

# **Advanced Energy Efficiency Design Strategies In Retail Buildings**

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# ADVANCED ENERGY EFFICIENCY DESIGN STRATEGIES IN RETAIL BUILDINGS

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## INTRODUCTION

This paper presents two U.S. retail building projects that were designed and constructed using the energy design process. These buildings, the BigHorn Center in Silverthorne, Colorado, and the Zion National Park Visitor Center in Springdale, Utah, were both completed and occupied during the spring of 2000.

To successfully realize any low-energy building, the design team must make cost-effective energy minimization a high-priority design goal. The building's energy use and energy cost depend on the complex interaction of many parameters and variables. This interaction is most effectively evaluated with hourly building energy simulation tools that have passed IEA BESTEST process [Judkoff, 1995]. The team followed a nine-step energy design process was followed throughout the design, construction, and commissioning of these low-energy buildings [Torcellini, 1999]. The design teams consisted of the owner, architect, and engineer, who fully executed each step to ensure the successful design. It was essential for at least one team member to act as the energy consultant and evaluate all design decisions.

Daylighting substantially reduces the electric lighting loads and minimizes the cooling loads in both buildings. Optimized envelope features include improved insulation, engineered glazing selection, and overhangs designed to optimize daylighting and building thermal requirements. The HVAC system includes radiant heating sources (e.g., slab heating, Trombe wall, and electric radiant panels), natural ventilation cooling through automatic window control and downdraft cooltowers (no mechanical cooling), and a transpired solar collector to preheat ventilation air. Photovoltaic (PV) systems incorporated into the design of both buildings significantly offset building electrical demands and loads. Both projects have a net metering agreement with the local utilities to receive full credit for power that the PV system exports back to the grid. The energy management systems (EMS) optimize operation of the electrical

lighting systems and other electrical and mechanical systems in the building.

## BIGHORN CENTER

BigHorn Center consists of a 1579-m<sup>2</sup> hardware store and a 2044-m<sup>2</sup> building materials warehouse.

### BigHorn Center Daylighting Design

Project architects incorporated aesthetic strategies that maximized the building's daylighting potential. The total glazing area was engineered to minimize the sum of heating, cooling, lighting, and ventilation costs while maximizing daylighting availability and avoiding glare in the retail space. Daylighting enters the retail space through south- and north-facing clerestory windows, north-facing dormer windows, and windows on the east and west ends of the buildings. Overhangs over the south-facing windows block summer solar gains and help reduce cooling loads.

Daylight enters the warehouse primarily through an east-facing dormer and translucent insulated ridgeline skylights. Providing daylight to the center of the warehouse was a more important design requirement than avoiding summer direct solar gain. In this particular case, the best design solution was to use skylights; however, it should be noted that this might not be the best solution in all climates and for all building types.

The daylighting distribution in both spaces is improved by reflecting light off the bright white interior ceilings and walls. The hardware store floor tile is also white. Efficient compact fluorescent fixtures (controlled by a photo sensor centrally located in the retail space and a second sensor in the warehouse) provide auxiliary lighting when there is insufficient daylighting.

Computer simulations show that the combined effect of the daylighting system and the energy-efficient lighting fixtures is expected to reduce building lighting loads 79% compared to the base-case building (Fig. 1).

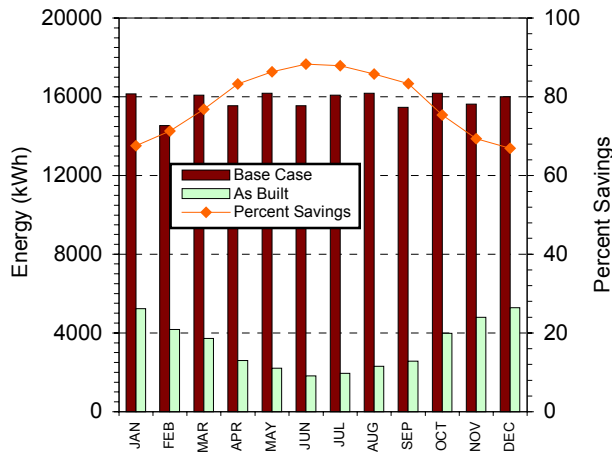


Fig. 1 Monthly lighting energy estimates for the base-case and as-built buildings showing percent savings.

### BigHorn Center Mechanical Systems

The building cooling loads were significantly reduced because daylighting minimized the lighting loads and overhangs minimized summer solar gains. The low cooling loads combined with the cool, dry summers (25°C DB/7°C WB) made it possible to use natural ventilation cooling to maintain occupant comfort during the summer.

The natural stack effect induces air movement through the building when the clerestory windows are open. The building's EMS automatically opens these windows when cooling is needed. Ventilation air enters the building through open doors in both the front and the back of the building and through manually operated windows located on the west façade. These open doors neither interfere with normal building activity, nor add security concerns for the owner.

A hydronic radiant slab is used to maintain comfort in the store during the winter without conditioning the large volume of air in the space. Temperature sensors located in the slab relay information to the EMS that governs the hot water produced by the boilers. The slab temperature is adjusted based on the occupancy schedule to provide more heat during occupied hours. Gas-fired, long-tube, overhead, reflective radiant heaters provide heat in the warehouse.

A Transpired Solar Collector (TSC) was installed on the entire available area of the ware-

house south wall. The BigHorn Center TSC is 209 m<sup>2</sup> and is constructed of dark brown, corrugated metal with flat slits cut into the material, through which ventilation air is drawn. When the fan is operating, solar energy absorbed by the dark façade is transferred into the warehouse.

PV modules laminated onto standing-seam metal roof panels were installed on the south-facing roof of the hardware store clerestory and the warehouse dormer. The amorphous-silicon PV modules were wired into three arrays, each serving one phase of the three-phase power system. The design capacity of the PV system is 8 kW, and the array covers all the available south-facing roof area.

The EMS optimizes operation of the mechanical and lighting systems in the retail store. The system controls setback of the heating system, operates the automatic window actuators, operates the ceiling fans, and balances daylighting and electric lighting to maintain constant lighting levels.

### Building Envelope

The building envelope was optimized to minimize heat loss/gain and infiltration. Extruded polystyrene insulation was installed on the outside of the steel stud walls to minimize thermal bridging. Batt insulation is located between the studs. Insulation was installed under the entire slab in the hardware store. All glazing is double pane with a low-e coating.

### Expected Building Performance

Computer simulations show that the energy-efficient building design saves about 21 kW in demand, making it possible to meet a significant portion of the annual building electrical load with an 8-kW PV system.

Figure 2 shows simulation results indicating that the BigHorn Center energy costs are expected to be 62% less than the code-compliant base-case building [Hayter, 2000].

The business plan for the project encompassed the ability to sell "green" products in the retail environment. To that end, the building became a statement to the sustainable mission, and the energy features were an integral part of the building. PV modules integrated into the roofing were an additional cost; however, the

marketing value of this investment, coupled with the other features, created a total cost-effective business plan. Even before construction of the BigHorn Center was completed, the owner saw increased sales in his existing facility, which he attributed to the publicity he received for installing the PV system and other sustainable design features.

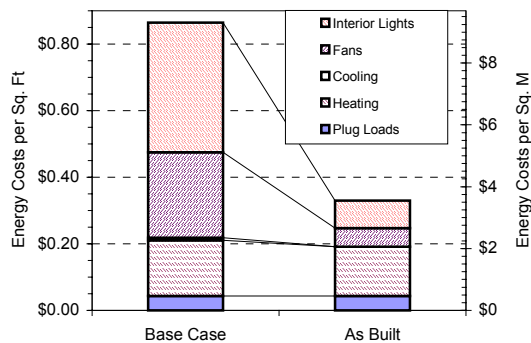


Fig. 2. Energy cost performance of the code-compliant base-case building compared with the as-built building.

The BigHorn Center is one of the first examples in the United States of integrated daylighting and natural ventilation cooling systems in a retail space.

### ZION NATIONAL PARK VISITOR CENTER

The Zion National Park Visitor Center and Comfort Station used the same integrated design process. The design team optimized the performance of the aggressive low-energy design strategies into the 808-m<sup>2</sup> Visitor Center complex. Design features include daylighting, unvented Trombe walls, downdraft cooltowers for natural ventilation cooling, energy-efficient lighting, and advanced building controls. Computer simulations show that these features save about 10 kW in electrical demand.

The optimized Visitor Center is smaller than the initial building design. Designers saved space by moving permanent exhibits outdoors and eliminating building mechanical systems. The estimated construction cost of the optimized building is 40% less than the initial design [NREL, 2000].

Zion National Park is located in a remote area of southern Utah, where power reliability is an issue. For this reason, an uninterrupted

power system (UPS) was required. The only additional cost to convert the UPS to a PV-for-buildings system was the PV array because the battery storage and balance-of-system components were already a part of the design.

A 7.5-kW roof-mounted PV system was installed on the south-facing roof of the Visitor Center. Because the daylighting and natural ventilation cooling systems minimize electrical loads, designers anticipate that the building's PV system will export power to the utility grid during the summer. During power outages, the building control system will shut down nonessential electrical loads so that the PV/UPS system will be capable of supporting enough building operations to continue business.

### SUMMARY

Using a whole building energy design process, two buildings were designed and constructed for similar costs as conventional construction. These buildings are currently being monitored to verify their anticipated energy performance. Initial data indicate that both buildings are operating according to their designs. The key to successful completion of these buildings was a committed owner and a design team willing to achieve established energy goals.

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