ASHRAE TECHNOLOGY AWARDS APPLICATION FORM (Page 1)
APPLICATION MUST BE COMPLETE TO BE CONSIDERED FOR JUDGING
(Required for Society-Level Competition)

1

(For ASHRAE Staff Use Only)

I. Identification (0 Points)

Name of building or project: Drug Retail Chain

II. Category - Check one and indicate New, Existing, or Retrocommissioning (RCx)

☒ Commercial Buildings	☒ New	☐ Existing	☐ RCx
Institutional Buildings:			
☐ Educational Facilities	☐ New	☐ Existing	☐ RCx
☐ Other Institutional	☐ New	☐ Existing	☐ RCx
☐ Health Care Facilities	☐ New	☐ Existing	☐ RCx
☐ Industrial Facilities or Processes	☐ New	☐ Existing	☐ RCx
☐ Public Assembly	☐ New	☐ Existing	☐ RCx
☐ Residential (Single and Multi-Family)			

III. Project Description (0 Points)

1. Type of building or process: Retail
2. Size – gross floor area of building (ft. sq. or m. sq.): 15,270 SF
3. Function of major areas (such as offices, retail, food services, laboratories, guest/patient rooms, laundry, operating rooms, warehouse/storage, computer rooms, parking, manufacturing, process, etc., or industrial process description:

   Retail Store with Grocery and Pharmacy
4. Project study period: 09/2012 (Begin date (mm/yyyy)) to 11/2013 (End date (mm/yyyy))
5. Project Occupancy and Operation Period: 11/2013 (Begin date (mm/yyyy)) to 07/2015 (End date (mm/yyyy))

The global retail pharmacy brand with over 8,000 stores, set out with a vision to create a scalable retail building design that would serve as a showcase for innovative, sustainable, and high-performance design to sustainability, architecture, engineering and retail communities. The Owner designed and built a new zero energy building without altering the operational characteristics of the store, and wants to share the lessons learned about this experience in a transparent fashion as a means of encouraging the adoption of green building practices.

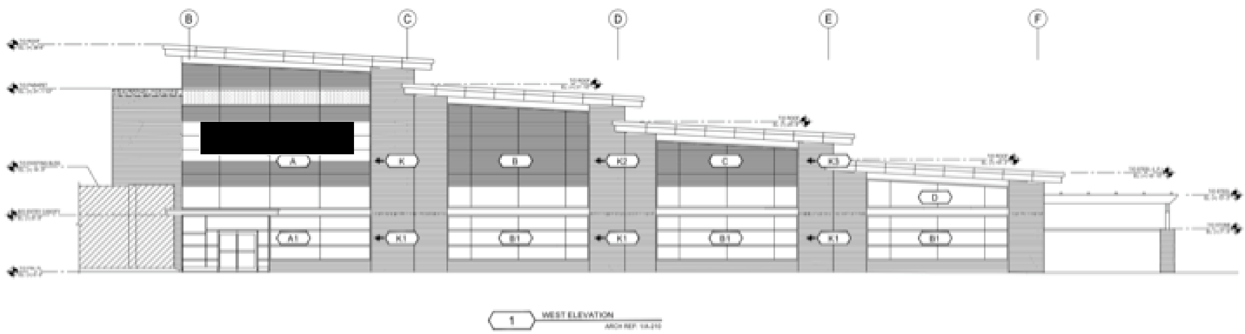
The store is designed to achieve net zero energy use by the NREL's most stringent definition of "Renewable Energy Generated within the Building Footprint", and is on track to achieve this milestone. The project has been recognized with design certifications including USGBC LEED Platinum, Green Globes, Living Building Challenge Net Zero, and U.S. EPA Green Chill Platinum.

Energy Efficiency

The net zero store had a fixed footprint and the Owner wanted to build this project using a prototypical floor plan, which consists of a rectangular single-story building with a flat roof (approximately 14,000 SF.) To generate as much renewable energy within the building footprint as possible, the project architects designed a three (3) degrees off horizontal sloped roof structure with four separate height tiers that had solar photovoltaic panels directly attached. The site is nine (9) degrees off the north-south axis, so the roof was rotated to a true north-south orientation, which resulted in a cantilever. With the additional area from the slope and cantilever, additional solar panels could be added and generation efficiency was improved. The final solar photovoltaic system design was estimated to generate 256,000 kWh/year of electrical energy on typical weather year. The average store in the Chicago area consumes an electrical equivalent of 425,000 kWh/year, which meant the net-zero design had to perform at least 60% better annually than the portfolio average. All elements of the building were considered in design to achieve this reduction.

Envelope Systems

The building design needed to permanently reduce the amount of energy consumed, particularly with regard to heating and cooling loads to minimize equipment size and optimize energy performance. The final building design included well-insulated, but not hyper-insulated, elements. The roof and walls were designed to achieve R-30 and R-20 respectively. Curtain wall glass covered a majority of the West façade (U-0.29 and SHGC-0.23 center-of-glass) and operable clerestory glass was incorporated between the south exposure roof tiers. The ground floor slab had closed-cell perimeter insulation and a revolving door was installed to reduce air changes.



As-Designed Properties		As-Built Properties	
Assembly U-Value:	0.41 Btu/h ft^2 °F	Assembly U-Value:	0.46 Btu/h ft^2 °F
COG U-Value:	0.32 Btu/h ft^2 °F	COG U-Value:	0.29 Btu/h ft^2 °F
SHGC:	0.26	SHGC:	0.23
VLT:	52%	VLT:	52%

Figure 1 - Curtain Wall System Performance (Design vs. As-Built)

Lessons Learned:

1. Actual curtain wall performance varied, unfamiliarity with curtain wall construction by some team members led to lower than expected performance.
2. The revolving door did not perform as hoped. Partially because the door was of poor quality, but also because many people favored using the automatic door, despite signage warning customers.

Lighting & Daylighting Systems

The lighting design incorporated a strategy of both direct and indirect lighting. All lighting in the store is LED and the sales area has eight daylight dimming zones. The building design has no east-facing fenestration so clerestory glass on the south and light-redirecting film on the western high glass (above 14’ AFF) help introduce daylight deeper into the building, further reducing lighting energy consumption. The film used on the upper glass redirects 90% of visible light towards the ceiling, eliminating glare that would have been a nuisance in the store checkout area. Lighting power density is set based on providing brand-required foot-candle levels on the shelving fixtures (~70-100 f.c.) By using customized optics and directionalized lighting patterns, the overhead linear LED fixtures were able to achieve those levels. This eliminated the need for 4 kW of under shelf lighting (~0.28W/SF) that was typically used in prototype stores with fluorescent overhead lighting. The building design connected lighting power density was a mere 0.89 W/SF (compared to ASHRAE Standard 90.1-2010 value for retail occupancies of 1.4 W/SF.) Performance of lighting systems was optimized during commissioning by setting up the system with a maximum operating power density of 0.65 W/SF. These additional savings were realized as the fixtures had no visible change in light output between 90% and 100% power. Automated shades were also added to the curtain wall glass (below 14' AFF) to reduce loads and glare. Shades operate based on an astronomical clock with cloud sensors that will reopen shades when daylight levels outdoors are reduced for a period of time.

Lessons Learned:

1. The LED lighting fixtures selected had no visible light change between 90% and 100% power, allowing for additional efficiency without loss of light quality. Below 20%, the LED lighting became very unstable and would flicker.

Plus Loads & Data Systems

While no consolations were made to the prototypical store layout, several areas where parasitic loads exist were identified and efforts were made to remove those loads. For example, a typical store has open refrigeration near checkout lanes. Discussions with the Owner led to the elimination of this load from the design. Where many stores may plug in holiday lights seasonally, efforts were made to educate store users and management of the negative impacts these loads have on the net zero goal.

Most onsite data loads are in support of the point-of-sale (POS) system, or checkout registers. Sub-metering systems were placed on POS circuits to monitor system power. The Owner's engineering department worked with the IT department to review the actual in-operation power consumption patterns, which showed a continuous energy consumption despite fluctuations in system use and off-hours. Recommendations for off-hour power reductions were considered and have since been implemented.

Lessons Learned

1. Retail stores have a lot more plug loads than anticipated. Security systems and sales systems are not typically configured for energy efficient operation but can be if you ask the right people.

HVAC&R Systems

A prototypical store of this size normally has three constant volume, direct-expansion, gas-fired rooftop units for space conditioning. Rooftop units were never in the plan for this project given the need for solar photovoltaic panels on the roof. The Owner had built a flagship store in Chicago in 2010 that incorporated distributed ground-source heat pumps with a vertical well geo-exchange system that has been performing very well, so geo-exchange was considered the baseline system for the net zero store. However energy modeling analysis determined that more than ground-source heat pumps was necessary to reach the net zero goal.

Refrigeration

The Net Zero Store 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 when unoccupied, refrigeration must run continually or products can spoil. Finding a way to capture the heat rejection from the refrigeration system and use it in a heat recovery application presented a challenge to the design team. The design team determined by using the geo-exchange system, the ground could store waste heat for use by HVAC and domestic water heating systems.

An energy model was used to compare system performance from different heat pump options, including: distributed water-source heat pumps with geo-exchange, central plant water-source heat pump chiller/heater with geo-exchange, and water-cooled variable refrigerant flow with geo-exchange. Prior to choosing a system type, the Engineer for the Owner requested that all natural refrigerants be a major consideration in system selection. A global search of HVAC equipment with natural refrigerants ensued and yielded a few companies that manufactured distributed water-source heat pumps and water-source chiller/heater heat pumps with CO_2 as the refrigerant. All were internationally designed and manufactured.

The search was exhaustive and took a considerable amount of time. Given the compact design timeline, the building was initially permitted using an HCFC-based central plant water-source heat pump chiller/heater. The permit was later revised once a manufacturer was selected to illustrate the CO_2 heat pump system. The revision required an educational discussion to explain the system and the potential hazards with the Authority Having Jurisdiction (AHJ) as they had not seen this configuration used in a commercial application before. Another issue that arose was system pressure ratings. U.S. regulations require piping to be rated at five (5) times the operating pressure, which creates materials and logistic issues at the elevated pressures with which CO_2 operates (~1,200 PSI.) Europe's regulations, where the equipment is manufactured and largely used, only require three (3) times the operating pressure.

The final central plant design consisted of a skid mounted, transcritical CO_2 heat pump system with three sets of compressors serving: low-temp (LT) evaporator (-20ºF), medium temp (MT) evaporator (25ºF) and chilled water evaporator (42ºF.) The system rejects heat to domestic hot water pre-heat (140ºF) and heating hot water (167ºF). A buffer tank connects the chilled water system to an eight-vertical bore geo-exchange system (500 foot deep bores.) Figure 2 illustrates the system configuration.

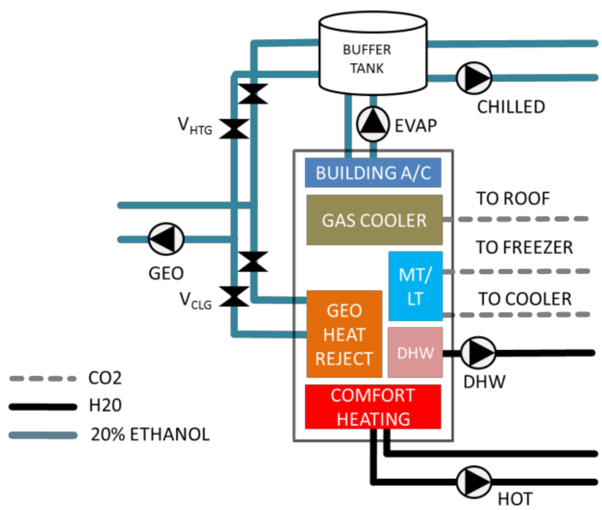


Figure 2 - Transcritical CO_2 Heat Pump Diagram

Modeling of this system with the building and refrigeration load profile indicated that the geo-exchange system would become heating overloaded and would quickly drift. To prevent drifting, an air-cooled gas-cooler with variable speed fans was also included to help balance the geo-exchange field over time. Logic in the controls helps monitor the system and dictates if the gas-cooler or geo-exchange system is the most ideal rejection source. For freeze protection, a 20% ethanol solution was used in the geo-exchange and chilled water system. Ethanol has lower density and less viscosity than a typical ppropylene glycol solution and was selected to help reduce pumping energy and for better coil selections. The chilled water, heating hot water and geo-exchange pumps all have variable speed drives. The performance of this system was predicted between 4 and 6 COP, data collected on actual performance validates these predictions.

HVAC Systems

A four-pipe VAV dedicated outside air system (DOAS), (3) 4-pipe single-zone VAV indoor air handling units, and (4) 4-pipe single-zone VAV fan coil units provide comfort cooling and heating to each zone. The DOAS unit provides ventilation to each space and speed is modulated based on measured CO_2 levels in the retail spaces. Back-of-house spaces are not varied for demand control ventilation as their ventilation quantity is necessary for the DOAS unit to operate at minimum VFD speed. The DOAS unit was evaluated for an energy recovery ventilator, however it was not effective in reducing energy given the small amount of total ventilation and the potential for increased fan energy because of added pressure drop. Making the system variable volume was the more energy efficient option. The air handling units and fan coil units are setup to duty cycle given the separate source of ventilation air, minimizing fan energy. Coil selection on these systems was a very difficult process given high temperature deltas and the use of ethanol. All equipment had pressure independent valves, which during operation, became an important lesson learned.

Lessons Learned:

1. Don’t use pressure independent valves unless you’re certain you have the flow rated designed correctly. In this application, we needed to make adjustments for flow to ensure performance and were fortunate that the cartridges in the installed valve were able to be reconfigured for the field adjustments that were needed.
2. Geo-exchange works very well with transcritical CO_2 refrigeration. As-built operation has shown the field maintaining a very stead temperature (~56ºF) and the heat pump unit has been operating with good efficiencies.

Renewable Energy

To minimize equipment in the building and to ensure occupant safety, the decision was made for renewable energy to be stored on the grid versus a battery system. Battery storage systems require a lot of area within the building, require ventilation, and can be expensive to maintain. Micro-inverters on each of the photovoltaic panels eliminated the need for a large electrical room and are simple to maintain. Micro-inverters convert DC power to AC at the panel rather than at a central inverter. The micro-inverter design also gives real-time visibility of each panel’s performance, helping with maintenance and reducing the risk of compromising solar generation that is common with central inverter system.

849 photovoltaic panels were directly attached to the metal pan roof. They had the same pitch (3º of horizontal) as the roof. Solar collection studies shows that a 7.5º off horizontal was the ideal pitch for the panels, however with the panels being directly attached to the roof, would have drastically changed the architectural design of the building. A 7.5º pitch would have yielded a roof more than 50 feet tall at the high side and would have looked like a ski slope. Lowering the slope reduced the collection capacity but left the building architecturally appealing and energy modeling indicated the reduced solar capacity would not be detrimental to the net zero goal.

Two vertical wind turbines were installed in the parking lot of the store. Each turbine was sized for 2.5 kW peak capacity and was predicted to produce approximately 8,000 kWh. To date, the turbines have produced no useful energy, not because they don’t rotate but because there are issues with the generators. Wind was never included in the goals for net zero. However as you drive up to the urban site, the wind turbines are an eye catching visual indicator of the stores high-performance, sustainable mission. The Mayor of Evanston had been a long proponent of wind power and this was the first installation during her term; she spoke to the importance of renewable energy during the store opening ceremony.

Lessons Learned:

1. It’s difficult to find a wind turbine manufacturer that is still in business from the time span between design and construction.

Energy Modeling

Predictive modeling was an enormous challenge given the design of the central heat pump system. The design team used two modeling software programs to simulate performance: IES<VE> and TRNSYS (note that eQuest was also used by the local Utility program to calculate new construction incentives.) IES<VE> generated the building load profile and this was used in a TRNSYS model that analyzed the refrigeration load profile and geo-exchange system. The design team worked very closely with the manufacturer of the heat pump to determine load dependent coefficients of performance that were also used in the TRNSYS model. The TRNSYS model created a system performance profile that was then used in the IES<VE> model to simulate whole building performance.

The commissioning agent used energy modeling to validate the projects top Owner Project Requirement: *Achieve Net Zero Energy*. Modeling was used at concept to advise on envelope system performance and to select HVAC systems. Daylight modeling evaluated the impact of daylight dimming, automatic shading and to review glare. The glare analysis led to the use of light redirecting film. Computational fluid dynamics (CFD) was also used to evaluate the performance of natural ventilation systems.

Throughout design, the energy model was updated countless times to inform design decisions. During design and early construction, weekly meetings were held that reviewed predicted performance of the building. No decision that impacted performance was made without first updating the energy model. During building commissioning, the energy model was used to help configure building control systems and set and validate parameters. The model was ultimately calibrated to match building operation post occupancy and has been used to advise on adjustments that will improve building performance.

Performance

The building has not yet achieved net-zero on a 12-month calendar basis. However net-zero performance on a monthly basis is common. The primary reason for not achieving net zero on a calendar year basis is heating season performance. Project engineers are continuing to tune the heat pump for high performance in winter months where the net zero energy goal is being depleted. Modeling the building for predictive performance using typical metrological year (TMY) data does not account for fluctuations in actual weather conditions. During design, modeling accounted for a buffer of 6% net positive over TMY weather data to account for heating/cooling sensitivities. In the first two winters (2014 and 2015), temperatures were abnormally colder than typical years (~8% increase in energy over the TMY data), and weather conditions exceed the buffer for net zero performance that was allocated. The design team is anticipating that changes made this past spring will get the building to a 12 consecutive month net zero goal.

Indoor Air Quality

The Owners promotional motto is [redacted]. Being a retail pharmacy store, creating a healthy environment for their customers is crucial. Patients are seen at this particular location so a comfortable and healthy indoor environment was at the forefront of design. The open design with high ceilings, large glass areas for daylight, and polished concrete floors gives a fresh, healthy feeling to the space. The design engineers added

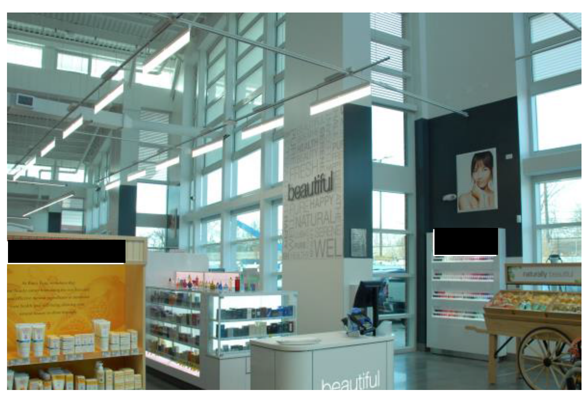


Figure 3 - Clean Indoor Environment

to this by designing the environmental systems to meet and exceed ASHRAE Standard 62.1-2010 and ASHRAE Standard 55-2010. Use of low- and no-VOC products and materials was also prevalent in the design.

Ventilation

A dedicated outdoor air unit (DOAS) provides for ventilation rates meeting ASHRAE Standard 62.1-2010 to every space in the building. Increasing base ventilation rates above the Standard was not pursued as the additional ventilation air would have negatively impacted the net zero goal. Demand control ventilation (DCV) was used in the retail area as the store has large fluctuation of customers throughout the day. Three CO_2 sensors located in the space monitor levels and adjust ventilation to maintain conditions less than 800 PPM. This level could be increased higher per ASHRAE 62.1, however the Owner wanted to keep more fresh air in the sales areas to promote a healthy environment.

Natural Ventilation

Natural ventilation was integrated into the design of the building to provide conditioning and increased fresh air to the retail space. With the tiered roof structure, clerestory glass was installed between the levels for additional daylight to interior spaces and windows systems were fit with actuators to allow for fresh air to be brought in. The windows operate based on a set of environmental conditions including: ambient dry bulb temperature, outside air enthalpy and wind speed, all measured from a building installed weather station. When active, windows at all tiers of the building open, air handling units in the space are locked out of operation and an automatic damper closes off the retail space from the DOAS unit. The system was not predicted to operate much during design but has proven to operate frequently, and for long periods of time in the shoulder months.

Comfort

Occupant comfort was reviewed carefully in design. There were considerations for setting sales floor temperatures higher in cooling season and lower in heating season than the brand standard (76ºF / 70ºF) to reduce energy. This was considered only in the retail sales areas where customers are walking constantly and typically dressed for the outdoor conditions, e.g. wearing coats in the winter and lighter clothing in the summer. A series of ASHRAE Standard 55-2010 calculations were performed to determine predicted satisfaction, but ultimately the brand standard conditions were kept to maintain the comfort of the full-time staff that occupies the space continually.

Innovation

The Owner set out with a vision to create a store that would be an innovation laboratory to test out products, materials, systems and equipment that could be incorporated into future prototype designs or retrofit throughout existing stores. And from the beginning, the Owner stated they wanted to share the results from this store opening with the public, design community and even their competition. The Owner designed the store to facilitate tours, which occur multiple times per week. They have even hosted

Figure 4 - Mechanical Room with a Tour Group

executives and designers from their retail competition.

Public education was one of many innovations on the project. Signs throughout the store describe sustainable features of the design. The mechanical room, which houses the heat pumps system, is located on a mezzanine above the coolers and freezer cabinets and features a large glass window to the store. Piping throughout the mechanical room was wrapped in colored jacketing and a key on the wall explains to tour goers what each pipe is doing. A Facebook page was started early in design and journals the entire design, construction and ongoing operation of the project [redacted] and the public is free to open discussions.

Among the specific design innovations was the use of light redirecting film. The film works as advertised and provides a tremendous level of lighting deep into the space while eliminating glare in the occupied zones. Additionally, it is a low maintenance product compared to the exterior light louvers that were being considered in its place. Exterior light louvers tend to collect snow and ice in the winter and require cleaning periodically.

All LED lighting packages are becoming more common, but the linear fixtures used on this project were an innovation. Keeping light levels on the shelving fixtures relatively even from bottom shelf to top shelf generally requires the use of undershelf lighting strips. The dimmable linear LED fixture used on the project was first tested in a mocked-up store to validate the light pattern before being installed. In addition to eliminating 4 kW of undershelf strip lighting, the fixture performs nearly 50% better than a common 28W T-8 fluorescent fixture. The LED system is now being incorporated into new prototype stores.

A highly detailed measurement and verification metering system was installed that monitors over 120 electrical circuits in the building. The system provides a level of visibility to equipment loads that the Owner has never before had. The use of this system has led to changes with how they manage data equipment as well as other loads throughout the building. The system has served as a valuable resource during commissioning an ongoing operation to fine tune systems and get early visibly on systems that are falling out of expected operating ranges. Data on how the building is performing is reported live to the public via a kiosk at the entrance of the building.

The commissioning process was handled in an innovative manner by using the energy model as validation tool. Given primary Owner Project Requirement of designing a net zero energy building, design team members provided ideas and concepts to the commissioning agent who updated the model throughout the project and reported to the team on how the design was tracking the project goal.

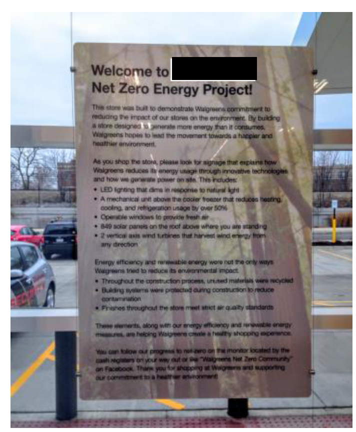


Figure 5 - Educational Signage

The building has many other innovative features and permanent signage is posted throughout the store for customer education. Some include storm water detention chambers, recycled bricks, low VOC materials and low-flow plumbing fixtures. But no innovation was bigger than the transcritical CO_2 heat pump system. A configuration of a single packaged CO2 heat pump handling three evaporator temperatures, domestic water pre-heat, space heating coupled with geo-exchange has never been designed before. While not a system that is planned for all future stores, it breaks down a historical barrier for U.S. retailers with grocery to use a natural refrigerant as well as not throw away useful heat from refrigeration systems.

Operation and Maintenance

These stores do not have onsite engineers that maintain equipment. So designing a net zero energy store that could be maintained easily was a constant conversation. Building staff was trained on local operation of the lighting and comfort controls and were made award of the warning systems associated with CO_2 system (e.g. leak detection system.) The stores are maintained by service contractors, who were specially trained to be aware and proactive with the energy efficient operation of the building systems.

The building automation, measurement and verification, and lighting control systems were all setup for remote monitoring and control. The Owner has personnel at the corporate office that can make adjustments to the comfort systems and monitor alarms. Additionally, project engineers and the commissioning agent have remote access and are constantly reviewing operation and making adjustments to fine tune building performance.

Micro-inverters on solar PV system allow for real-time feedback on the performance of the system. If panels are covered in snow, dirty or go bad, notification is sent to maintenance personnel and they can be individually replace with minimum impact to energy performance. Micro-inverters also allow for the system to stay online when a single panel or multiple panels go off. Conversely had a central inverter been installed, a single panel going offline can take down an entire array or sub-group. With the panel clip system on the metal pan roof, panel replacement is quick and easy.

The heat pump system is the most difficult to maintain. Most refrigeration service contractors are not setup to maintain a CO_2 systems like this and parts for 80 bar systems are not readily available in the U.S. The refrigeration contractor was trained on operation of the heat pump unit and the manufacturer installed a remote monitoring system to allow their personnel to troubleshoot and assist remotely (from Europe) if necessary.

Lessons Learned:

1. US refrigeration equipment suppliers lack sufficient stock of 80 bar rated components, which will hopefully change as more equipment is adopted into similar applications.

Cost Effectiveness

The Owner has not yet publically stated the cost for the entire project, although total package payback was never an objective. The only cost effectiveness metric being shared at this time is that the store is realizing a 20% investment rate of return, based on energy and revenue. Because the store was designed to be an innovation laboratory, additional money was spent on products, materials, systems and equipment that the retailer was interested in experimenting with and that could potentially be included in future prototype store design or retrofit throughout the 8,000 plus existing stores.

The Owner has shared publicly that it used a strategy of using marketing funds to offset portions of the additional construction costs. While annual utility costs for this building are less than what the previous store on this site cost to operate every two months, energy isn't the only consideration for cost effectiveness. Harder to quantify metrics such as brand recognition and trust factor into how the stores generate revenue. They also have stated that sales revenue at the new store has significantly exceeded that of the store that previously resided on the site, and that the project was well worth the added expense. Features such as LED lighting have proven to have a great return on investment and are being incorporated into future store designs. The heat pumps system was a very large cost and isn't yet cost effective for future stores, however the use will hopefully promote wider adoption or more mainstream production of equipment, thus reducing system cost.

Environmental Impact

The building design achieved LEED Platinum Certification in 2014 and several key environmental conservation factors contributed to that, including: conservation practices and recycling during construction, storm water detention, recycled content in materials, no-mercury lighting, onsite renewable energy generation, electric vehicle car charging stations, low-flow plumbing fixtures, all variable speed HVAC equipment, and an all-natural refrigerant HVAC&R systems. The near zero annual energy footprint (soon to be net zero or net positive) and the use of all natural refrigerants are the biggest environmental impact from the project.

The following metrics demonstrate the actual performance of the building and the environmental impact. The figure displays 2014 and 2015 year-to-date net energy performance.

2014 Calendar Year Metrics

2014 Site Energy Use:	330,007 kWh/year (36% grid | 64% solar)
Site EUI (Store | National Median)*:	71.0 kBtu/ft^2 | 162 kBtu/ft^2 (-56%)
Source EUI (Store | National Median)*:	131.1 kBtu/ft^2 | 288 kBtu/ft^2 (-54%)
Annual Net Electricity from the Grid:	18.6 kBtu/ft^2
Onsite Renewable Energy:	52.4 kBtu/ft^2
Calibrated Model 90.1-2007 Savings vs. Baseline:	95.5% by energy (including solar PV)
Carbon Footprint*:	226.2 $MTCO_2e$

*Metrics from ENER GY STAR Portfolio Manager for 2014 Calendar year.

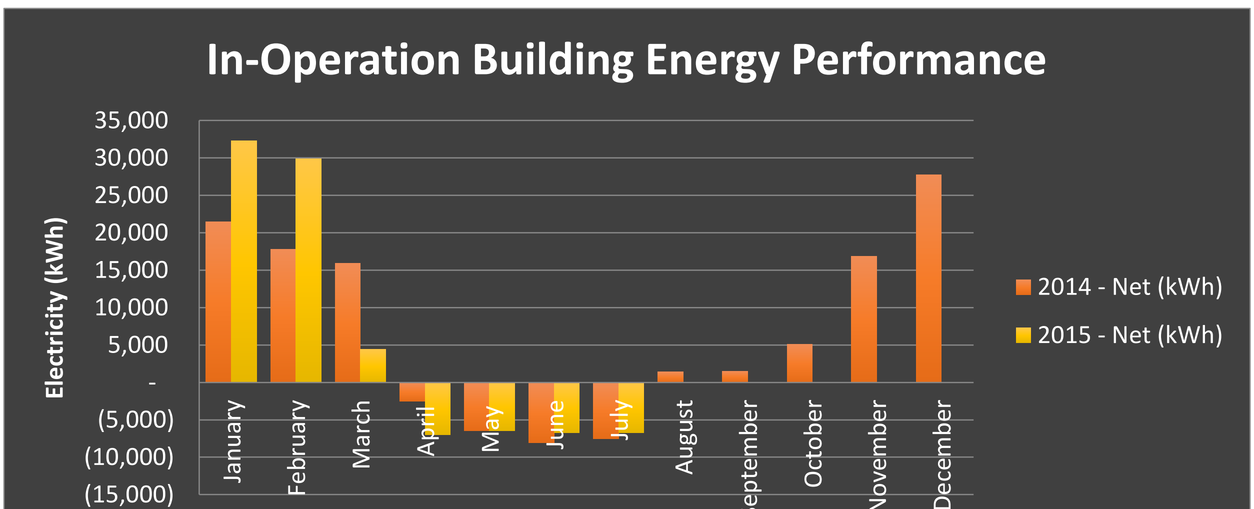


Figure 6 - 2014/2015 Net Energy Performance

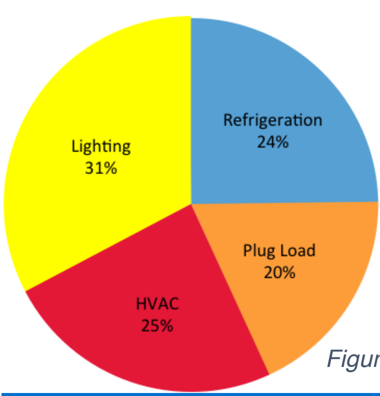


Figure 7 – Annual Energy by End Use