Emerging Zero Net Energy Building Case Study

Photos: LPAS Architecture + Design

OVERVIEW

Location: Santa Fe Springs, CA
Project Size: 12,840 SF
Construction Type: Retrofit
Completion Date: 2015
Building Type: Office
CA Climate Zone: 9
Total Building Cost: $5,744,000
Cost/Sf: $447
Hard costs: $5,016,000
Soft costs: $728,000

Measured Energy Stats

22.1 - 22.2 = -0.1

BUILDING'S TOTAL EUI	RENEWABLE PRODUCTION RPI	BUILDING'S NET EUI

Site Energy Use Index (EUI) kBtu/SF/year

The Energy Equation: **the building energy use** *minus* **the renewables production** *equals* **the net energy of the building**. Buildings may be 'Getting to Zero' and have a net EUI above zero. If renewable production exceeds energy use its net EUI is below zero (negative) and it is creating surplus energy.

nbi new buildings institute

For more information:
newbuildings.org/zero-energy

CALIFORNIA STATE LOTTERY SANTA FE SPRINGS DISTRICT OFFICE

The California State Lottery District Office in Santa Fe Springs is a retrofit of an existing 12,840-square-foot warehouse and is one of the first state-owned and operated buildings to target zero net energy (ZNE). The Lottery partnered with LPAS Architecture + Design to retrofit the building using passive design strategies including daylighting and an energy-efficient envelope, as well as a rooftop photovoltaic (PV) system to achieve the ZNE result. The project was completed in September 2015. The California State Lottery plans to upgrade 11 of its other locations using a similar deep energy retrofit process.

Planning & Design Approach

Both the Lottery team and LPAS attended classes and met with staff from the California Department of General Services to learn about ZNE. They also toured existing ZNE structures and gathered strategies for ZNE design. The Lottery incorporated some of these broad, cost-effective methods into its Facilities Master Plan, including a familiar HVAC system, optimal daylighting, and an efficient thermal envelope. Each strategy applies to the full range of diverse California climate zones throughout which the Lottery facilities are spread.

Due to constraints on the move-in date for the facility, as well as a desire to reduce the cost of the project, the Lottery chose to renovate an existing structure with an uninsulated roof and walls, rather than construct a new building. The existing roof and landscape placed restrictions on the available surface area for solar generation which forced the team to focus on reducing energy consumption, rather than attempting to offset higher energy consumption. A daylight model, the diagram shown on page four, helped to significantly reduce the necessary lighting power density. During the energy modeling process, the team added a 15% buffer to the

Team/Owner Details

Architect: LPAS Architecture + Design

Contractor: DPR

Structural Engineer: KPFF

MEP Engineer: Interface Engineering

Building Performance Engineer: Integral Group

Builder: DPR Construction

Awards

Anticipates LEED Gold certification

calculated renewable production. This was a conscious effort to counterbalance grid-sourced electricity and account for unexpected changes in design and building performance. This ultimately allowed for the late addition of electric vehicle charging stations.

An early plug load study identified areas for potential improvements, and established a baseline for occupant power usage. That estimated consumption along with climate data and baseline design energy assumptions, were used to calculate how much power would need to be generated by PV panels to achieve ZNE. Thorough daylight modeling predicted the ideal combination of top lighting and interior glass walls to properly illuminate the space. The design team also worked with the construction firm and equipment managers early on to understand the mechanical systems' needs and prepare the existing structure for retrofit.

Policy

Drawing on state mandate that all new buildings and major renovations for state facilities be ZNE beginning in 2025, the Lottery saw the Santa Fe Springs office as an opportunity to test various ZNE design choices to prepare to meet this target. The Lottery's 2013 Facilities Master Plan recognized the need to update several of its outdated buildings and chose to begin working toward these ZNE goals immediately.

Financing Costs & Benefits

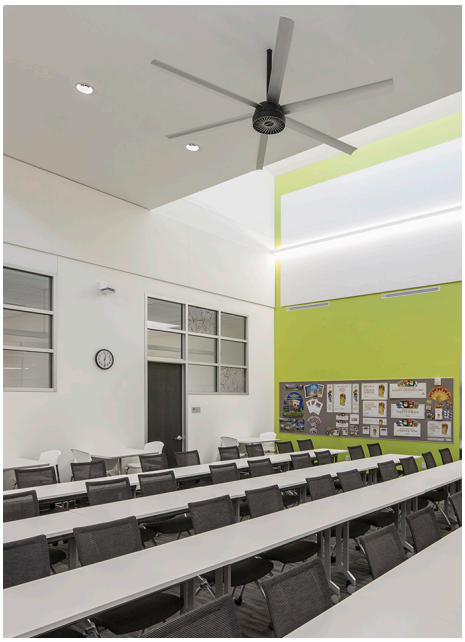
Design & Construction Costs

The entire retrofit process, excluding the purchase of the existing structure, cost $5.7 million. Approximately 13% of this was applied toward soft costs which accounted for all expenses, excluding construction. Design fees included a plan reviewer hired by the Lottery, as well as a program manager who assisted throughout the design and construction process.

Construction costs accounted for $5 million of the total project cost. To build the facility to only meet code would have cost the Lottery $4.3 million. Instead, it agreed to the 14% increase in construction costs necessary to achieve ZNE because of its commitment to sustainable design. The addition of PV panels accounts for $240,000 of this increase, or 4% of the total project cost. Several design studies helped reduce the energy required for lighting and plug loads, which reduced the number of renewables required on the project and translated to nearly $48,000 in savings on the initial cost estimate.

Operating Costs

The Lottery anticipates an annual operating cost of $63,000 for the site, which includes utilities, landscaping, maintenance, and custodial services. Adjusting for costs associated with leasing the previous facility and owning the new building over a 39.5-year timeframe, this amounts to savings of approximately $10,000 annually, which is a 5% savings over previous cost, for a facility that is 44% larger. The annual expense, including operating cost of the new owned facility is only $18 per square foot, a savings of $10 per square foot from the previous leased office.



Photos: LPAS Architecture + Design

Financing & Incentives

As a state agency, the Lottery received no tax incentives for integrating sustainable features in its building. Still, the Lottery's commitment to ZNE, as well as the financial benefits of reduced operating costs, justified the design approach.

Appraisals & Asset Value

Ownership and the savings associated with owning a building was a motivator for the Lottery to transition all existing offices and warehouses from average leased buildings to energy-efficient owned facilities. Energy-efficient buildings often have a higher value—up to 16% higher— than their standard counterparts. They also offer increased occupant comfort and lower operational expenses.

In 2012, the California Energy Commission (CEC) developed the Building Energy Asset Rating System (BEARS) that is a valuable tool in financial or real estate property valuation. As the system is refined, more buildings in California will soon adopt BEARS to reflect the value of energy investments in buildings. A tool like BEARS allows for an easy auditing process that can help owners like the Lottery further financially justify their energy investments and identify target areas for upgrades. Additionally, the rating will help to prioritize efficiency in the real estate market, support policy and design decisions, and allow owners to recognize the financial impacts of energy use.

Return on Investment

The increased cost of improvements above a code baseline efficiency level yields a 32-year simple payback from energy related savings. Often, non-energy benefits, such as employee satisfaction, higher worker productivity and retention, yield even greater savings which further improve the project's return on investment.

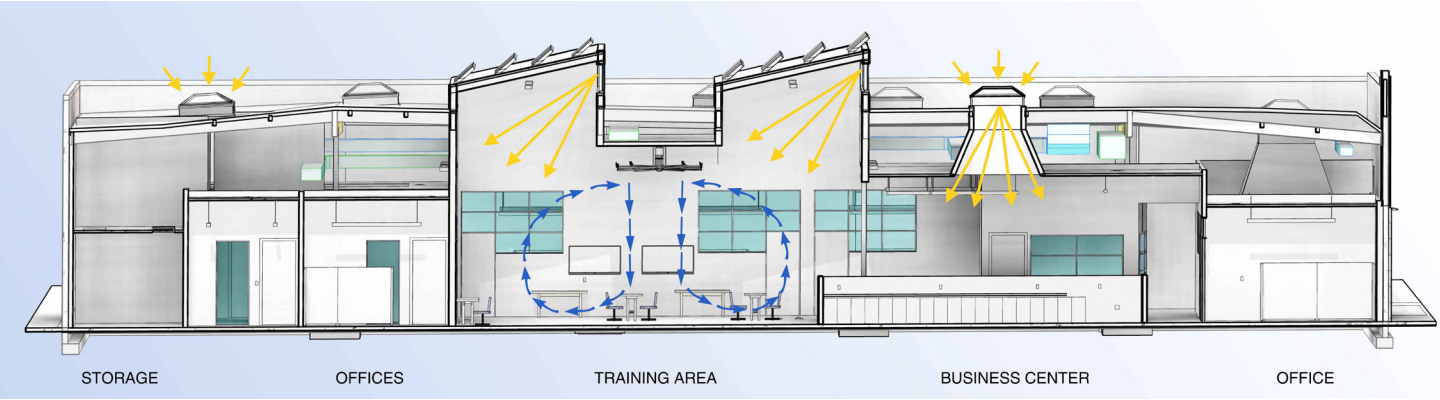


Diagram: LPAS Architecture + Design

North-South Section Diagram: toplighting by skylight, solar tube, and light monitors; air circulation by high-efficiency fan

Energy Efficiency Strategies & Features

Lighting & Daylighting

Despite the fact that the existing warehouse contained few windows, and only two facades offered daylight, daylighting is now the primary source of illumination. Property lines and building codes prohibited the design team from adding facade fenestration to bring in more daylight. Instead, they optimized the roof to enhance daylighting opportunities by including 22 prismatic lens skylights, four solar tubes, and two north-facing light monitors to strategically illuminate workspaces and circulation paths. Interior glass walls (known as relights) distribute this light throughout the office and work to provide even light levels. Exterior glass curtain walls bring diffuse daylight into the lobby from the north and east. High-efficiency LED lights supplement these daylighting strategies when the natural light levels decrease below an acceptable value.

Envelope

A highly-efficient envelope helps reduce heating and cooling loads in the building, which allowed for downsizing the HVAC system. Interior batt insulation and 3” rigid insulation yield an R-value of 38, a level twice as efficient as that required by California’s 2014 energy code. Roof insulation, with 1” wool in addition to the batt and rigid insulation of the walls, offers a 30% improvement above code with an R-value of 40. All windows use glazing units that exceed code for solar heat gain coefficient (SHGC), with the curtain wall offering a U-value of 0.35 and an SHGC of 0.5.

HVAC

After addressing lighting, the reduction in cooling loads offered the most dramatic savings. The design team was unable to incorporate natural ventilation because security concerns for the Lottery prohibited additional openings in some rooms. The HVAC system needs to run year-round so efficiency of the system was crucial. Three large, high-volume, low-speed fans circulate air more evenly keeping occupants comfortable in both summer and winter. An intelligent HVAC system uses an efficient, single zone, variable air volume (VAV) system. Controls sense room temperature and automatically adjust the frequency and volume of air released as needed. The system prevents overheating and overcooling which typically account for a high percentage of energy use in buildings built to code.

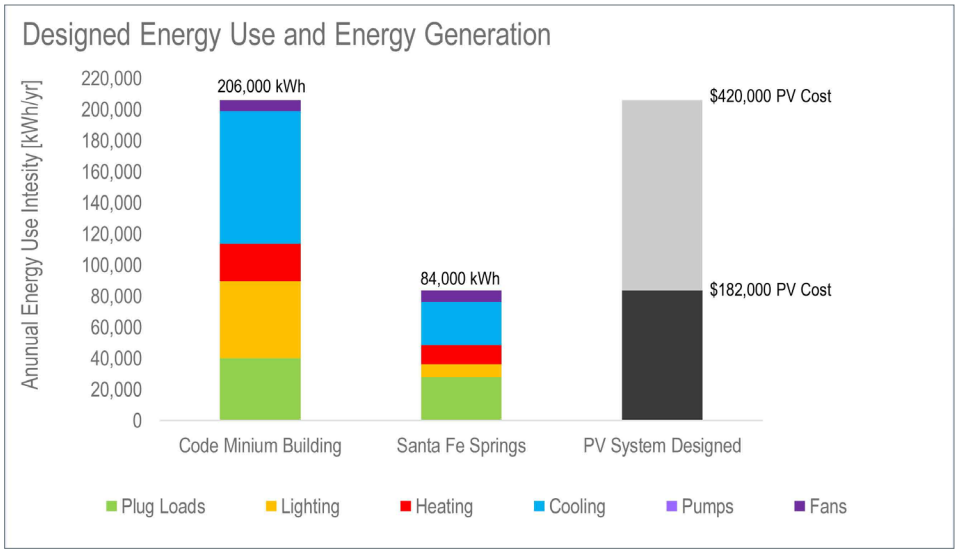


Diagram: LPAS Architecture + Design

Controls

Many of the building's systems are designed to increase ease of operation for the occupants. Lights operate with motion sensors to reduce unnecessary lighting energy use, and photocells automatically adjust the lighting to the amount of daylight in the space. The HVAC system requires minimal user attention to function efficiently. A thermal sensor detects the room temperature, which allows diffusers to run only when necessary and release an appropriate amount of air. A building management system incorporates the HVAC, lighting, plugs, and PV energy system.

Plug Loads

The design team began with a plug load analysis based on previous office plug load energy use. Analysts tracked energy use in the Lottery's previous office in 12 types of spaces. The data revealed that the building's off-hours plug load accounted for 36% (6,020 kWh) of its total plug load. The analysis revealed that turning off lottery machines and printers during nights and weekends could save 65% of this unnecessary energy consumption. Shutting down computers and monitors could further reduce the off-hours plug load to nearly zero. To help manage this energy use in the new office, the design approach integrated smart plugs at each workstation which allows workers to customize the shutoff times to their office hours, so systems are turned off when not in use.

Sizing the PV system to the energy use estimated from the previous plug load analysis rather than standard office building modeled plug loads helped reduce the anticipated plug load EUI from 8.1 kBtu/sf/yr to 4.6 kBtu/sf/yr. This alone decreased the cost of the system by $33,750. Reducing plug loads using the design approach noted above decreased the cost of the PV system by another $15,000, which more than offset the design modifications needed to address the off-hours plug load. Shown in the bar graph above, efficient design strategies such as integrating energy-efficient HVAC systems, upgraded envelope design, and reduced plug loads resulted in a greater than 50% reduction of PV necessary to achieve ZNE.

Occupant Engagement & Training

An energy dashboard in the lobby displays real-time performance data to encourage occupants to balance their energy use with PV generation. The public can also access a live online dashboard which shares electricity consumed and produced. Users can interact with the data to modify the timescale and view kilowatt hours, dollars, or equivalent carbon emissions. Graphs also display the daily distribution of energy-consuming systems in the building. The dashboards encourage occupants to engage in energy-conserving behaviors and monitor whether their interaction with the building allows it to perform at ZNE. Additionally, occupants have individual thermal comfort controls that allow them to actively participate in the building's energy performance.

"The essential goal is to design an efficient building and then see if you can meet the demand with onsite solar generation."

– Terry Murphy, Deputy Director of Operations, CA State Lottery

Renewable Energy Generation & Storage

If the building retrofit was designed to only meet the energy code, the roof of the building would not have provided enough space to accommodate a PV system large enough to offset the energy consumption of the building and would therefore not have met the standards established by the Lottery. Improving the passive strategies, building envelope, and efficiency of building systems allowed the PV system to be downsized, cutting the total cost of PVs in half compared to a retrofit to meet code. The design team maximized solar by mounting an 84,000 kWh PV system on the roof comprised of 131 panels. The energy savings the system provides offers approximately a 30-year simple payback on the total system cost.

The building is expected to over-generate from February to May and October to November. Building models predict that the building will produce 22.3 kBtu/sf/yr and consume only 22.2 kBtu/sf/yr, resulting in a slightly positive energy generation. The building will generate nearly 400 kWh annually in excess of what it uses. Data for the first five months of 2016 reveal the building generated 32,713 kWh of electricity while only consuming 26,137 kWh. Performance during these first five months of occupancy aligns with the energy performance anticipated by the energy model.

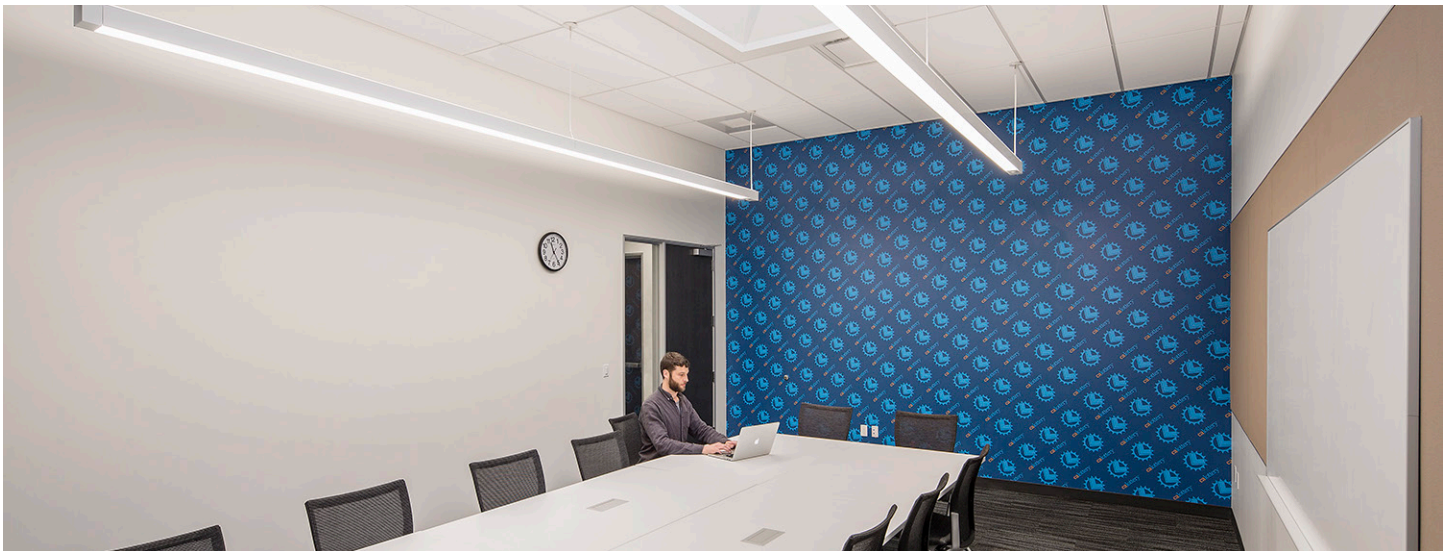
Photos: LPAS Architecture + Design

Post Occupancy

Commissioning

Commissioning is often one of the most effective strategies to reduce energy use in buildings, and its relatively low cost yields a short payback period. Post-construction commissioning revealed that crossed wires were causing the PV and HVAC meters to be read incorrectly by the building monitoring system. The outputs after the Lottery corrected this issue revealed that solar panels were not performing to their full potential. Commissioning by an electrician and the PV system installation company found an issue in one of three PV inverters. Rectifying this problem increased solar production by 50%. Facilities managers also discovered a less than 10% discrepancy between the monitoring system's outputs and the utility meter's readings.

Additional commissioning identified faulty sensors in the duct work which affected building pressurization and balancing of VAV diffusers. The Lottery is still working to ensure all parts of the building are working properly and the office is performing as designed.



"Many of the systems, like the lighting, are designed to turn off automatically and we have a sophisticated HVAC system with Accutherm diffusers that really makes it easy to provide a comfortable environment without occupants having to try hard to operate the building."

– Derick Brickner, Project Manager, CA State Lottery

Monitoring

The building management system allows operators to closely track the building's performance and identify issues such as unexpectedly high plug loads. The Lottery used this tool to discover that onsite electric vehicle charging stations were frequently being used by the public, resulting in a significantly higher overall energy use than expected. The monitoring system enables facilities managers to observe the building's performance remotely from their office in Sacramento and immediately recognize when a system is malfunctioning.

This monitoring system also enabled the Lottery to identify the issue with the PV inverter. Had facilities managers not been able to observe trends across months of data which indicated PV performance significantly below predictions, the problem could have persisted much longer.

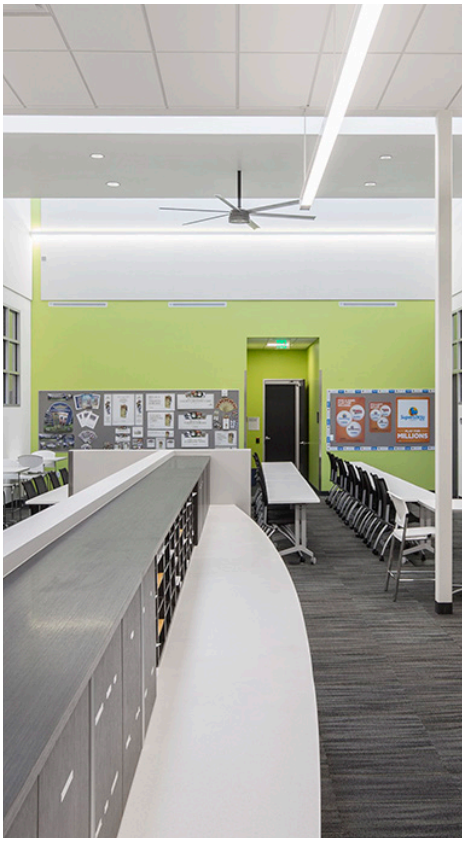
Behavior

The Lottery has a staff sustainability analyst available to help occupants reduce energy and water consumption, as well as suggest efficiency improvements to building operators. The Lottery encourages workers to turn off their workstations at night.

Successes

Despite the restriction on area available for PV panels, the design team was able to produce a modeled ZNE building. Occupancy thus far shows consumption was lower and generation was higher than predicted, which suggests the building is likely to achieve ZNE as expected, even with the positive net energy use anticipated during winter months.

Building occupants have given positive feedback to the Lottery regarding their new environment, agreeing that it is a comfortable office space. They particularly appreciate the abundant daylighting, as well as the spacious, open feel of the office. Both traits were the success of passive design choices made in an attempt to reduce lighting and ventilation loads.



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The Lottery intends to upgrade 11 of its locations using many of the same energy reducing features, according to its Facilities Master Plan. Its subsequent project, the Southern Distribution Center warehouse in Rancho Cucamonga, opened in September 2016. The process for this project ran more smoothly because the Lottery and design team were able to borrow design elements from the Santa Fe Springs design and construction and apply the ZNE research conducted in preparation for that initial project. The commissioning agent is able to monitor the Rancho Cucamonga project for issues similar to those identified in Santa Fe Springs.

Lessons Learned

- The amount of top lighting and PVs necessary for the project resulted in a substantial increase in the roof load, which required an upgrade in structure. These improvements may have been more cost effective if an entirely new roof had been constructed, rather than reusing the existing roof structure. For its future retrofit projects, the Lottery plans to favor newer cold shell structures which have an unfinished interior and no insulation or mechanical, electrical, or plumbing services so that it can more easily and cost-effectively upgrade the shell and building systems.
- Building operators learned the importance of involving commissioners throughout the entire construction process so that issues can be resolved before the building is occupied. They also recognize the value of getting meters working as soon as possible so that trends in energy use can be observed sooner and issues can be corrected early.
- There is an ideal balance point between energy efficiency and renewable energy generation which should be targeted. Given the decreasing cost of solar energy systems, the Lottery needed to consider the cost and tradeoffs of investing in energy efficiency versus additional renewable energy systems to achieve ZNE. Project managers are still working to target an optimal design approach in future projects.

Resources For More Information

- CA Lottery Building Dashboard: http://buildingdashboard.com/clients/calottery/santafesprings/