid Net Flow Graphs for Three Versions of the Shanley Building*

Note: To see the annual Summary report that we used for the code building see *Annual Summary*
### Numeric Comparisons for Three Versions of the Shanley Building

**EVALUATION:**

Peak Loads for each season
The initial run showed large decreases in peak loads in both summer and winter, relative to the mostly uninsulated original design. Our Intermediate Re-Design was 26% better than the Code Building on a typical winter day, but only 5% better in summer. Since the building had reasonably good shading to begin with, we can assume that on hot days, when the building must remain closed, the difference between our envelope loads and those of the code building is not much. On average days, the better performance of the Intermediate building came from better ventilation.

In the Final design, a few more detail changes allowed improved ventilation and more mass storage, thus cutting the peak loads further: 60% better than code in winter and, because there is zero load all day in summer, there is no average day peak load! However, our extreme day peak loads show 52% and 33% improvements for winter and summer, respectively. This indicates that our re-design may have cut the mechanical equipment and duct sizing by about 1/2 for winter and by 1/3 for summer. The improvement is primarily due to the effects of mass in delaying and spreading peak load.

While these values are an indicator of peak load, they should not be used to size equipment, because the site forces of sun and wind may combine to create more extreme conditions. Equipment sizing is conventionally based on the maximum heat loss or gain under the design day conditions, ignoring the effects of passive strategies such as mass, ventilation, and solar heating. When taking account of these effects in sizing equipment, a more detailed assessment should be made in the design development stage, using conservative assumptions about site resources.

Compare the Total Net Loads for each season
The total net load is the sum of hourly loads for each of the 24 hours on the day modeled. The is can be determined easily from the Annual Summary portion of the Energy Performance Report in ES.

Upgrading to the MEC standards cut energy use on typical days by 56% in winter and 22% in summer. Our Intermediate design improved on this by 76% in winter and 78% in summer! Not bad. The final improvements cut the summer day to flat line balance and reduced winter days to 84% of the MEC building.

Evaluate how your final design performed relative to your Energy Use Goal
We substantially surpassed our design goal of reducing energy use to 50 below MEC requirements. Think of what one could do with a newly constructed building!

---

Return to the [EXAMPLE OUTLINE](#)
RECYCLING WITH ENERGY SCHEMING:
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   .5MB
   zipped

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C. ANALYZING: understanding energy patterns
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   zipped

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   zipped