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Zion National Park Visitor Center: Performance of a Low-Energy Building in a Hot, Dry Climate

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Zion National Park Visitor Center: Performance of a Low-Energy Building in a Hot, Dry Climate

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Introduction

Zion National Park (ZNP) in southwestern Utah has experienced substantial growth in the number of visitors over the last two decades. Associated with these large crowds were impacts to resources and visitor experience. To reduce environmental impact and improve visitor experience, National Park Service (NPS) staff planned the development of a new Visitor Center Complex to complement the natural beauty of the Park and minimize energy use. Saving and protecting natural resources is core to the mission of the Park and minimizing energy resource use is considered part of the natural resource. The NPS worked with the National Renewable Energy Laboratory (NREL) to integrate energy efficiency into the design process of the new Visitor Center.

Site and Building Description

The ZNP facility is located in a deep, narrow gorge with high canyon walls. The area is semi-arid, only receiving 15 inches (38 cm) of precipitation per year. Winters are sunny with 3,435 HDD (65ºF (18ºC) base). The summers are hot and dry with 961 CDD (75ºF (24ºC) base). The facility opened in May 2000 and includes an 8,800-ft^2 (817 m^2) Visitor Center (with interpretative displays, offices, and retail space) and a 2,756-ft^2 (256 m^2) Comfort Station (restrooms).

The Visitor Center has a well-insulated building envelope to minimize heating and cooling loads. To minimize heating loads, the building was designed with a Trombe wall and concrete floors to provide high thermal mass. The clerestory was designed to provide daylighting. These windows also provide direct winter solar gain and are protected from the summer sun with overhangs. An illustration of the ZNP Visitor Center building along with some of the energy-efficient features is shown in Figure 1. The Comfort Station contains similar features, but it is smaller. Glass on the north and west facades use a suspended film to achieve very low SHGCs and low U-values. The main entrance to the building is to the northwest as most of the visitation is in the summer. This allowed use of landscaping to help minimize the summer sun and increase visitor comfort.

A key part of the design process was to use computer simulation to minimize heating, cooling, and lighting loads using the envelope of the building. A heating and cooling system was designed to match the loads for the space. Most of the cooling is done with natural ventilation via the operable clerestory windows. Additional evaporative cooling is provided with passive downdraft cooltowers. When natural ventilation is inadequate, the cooltowers are enabled. The cooltowers were designed to operate on natural convection driven primary by buoyancy forces. Water is pumped to four sets of pads on the top of the tower. The water evaporates providing cool air. This cool, dense air “falls” through the tower and exits through the large openings at the bottom of the towers. The cool air drawn into the building by the cooltowers causes the hot air already inside the space to rise and exit the building through the open clerestory windows. There are no fans in either of the towers. The only energy required for each tower is a 1/3-hp (249 W) water pump.

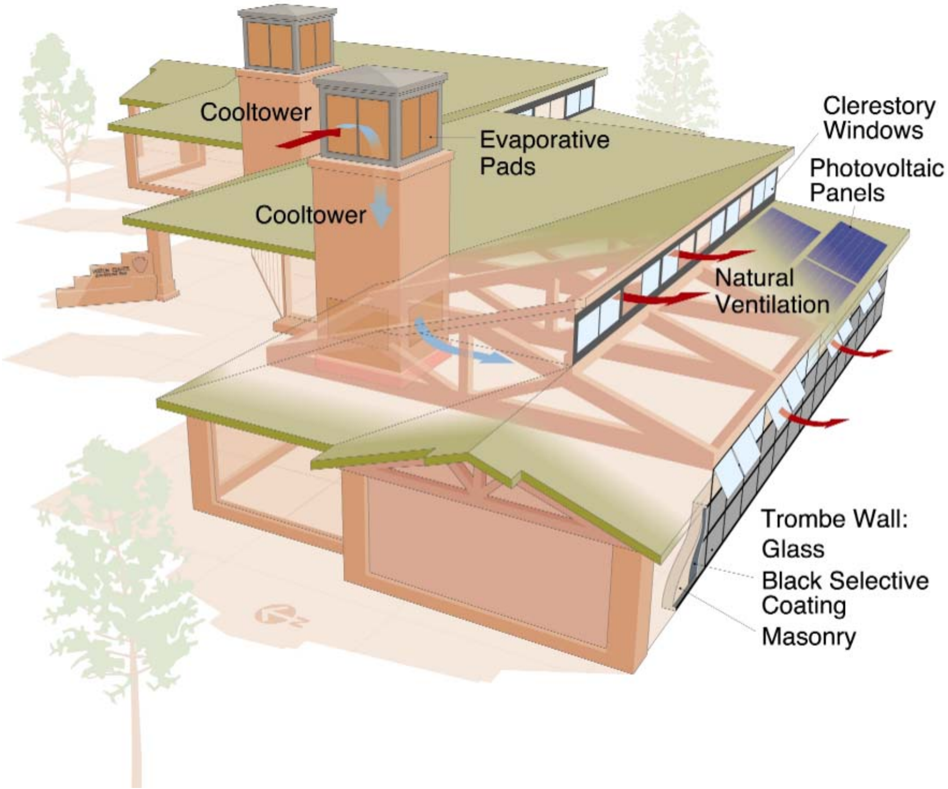

Figure 1 **Illustration of the layout and some of the energy features of the Zion National Park Visitor Center.**

The heating is accomplished by combining passive solar gains through windows, the use of a Trombe wall, and a series of electric radiant panels. The Trombe wall provides 25-40% of the space heating. Radiation from the sun is absorbed and stored in the masonry wall. The collected heat is then released back into the building when the temperature drops later in the day. The exterior sheet of high-transmittance glass and a black selective coating maximize the solar absorptivity while minimizing heat loss to the exterior. The interior warm surface provides radiant comfort. Electrical radiant ceiling panels provide supplemental heat when cloudy conditions inhibit solar radiation from reaching the Trombe wall to meet the heating load.

The primary source of light in the Visitor Center is daylight entering through clerestory windows and a strip of windows located high on the walls. Electric lighting was installed to provide additional light when needed. T-8 lights were installed above displays. Most of the Visitor Center fixtures are 88% indirect with 11% direct. Fluorescent fixtures were used on most exterior walls. The offices, back hall, break area, storeroom, and restroom in the Visitor Center use fluorescent fixtures connected to motion sensor controls. The lighting power density (LPD) in the offices is 1.0 W/ft^2 (11 W/m^2) and 0.9 W/ft^2 (9.7 W/m^2) in the bookstore and display areas.

A 7.2-kW roof-mounted PV system offsets building electrical loads and ensures a power supply during the frequent utility grid outages by using an uninterruptible power supply (UPS) circuit. The UPS system contains 200 Ah of battery capacity, enough to run the UPS for several hours without solar insolation. Excess power produced by the PV system is fed into the utility grid. Electrical loads are controlled by a Building Automation System (BAS) that maintains the energy-efficient lighting system as well as the heating and cooling systems. The BAS also monitors energy consumption and environmental variables for demand limiting and data analysis. One BAS was installed in the Visitor Center, and one in the Comfort Station. More information on this building is listed in the DOE High Performance Building Database (DOE 2004).

Energy Performance Evaluation

The evaluation measured the performance of the building during typical operation. This included assessing the Visitor Center and Comfort Station measured energy performance from September 1, 2000 to June 1, 2003. The energy performance savings were calculated using data from November 2001 through October 2002.

An energy simulation of a baseline building was completed to better understand the energy performance and to provide a comparison to the measured data. The baseline floor area was modeled with an 11,726-ft^2 (1,089.4 m^2) square floor plan with solar neutral fenestration and similar functionality of the as-built building. The baseline model met the minimum thermal efficiency requirements of ASHRAE Standard 90.1-2001 (ASHRAE 2001). The baseline building model was calibrated with the building operations and measured weather data. All the heating and cooling set points and occupancy schedules were modeled based on actual set points and occupancy schedules. All of the simulations were conducted with DOE-2.1E (DOE-2 2003).

After calibrating the baseline model, the model was compared to the measured data to show the performance and savings. The annual site energy consumption by end use for the baseline model and measured data are shown in Figure 2 and Table 1. The net site energy saving was 62% and the net source energy saving was 65%, which includes the measured energy production from the PV system. The energy cost saving was 67%.

The natural ventilation and cooltowers had an energy saving of 93%, the largest energy savings when compared to the baseline cooling system of a heat pump. The energy consumption of the cooltowers was very small because the only energy used was to pump the water. Ceiling fans and exhaust fans in the offices help to distribute the cooltower air. The total cooling energy (both cooling tower pumps and fans) for the complex during 2001 was only 7.5% of the total consumed energy for the complex. The building uses controls to pre-cool the building during nighttime periods if certain conditions are met. The purpose of the night cooling is to remove any excess heat in the building, such as Trombe wall heat, during the night while the temperatures are cooler.

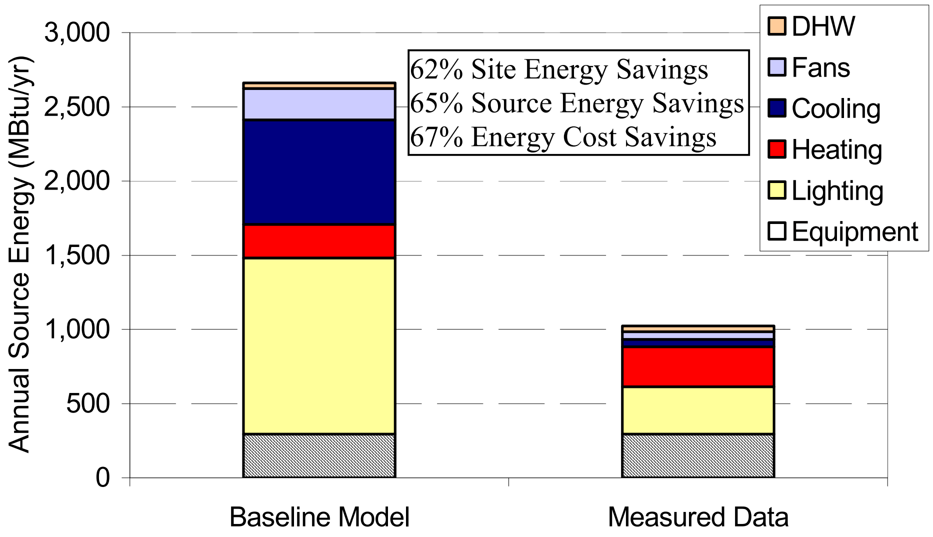

Figure 2 Annual source energy consumption for the Baseline Building and As-Built Building models using an average year weather file.

Table 1 Annual Facility Energy Use from the As-Built Simulations (end use numbers are for site energy use)

Performance Metric	Units	Baseline Model	Measured Data	% Savings
Lighting	MMBtu/yr *GJ/yr*	1186 *1251*	319 *337*	73%
Equipment	MMBtu/yr *GJ/yr*	295 *311*	295 *311*	0%
Heating	MMBtu/yr *GJ/yr*	227 *239*	270 *285*	-19%
Cooling	MMBtu/yr *GJ/yr*	703 *742*	48 *51*	93%
Fans	MMBtu/yr *GJ/yr*	211 *223*	52 *55*	75%
Domestic Hot Water	MMBtu/yr *GJ/yr*	38 *40*	38 *40*	0%
Total Site EUI	**kBtu/ft^2·yr** ***MJ/m^2·yr***	70.3 *798*	27.0 *307*	62%
Net Site EUI	**kBtu/ft^2·yr** ***MJ/m^2·yr***	70.3 *798*	24.7 *281*	65%
Total Source EUI	**kBtu/ft^2·yr** ***MJ/m^2·yr***	227.0 *2578*	87.2 *990*	62%
Net Source EUI	**kBtu/ft^2·yr** ***MJ/m^2·yr***	227.0 *2578*	79.8 *906*	65%
Total Energy Cost Intensity	**$/ft^2·yr** ***$/m^2·yr***	$1.30 *$14.0*	$0.43 *$4.63*	67%

The electric heating increased compared to the baseline values because of the smaller internal gains. Although the expected energy increased compared to the baseline, the performance of the passive solar heating and Trombe wall was effective. During the first three months of the 2002-2003 heating season, the total electrical heating energy needed was 5,389 kWh, while the Trombe wall provided approximately 41% of the energy or 3,800 kWh. This percentage was greater than the previous 2001-2002 heating season of only 20% due to improvements in controlling the electrical heating system and differences in weather. The impact of the Trombe wall during the winter is net positive and provides a large portion of the heating.

The lighting systems at ZNP are very effective at reducing energy consumption. The overall energy savings were 73% compared to the energy use by using the lighting levels allowed by energy code. Reducing the lighting loads also reduced the amount of cooling needed; however, it negatively impacted the amount of heating required.

The PV system offsets about 8% of the total annual energy load. During the monitored year, the PV system produced 7,990 kWh. The maximum 15-minute averaged PV production was 5.43 kW and occurred in March. The PV and UPS system worked effectively to provide continuous power to the facility. During a subset-measuring period of 4,131 hours, the total time the UPS system functioned while the grid was unavailable was 107.4 hours or 2.6% of the time. The UPS maintained power to the building and the BAS 100% of the time. There were two instantaneous outages when the inverter could not manage the erratic power from the utility.

Conclusions

The NPS staff, in conjunction with NREL, created a low-energy facility using computer simulations to design the building envelope. The end result was an integrated building system where the envelope contributes to the heating, cooling, and ventilation of the building.

Overall, the Zion National Park Facility uses 65% less source energy and has 67% lower energy costs than a typical building of the same size and operation. The innovative cooling solution effectively combined natural ventilation and direct evaporative cooling to reduce the cooling requirements by 93%. For the climate and scale of the Visitor Center Complex, it is possible to eliminate mechanical air systems and use simple localized heating systems to augment passive heating and cooling to provide occupant thermal comfort. Installing the PV and UPS system added a substantial value to the building because of the poor power reliability.

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14. **ABSTRACT** *(Maximum 200 Words)*

Zion National Park in Utah has experienced substantial growth in the number of visitors to the park, leading to a negative impact on visitor experience and the surrounding environment. To reduce environmental impact and improve visitor experience, National Park Service (NPS) staff planned the development of a new Visitor Center Complex. Saving and protecting natural resources is core to the mission of the Park and minimizing energy resource use is considered part of the natural resource. NPS staff worked with NREL to integrate energy efficiency into the design of the new Visitor Center.

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