Appendix C: Commercial, Nonprofit, and Public Buildings

Page

C.1 Setting Goals and Implementing Energy Efficiency Strategies

Shanti Pless, Lynn Billman
National Renewable Energy Laboratory

Setting Goals and Implementing Energy Efficiency Strategies

Greensburg, Kansas

US Department of Energy
Through the
National Renewable Energy Laboratory

November 13, 2007

Shanti Pless
Lynn Billman

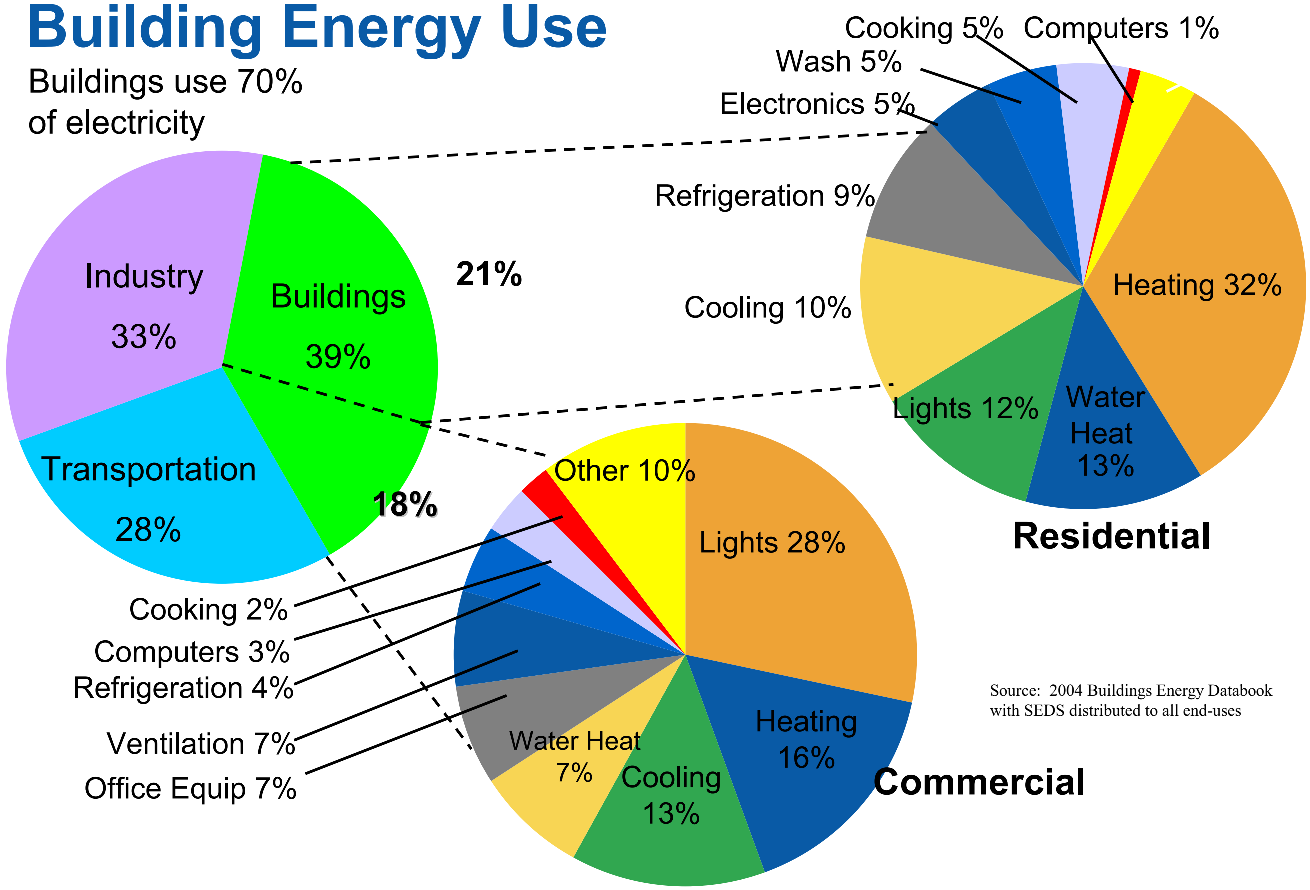
www.highperformancebuildings.gov

NREL Building Technologies Program

- Commercial Building Energy Efficiency
- Design Analysis
- Computer Simulation Tool Development
- Solar Strategies
  - Daylighting, Passive, PV, Thermal
- Whole-Building/Integrated Design
- Field Evaluation

Building Energy Use

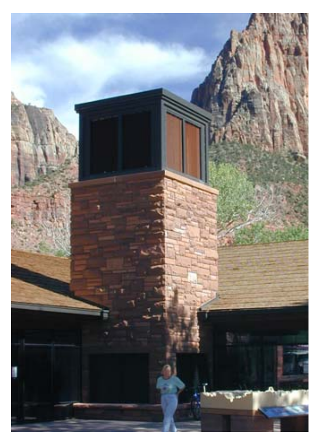
Buildings use 70% of electricity



Source: 2004 Buildings Energy Databook with SEDS distributed to all end-uses

What is a "Green" Building?

- Energy Efficiency
- Water Efficiency
- Material Efficiency
- Site Efficiency
- Enhanced Comfort and Control
- Indoor Air Quality



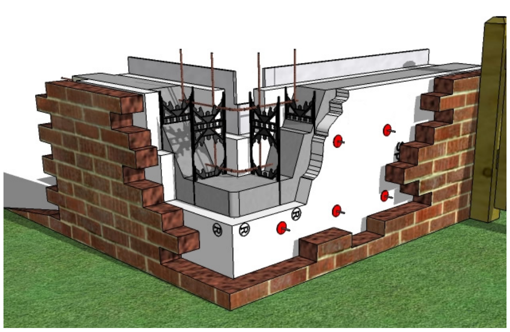
Green Building Rating

Leadership In Energy and Environmental Design (LEED)

- System to design and measure “green” buildings
- LEED Certified, Silver, Gold, Platinum
- Points in 6 categories:
  - Sustainable Sites
  - Water Efficiency
  - Energy
  - Materials
  - Indoor Environmental Quality
  - Innovative Design
- Industry Average Costs:
  - 0%-5%, 10% max

Energy Efficiency and Green

- Doing more with less
- Primary driver is owner demand
- Owner demand for reduced operating costs
- Disaster resistance
- Marketing and image value added

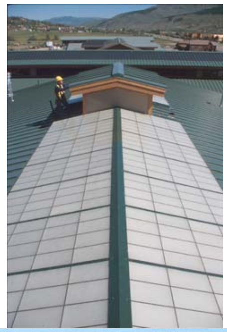


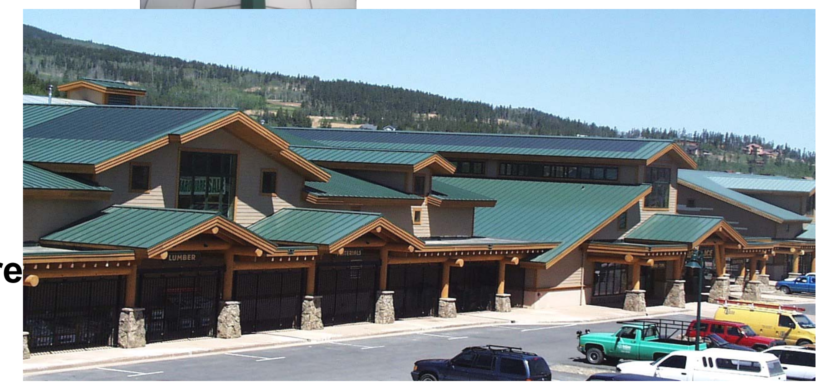
Bighorn Home Improvement Center

Silverthorne, Colorado

Energy Efficiency Features:

- Additional wall, roof, and floor insulation
- Full daylighting with clerestories
- Efficient electrical lighting system
- 9kW PV System
- Radiant floors with efficient boilers
- Natural ventilation
- 400W Wind Turbine
- **53% Energy Cost Savings**
- **Widespread Media Exposure**





National Renewable Energy Laboratory

Starting Point… Goal Setting

Measurable energy goals are better

From bad to good…

- I want a green building
- Design a LEED <rating> building
- Design a building to use 30% less energy than Code
  - Energy efficient buildings that are Code compliant are the legal minimum
- Design a building to use less than $0.50/ft²

Set measurable energy goals and have the architects and engineers strive to meet these goals

National Renewable Energy Laboratory

How to Achieve Energy Savings…

1. Daylighting (includes site selection)
2. Lighting design to match daylighting
3. Good envelope (including overhangs)
4. Plug loads
   - Design vs. owner loads
5. HVAC designed for the remaining loads
6. Commissioning (making sure the building works)
7. Metering and evaluation
8. Make it Simple

9. Renewable Generation

Design Process

Cost effective integrated design is about making decisions and trade-offs:

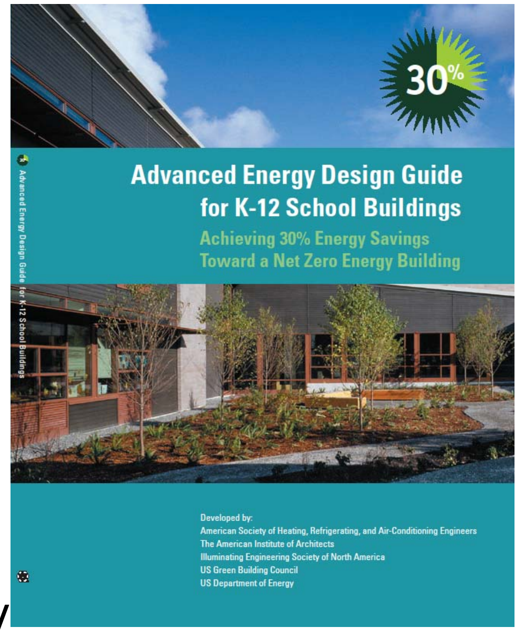
- Increase insulation
- Daylighting
- Optimize window size and placement
- Then, right size HVAC and lighting equipment

- Capital cost whole building trade-offs

Requires architects and engineers to work together from the start

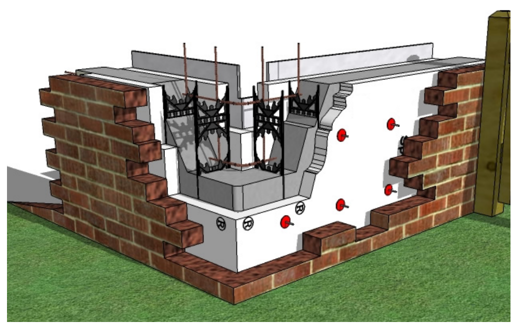
Advanced Energy Design Guides

- Developed by ASHRAE, AIA, USGBC, IESNA, and DOE
- Easy to use guidance to achieve 30% in Small Offices, Small Retail, Warehouses, and K-12 Schools
- Low- to no-cost solutions by climate zone
- 4 LEED energy points
- Pre-engineered solutions—hourly simulations done by NREL

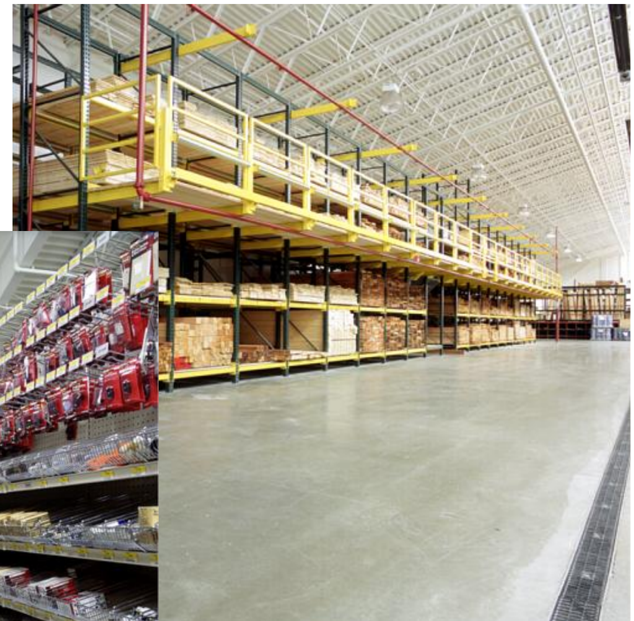


Envelope Recommendations

- **Roofs**
  - R-25 continuous insulation above deck
  - R-38 attic insulation
- **Walls**
  - R-11.4 continuous insulation mass wall
  - R-13 + R-7.5 c.i. steel or wood framed
- **Windows**
  - Overhangs on South, East, and West
  - U-0.42 (double pane, low-e)
  - SHGC-0.46 (0.75 with overhangs)
- **Interior Finishes**
  - 80% reflectance or higher on ceilings, walls above 7’
  - 70%+ reflectance on wall below 7’



Electric Lighting and Daylighting

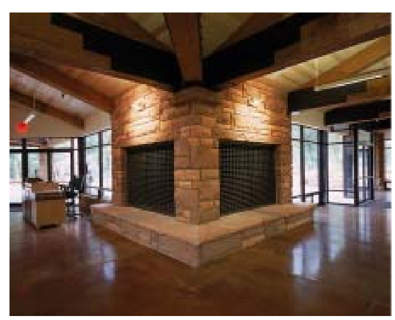


Tubular Daylighting Devices

More Daylighting…

HVAC Recommendations

- Higher efficiency air conditioners and furnaces
- Better control of outside air
- Energy recovery from exhaust air
- Economizers
- Radiant heating



NREL National Renewable Energy Laboratory

Education and Marketing

Image…

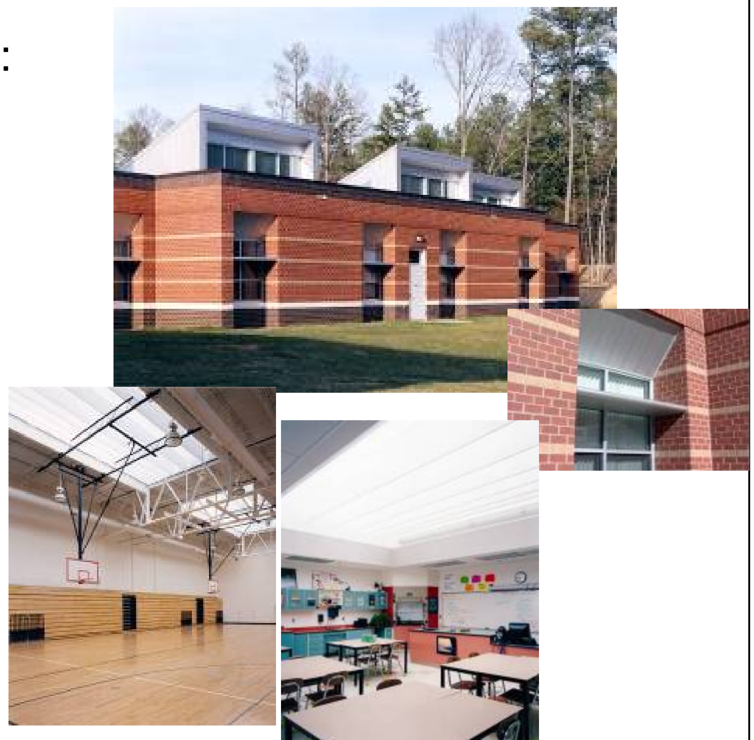
NREL National Renewable Energy Laboratory

Smith Middle School

Zone 4 – Chapel Hill, North Carolina

Energy Efficiency Features:

- 30 kBtu/sq.ft/year
- Daylighting with Roof Monitors in the Classrooms and Gym, Light Shelves on South Windows
- R-19 Wall Insulation
  R-30 Roof Insulation
- 85% Efficiency Boilers
- 2 kW PV System, Solar Domestic Hot Water System

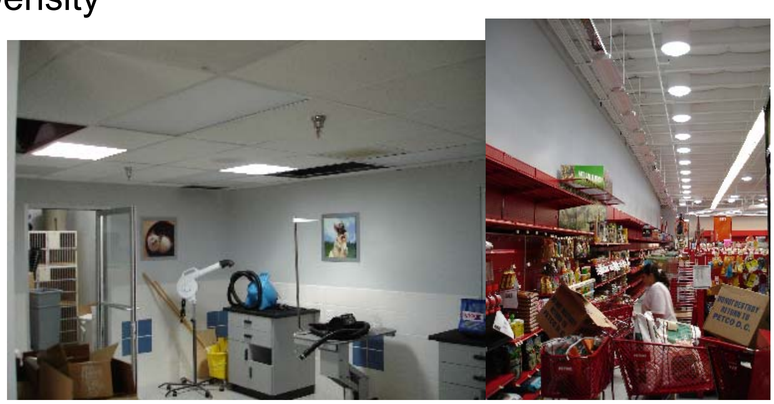


Petco Energy Showcase Store

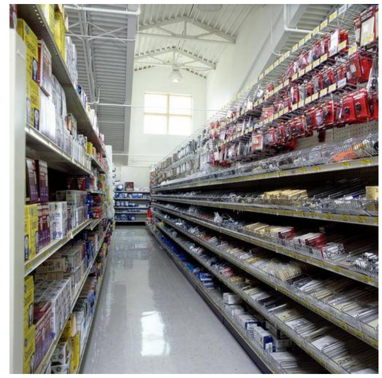
Zone 3 – Elsinore, California

Energy Efficiency Features:

- Tubular Daylighting
- Lighting Controls
- Tankless Gas Hot Water Heater
- T-8 Electrical Lighting
- 1.2 W/sqft Lighting Power Density
- OA Ventilation Control



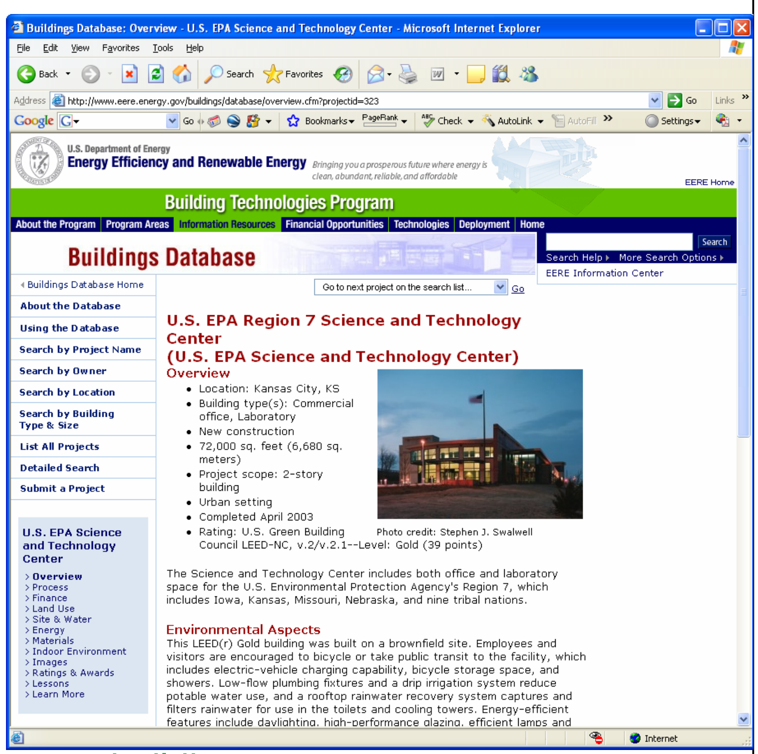
DOE Can Provide:



- Facilitating integrated design
  - Help with goal setting
  - Identifying trade offs
  - Energy modeling expertise
  - Application of Advance Energy Design Guides
- If you have designs that are very low energy
  - Data analysis from monitoring and evaluation
    - Need meters for HVAC, Lighting, and all other loads
  - Case studies (4-pagers, DOE database, and technical reports)
- Other needs?

DOE High Performance Buildings Database

- Share successes and lessons learned about projects
- Public database
- EnergyStar
- LEED



www.highperformancebuildings.gov

Final Thoughts…

•Set energy goals

•Use the architecture to reduce heating and cooling loads

•Harvest the daylighting potential

•Right-size heating and cooling systems

•Turn systems off when not in use

•Keep it Simple

•We can help with the details

Questions?

www.highperformancebuildings.gov

Creative Financing

•EPACT 2005

- 30% tax credit of total costs of solar (PV and hot water) for commercial installations
- \$1.80/ft^2 tax deduction for 50% energy savings over code for new commercial buildings

USDA Rural Development

- 25% grant for total costs of renewable in new, for-profit commercial installations
  - Wind, PV, Geothermal, Biomass
  - Also for efficiency reterofits
- 50% load for total costs of renewables in new for –profit commercial installations

C.2 Setting Goals and Implementing Energy Efficiency Strategies for the Kiowa County Memorial Hospital

Paul Torcellini, Shanti Pless, Lynn Billman
National Renewable Energy Laboratory

Setting Goals and Implementing Energy Efficiency Strategies for the Kiowa County Memorial Hospital

US Department of Energy
Through the
National Renewable Energy Laboratory
October 31, 2007

Paul Torcellini, Ph.D., PE
Shanti Pless
Lynn Billman

NREL is a national lab for the US Department of Energy with a single mission to develop renewable and energy efficiency technologies.

Commercial Buildings Team

- Develop energy simulations
- Optimize building designs through simulation application
- Develop standardized metrics and implementation of these metrics
- Evaluate energy performance of buildings

Starting Point… Goal Setting

Measurable goals are better

From bad to good…

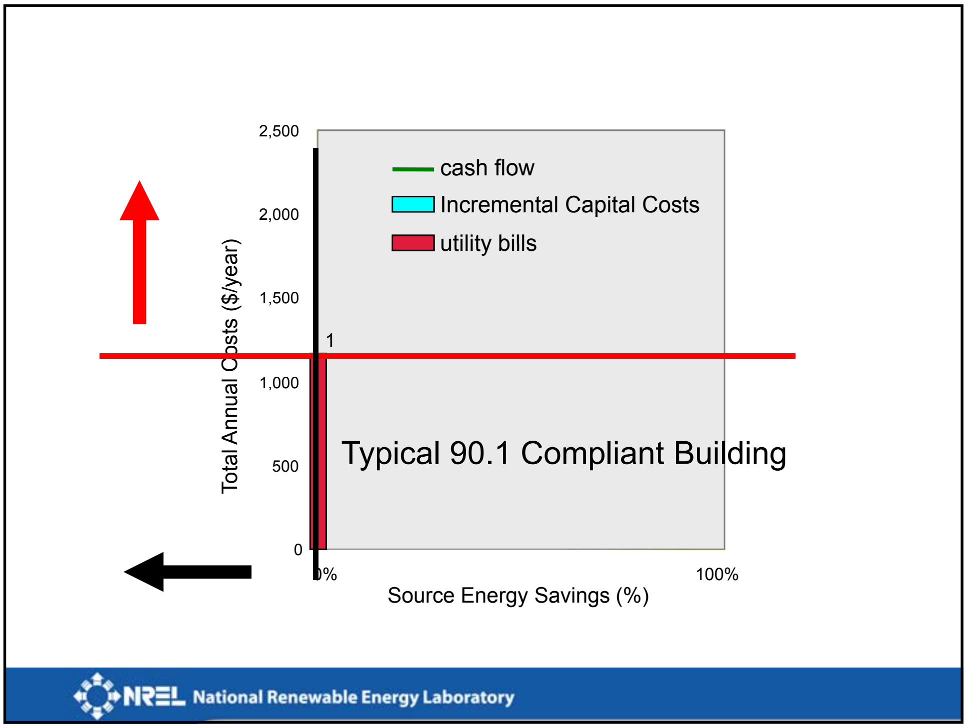
- I want a green building
- Design a LEED <rating> building
- Design a building to use 30% less energy than ASHRAE 90.1-2004
- Design a building to use less than 30,000 BTU/sqft

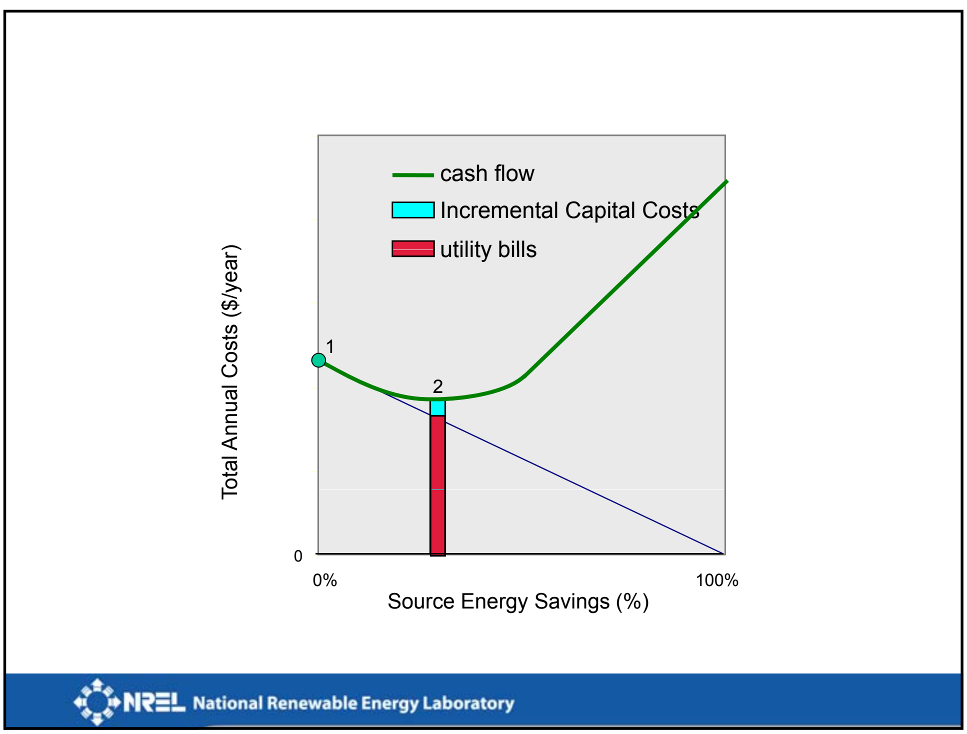
Design Process

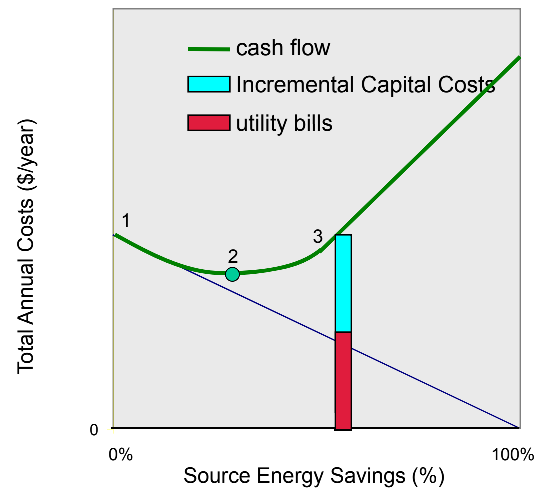
Design is about making decisions and trade-offs

- More insulation, daylighting, or ERVs – smaller HVAC?
- Capital cost whole building trade-offs

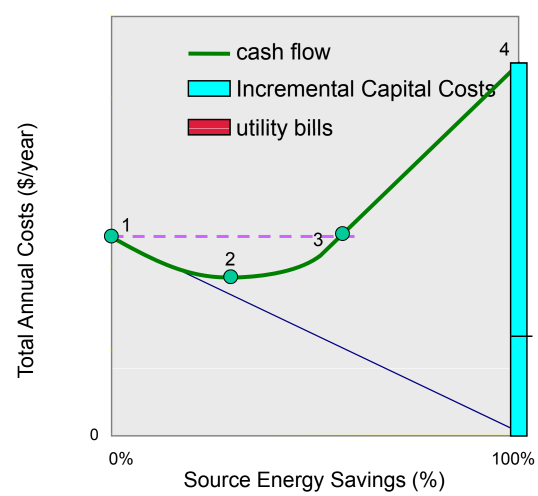
Integrated Design should not cost more


2,500
2,000
1,500
1,000
500
0
Total Annual Costs ($/year)
cash flow
Incremental Capital Costs
utility bills
1
Typical 90.1 Compliant Building
0%
100%
Source Energy Savings (%)
NREL National Renewable Energy Laboratory


Total Annual Costs ($/year)
cash flow
Incremental Capital Costs
utility bills
1
2
0
0%
100%
Source Energy Savings (%)
NREL National Renewable Energy Laboratory

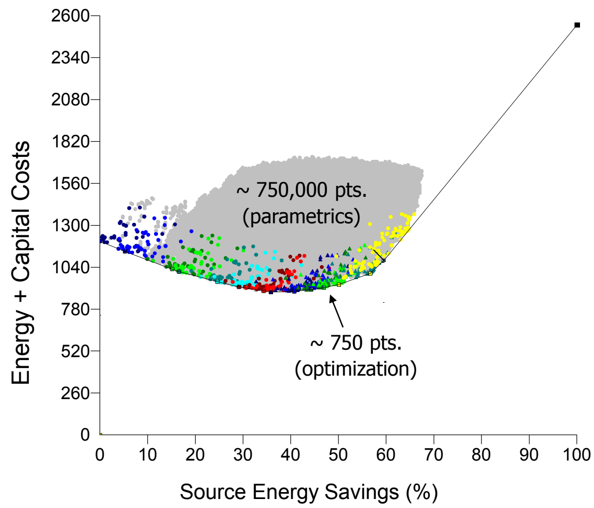


National Renewable Energy Laboratory



National Renewable Energy Laboratory

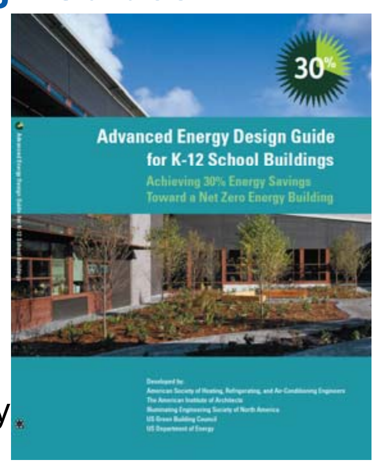
Parametrics / Optimization



National Renewable Energy Laboratory

Advanced Energy Design Guides

- Developed by ASHRAE, AIA, USGBC, IESNA, and DOE
- Easy to use guidance to achieve 30% in Small Offices, Small Retail, and K-12 Schools
- Solutions by climate zone
- 4 LEED energy points
- Pre-engineered solutions—hourly simulations done by NREL



National Renewable Energy Laboratory

How to Achieve Energy Savings…

1. Daylighting (includes site selection)
2. Lighting design to match daylighting
   - Occupancy sensors
3. Good envelope (including overhangs)
4. Plug loads
   - Design vs. owner loads
5. HVAC designed for the remaining loads
   - Energy recovery
6. Commissioning (making sure the building works)
7. Metering and evaluation
8. Make it Simple
9. Renewable Generation

NREL National Renewable Energy Laboratory

Envelope Recommendations for Small Office

- Roofs
  - R-20 continuous insulation above deck
  - R-38 attic insulation
- Walls
  - R-11.4 continuous insulation mass wall
  - R-13 + R-7.5 c.i. steel or wood framed
- Windows
  - Overhangs on South, East, and West
  - U-0.42 (double pane, low-e)
  - SHGC-0.46 (0.75 with overhangs)
- Interior Finishes
  - 80% reflectance or higher on ceilings, walls above 7’
  - 70%+ reflectance on wall below 7’

NREL National Renewable Energy Laboratory

Way Station Headquarters

Frederick, MD

- •30,000 ft^2 Mental Health Facility
- •R-25 roof insulation, R-15 wall insulation
- •Daylighting with roof monitors and light shelves on south facing windows
- •Greenhouse for passive solar heating
- •Double pane, low-e windows
- •High efficiency boilers
- •Ice storage
- •Details in the DOE High Performance Buildings Database

SMDC Health System

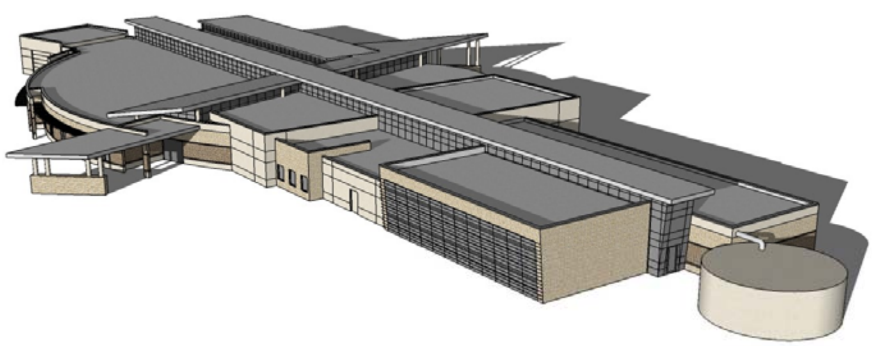
Duluth, Minnesota

- •LEED Gold Certified
- •22% energy savings
- •236,000 ft^2
- •Daylighting in central atrium and outlying clinics
- •Dimming controls and occupancy sensors
- • R-30 roof, R-26 walls
- •Water cooled chiller with VFDs
- •83% efficient steam boilers
- •Heat recovery from exhaust air
- •Permanent commissioning program
- •More info in July ’07 Eco-Structure

Greensburg Concept

NREL National Renewable Energy Laboratory

Greensburg Concept



NREL National Renewable Energy Laboratory

NREL Can Provide:

- Help with goal setting
- Energy modeling expertise
- Application of Advance Energy Design Guides
  - Development of Hospital AEDG

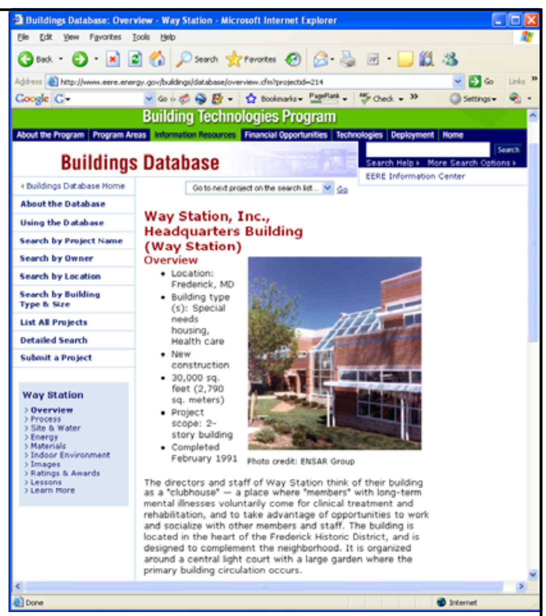
- If you have designs that are very low energy
  - Data analysis from monitoring and evaluation
    - Need meters for HVAC, Lighting, and all other loads
  - Case studies (4-pagers, DOE database, and technical reports)

- Other needs?

NREL National Renewable Energy Laboratory

Additional Resources

- Share successes and lessons learned about projects
- Public database
- Green Guide for Health Care
  - http://www.gghc.org/



www.highperformancebuildings.gov

NREL National Renewable Energy Laboratory

C.3 Applying a Whole-Building Design Process for New Commercial Buildings in Greensburg

Shanti Pless
National Renewable Energy Laboratory

The following best practices should be applied to future low-energy Greensburg commercial buildings:

- Use a whole-building design process to design, construct, and operate future low-energy buildings. This includes:
  - Set a specific, quantifiable energy design goal that is used to guide the design process and can be verified during operation.
  - Include everyone involved in the project at the earliest stages of the design process.
  - Use whole building simulation tools to determine the energy performance of the building at all stages of design, construction, and occupancy. The whole-building design process is a simulation-based, quantitative, and qualitative method to help architects and engineers create low-energy buildings. Low-energy design is not intuitive. The energy use and energy cost of a building depend on the complex interaction of many parameters and variables. The problem is far too complex for "rules of thumb" or hand calculations. The interactions are best studied with computerized energy simulation software to thoroughly evaluate all interactions between the building envelope, HVAC system, and design features.
  - Design the building envelope such that it can be used to meet as many of the loads as possible. The envelope should be the first method of creating low-energy buildings; the mechanical and lighting systems should then be sized to meet any remaining loads. Low-energy architecture is not effective if mechanical systems have to solve problems from the architectural design.
  - Update the design simulations from predesign through occupancy to ensure the design simulations will measure up to actual performance.

In the traditional building design process, the architectural team works with the owner to create a building program that specifies the needs for the building and parameters that should be considered in the design. The architect designs the building to satisfy the program requirements, and then the project engineers design the electrical and mechanical systems and evaluate compliance with energy codes and acceptable levels of environmental comfort. However, because many important architectural decisions are set at this point, few changes can be made that would improve energy performance. Typically, no energy performance goals are established. The architect and engineers may try to design efficient systems, but they have little interaction or goals to direct the design, so the results are usually mediocre.

In contrast to the traditional building process, the whole-building design process requires the team—the architect, engineers (lighting, electrical, and mechanical), energy and other consultants, and the building's owner and occupants—to work together to set and understand the energy performance goals. The purpose of whole-building design approach is to enable the full design team to interact throughout the design process to fully understand the building systems interdependences. The full design team focuses from the outset on energy and energy cost savings. The process relies heavily on energy simulation, includes design charrettes involving all members of the design team, and establishes energy goals early in the process. The whole-building design process begins with predesign, where often little more than the building size, type, location, and use are known. To be effective, the process must continue through design, construction, and commissioning (Deru 2004).

The best time to develop performance targets is at the beginning, before any design concepts have been developed. Once everyone has committed to an energy-saving goal, the process can be used to guide the team toward good decision-making and trade-off analysis without sacrificing programmatic requirements. Team members must commit to an energy goal early in the process so that they thoroughly understand the interdependencies of the architecture and systems and can create more efficient and cost-effective buildings. To realize low-energy buildings, the project team must not only set a low-energy performance goal, but must *commit* to it. Each member is encouraged to find solutions and offer suggestions that benefit other disciplines, the process, and ultimately the building design.

Whole-building energy simulations guided the designs of some of the buildings in Greensburg. Some used ASHRAE's Advanced Energy Design Guides (http://www.ashrae.org/technology/page/938), which provides prescriptive recommendations for a given level of energy savings. Energy simulation in pre-design helped to set quantified goals, and identified areas with high potential for energy savings and peak reductions. In addition, energy simulations are a crucial tool for understanding the impact of design decisions on energy performance. Experience has shown that the chances of energy analysis affecting the design of a building decrease rapidly as the design proceeds.

- Some of the most important concepts to remember when using energy modeling as part of an integrated building design are as follows:
    - A whole-building design approach is a good way to lower energy use and cost. An integrated whole-building approach begins with a design team that is committed to the energy goals. The building must be engineered as a system if the technologies are to be integrated in design and operation. The integrated design process starts with predesign and is applied through construction and operation, ensuring that the building is built to plan. Whole-building energy simulation, or energy modeling, is a great help in setting goals, informing the design process, and evaluating the energy impacts of design and construction decisions.
    - Owners provide the main motivation for low-energy buildings. The owner is the driving force in many cases. The owner, along with the design teams, sets the goals and makes decisions to keep the project on track. The architects and engineers strive to meet the goals of the building owners, which result in a whole-building design process.
    - Setting measurable energy saving goals at the onset of the project is crucial to realizing low-energy buildings. In many cases, the owners and design teams set

aggressive energy saving goals at the outset. The goals ranged from 30% better than code to obtaining a high LEED score. Design teams are motivated to achieve when they set the goals. Setting such goals enables owners to make decisions that align with the goals. In general, the teams that set the strongest energy performance goals and used energy simulation to understand the energy impacts of design decisions had the best energy performance. Past projects have shown that defining specific, measurable energy saving goals early in the design process helps the design team achieve better results.

- Use the envelope as the first method of creating low-energy buildings. Engineer the envelope to reduce loads with features such as increased insulation, window tuning, and self-shading, and at the same time integrate passive solar heating, cooling, daylighting, and natural ventilation technologies. A better envelope and favorable building orientation are typically the most cost effective energy efficiency measures. Energy modeling is necessary to understand how to best do this. Then size HVAC equipment to meet the remaining loads. Use the mechanical system to make up for what cannot be accomplished by architectural form and envelope, not to correct for an architectural design that is climatically ill conceived.

  In general, the envelope should be designed to both reduce the loads, and meet as many needs as possible. Building siting and envelope should be the first method of creating a low-energy building. Low-energy architecture is not achievable if mechanical systems have to solve problems from inadequate envelopes or ill conceived siting.

  The best way to reduce the cost of low-energy features and ensure successful integration is to incorporate them into the architecture early. If low-energy features such as good orientation, daylighting, clerestories, or cooltowers can be integrated into the architectural design and statement, they can be included as part of the architecture costs.

The “green” building industry has generally recognized the value of whole-building design. The *Whole Building Design Guide* (NIBS 2008) offers up-to-date tools, design guidance, and technologies related to applying the whole-building design process. Further details of the whole building design process are outlined in Table 1 (Torcellini, et al. 2006).

Table 1. Ten-Step Process for Designing and Constructing Low-Energy Buildings

Predesign	1. Set specific and measurable energy performance goals, which may include percent energy savings, percent energy cost savings, and emission reductions. The entire team must understand these goals and how they are affected by design features. Also at this stage, the design team should develop a thorough understanding of the building site, local weather patterns, and building functional requirements. At this point, the design team should brainstorm energy solutions, especially those that affect the architecture. Each building is unique and will have a different minimization strategy. Energy simulation at this stage helps to set quantified goals, and identifies areas with high potential for energy savings and peak reductions. 2. Create a base-case building model to quantify base-case energy use and costs. The base-case building is solar neutral (equal glazing areas on all wall orientations) with equivalent floor area and meets the requirements of applicable energy efficiency codes such as ASHRAE Standard 90.1 (ASHRAE 2004). When building designs and operations change, the baseline has to evolve along with the building under consideration. 3. Complete a parametric analysis of the base-case model to determine sensitivities to specific load components. Sequentially eliminate loads such as conductive losses, lighting loads, solar gains, and plug loads from the base-case building. 4. Develop preliminary design solutions. The design team brainstorms possible solutions, which may include strategies to reduce lighting and cooling loads by incorporating daylighting or to meet heating loads with passive solar heating.
Schematic Design	5. Incorporate preliminary design solutions into a computer model of the proposed building design. The energy impact and cost effectiveness of each variant are determined by comparing the calculated energy performance with the original base-case building and to the other variants. Variants with the most favorable results should be incorporated into the building design. 6. Prepare a preliminary set of construction drawings. These drawings are based on the decisions made in Step 4. Architectural decisions made during the schematic design phase can have the greatest impact on the long-term building energy performance.
Design Development	7. Identify the HVAC system that will meet the predicted loads. The HVAC system should complement the building architecture and exploit the specific climatic characteristics of the site for maximum efficiency. Often, the HVAC system capacity is much less than in a typical building. Verify that baseline and design simulations are updated with design changes.
Construction Documents and Bid	8. Finalize plans and specifications. Ensure that the building plans are properly detailed and that the specifications are accurate. The final design simulation should incorporate all cost-effective features. Savings that exceed 50% from a base-case building are frequently possible with this approach.
Construction	9. Rerun simulations before changes are made to the design during construction. Verify that changes will not adversely affect the building's energy performance.
Postoccupancy Evaluation	10. Commission all equipment and controls. Educate building operators. Only a properly operated building will meet the original energy efficiency design goals. Building operators must understand how to properly operate the building to maximize its performance. Measure and evaluate actual energy performance to verify design goals were met.

In addition, the U.S. Green Building Council has established rating systems and provided extensive information on high-performance commercial buildings on their website (http://www.usgbc.org).

Deru, M.; Torcellini, P. (2004). *Improving Sustainability of Buildings Through a Performance-Based Design Approach: Preprint*. NREL Report No. CP-550-36276. World Renewable Energy Congress VIII, Denver, CO, August 29 - September 3, 2004. Golden, CO: National Renewable Energy Laboratory, 8 pp. www.nrel.gov/docs/fy04osti/36276.pdf (PDF 381 KB)

NIBS. (2008). *Whole Building Design Guide.* National Institute of Building Sciences. http://www.wbdg.org/wbdg_approach.php Last accessed March 2008.

Torcellini, P.; Pless, S.; Deru, M.; Griffith, B.; Long, N.; Judkoff, R. (2006). *Lessons Learned from Case Studies of Six High-Performance Buildings*. NREL Report No. TP-550-37542. Golden, CO: National Renewable Energy Laboratory, June 2006. 151 pp. www.nrel.gov/docs/fy06osti/37542.pdf (PDF 3.9 MB)

C.4 Recommendation: Greensburg, Kansas, Should Adopt the Best Green Municipal Building Requirement in the United States

Shanti Pless
National Renewable Energy Laboratory

Requirement: All new, occupied city buildings, of any size, shall be designed, contracted, and built via a "green building" approach to achieve certification in the Leadership in Energy and Environmental Design (LEED®) Program at the Platinum certification level – the highest benchmark awarded by the U.S. Green Building Council.

"Green building" is a whole-systems approach utilizing design and building techniques to minimize environmental impact and reduce the energy consumption and utility costs of a building while contributing to the health of its occupants and building durability. This requirement includes:

- Fifty percent energy cost savings compared to a typical building built to code
- A healthy indoor environment
- Fifty percent reduction in water use compared to a typical building
- Use of renewable energy generation wherever appropriate
- Use of locally available and recycled materials while minimizing construction waste
- Reducing the overall environmental impact from the site

C.4.1 What are the Benefits of Green Building and LEED Certification to City Leadership?

By adopting this approach the city will:

- Reduce utility costs
- Substantially reduce negative environmental impacts
- Enhance building value and marketability
- Increase occupant comfort and worker productivity
- Set the example for other public buildings, businesses, and homeowners in Greensburg
- Receive extensive media coverage potentially leading to economic growth

C.4.2 How Will Greensburg Compare to Other Cities?

- Ninety other local governments have adopted LEED certification requirements
    - None in Kansas
    - None LEED Platinum
- Greensburg will be the first city in the nation to:
    - Have *all* of its municipal buildings LEED certified
    - Have municipal buildings certified to the LEED Platinum level

C.4.3 What are the Cost Impacts?

- The best designed larger buildings have been documented to have *no* increase in cost
- Cost increases may be 3%-10% for Greensburg's smaller buildings

C.5 Recommendation: The City of Greensburg, Kansas, Should Encourage Green Commercial, Nonprofit, and Public Building Design to Align with the Community Master Plan

Shanti Pless
National Renewable Energy Laboratory

All new commercial, non-profit, and non-city-owned public buildings of any size are encouraged to be designed, contracted, and built via a "green building" approach to achieve at least 30% energy efficiency compared to current building code. Additional green features, as outlined in the Leadership in Energy and Environmental Design (LEED®) Program, should be incorporated to achieve the Silver certification level or higher.

The City of Greensburg has set an aggressive goal of LEED Platinum and 42% energy savings for all city-owned buildings. The purpose of setting this aggressive goal was to provide leadership and to foster a future sustainable business environment. In line with the master plan, we recommend that the city encourage all commercial and non-city public buildings to build "green".

"Green building" is a whole-systems approach utilizing design and building techniques to minimize environmental impact and reduce the energy consumption and utility costs of a building while contributing to the health of its occupants and building durability. This recommendation focuses on a 30% energy cost savings compared to a typical building built to code. To meet the recommended level of energy savings, follow the simple, prescriptive energy efficiency recommendations, when life cycle cost effective, available in the Advanced Energy Design Guides, available from www.ashrae.org/aedg.

In addition to energy savings, green building features include:

- A healthy indoor environment
- Thirty percent reduction in water use compared to a typical building
- Use of renewable energy generation wherever appropriate
- Use of locally available and recycled materials while minimizing construction waste
- Reducing the overall environmental impact from the site

C.5.1 What are the Benefits of Green Building and LEED Certification to the City Leadership?

By adopting this approach, commercial and public buildings will:

- Reduce utility costs
- Substantially reduce negative environmental impacts
- Enhance business marketability and image
- Increase occupant comfort and worker productivity
- Align with the city's Sustainable Comprehensive Master Plan
- Receive extensive media coverage, potentially expanding economic growth

C.5.2 What are the Cost Impacts?

- Recommend 30% energy savings and sustainable design when life cycle cost effective

C.6 Metal Building Recommendations for Greensburg, Kansas

Shanti Pless
National Renewable Energy Laboratory

Recommendations

We expect these recommendations would result in at least 30% energy savings for metal buildings in the Greensburg climate zone. These recommendations are based on those in the Small Retail Advanced Energy Design Guide, but with additional details.

Site Orientation

During site selection, preference should be given to sites that permit elongating the building in the east-west direction and that permit orienting more windows to the north and south. North and south glass can be more easily shielded and can result in less solar heat gain and less glare than do east- and west-facing glass.

Roof Insulation

We recommend that the roof assemblies are a minimum of R-25. The general concept is shown below. Additional insulation is needed between the purlins, or as continuous insulation foam board (not draped) or insulated panels on exterior of the purlins. The insulation can be sprayed in, integral to a metal panel, or standard fiberglass, as long as the assembly is R-25 or greater. The best type of insulation will depend on local costs and availability of installers and materials. See Figures 1 and 2 for different examples of metal roof insulation. The best strategy will depend on local installation and materials, as long as the total roof assembly achieves a minimum of R-25.

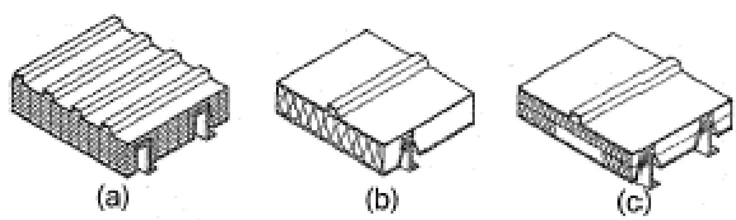


Figure 1: Pre-fabricated metal roofs showing various options for thermal blocking of purlins

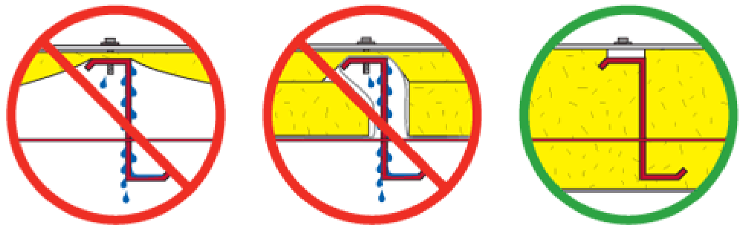


Figure 2: Recommended roof insulation mounting (from http://thermaldesign.com/systems/simplesaver/concept.html)

Various suppliers are available. Designs similar to:

- http://thermaldesign.com/systems/simplesaver/concept.html
- http://www.suspenderbar.com/index.html
- http://www.rhinobldg.com/steel-building-insulation.htm

Wall Insulation

We recommend that the wall assemblies are a minimum of R-19. Typical insulation systems in metal buildings are installed in a way that compresses the insulation, which decreases the R-Value. Below are various recommendations to achieve the recommended whole-wall R-19.

- Fill the purlin and girt cavities completely with uncompressed insulation. An additional thermal barrier of insulation over the purlins and/or the placement of thermal blocks greatly decreases the thermal bridging. See Figure 3.
- Use one layer of fiberglass batt insulation along with a layer of rigid continuous insulation (c.i.). The fiberglass layer is installed continuously perpendicular to the exterior of the girts. The rigid c.i. insulation is installed on the inside of the fiberglass layer. The fiberglass layer is compressed as the metal skin is attached to the girts.
- Spray foam insulation is another possible method for obtaining the recommended R-value.
- Use exterior metal wall panels with integral insulation to obtain the recommended R-value.

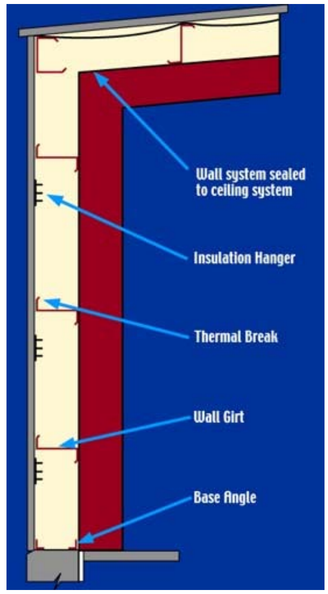


Figure 3: Cross section of typical metal wall
red layer is the structural beams, yellow layer is the insulation

Windows and Daylighting from the Walls

A good design strategy minimizes glass that does not contribute to the daylighting of the space. If possible, configure the building to maximize north and south-facing walls and glass by elongating the floor plan. Since sun control devices are less effective on the east and west façades, the solar penetration through the east- and west-facing glazing can cause a problem with glare and is usually shaded in the retail environment. This can be done by reducing the area of glazing, reducing the Solar Heat Gain Coefficient, and using diffusing panels or films.

- Avoid placing windows below 3 feet. Low windows do not contribute to daylighting.
- Place daylighting glass as high as possible on the exterior walls, with 12in. – 18in. strip of glass dedicated to daylighting.
- Minimize eastern and western exposures.
- For daylighting, wall areas should be made up of 20% to 40% windows.
- Windows should have a thermal transmittance of U-0.42 or lower.
- Windows should have a solar heat gain coefficient of approximately 0.46 for all window orientations.
- Overhangs with a projection factor of 0.5 should be used on south facing windows (see Figure 4).

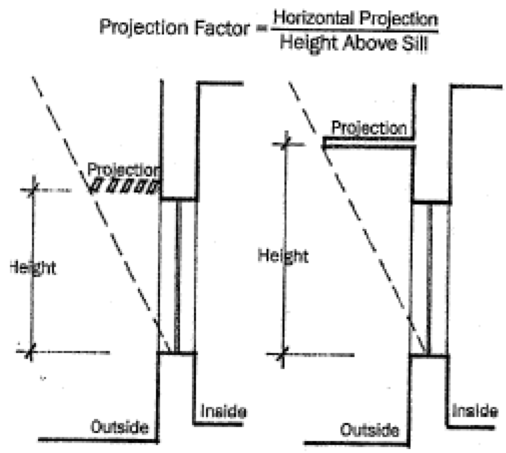


Figure 4: Overhang Projection Factor

Daylighting from the Roof

- Place top lighting with clerestories, roof monitors, diffusing panels, or tubular daylighting devices in all zones without side daylighting.
- Clerestories, diffusing panels, and roof monitors should make up not more than 10% of the roof area.
- Tubular daylighting devices should make up not more than 3% of the roof area.

Slab Insulation (Heated and Un-heated)

- Heated slabs should have full slab thickness and R-10 continuous insulation that runs underneath the heated portion of the slab. Bubble wrap is not recommended.
- Unheated slabs should have 24 in. of R-10 continuous insulation that runs along the perimeter of the slab.

Doors

- Single swinging doors should be used as much as possible.
- If double swinging doors are used, include a center post.
- Swinging doors should have a U-value of approximately 0.70.
- Non-swinging doors, such as overhead doors, should have a R-value greater than R-6. Highly insulated overhead doors are available, with an R-value of approximately R-14. An example is shown at http://www.chiohd.com/commercial/3216/. For walls that contain large overhead doors and represent a significant percentage of the gross wall area (door-to-wall area >10%), this type of insulated overhead door is recommended.

- ***Lighting Power Density***
  - Average building lighting power density: 0.9 W/ft^2
  - Office: 0.9 W/ft^2
  - Retail: 1.3 W/ft^2
  - Lobby: 0.7 W/ft^2
  - Corridor/mechanical: 0.5 W/ft^2
  - Bathroom: 0.5 W/ft^2

    - Service: 0.9 W/ft^2
    - Classroom: 0.9 W/ft^2
    - Storage: 0.5 W/ft^2
- Keep controls simple
- No incandescent lamps for general space lighting
- Compact fluorescent lights in spaces less than 25 sq ft
- No emergency ballasted egress lighting
- General space lighting should come from T-8s or T-5s linear fluorescent lighting
- Electronic ballasts should be used for all fluorescent lighting
- Electronic lighting should be dimmable or switchable to make use of the available daylighting
- Occupancy sensors should be used to turn off electronic lighting in spaces with variable occupancy (bathrooms, storage, corridors, etc.)
- Use light-colored surfaces (>70% reflectance) for interior walls and ceilings to maximize use of daylighting

Radiant Slab Heating, Boiler Efficiency, Energy Efficiency Ratio of Air Conditioners

- Radiant slab heating or direct gas burner heating in automotive service bays
- No heating or cooling in vestibules
- Boiler
    - Condensing Boiler with 95% (or greater) efficiency
- Air Conditioners
    - Air Conditioner (0-65 kBtuh): 13.0 EER
    - Air Conditioner (>65-135 kBtuh): 11.0 EER/11.4 IPLV
    - Air Conditioner (>135-240 kBtuh): 10.8 EER/11.2 IPLV
    - Air Conditioner (>240 kBtuh): 10.0 EER/10.4 IPLV
- Gas Furnace
    - Gas Furnace (0-225 kBtuh – single package): 80% AFUE
    - Gas Furnace (0-225 kBtuh - split): 90% AFUE
    - Gas Furnace (>225 kBtuh): 80% efficiency
- Economizer
    - Economizers should be used on air conditioners to save energy by providing free cooling when ambient conditions permit
- Solar and Water Heating
    - The water heating system should be sized to meet the anticipated peak hot water load
    - Gas storage: 90% efficiency
    - Gas instantaneous: 81% efficiency

Plug Loads

- Turn off plugs when not in use
    - www.greenswitch.tv

- Energy Star appliances
    - http://www.energystar.gov/
- Use LCD computer monitors.

Exterior Lights

- Control with an exterior photosensor to turn off during the day

Allow for Renewable Generation Options

- Tilt of roof for PV
- Conduit for future installation of PV or wind

Performance Metrics

- Report metrics to evaluate energy efficiency design
- Lighting power density per zone (W/ft^2)
- Cooling capacity (ft^2/ton)
- Energy savings over code
- Site energy use ($kBtu/ft^2$)
- Energy cost intensity ($\$/ft^2$)