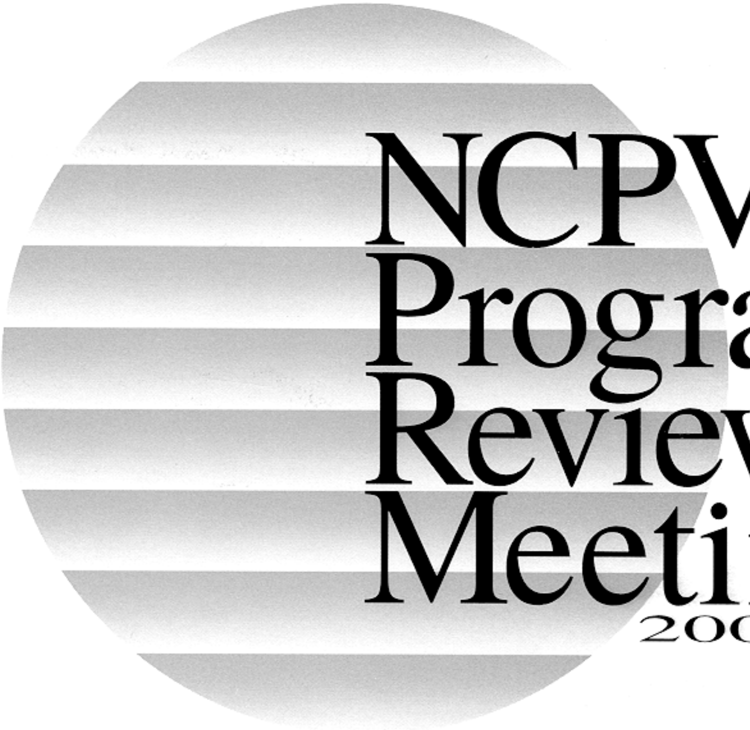
PROGRAM AND PROCEEDINGS



NCPV Program Review Meeting 2000

April 16–19, 2000

Adam's Mark Hotel

Denver, Colorado

NREL

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High-Performance Building Design: Keys to Success

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ABSTRACT

The energy-design process optimizes the interaction between the building envelope and systems. Buildings designed and constructed using this process can save between 30% and 75% in energy costs. In addition, these buildings can be constructed for the same, or nearly the same, first cost as a non-energy-efficient building with no sacrifice of comfort or functionality. A design team must set energy efficiency goals at the beginning of the pre-design phase. Detailed computer simulations are used throughout the design and construction phases to ensure the building is optimized for energy efficiency, and that changes to the design do not adversely affect the energy performance. Properly commissioning the building and educating the building operators are the final steps to successfully constructing a low-energy building. This paper defines the energy-design process and shows actual projects in which energy costs were reduced by more than 60%.

1. Energy-Design Process

To successfully realize a low-energy building, the design team, which consists of the owner, architect, and engineer, must make cost-effective energy minimization a high-priority design goal. Low-energy design is not intuitive. The building's energy use and energy cost depend on the complex interaction of many parameters and variables that can only be effectively evaluated with hourly building energy simulation tools. The nine-step energy design process described here is a guideline for designing, constructing, and commissioning low-energy buildings [1]. The design team must fully execute each step to ensure the successful design of a low-energy building. At least one team member should act as the energy consultant and evaluate all design decisions using computerized tools.

<u>Pre-Design Steps</u>

1. Simulate a base-case building model and establish energy use targets
2. Complete parametric analysis
3. Brainstorm solutions with all design team members
4. Perform simulations on base-case variants considering economic criteria

<u>Design Steps</u>

5. Prepare preliminary architectural drawings
6. Design the heating, ventilating, and air-conditioning (HVAC) and lighting systems
7. Finalize plans and specifications

<u>Construction/Occupation Steps</u>

8. Rerun simulations before making construction design changes
9. Commission all equipment and controls. Educate building operators to ensure that they operate the building as is intended.

2. Thermal Test Facility

NREL's Thermal Test Facility (TTF) is a 10,000-ft^2 (929-m^2) open laboratory building with office and support areas. A stepped building design accommodates clerestory windows for the mid- and high-bay laboratory areas and maximizes the building's daylighting potential. Daylighting meets all the TTF lighting needs except in the minimal-use areas of the building's core (e.g., restrooms, electrical rooms). Daylighting-occupancy sensors control operation of the electric lighting in the daylit areas, maintaining 50-foot-candles (538 lux), and occupancy sensors govern electric lighting use in other areas. The total lighting load of this building is approximately 75% less than in an equivalent, non-daylit building.

Reducing unwanted summer solar gains with engineered window overhangs and lowering internal gains by offsetting electrical lighting with daylighting, reduced the building cooling load by 43%. Installing a direct/indirect evaporative cooling system, which is less expensive to operate compared to a conventional chilled-water or DX system, further reduced cooling costs.

The heating loads in the building increased slightly when the lighting internal gains were eliminated. Storing winter passive solar gains in the high thermal mass of the building envelope offset some of this increase.

Figure 1 shows that the total energy cost of the TTF was reduced by 63% compared to a code-compliant base-case building [1].

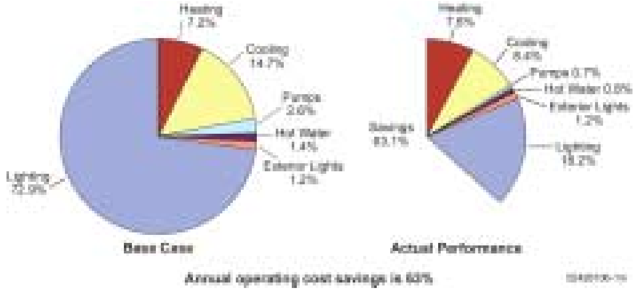

Fig. 1. TTF energy cost savings

3. BigHorn Center

The BigHorn Center is a collection of five retail spaces in Silverthorne, Colorado. The complex was constructed in three phases. Phase III houses a 17,000-ft^2 (1579-m^2) hardware store and support areas and a 22,000-ft^2 (2044-m^2) building materials warehouse. This phase incorporates the most aggressive sustainable design strategies of the three phases. These strategies include daylighting, advanced lighting technologies, natural ventilation cooling, transpired solar collector, building-integrated photovoltaics (PV), improved envelope features, and integrated controls.

Daylighting combined with energy-efficient lighting fixtures and advanced lighting system control is expected to reduce building lighting loads 79%. Decreasing lighting loads has the added benefit of reducing the internal gains on the building during the summer when the cooling loads are the highest. Glazing selection and overhang lengths were engineered to work with the daylighting and thermal requirements of the building. These features minimized the cooling load so that natural ventilation can meet the load. Natural ventilation occurs when the building control system automatically opens the clerestory windows to induce the stack effect in the building.

Radiant heating systems meet heating loads in the store and warehouse. A transpired solar collector preheats ventilation air for the warehouse. The building control system maximizes the ability of the roof-integrated PV system to reduce building electrical demand.

Figure 2 shows simulation results indicating that the BigHorn Center Phase III energy costs are expected to be 62% less than the base-case building [2,3].

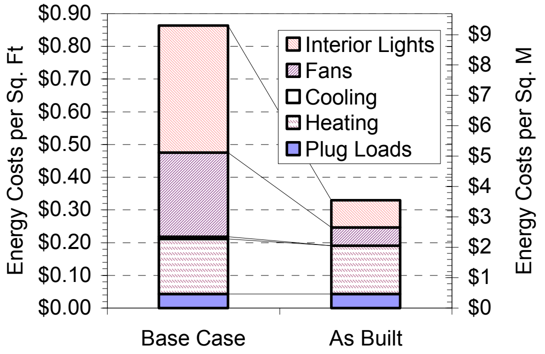

Fig. 2. Energy cost performance of the code-compliant base-case building compared with the as-built building.

5. Zion National Park

The Zion National Park Visitor Center and Comfort Station will be two of the National Park Service's (NPS) most efficient buildings. The design team optimized the performance of aggressive low-energy design strategies into the 7600-ft^2 (706-m^2) Visitor Center and 1100-ft^2 (102-m^2) Comfort Station. Design features in both buildings include daylighting, Trombe walls for passive solar heating, downdraft cooling towers for natural ventilation cooling, energy-efficient lighting, and advanced building controls.

The NPS plans to install a 7.5-kW, grid-connected PV system on the roof of the Visitor Center. Because of the low-energy design, designers anticipate that the PV system will export power to the grid after meeting all building electrical loads.

The optimized Visitor Center is smaller than the initial building. 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 and 10% less than a non energy-efficient building whose floor area is the same as the optimized design (Fig. 3).

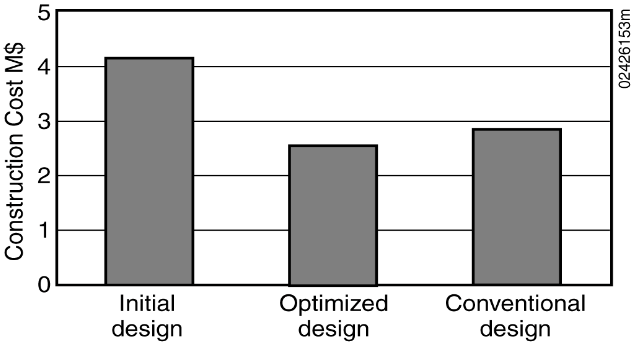

Fig. 3. Visitor Center construction cost comparison

6. Performance Monitoring

The TTF performance reported in this paper is based on actual data recorded for the building. Construction for the BigHorn Center and the Zion National Park Visitor Center will be completed in April and May 2000, respectively. Upon completion, researchers will monitor and evaluate their performance as well. The performance data will help researcher verify the accuracy of the simulations used to design the buildings. Researchers will also use the data to perfect the building control strategies and further improve performance.

7. Acknowledgements

The National Renewable Energy Laboratory's High-Performance Buildings Research Project provided support for the energy design of the buildings described in this paper. The U.S. Department of Energy provides funding for this activity from the Office of Building Technology, State and Community Programs.

8. References

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