

Phoenix RISING

BY JAY S. ROBINS

A vibrant open office is created by natural daylight and ventilation, which promotes a positive work environment for employees, inspiring collaboration, creativity and enjoyment.

Gregg Mastorakos

Before 2010, one might not have imagined that a chronically neglected and abandoned building—a former home for an adult boutique in Phoenix—could be transformed into a highly sustainable, net zero energy building. But the design and operation of the DPR Construction Phoenix Regional Office has made this once unfathomable idea a reality, thanks in part to another seemingly outlandish idea for a building in the middle of the desert: using passive strategies to condition the office for much of the year.

Before its life as an adult boutique, the 1970s retail building housed a paint store for 20 years. The distressed building stood empty several years after the paint store moved out, and was vacant again when the adult boutique left in the mid-2000s. DPR Construction bought it in 2010 with the goal of creating a sustainable, “living laboratory.”

A Team Approach

Collaboration is key to a successful project, so the design and construction team was selected to come to the table with ideas to provide a highly sustainable building. The design was guided by the bold vision that the building would not only become a leading example of urban revitalization, but be a sustainability pacesetter—earning International Living Future Institute Net Zero Energy Building (NZEB) certification and, as a result of the net zero energy design goal, LEED-NC Platinum certification.

But a question was quickly raised: “Can we do a net zero energy commercial office building in Phoenix, where temperatures drive higher energy consumption?”

The answer was “yes.” The goal was not to just add photovoltaics, but to dig deeper. DPR challenged the team to think innovatively. No idea was a bad idea, the owners insisted.

Ideas were thrown on the wall, and the best ones selected for further review. “Natural ventilation in an arid climate? Why not? Nine months of the year, the temperatures in Phoenix are great,” said one team member.

During the ensuing weeks, every decision was questioned, energy

evaluated, cost validated and life cycle tested to an eight-year payback to meet the owner’s budget. The outcome was then brought back to the table, discussed and the direction set.

Preliminary designs were developed based on the goal-setting concepts. Strategies included natural ventilation with a solar chimney, operable windows and a shower tower evaporative cooling system to extend the cooling season, large-diameter fans to increase air movement, analysis of daylighting via solar tubes and load reduction.

The Transformation

The derelict building was surveyed to determine what could be saved. More than 90% of the existing building structure was maintained in the final design, while the interior was demolished.

With building orientation predetermined by the existing structure, the design approach involved creating an adaptive response to the environment. The previous paint store windows were removed for the bookstore, so the design involved adding windows to provide daylighting in the office.

South and west façades are largely intact with little to no openings, helping to buffer the space from the harsh desert sun. The east and north façades are modified to allow natural light and ventilation, including the addition of high performance glass, horizontal shading devices and operable windows.

Large glass areas are designed to connect occupants to the exterior courtyard where custom vertical steel green screens draped in indigenous vines aid in filtering light, air and



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Corner sliding glass doors on this room, as well as segmented glass roll-up doors on three exterior doors, extend natural daylighting and ventilation strategies.

BUILDING AT A GLANCE

Name DPR Construction Phoenix Regional Office

Location Phoenix (seven miles east of downtown)

Owner DPR Construction

Principal Use Office building
Includes Office functions with conference rooms, training and planning rooms, exercise space, break room, marketing rooms, server closet, meditation room

Employees/Occupants 60

Expected (Design) Occupancy 60
Percent Occupied 87%

Gross Square Footage 16,500

Distinctions/Awards Net Zero Energy Building (NZEB) certification from the International Living Future Institute, 2013; LEED-NC v2009 Platinum, 2012

When Built 1972

Major Renovation 2011

Renovation Scope Retained roof, walls and structure; reused materials

Total Renovation Cost \$3.8 million
Cost per Square Foot \$228



Above The vibrant red color at the building's main entry expresses DPR's bold identity. Passive cooling shower towers, which extend above the roofline, also create a distinctive architectural element.

Above right A garage-style roll-up door on this training room opens to the outdoors for fresh air ventilation, while solar tubes daylight the space. Similar doors are located in the cafe kitchen area and in the exercise space, and help accomplish a project goal of bringing the outdoors inside.

dust; screen views of adjacent parking; and bring nature into view. The vines and these features combined to create 2,600 ft² of outdoor wellness space and extend the areas to year-round use.

Daylighting. A daylighting analysis helped determine the number and placement of solar tubes to maintain the work surface's 25 footcandle lighting level minimums. Combined with the natural light provided by the new windows, the 82 solar tubes provide enough light to reduce artificial light use by more than 80%. The owner has found that the daylighting strategies provide enough natural light to allow artificial lights to be shut off completely.

Envelope. The existing building's perimeter walls and roof were inadequately insulated. New insulation

was added to the roof and walls to increase the R-values. The roof also received a new reflective coating to reduce heat gain.

Environment Friendly Choices.

Reducing the environmental impact of the project started with the decision to renovate rather than build new. Inside, the owner also wanted the new space to accommodate the company's built-in workstations from its existing leased office. In the

Steel green screens draped in vines provide shade, filtered air and a noise buffer from the adjacent streets. The screens create a welcoming outdoor space for building occupants to relax or collaborate.



end, 32 workstations were reused and 25 new workstations were built for the new space.

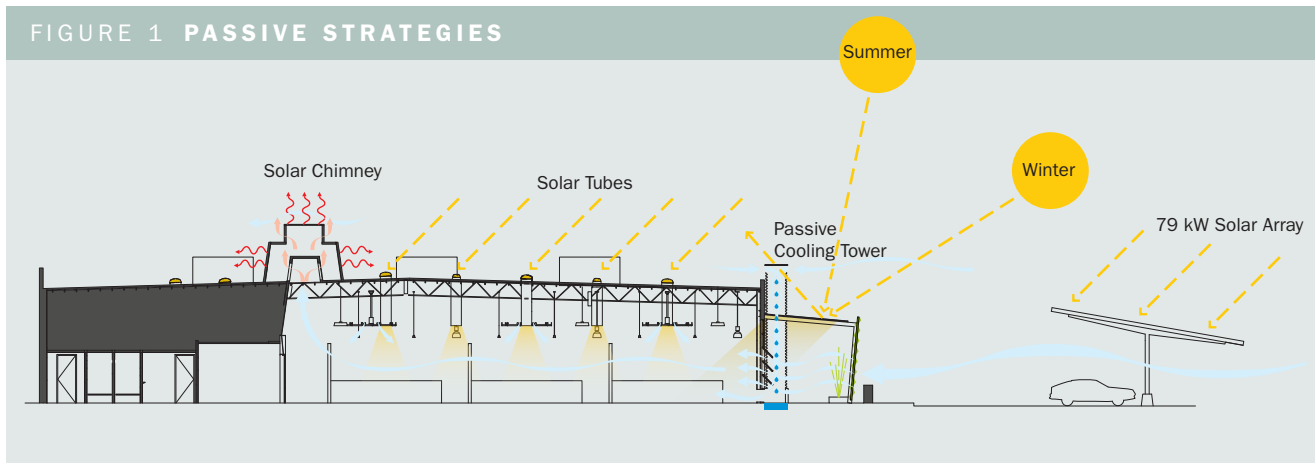
Priority was given to materials with lower environmental impact. Nearly 100% of the wood used on the project came from Forest Stewardship Council (FSC) certified sources.

Screen walls located throughout the office are made from FSC bamboo, a rapidly renewable product that accounts for 3.4% of the project's material value. All finishes are low or no VOC content. Recycled content material represents more than 32% of the project's new material value, and regionally extracted and manufactured materials represent more than 12% of new material value. Some 78% of all materials removed from the site were designated for recycling and reuse, reducing landfill waste by 252 tons.

Passive Ventilation and Cooling.

Natural ventilation was explored extensively with computational fluid dynamics (CFD) modeling, which led the design team to develop a thermal chimney/shower tower system to increase airflow and cooling. The zinc-clad thermal chimney on the roof is 87 ft long and 13 ft high.

FIGURE 1 PASSIVE STRATEGIES



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The solar chimney, clad in repurposed zinc, is reminiscent of chimneys constructed in ancient adobe or stone buildings. It was designed with the help of computational fluid dynamics to be passively heated by the sun and draw up air from the interior, helping to naturally ventilate the space. Inside, the chimney provides expansive ceiling height and volume, providing a clerestory effect from solar tubes placed on top of the chimney. This view also shows the solar tubes (small domes projecting from roof and solar chimney) and solar hot water panels (left rear).

The sun heats up the chimney and the air inside, causing the air inside to rise out via air inlets, while drawing up air from the interior space.

The shower towers consist of four black corrugated pipes on the building's eastern façade. Internal showerheads and misters at the top of the towers create passive forced pressure, and the misters increase the cooling effect. The negative pressure sucks air from the inlet at the top of the tower, pushing it into the work space.

The thermal chimney and shower towers work in concert to create

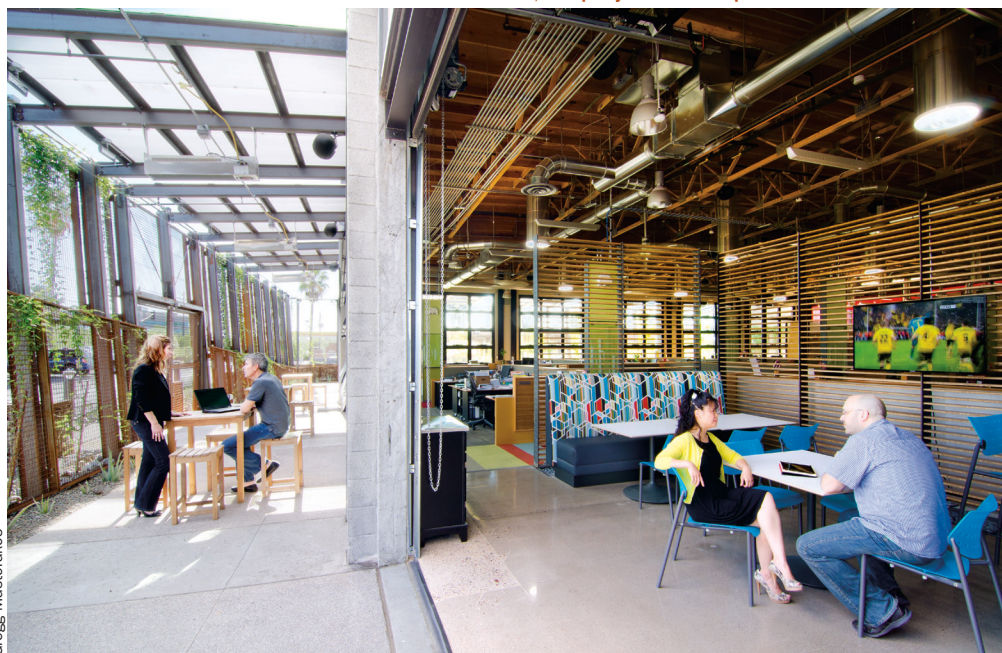
constant airflow and a comfortable indoor environment while the building is in natural ventilation mode. On the roof, a weather station reads climatic conditions and adjusts systems accordingly. The station has the ability to open windows, activate the passive evaporative cooling towers and control heat through the solar chimney.

These systems combine to generate 16 tons of natural cooling effect, enough to cool the open office space.

The systems reduce annual mechanical cooling/heating needs by 24%.

Occupant Adjustment. Part of a bioclimatic response must come from the occupants. Living in the desert is an exercise in compromise and DPR employees elected to adjust their comfort conditions to

A garage-style roll-up door gives occupants easy access to the outdoors and brings the outdoors inside. Screen walls located throughout the office (pictured right) are made from bamboo, a rapidly renewable product.



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When the building is in natural ventilation mode, the 87 operable motorized windows open, and the air conditioning is shut off by the building management system.

accommodate higher temperatures inside the building.

Thirteen 8 ft diameter ceiling fans provide one aid in achieving occupant comfort. They allow for expanded temperature setpoint ranges by increasing airflow, moving from a 72°F to 75°F range to a 68°F to 82°F range.

AUTOMATED WINDOWS: INITIAL ANNOYANCE BECOMES OUTDOOR CONNECTION

Along the north and east façades are a series of large operable window walls. All of the windows are controlled climatically and open based on the ideal conditions for natural ventilation. They open in stages to allow for more fine-tuned control, and their operation makes a humming sound.

At first, several people felt the sound was a distraction, even complaining about it. Later, they came to associate the noise of the motors with it probably being nice outside, prompting them to take their work into the courtyard. The notion that our buildings can connect us to the rhythms of the day is both foreign and profound.

Source: International Living Future Institute

As part of a holistic approach, DPR explained the system and adjustments in the temperature range to staff, obtaining buy-in from the group and giving staff flexibility to adapt to the new conditions. First year surveys indicate that the expanded temperature range maintained occupant satisfaction and saved a considerable amount of energy.

Plug Loads. Reducing plug load was another substantial focus, as computer loads can't simply be turned off. After design and operation of its net zero energy office in San Diego, DPR realized the importance of plug load reduction strategies, as 49% of the overall energy was plug loads. For the new Phoenix office, DPR evaluated every piece of equipment for energy efficiency and implemented a “vampire” shut-off switch.

Located at the main entrance, the “vampire” switch connects with all nonessential loads. The building occupants were trained to walk the building when leaving for the day, and the last person out the door hits the switch, shutting off 98% of the after-hour “phantom”

loads. These strategies resulted in a 38% reduction in plug loads from predictions, based on one year of measured performance.

Right-Sizing Equipment. Through deeper exploration of the energy model outputs, the team investigated infiltration, daylighting, increases to envelope insulation and adjustments to the peak design conditions, aligning these with more realistic conditions. This analysis led to right-sizing the equipment, eliminating the typical over-design of heating and cooling systems by 25% and 15%, respectively. In aggregate, each of these adjustments led to a 35% reduction in building

WATER AT A GLANCE

Annual Water Use	
Domestic Water	48,912 gallons
Irrigation	393,401 gallons
Shower Towers	9,497 gallons

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI) (Site)	
26.8 kBtu/ft ² (before PV)	
Electricity (From Grid)	26.8 kBtu/ft ²
Annual Source Energy -9 kBtu/ft ²	
Annual Energy Cost Index (ECI) \$0/ft ²	
Annual On-Site Renewable Energy Exported 29.5 kBtu/ft ²	
Annual Net Energy Use Intensity -2.7 kBtu/ft ²	
Savings vs. Standard 90.1-2007 Design Building 45.5%	
Heating Degree Days (Base 65°F) 923	
Cooling Degree Days (Base 65°F) 4,626	
Annual Hours Occupied 2,080	

Note: The project originally included radiant patio heaters for special events. These were the only consumers of natural gas. They were removed from the project during the first year due to lack of use.

Advertisement formerly in this space.



Functionality and maintenance were considered equally when selecting the design materials for the shower towers, including the high density polyethylene pipes seen here.

loads, which then downsized the air-conditioning equipment.

Efficient HVAC Units. The existing building had 4- and 5-ton rooftop single zone air-conditioning units. Initially, the building team elected to maintain these units since they

provided the least expensive solution for a building of this size, and provided individual zone control.

And, a life-cycle cost review of the existing mechanical units revealed that replacing them with higher efficiency units did not meet the required maximum eight-year payback. With maintenance, operating cost and replacement cost, the life-cycle run indicated a payback in excess of 20 years.

However, due to the age of the equipment and the new building's life expectancy, the owner opted to replace all the existing mechanical units with high-efficiency units. Direct digital control of these units provide precise temperature control and make smart operational decisions, providing energy and operating cost savings when compared to the former units. The mechanical systems are separately metered to allow for continuous feedback and adjustment of the controls and operation of the equipment.

After several months of operation, the HVAC system actually used

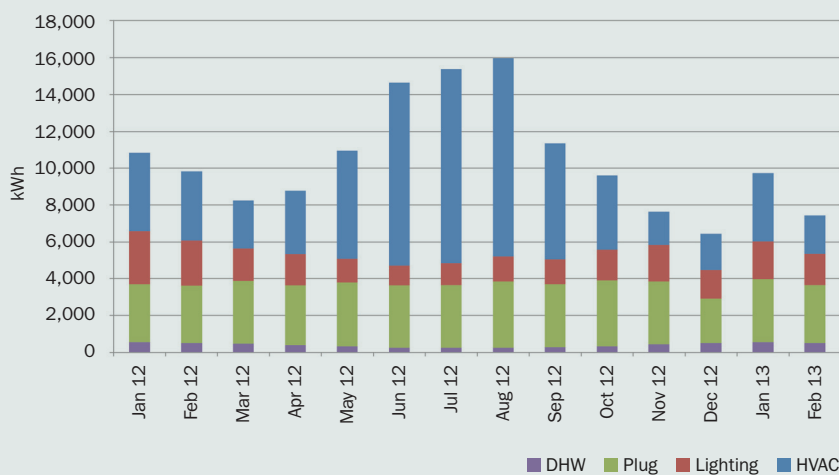
PLUG LOADS: LAST REFUGE OF ENERGY REDUCTION

The design team's significant efforts to address plug loads had a tremendous impact on the project. All computers are laptops with docking stations, no under desk heaters are allowed, task lights are subject to review and all printers are localized. The staff is constantly reminded to shut off unused lights, while the "vampire" shut-off switch kills all after-hours "phantom" loads and shuts off large screen televisions, printers, etc.

In high performance facilities, plug loads often become the predominant load and last refuge of energy reduction in a facility. While many clients are unwilling to invest the time or money associated with these strategies, the result at DPR—a 38% reduction—is remarkable, and speaks to the economic benefits of these strategies. These results also speak to the power of engagement with staff and getting their buy-in and ownership of the overall project goals. Without DPR's commitment to reducing energy use throughout the year, these results would not have been possible.

45% more energy than estimated, primarily due to occupant operation during the summer months. But, that increase was more than offset by other strategies.

FIGURE 2 MONTHLY ENERGY END USE, JAN. 2012 – FEB. 2013



Further Energy Reductions. After monitoring daily energy use, the owner began to educate staff about energy goals and limit adjustments to the thermostats. Another strategy involved shutting the HVAC units off at night and letting the temperature float until morning. This brought the energy back in line with the projected target.

High-efficiency compact fluorescent light fixtures and daylight sensors are used throughout the open office space. Occupancy sensors are placed throughout the other office spaces.

Overall, daylighting, controls and occupant motivation to reach the

DPR



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The open office is enhanced by operable windows on the north and east façades where natural ventilation and daylighting provide a connection to the outdoor environment. Natural lighting, which is enhanced by solar tubes throughout the building, is the project's most significant energy saver.

energy target helped reduce lighting energy use by 23% from what was predicted in the energy model. LED fixtures were installed for all exterior lights, which turn off during unoccupied hours to minimize energy use. All lighting is separately metered to provide continuous measurement and verification.

Water Conservation. Water remains a critical resource for much of Arizona, and reduction strategies were reviewed to meet the eight-year payback period. Many water reuse strategies did not meet the payback requirements since the site has limited access to rainwater and graywater.

The facility uses highly efficient fixtures such as waterless urinals;

LESSONS LEARNED

All projects could benefit from monitoring post-occupancy energy use and gaining operational feedback from the users. The DPR Phoenix Regional Office clearly demonstrates the value of gaining such information. During the first year, several adjustments were made to avoid energy peaks and modify operations based on user input.

Daylighting Eliminates Need for Artificial Lighting. Daylighting strategies actually exceeded expectations; solar tubes provide the minimum light levels without artificial lighting. Building user input during the first year of occupancy documented that occupants felt the daylighting provided more than enough light to accomplish work, and the lights in the main office areas were turned off.

Eliminating Patio Heaters. Natural gas radiant heaters were added to the patio areas for events. Since this addition was more “desire versus a need,” and the heaters were seldom used, they were later removed to eliminate the need for fossil fuel. (Grid electricity is hydropower.)

Dealing with Dust. Connection to the environment through operable windows and large doors meant an unwelcome visitor: dust, a fact of life that comes with desert living. The higher energy and maintenance cost of adding filters was not the answer. It proved to be

less expensive to increase cleaning, which created a new job opportunity.

A Low-Tech Solution: Paperweights. Increased airflow from large-diameter ceiling fans helped the cooling effect, but resulted in another unanticipated requirement: paperweights for occupants' desks. (Adjusting fan speed also helped.)

Adjustments to Provide Occupant Comfort. In the first year of occupancy, a post-occupancy survey was completed. On a summer 92°F day, 71% of occupants indicated the building met their thermal comfort expectations. The winter revealed the 65°F setpoint was too low and occupants were cold. The temperature was raised to 68°F to increase occupant thermal comfort.

Fans Reduce Heating Loads. In late 2012 and early 2013, a peak heating energy load was defined and reduced by using the 8 ft diameter rotary ceiling fans. The 13 fans used throughout the open office space and in the training room and exercise room do not operate in reverse, so they were programmed to operate at a very low speed in the colder months to simply mix the volume of air in the office. This reduced the peak heating demand. (See *Figure 3 Predicted, Actual Energy Use and Production, Jan. 2012–Feb. 2013*, P 15.)



The building is a phoenix of sorts. Twice abandoned by former occupants, it sat vacant as an eyesore on a busy Phoenix intersection for several years before being purchased by DPR in 2010. The sustainable overhaul of this repurposed building, extends its life for future generations.

dual flush water closets; 0.5 gpm, 10 second duration, automatic sensor lavatory faucets; and 1.5 gpm showerheads. The kitchen sink even uses a 0.5 gpm aerator.

All of these features combine to reduce predicted interior water use by 41% over LEED 2009 baselines. Actual domestic water use for 2013 was 48,912 gallons, or a savings of

“We adjusted and tweaked some things to find a middle ground of comfort. Everyone’s different—some people run hot, some run cold, but people adjusted their expectations and the space works. There was some trial and error. For example, in winter time, when everyone was in hats and gloves in the offices, we realized that the [temperature] window was too broad, so we tightened that up and adjusted accordingly.”

DPR Construction Blog

95%. For drinking water, a water purification system was installed to remove residual chlorine while filtering. This system saves significant volumes of water compared to a more traditional reverse osmosis treatment system. As corporate office building hot water use is minimal, a small packaged, low-cost solar water heater proved to meet the payback period and was incorporated.

Outside, drought-tolerant indigenous landscaping and a drip irrigation system combine to reduce predicted outdoor potable water use by more than 75% over LEED 2009 baselines. Actual annual water use for irrigation is 393,401 gallons, which represents 19% savings over the baselines. Condensate is captured from the building’s multiple roof-mounted heat-pump units and used as replacement water for the building’s shower towers, which used 9,497 gallons in 2013.

Renewable Energy. After reducing all other sources of energy use, the team focused on the amount of photovoltaics that needed to be added to offset the yearly consumption. A detailed analysis of all the loads was performed, revealing a 79 kW PV array would provide enough power to achieve net zero. The PV array also provides covered parking for employees, shading vehicles from the harsh Arizona sun, while reducing the site heat island effect.

Continued Evaluation. Construction was completed in October 2011, and the project was fully commissioned to the enhanced commissioning level outlined in LEED-NC 2009. The

owner moved in and began monitoring daily power consumption.

The project has two energy monitoring panels, centrally located where clients and employees can visually monitor building performance. DPR uses real-time, daily monitoring to tweak and adjust the building’s

BUILDING ENVELOPE

Roof

Type Existing wood deck with new insulation and foam roof
Overall R-value 43

Walls

Type Existing block with new insulation
Overall R-value 19
Glazing Percentage North 43%, south 0%, east 38%, west 0%

Windows

Effective U-factor for Assembly 0.15
Solar Heat Gain Coefficient (SHGC) 0.28 (glass)
Visual Transmittance 53%

Location

Latitude 33.42° north
Orientation North/south

KEY SUSTAINABLE FEATURES

Water Conservation Low flow water closets, faucets and showers.

Recycled Materials Every existing component of the building was considered to be recycled. Some 78% of waste diverted from landfill.

Daylighting Large windows on the north and south protected by steel green screens, solar tube lighting for all spaces.

Individual Controls Individual space thermostats and solar tube daylight controls.

Transportation Mitigation Strategies

Within 0.25 miles of the Phoenix Transit Light Rail. Local bus service on edge of property.

Other Major Sustainable Features

Natural ventilation with operable windows and large doors, solar chimney and passive evaporative cooler (shower towers).



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Photovoltaics and the shower towers create visual interest at the front of the building, making a statement about the building's sustainability and energy efficiency. The 79 kW PV array, which produces more electricity than the building consumes on an annual basis, also provides covered parking.

performance and continuously improve all building systems.

During its first year of operation (2012), the building consumed 129,589 kWh (26.8 kBtu/ft²), which was 6% below predicted energy use. The solar array produced 142,844 kWh (29.5 kBtu/ft²), resulting in a net energy use intensity of -2.7 kBtu/ft².

Green Premium

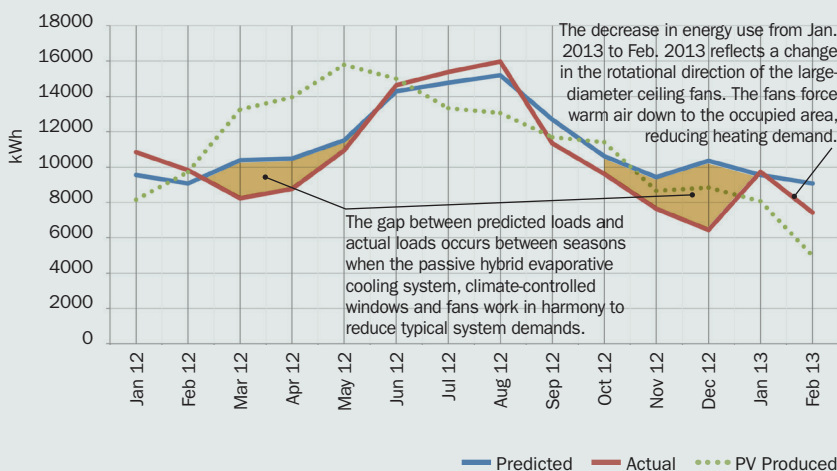
“What’s the cost of sustainable strategies?” everyone asks. In this case, the premium was less than 15% above the regular construction costs. Armed with energy-saving strategies with eight-year paybacks, the 15% increase in construction cost easily met the owner’s budget. The overall payback period was originally predicted to be 10 years (higher than eight-year payback maximum due to the longer payback

period for the high efficiency HVAC units). But after two years of operation and continuous improvements, the overall payback period is expected to be closer to eight years.

Conclusion

From a neglected and twice abandoned 1970s retail building to a highly sustainable, net zero energy office building serving as a “living lab” for DPR Construction, the result achieves project goals of setting an example for urban revitalization and aggressive sustainability. The building has received net zero energy building (NZE) certification from the International Living Future Institute, which verifies net zero operation via monitoring. It’s a building transformed—and one well prepared to live on for another 50 years. ●

FIGURE 3 PREDICTED, ACTUAL ENERGY USE AND PRODUCTION, JAN. 2012–FEB. 2013



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BUILDING TEAM

Building Owner/Representative, General Contractor DPR Construction

Architect, Mechanical and Electrical Engineer, Landscape Architect SmithGroupJJR

Mechanical, Electrical and Plumbing Engineer Bel-Aire Mechanical, Inc.

Energy Modeler DNV KEMA Energy & Sustainability/SmithGroupJJR

Structural Engineer Paul Koehler Associates

LEED Consultant DNV KEMA Energy & Sustainability