

Two wind turbines at the net zero energy Walgreens store produce a small amount of renewable electricity. Native and adaptive landscaping eliminates the need for irrigation. Walgreen Co. plans to replicate successful lessons learned from this project in future stores across the country.

Revealing Net Zero

SEVENTY-SIX PERCENT OF AMERICANS live within five miles of a Walgreens store. With such a large footprint, the corporation decided that creating a net zero store was the next logical step to reduce its impact on the environment and to save on energy costs.

BY JASON ROBBINS, P.E., MEMBER ASHRAE; BENJAMIN SKELTON, P.E., MEMBER ASHRAE; ROB OLDEN, P.E., MEMBER ASHRAE

When Walgreens razed an existing store in Evanston, Ill., they initially had no plans to replace it with a net zero building. They had assessed other sites for the next zero store. However, because the Evanston location (only 15 miles from corporate headquarters) was ideal for their engineers to access easily, Walgreens ultimately decided on that location for its first net zero store.

This decision led to some challenges for the design and construction teams. First, they only had 18 months to start from scratch to design and construct a

new building. Additionally, Chicago's climate created an engineering challenge for net zero design with seasonal solar exposure and extreme winter and summer conditions. The fixed urban site also caused some problems.

Scalable Design

An objective of the project was to create the design so that it could be used for emerging or new technology research without changing the prototypical-store operational characteristics. The design could not substantially change how retail customers shop and had to maintain the building

footprint in both size and shelving layout. The amount of refrigeration cabinets, lighting levels, and natural light and views also needed to maintain minimum Walgreens standards. By keeping the operational aspects of the building standard, the idea was that successful lessons learned from the project could be replicated more easily on future projects across the country.

Setting the Goal

The short timeframe for design, fixed footprint, and urban site limited the opportunity for a "blue-sky" net zero

building design. Walgreens determined the design should be based on generating renewable energy from within the building footprint, as opposed to solar and wind generation spread throughout the site. This decision meant the store energy signature would be defined by energy generation capacity solely from photovoltaic panels on the roof. Two vertical wind turbines were included in the project but were not factored into the net zero performance analysis.

The site itself is nine degrees off the north-south axis, which presented a challenge in regards to maximizing the solar energy generated while optimizing the site layout to include ample parking, receiving and drive-thru pharmacy window access. As such, the project architects designed a tiered roof that was rotated to a true north-south orientation to maximize solar exposure. The rotation resulted in a cantilevered roof over the West façade. A canopy roof was extended over the pharmacy drive-through to provide additional solar collection.

Also, a typical Walgreens store design has a flat roof that has limited area for solar photovoltaic panels. To increase generation capacity, the roof was pitched to maximize the quantity of solar panels (840 installed panels), which were attached directly to the metal pan roof at the same pitch. A fixed 7.5 degrees off horizontal roof pitch was the optimized angle based on solar energy collection studies. However, this would have created a peak building height at the entry of over 50 ft, which would have substantially increased the cost of the building and would have given it the aesthetic of a ski jump. A final roof tilt of approximately 3 degrees was determined to be architecturally pleasing and sufficient for renewable energy production.

Furthermore, the fixed store footprint limited space for electrical equipment supporting photovoltaic production.



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All lighting in the store is LED. Customized optics and directionalized lighting patterns further improve efficiency, allowing the overhead fixtures to achieve specified lighting levels for store shelves. This design eliminated the need for under shelf lighting.

To minimize equipment in the building and to ensure occupant safety, the decision was made to store renewable energy to be stored on the grid because battery storage systems require large areas within the building, ventilation, and are typically expensive to maintain. Micro-inverters (which convert dc power to ac at the panel rather than at a central inverter) on the photovoltaic panels also eliminated the need for a large electrical room and are simple to maintain. The micro-inverter design also gave Walgreens real-time visibility of each panel's performance, helping with maintenance and reducing the risk of compromising solar generation that is common with a central inverter system.

Designing to Net Zero Energy

The average Walgreens Store in the Chicago area consumes 425,000 kWh/year, which is significantly more than the expected 256,000 kWh/year of electric energy generation of the photovoltaic panels. Because the operational characteristics of the store could not be drastically changed, the design team had to identify features

in the envelope, lighting, HVAC and refrigeration systems that could reduce annual energy consumption by at least 57%.

Thus, the building design needed to permanently reduce the amount of energy consumed, particularly with regard to heating and cooling loads. The ideal net zero configuration would have been a highly-insulated, closed box with no glass and large thermal masses; however, this would have rendered the building not functional for retail use. Thus, the building was designed to include well-insulated, but not hyper-insulated, elements. And, the roof and walls were designed to achieve R-30 and R-20, respectively. Walgreens wanted to make the store inviting to the public, so a curtainwall glass design was incorporated on the west face (the primary façade) of the building. South-facing, clerestory glass was incorporated in between the roof tiers.

Additionally, the clerestory glass was made operable with control actuators that allow the windows to open automatically, providing natural ventilation into the store. A weather station mounted on the store monitors temperature, humidity, precipitation and wind speed. When weather conditions (dry-bulb temperature, enthalpy, wind speed) are adequate to condition

BUILDING AT A GLANCE

Name Walgreens Net Zero Store

Location
635 Chicago Avenue, Evanston, Ill. 60202

Miles from nearest major city 10 Miles North of Downtown Chicago

Owner Walgreen Co.

Principal Use Drugstore
Includes Pharmacy, grocery, beauty

Employees/Occupants
15 employees / 30 customers (average)

Expected (Design) Occupancy 45 People
Percent Occupied 60%

Gross Square Footage 13,968 (footprint); 15,270 (including mezzanine, used for EUI)
Conditioned Space 100%

Distinctions/Awards EPA Green Chill Platinum; LEED Platinum; ASHRAE Illinois Chapter Technology Award, First Place New Construction; ASHRAE Region VI Technology Award First Place New Construction, Green Globes Certified

Substantial Completion/Occupancy
November 21, 2013

BUILDING ENVELOPE

Roof
Type Standing seam metal roof with insulation entirely below deck
Overall R-value R-30
Reflectivity 0.30

Walls
Type Brick on block with continuous insulation
Overall R-value R-20
Glazing Percentage 31%

Basement/Foundation
Slab Edge Insulation R-value R-10
Basement Wall Insulation R-value N/A
Basement Floor or Under-Slab Insulation R-value N/A

Windows
Effective U-factor for Assembly U-0.46
Solar Heat Gain Coefficient (SHGC) 0.23
Visual Transmittance 0.52

Location
Latitude 42.017
Orientation -87.684

ENERGY AT A GLANCE

Annual Energy Use Intensity (EUI) (Site) 71.0 kBtu/ft² (2014 Calendar Year Gross)
Natural Gas N/A
Electricity (From Grid) 18.6 kBtu/ft² (net electricity)
Renewable Energy 52.4 kBtu/ft²

Annual On-Site Renewable Energy Exported 0 kBtu/ft²

Annual Net Energy Use Intensity 18.6 kBtu/ft²

Annual Source (Primary) Energy 58 kBtu/ft²

Annual Energy Cost Index (ECI) \$0.87/ft²

Annual Load Factor 0.57%

Savings vs. Standard 90.1-2004 Design Building 95.5% by energy (including renewables); 47% by cost (not including renewable cost); <5% short of net zero using actual 2014 weather data.

ENERGY STAR Rating 92

Carbon Footprint 226.2 MTCO₂e

Percentage of Power Represented by Renewable Energy Certificates 0% (No RECs are represented in the numbers above, those are on-site produced only; however, Walgreens did purchase 115,003 kWh/year in RECs for LEED purposes.)
Number of Years Contracted to Purchase RECs Two years at 115,003 kWh

Heating Degree Days (Base 65°F) 7,174

Cooling Degree Days (Base 65°F) 919

Annual Hours Occupied 5,356

WATER AT A GLANCE

Annual Water Use 55,600 gallons

KEY SUSTAINABLE FEATURES

Water Conservation Low-flow fixtures

Recycled Materials Bricks

Daylighting The retail zone has eight daylight dimming zones.

Individual Controls Rooms have vacancy sensors; restrooms have dual technology occupancy sensors.

Carbon Reduction Strategies Net zero energy operation.

Transportation Mitigation Strategies Close proximity to light and commuter rail, along bus line.

BUILDING TEAM

Building Owner/Representative Walgreen, Co.

Architect Camburus & Theodore

General Contractor Osman Construction

Mechanical Engineer GI Energy/WMA Consulting Engineers, Ltd.

Electrical Engineer WMA Consulting Engineers, Ltd.

Energy Modeler Seventhwave/Cyclone Energy Group

Civil Engineer Gewalt Hamilton Associates, Inc.

Landscape Architect Teska

Lighting Design Walgreen Co.

LEED Consultant WMA Consulting Engineers, Sustainable Solutions Group

Commissioning Agent Cyclone Energy Group

the store, the windows are opened and HVAC systems in the store are turned off. In the first year of operation this system operated significantly more than was predicted with no comfort issues.

One of the more controversial elements was the entrance door. Doors protect the thermal environment, but also are a barrier to entry to customers. A prototypical store design has an airlock vestibule with automatic doors. Energy modeling during a value engineering exercise indicated that a revolving door could reduce infiltration and decrease estimated energy consumption by as much as 5%—the equivalent of 43 fewer solar panels. The revolving door was ultimately incorporated into the final design, and a handicap-accessible door was added to the side with an air curtain.

While modeling indicated the potential for savings, it has been difficult to assess quantitatively. First, the revolving door did not pass envelope commissioning tests because it allowed an extraordinary amount of infiltration.

Compounding the difficulty, many customers prefer to use the accessible door, which has a 20 second open-to-close cycle. Walgreens eventually added a sign on the door to make customers aware that the door should only be used for accessibility because over-use negatively impacts their net zero goal.

Internal Loads

The high-glass west façade was not ideal for reducing energy flow. To counter this, the design incorporated a strategy of direct and indirect lighting. All lighting in the store was LED, and the sales area had eight daylight dimming zones. With no east-facing fenestration, clerestory glass on the south and light-redirecting film on the western high glass helped introduce daylight deeper into the building, further reducing lighting energy consumption. The film redirects 90% of visible light



“The design and construction teams had only **18 months** to start from scratch and do something new.”

onto the ceiling, eliminating glare and increasing natural light use.

Additionally, lighting power density is set based on providing brand-required, foot-candle levels on the shelving units. By using customized optics and directionalized lighting patterns, the overhead linear LED fixtures were able to achieve those levels, eliminating the need for 4 kW of under shelf lighting (~ 0.28 W/ft²). The building design connected lighting power density was a mere 0.89 W/ft² (compared to ASHRAE Standard 90.1-2010 value for retail occupancies of 1.4 W/ft²). Optimizing performance, lighting systems were setup during commissioning at a maximum operating power density

Clockwise from top left (Photos 1, 2, 3) An underground open-bottom detention system is installed beneath the store's parking lot. The system collects and filters all storm water on site, slowly releasing water back into the site's sandy soils.

All overhangs are insulated to avoid thermal bridging between the exterior and interior of the store.

Drilling the geothermal wells less than 1,000 ft from Lake Michigan caused challenging ground water management issues. However, the site soil conditions were extremely sandy, and the site drained itself.

of 0.65 W/ft². Automated shades were also added to the curtainwall glass to reduce loads and glare. Shades operate based on an astronomical clock with cloud sensors that will reopen shades if daylight levels outdoors are reduced for a short period of time.

Sustainability Across Walgreen's Portfolio

Figure 1 2014 IN-OPERATION BUILDING ENERGY PERFORMANCE

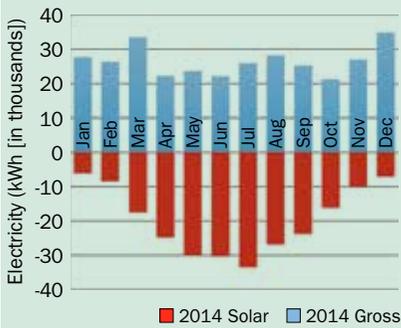


Figure 2 DAYLIGHTING DESIGN

Light re-directing film helps distribute natural light throughout the store, reducing the need for artificial light.

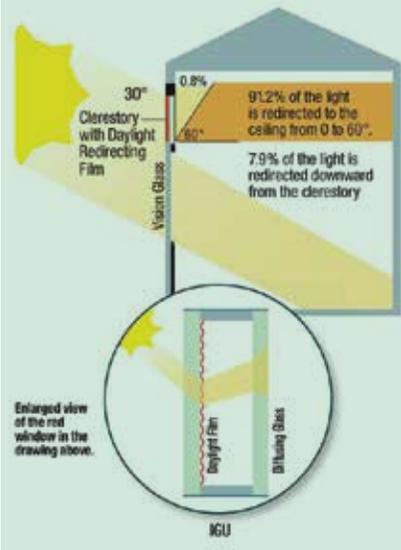
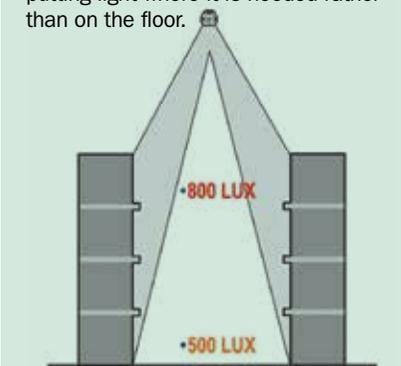


Figure 3 LIGHTING

LED fixtures are designed to direct light to the product shelving. A small lens on the fixture focuses light downward to the left and the right, saving energy by putting light where it is needed rather than on the floor.



Long before it set out to operate a net zero retail store, Walgreen Co. was reducing the energy use and environmental impact of its thousands of stores. While each store's footprint is relatively small compared to big box retailers and corporate office buildings, savings from a small change made across the drugstore chain's portfolio multiplies quickly.

For instance, after analyzing how the already energy-efficient 28 W T8 fluorescent light bulbs performed in stores, the company wanted to know what sort of change a 25 W bulb could make. So, Walgreens worked with the manufacturer to create that bulb.

Though the difference in wattage was only three watts per light, the change made in 2012 meant thousands of dollars saved as it impacted more than 4.3 million lights at nearly 7,000 stores. The net zero store, which opened in 2013, and all stores constructed since then use LED bulbs.

The company started taking on solar panel projects in 2007, and now has more than

200 solar installations across the country in California, Illinois (including the net zero store), Oregon, Ohio, New Jersey and Connecticut. On average, rooftop solar power systems provide 15% to 20% of the power at specially equipped Walgreens stores.

Walgreens stores also recycle shrink wrap and cardboard as well as construction debris. When the company replaces HVAC units with more efficient models, the parts from the old units are warehoused for maintenance of units not yet replaced. Any unusable parts are recycled.

The net zero store is part of the drugstore chain's plan to reduce energy use by 20% by 2020 in its more than 8,000 stores. Company officials have not yet said whether they plan to pursue other net zero stores, but Walgreens is using the Evanston store to evaluate sustainable strategies and incorporate them across portions of its U.S. portfolio. Some of those strategies include installing doors on open-front coolers, using daylight harvesting and installing energy management systems.

Sources: www.Walgreens.com, Jason Robbins, The New York Times

Refrigeration

The Evanston Walgreens is a scaled down grocery store with 54 linear feet of cooler and freezer cabinets. While lights and other equipment loads can be turned off at night, refrigeration must run continually to prevent spoilage. A prototypical store has a halocarbon-based refrigeration system with an air-cooled gas cooler. The decision was made to assess recovering the heat that is usually discharged outdoors for other potential uses in the store. The solution was the ground below the parking lot.

Geoexchange presented an ideal opportunity for energy storage, and Walgreens had previous experience with ground-source geoexchange in a Chicago store. The engineers designed an HVAC system using a central ground-source geoexchange heat pump system that maintains the evaporators, and produces chilled and heating hot water. The heat pump compressors in this system send waste heat through the geoexchange system and store it in the ground like a battery. When heat is needed

by the system, it extracts it from the geoexchange system, which requires monitoring of temperatures to keep the ground from drifting over years of use. Drifting is the saturation of the soil over time and can ultimately reduce the system's capacity. To prevent drift, the system has a gas cooler with variable speed drives to reject heat to the outdoors.

There were common heat pump systems with HCFC refrigerants that could work for this application, but Walgreens requested the use of only natural refrigerants. Carbon dioxide refrigeration systems are emerging in the United States for small applications, but a system capable of producing chilled water, heating water, and maintaining evaporators simultaneously with a geoexchange source was not easily found.

An energy consultant discovered a manufacturer in Sweden that had a CO₂-based system that could quickly create the requested system. The heat pump manufacturer engineered a transcritical CO₂-based heat pump system that simultaneously maintains

Clockwise from top left Wind turbines outside of the net zero energy Walgreens store are one of the most noticeable elements that point to the store's energy goals. The project team was challenged to incorporate emerging or new technology research without substantially changing prototypical store design or how customers shop.

Red geothermal system piping is visible in this view of the store from the mechanical room mezzanine. Designers included a walkway for tours and left this space open to the store for educational purposes.

This geothermal cooled transcritical CO₂ heat pump system offered the highest efficiency and lowest total environmental impact to meet the store's refrigeration, heating and cooling demands. This project is the first in the U.S. to use this type of CO₂ heat pump system in its design. The system has performed well, with little down time, and efficiencies are at or above expected performance.

South-facing clerestory windows supplement daylighting from the west glass façade. Every other clerestory window is operable, opening when conditions allow for natural ventilation.

The challenges of high-glass west façade are mitigated by light-redirecting film that is applied to the glass at 13 ft and higher, and directs light onto the ceiling. Automatic shades raise and lower according to the sun's position. These measures help reduce heat gain and glare, and prevent potential product damage from direct sunlight, such as melted cosmetics.

a -20°F freezer and a 25°F cooler and produce 42°F chiller water and 167°F heating hot water. The system included an air-cooled gas cooler to allow for temperature optimization of the geexchange system.

This system served as the heart of the project. The heat pump system recovers heat from the freezers and coolers and rejects it back into the building, domestic hot water or geexchange system depending on the time of year. The compressor COP's operate in a typical range between 4 and 6. The chilled and heating water is then circulated through variable speed pumps to single-zone, four-pipe, variable air volume air-handling (VAV) units throughout the space. A dedicated VAV outdoor air-handling unit provides ventilation to the store with demand control ventilation. A site weather station was installed to monitor the microclimate.



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“It is possible to achieve a LEED Platinum and net zero energy retail store **without sacrificing aesthetics.”**



Padgett and Company



Cyclone Energy Group



Tuning to Net Zero Performance

Sharing the findings, research, analysis, and performance of the project with the architecture, engineering, and sustainable communities at-large was a key element of the project's mission. To present the information to the public, Walgreens created a Facebook page (<http://tinyurl.com/q9ptj8t>) where the design, construction and ongoing operation were all documented. Walgreens has welcomed and responded to posted questions and comments.

Walgreens also invested in an extensive building automation and energy management system that provides detailed end-use measurement and remote monitoring and control of systems. Given the compact project schedule, systems were not complete enough to commission until after the store opened on November 21, 2013.

The designers knew that the building would not be net zero out of the gate. Measurements and adjustments would need to be done first. A weather analysis was performed during design to determine sensitivity and allow for reasonable weather fluctuations. However, the winter of 2014 exceeded the allowable sensitivity; from January through March, temperatures dropped as low as -24°F, and the mean temperature was almost 10°F below the average temperature from a typical meteorological year (TMY3 weather was used in the design model.) Updating the design energy model with actual weather data from 2014 increased the heating and cooling energy on the building 36% and decreased solar generation by 4% over the design model.

Extreme weather aside, the net zero clock was not ready to start in 2014. Issues with the utility net-metering

Lessons Learned

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- ❑ Don't do this project before historically cold winters. A few weeks after the store's opening in November 2013, temperatures dipped to -13°F three nights in a row. If systems do not run as designed while the store is occupied, you may need to supplement failing system with unsightly temporary solutions (see photo of heaters above).
- ❑ Make sure your verification systems are calibrated and accurate. The energy trending is valuable for ensuring performance.
- ❑ Responsibility for measurement and verification systems can become lost between contractor trades. Therefore, the designer of the M&V plan needs to witness the construction, calibration and commissioning of the system to ensure it works as planned.
- ❑ Natural refrigerants can be used successfully in small scale applications with moderate effort and planning.
- ❑ A natural refrigerant system can be just as efficient as, or more efficient, than HFCs.
- ❑ Natural refrigerants and high efficiency designs need to work together for the lowest possible environmental impact.
- ❑ It is possible to achieve a LEED Platinum and net zero energy retail store without sacrificing aesthetics and branding of the facility.
- ❑ U.S. regulations require piping to be rated at five times the operating pressure, which creates materials and logistic issues at the elevated pressures CO₂ requires. Europe's regulations only require three times the operating pressure. The higher U.S. requirement eliminates the use of aluminum and copper piping. The design team used stainless steel and carbon steel piping, which were more expensive and were not readily available. U.S. refrigeration equipment suppliers lack sufficient stock of the components that meet requirements.
- ❑ Incorporating HVAC into refrigeration racks breaks down the historic barrier to innovation. HVAC and refrigeration typically have been designed as completely separate systems. Finding someone to incorporate both into a single system was difficult. But no major technical challenges were encountered in designing the system.
- ❑ Geothermal loop adds redundancy and increases operational flexibility. When the gas cooler malfunctioned, the refrigeration system continued operating thanks to the geothermal system, which was able to provide additional capacity and keep the system running. Reliability is very important for refrigeration, and having redundancy helps prevent loss of product in the event of an unexpected failure.
- ❑ Real-time monitoring and transparency are vital.

were discovered in January 2014, and end-use metering was determined invalid in March 2014. Once these issues were resolved, data collection was confirmed to be accurate.

The fine-tuning of sequences and operational strategies began with the heat pump system. Initially, water temperatures were adjusted to try to maximize efficiency. However, excessive cycling led to the eventual replacement of compressors that more closely matched the load. Design of the heat pump happened so rapidly that they were oversized to ensure adequate capacity. Modeling the difference in performance between former and current compressors resulted in an expected 10% annual reduction from the heat pump system, the building's largest single energy end-use.

End-use branch level metering is currently being used to compare actual building performance to the expected performance of the energy model. Actual site weather data and any changes to the design were incorporated into the model to get more valid energy use predictions. Through the detailed study model, the team was able to identify the parts of the design that are or are not performing as expected, look for solutions for the problem areas, and improve the building's overall energy performance. By pinpointing the problem areas, the team has been able to find some quick fixes (e.g., staff training on equipment operation), and to identify takeaways or lessons learned for similar projects in the future.

Net Zero Yet?

The building is not quite performing at net zero. However, the trends indicate 2015 will be close as a result of the adjustments made in 2014.

In 2014, the building first was net zero in April, which lasted until August. In calendar year 2015, the building was nearly net zero in March and is predicted to be through

Figure 4 CO₂ DIAGRAM

This image shows how all the building heating and cooling loads are integrated in this single heat recovery heat pump. The CO₂ refrigerant moves the heat to the most appropriate sink within the heat pump. This resulted in substantial cost savings compared to a system that would typically require multiple compressor packs and intermediate hydronics.

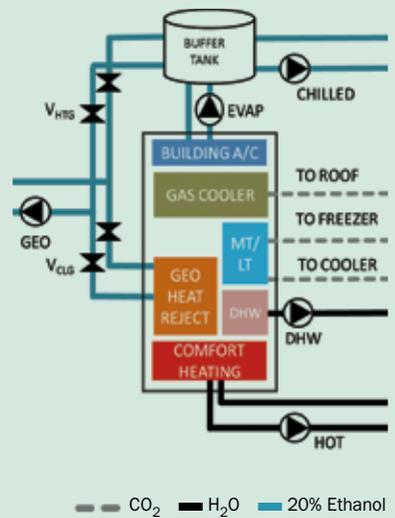


Image courtesy of Element Energy Consulting, LLC.

September. The calendar year net energy will likely not be net zero because January and February were heavy gross energy consumer months. Additional measures are being taken to reduce the heavy winter consumption.

Was It Worth It?

It was definitely worth it. Even with the store not performing to net zero in 2014, the annual operating cost per year is what the previous store (with a slightly smaller footprint) cost every two months. ●

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