The hot summers and cold winters in Golden, Colorado, make energy-efficient building design a challenge. But when outlining plans for its Thermal Test Facility, built in 1996, the National Renewable Energy Laboratory used a simple design to create a high performance building. An integrated approach—considering how all the building technologies work together most efficiently—was at the heart of the design process.

The cost-effective, energy-efficient building incorporates features, such as daylighting and an evaporative cooler, that take advantage of Golden’s abundant sunshine and arid climate. Researchers monitor the performance of the 11,000-square-foot building, which boasts an energy cost savings of 63% for heating, cooling, and lighting.

The basic plan of the building can be adapted to many needs, including retail and warehouse space; the Thermal Test Facility contains office and laboratory space. Appropriately, research in the facility centers on the development of energy-efficient and renewable energy technologies that are cost effective and environmentally friendly.
Low-energy design and renewable energy at the Thermal Test Facility

Cooling
The building’s shell, or envelope, was designed to minimize cooling needs. Window overhangs shade the windows from the high summer sun, reducing the amount of heat absorbed by the building. Daylighting minimizes the use of electrical lights, further reducing cooling loads.

When necessary, the building is cooled with an indirect/direct evaporative cooling system. Outdoor air is drawn first through the indirect section, which is a heat exchanger. The air moves through one side of the exchanger, while on the other side warm indoor air is exhausted through a water-soaked evaporative media to the roof. The exhausted air is cooled as it moves through the evaporative media. Because the incoming and exhausted air streams are divided by just a thin membrane, the process removes heat from the incoming air without adding humidity. The pre-cooled air is then pulled through the direct section. It moves through a honeycomb material through which water is seeping. The water evaporates, adding humidity. The pre-cooled air is then divided by just a thin membrane, the process removing heat from the incoming air without adding humidity.

HVAC System — Cooling Mode

Indirect section

Direct section

Damp (open)

Fiber

Return air from building

Exhaust to roof

T-8 fluorescent lighting

Clerestory windows

State air exhaust

Winter Sun

Summer Sun

Optimized overhangs

South windows accept direct sunlight to light and warm building interior

South windows accept indirect sunlight to light building interior while minimizing heat gain

Air Circulation
Fresh air for the building is introduced with an air-to-air heat exchanger. This unit minimizes heating and cooling needs by transferring energy between exhaust air leaving the building and fresh air entering the building, without allowing the two streams to mix.

Windows
Designers used computer simulations to select window sizes and glass types that would minimize heat transfer and maximize daylighting potential. The clerestory windows are clear double-pane glass with a low-emissivity coating designed to reduce heat flow while allowing the visible light to enter. The glass near office space has a slight gray tint with a low-emissivity coating to reduce solar gains in an area that needs minimal heating.

Most windows are located on the south side of the building, with few on the east and west. Windows were included on the north side to increase daylighting.

Thermal Envelope
A rigid exterior insulation and finish system (EIFS) covers the exterior surface of the outside walls in the building. This insulation helps to maintain building temperature. Some exterior walls are constructed of concrete, which increases their ability to store heat.

Energy Management System
A computer monitors the conditions (temperatures, humidity, air pressure, duct pressure, light levels, and carbon dioxide levels) of the building to determine the most efficient method for maintaining a comfortable level in the occupied space. For example, the system may turn on the ceiling fans to circulate cool or warm air through the building instead of operating the more energy-intensive main air handling unit. The system also monitors and records building performance.

Lighting
Daylight from clerestory windows is the building’s primary source of light; it is enhanced by white interior surfaces that reflect sunlight. Computer simulations during design help size and locate the windows to collect the right amount of light. When daylighting is insufficient, it is supplemented by T-8 fluorescent lamps and compact-fluorescent lamps. Motion and light sensors help the energy management computer balance electric lighting with daylighting. Motion detectors trigger lights in lieu of constant security lighting, further increasing the savings. Daylighting and energy-efficient lighting constitute the most significant energy cost savings in the building.

Heating
In the winter, the sun shines in through clerestory windows, warming the building through passive solar heating. If needed, hot water circulates through heating coils and transfers heat to the air. Hot water is supplied to these coils from a boiler located in a nearby building.

Landscaping
Water conservation is especially important in this arid climate, so the land surrounding the Thermal Test Facility is landscaped with rocks and drought-resistant shrubs, also called xeriscaping.

Actual Energy Comparison*

<table>
<thead>
<tr>
<th>Code-Compliant Building</th>
<th>Actual Energy Comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>Heating</td>
</tr>
<tr>
<td>Cooling</td>
<td>Cooling</td>
</tr>
<tr>
<td>Fan</td>
<td>Fan</td>
</tr>
<tr>
<td>Hot water</td>
<td>Hot water</td>
</tr>
<tr>
<td>Exterior lights</td>
<td>Exterior lights</td>
</tr>
<tr>
<td>Lighting</td>
<td>Lighting</td>
</tr>
<tr>
<td>HVAC system</td>
<td>HVAC system</td>
</tr>
</tbody>
</table>

*This comparison does not include plug loads, which are not allowed.

Energy Efficiency

63% energy cost savings

Thermal Test Facility

*HVAC System — Cooling Mode*

- Variable speed high efficiency fan
- Outdoor air
- Inside air
- HVAC air
- Ceiling fans distribute air
- T-8 fluorescent lighting
- Clerestory windows
- State air exhaust

*Air Circulation*

- Minimal ductwork
- Outside air
- HVAC air

*Windows*

- Evaporative cooler
- Synthetic stucco finish
- Rigid insulation

*Thermal Envelope*

- Insulation
- Finish
- Exterior walls

*Lighting*

- Motion detectors
- Trigger lights

*Heating*

- Heating coils
- Stale air

*Energy Management System*

- Energy efficiency
- Building performance

*Landscaping*

- Xeriscaping
- Water conservation

*63% energy cost savings*
Reducing Energy Use in Buildings

Because 60% of electricity consumption in the United States is used to heat, cool, and operate buildings, potential savings through energy-efficient mechanical systems are enormous. Many advanced energy-saving building technologies are researched and developed at the National Renewable Energy Laboratory in the Thermal Test Facility.

The open-space, high-bay design of the building is flexible and well-suited for state-of-the-art research.

More Information

The following table shows some of the energy-efficient features of the building as designed, compared to a similar, conventional building. R-values and U-values measure how well the insulation or windows transfer heat—the higher the R-value or lower the U-value, the more resistance. Window solar heat gain coefficients (SHGC) measure the amount of solar heat that enters a building through the glass. High SHGCs allow more heat to pass through and are useful for passive solar applications.

<table>
<thead>
<tr>
<th>Key Energy-Efficiency Features</th>
<th>Base Case</th>
<th>TFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall insulation</td>
<td>R-value = 11</td>
<td>R-value = 13</td>
</tr>
<tr>
<td>Roof insulation</td>
<td>R-value = 19</td>
<td>R-value = 13</td>
</tr>
<tr>
<td>Floor insulation—Perimeter</td>
<td>R-value = 10</td>
<td>R-value = 10</td>
</tr>
<tr>
<td>Windows</td>
<td>SHGC = 0.78</td>
<td>Double pane low-e</td>
</tr>
<tr>
<td>Windows</td>
<td>U-values = 0.55</td>
<td>0.68 clerestones</td>
</tr>
</tbody>
</table>

Photo Credits

Warren Gretz: Cover—PIX04117; Cover inset—PIX05172; Back top—PIX05171
David Parsons: Back center—PIX05638

Top: NREL researcher Paul Torcellini checks the amount of daylight and the accuracy of lighting sensors.

Bottom: In a Thermal Test Facility laboratory, researcher Steve Slayzak inspects a desiccant cooling wheel—an energy-efficient method for conditioning air in humid climates.