Walmart is using highly efficient light-emitting diode fixtures to highlight its produce section. *Photo by Dennis Schroeder, NREL 32771*

Walmart — Saving Energy, Saving Money Through Comprehensive Retrofits

Walmart, the world's largest retailer, was founded in 1962 by Sam Walton. It owns and operates more than 11,000 retail units under 71 banners in 27 countries, and comprises 1.1 billion ft^2 of floor space. In 2009, Walmart partnered with the U.S. Department of Energy (DOE) to develop and demonstrate energy retrofits for existing buildings. The goal was to reduce energy consumption by at least 30% versus ASHRAE Standard 90.1-2007 or versus pre-retrofit energy consumption as part of DOE's Commercial Building Partnerships (CBP) Program.[1] The project presented here is the retrofit of a 213,000-ft^2 store in Centennial, Colorado, with energy efficiency measures (EEMs) across multiple building systems. It is part of Walmart's ongoing environmental sustainability program, which originated in 2005. The National Renewable Energy Laboratory (NREL) provided technical expertise in collaboration with Stantec, which provided detailed energy modeling services for the project. NORESCO and Mountain Engineering Partnership were responsible for the project measurement and verification. In addition to contributing to DOE's CBP program, the solutions installed and tested during the Centennial retrofit project will contribute to Walmart's Better Buildings Challenge commitment to reduce its U.S. energy use per square foot by 20% by 2020. These solutions are also expected to contribute significant benefits to Walmart's bottom line through reduced energy costs. The lessons learned from this study will be replicated at a large scale in Walmart stores and

[1] A DOE public/private cost-shared initiative to demonstrate cost-effective replicable ways to achieve dramatic energy savings in commercial buildings that are applied to specific new construction and retrofit building project(s) and that can be replicated across the market.

Project type	Retrofit
Building type	Walmart Supercenter with an auto center, garden center, pharmacy, grocery, and a McDonald's (big-box retail)
Climate zone	5B (cool and dry), ASHRAE 90.1-2007
Barriers addressed	• Measures must not interfere with customer experience or sales operations • Store must be open and operational 24/7 during the retrofit work
Square footage of project	213,000 ft^2
Energy savings	Electricity savings • 507,800 kWh (pre-retrofit baseline) • 2,811,900 kWh (ASHRAE 90.1-2007 baseline) Natural gas savings • 27,800 therms (pre-retrofit baseline) • 3,700 therms (ASHRAE 90.1-2007 baseline)
% energy use savings	• 19% (pre-retrofit baseline) • 34% (ASHRAE 90.1-2007 baseline)
Energy cost savings[2]	• $66,600 (pre-retrofit baseline) • $258,500 (ASHRAE 90.1-2007 baseline)
% energy cost savings	• 14% (pre-retrofit baseline) • 37% (ASHRAE 90.1-2007 baseline)
Expected simple payback time of retrofit measures	3-5 years (pre-retrofit baseline)[3] <2 years (ASHRAE 90.1-2007 baseline)
Annual avoided carbon dioxide emissions	1,097,000 lb/yr (pre-retrofit baseline)[4] 4,318,000 lb/yr (ASHRAE 90.1-2007 baseline)
Retrofit completion date	May 2013

[2] Calculated using a virtual charge of $0.091/kWh and annual average natural gas consumption charge of $0.7107/therm based on Xcel Energy: Secondary General Rates: Rate Summation on pages 20–23. Retrieved on October 16, 2014.
[3] Several retrofit measures were installed as first-time pilot projects that required additional engineering to be integrated successfully. The ultimate goal is for an overall simple payback of 3–5 years once those systems have been optimized for broad rollout.
[4] Calculated using the EPA Greenhouse Gas Equivalencies Calculator. Accessed February 20, 2015.

will set an example for other big-box retail companies throughout the nation.

The Centennial store includes several spaces with 24-hour operation: a grocery sales area, a general merchandise sales area, a garden center, stockrooms, receiving racks, and back offices that are mainly occupied by Walmart associates. Non-24-hour spaces include the service deli, the McDonald's restaurant, the vision center, the pharmacy lab, and the auto center. Refrigerated cases are located in the stockrooms and in the grocery sales area. The store includes an extensive electrical submetering system installed by NREL that has been collecting data from various store end uses since 2006. Data from this system were used to benchmark the performance of Walmart's new high-efficiency prototype store design and to calibrate the CBP baseline energy models. This data acquisition system was augmented to capture detailed performance data on the EEMs, most of which were installed in early 2013.

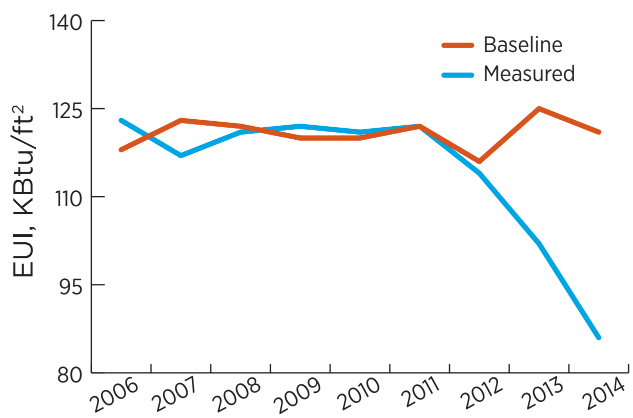
Walmart's building efficiency work is part of a wider Environmental Sustainability initiative—one designed to move the company to 100% renewable energy and reduce overall demand for energy. More specifically, the company aims to drive the production or procurement of 7 billion kWh of renewable energy by the end of 2020 and reduce its energy consumption per square foot by 20% by the end of 2020, versus a 2010 baseline across its global building portfolio. The company's strategy for achieving a 100% renewable energy supply follows a tiered approach including direct ownership, onsite generation facilitated by third-party power purchase agreements, and green power purchases (either wholesale or through utility green power purchasing programs). Walmart is currently the largest U.S. onsite green power generator, according to the U.S. Environmental Protection Agency's Green Power Partnership.

The remainder of this case study presents the measured whole-building energy savings and discusses the EEMs comprising the CBP retrofit project: the criteria for selecting the EEMs, a description of each, and the individual and aggregate energy savings. It also discusses lessons learned for each EEM.

Whole-Building Energy Savings

Utility bills from as early as 2006 were available to compare pre- and post-retrofit energy consumption. Energy models (described on page 5) were calibrated using the utility bills and submetered electricity data. The bills were also used to evaluate the energy savings provided by the EEMs implemented at the store. The statistical relationship between monthly electricity and gas consumption and outdoor air temperature (OAT) from 2006–2012 (pre-retrofit) was used to estimate baseline energy consumption (i.e., how much energy the building would have consumed in 2013 and 2014 if EEMs had not been implemented). This baseline served as a benchmark for post-retrofit performance. Figure 1 shows a graph of energy use intensity (EUI, which is the onsite whole-building energy consumption normalized by floor area) for 2006–2014. The figure includes the estimated annual baseline consumption (red), calculated using the measured monthly average OAT, and measured annual consumption (blue). For 2006–2012 the two lines are in fairly close agreement because these years preceded the major energy retrofits. The baseline did not agree perfectly with pre-retrofit energy use, because gas and electricity consumption variability was not perfectly explained by OAT. Comparing the measured whole-building energy consumption averaged over 2013–2014 (after the energy retrofits were implemented) to the pre-retrofit baseline showed a 24% reduction (18% in 2013 and 29% in 2014), which exceeded the 19% energy model-based prediction. The difference in savings between 2013 and 2014 reflected some of the early challenges of integrating new technologies such as refrigeration waste heat reclaim into the store. Interestingly, the drop in energy use in 2012 was apparently caused mainly by an unusually warm winter and an early spring rather than by actions taken to improve efficiency. The 24% average reduction in total annual whole-building energy use reflected a 15% reduction in electricity use (~650,000 kWh) and a 39% reduction in gas use (~36,500 therms) versus the baseline.

Figure 1. Baseline and measured EUI



Decision Criteria

The decision-making process was based on the following guiding principles:

- Maintain proven customer experience as the #1 priority.
- Protect customers: store and parking lot security was a key component of the project.
- Ensure the cost effectiveness of all EEMs.
- Keep the design simple, functional, and low maintenance.
- Emphasize the reproducibility of measures in other store retrofits.
- Maintain 24/7 store operations.
- Be proud of the quality of the final project.
- Maintain visual light levels needed for sales and signage.

- Respect the concerns of the store's third-party food services, vending machine, and ad placement partners.
- Maintain good produce quality.

Economic, operational, and policy considerations also contributed to the decision-making process.

Economic Considerations

Walmart has traditionally operated in the low-cost market segment; however, it has recently repositioned itself as a value leader. Significant economic factors are:

- Walmart is a large publicly traded company that emphasizes profits. It has chosen to focus on energy efficiency as a way to control operating costs and demonstrate environmental responsibility.
- Walmart selects EEMs with favorable simple payback periods of typically 3–5 years.
- Because Walmart often buys equipment directly from the manufacturers and can buy in volume, it can negotiate lower first costs that make EEMs quite economical.
- The DOE Better Buildings Alliance facilitates the banding together of big-box retailers to further increase the market pull for cost-effective energy efficiency technologies.
- By selling energy efficient products, Walmart can also provide consumers with opportunities to save energy and money.

Operational Considerations

Walmart updates its stores on a rolling 7-year cycle. Some building systems, such as lighting, are refreshed with each cycle. Others, such as mechanical systems, are updated on alternate cycles (i.e., every 14 years). The cycles are not fixed, and Walmart will move aggressively to integrate a beneficial new technology into its business.

- The entire operation revolves around maintaining customer comfort and satisfaction by meeting set points for temperature, lighting levels, and air quality.
- Each building system currently works independently with little or no regard for the other systems. One goal of this project is to optimize the operation as a whole system for cost and performance.
- Solid-state lighting fixtures for spotlights, refrigerated cases, exterior security, and parking lots have long lifetimes that can lower maintenance costs.

Policy Considerations

The guiding policy was shaped by the project's overarching goal: test robust, easily deployed EEMs in multiple building systems that save on energy use for Walmart stores supporting the company's 20% site EUI reduction by 2020 goal and that can be replicated by other big-box retail stores (see the sidebar on page 1).

Energy Efficiency Measures

Table 1 (page 4) lists the EEMs that were implemented in the project based on the economic, operations, and policy decision criteria mentioned earlier. The measure-by-measure impacts of the implemented EEMs are presented relative to the pre-retrofit baseline model to give a realistic estimate of savings. The individual EEM estimates were calculated by applying each EEM one at a time to the pre-retrofit model. This comparison was not possible for the ASHRAE baseline; many other building parameters besides the EEMs were different because original building design decisions were made before the retrofit was accomplished. Energy savings for each building end use is presented relative to both the pre-retrofit baseline and the code-compliant (ASHRAE 90.1-2007 baseline) model. The sum of the savings estimates for the individual EEMs may differ from those estimated for all EEMs applied together because some measures interact.

An NREL engineer checks the operation of the refrigeration system. *Photo by Dennis Schroeder, NREL.*

Table 1. Energy Efficiency Measures

		Expected Annual Savings			Simple Payback (Years)	Installed Cost to Achieve 3–5 Year Simple Payback
		$/year	kWh/year	Therms/year		
	Lighting					
L1	Perimeter light reduction: removed two lamps from each of the 111 4-lamp perimeter fixtures on the general merchandise sales floor. Lighting in the grocery perimeter fixtures was retained as is.	$4,500	61,500	(800)	<1	N/A
L2	Produce lighting upgrade: replaced 48 100-watt metal halide fixtures with 96, 12-Watt, 1000-lumen LED spotlights.	$2,700	46,200	(1,400)	>5	$8,100–$12,300
L3	Canopy downlighting upgrade: replaced 32 recessed 70-watt metal halide downlights with LED downlights and retrofit kits.	$900	10,100	–	>5	$2,700–$4,500
L4	Pharmacy canopy lighting upgrade: replaced 6 pharmacy canopy 70-watt metal halide fixtures with 36-watt recessed LED fixtures.	$200	1,900	–	>5	$600–$1,000
L5	Wall-mounted security light upgrade: replaced 17 175-watt metal halide lamps with 13 20-watt and 4 202-watt LED fixtures. The connected lighting load decreased from 3.4 kW to 1.1 kW. The lights operate an average of 11 hours per day.	$1,000	9,500	–	<3	N/A
L6	Garden center bulk storage area lighting upgrade: replaced 8 400-watt metal halide lamps with 8 202-watt LED fixtures. The connected lighting load decreased from 3.8 kW to 1.7 kW; the lights operate an average of 11 hours per day.	$900	8,900	–	<3	N/A
L7	Parking lot lighting upgrade: replaced 50 1,000-watt lamps with 87 263-watt LED fixtures. The LEDs exceed Illuminating Engineering Society of North America RP-20 minimum light levels. The site-connected lighting load decreased from 70 kW to 25.5 kW. The lights operate an average of 11 hours per day.	$12,000	124,400	–	>5	$36,000–$60,000
L10	Installed back-of-house occupancy sensors.	$200	2,000	(5)	>5	$600–$1,000
L11A	Garden center outside bag goods area: turned lights off during daytime (before retrofit the lights were on 24/7).	$1,400	16,700	–	<1	N/A
L11B	Garden center shade cloth area: turned lights off during daytime (before retrofit the lights were on 24/7).	$300	4,800	–	<1	N/A
	Lighting Subtotal	**$24,100**	**286,000**	**(2,200)**	**3–5**	**$72,300–$120,500**
	Heating Ventilation, and Air Conditioning					
H3	Use waste heat from 2 medium-temperature refrigeration systems to preheat ventilation air for the grocery sales area. The energy savings from this EEM depends on climate and should be evaluated carefully before implementing.	$10,000	(49,000)	18,800	>5	$30,000–$50,000
H7	Direct evaporative cooling of rooftop unit (RTU) condensers combined with indirect evaporative precooling of ventilation air on 6 of the 8 20-ton sales RTUs. The energy savings from this EEM depends on climate and should be evaluated carefully before implementing.	$7,500	49,900	(100)	>5	$22,500–$37,500
	HVAC Subtotal	**$17,500**	**900**	**18,700**	**>5**	**$52,500–$87,500**
	Refrigeration					
R1	Anti-sweat heater control upgrade: repaired and upgraded the existing control panel.	$10,300	123,500	(400)	<1	N/A
R2	Glass doors and LEDs added to medium-temperature dairy, deli, and beer cases, but not horizontal “coffin”-style cases. Calculated savings includes the negative impact of added anti-condensate heaters.	$14,200	68,600	12,700	>5	$42,600–$71,000
R3	Replace permanent split capacitor evaporator fans with electronically commutated motor fans in all walk-in freezers and coolers (59 motors total).	$3,100	41,900	–	>5	$9,300–$15,500
	Refrigeration Subtotal	**$27,600**	**234,000**	**12,300**	**3-5**	**$82,800–$138,000**
	Total					
	Total Post-Retrofit Versus Pre-Retrofit Baseline	**$69,200**	**520,900**	**28,800**	**3-5**	**$207,600–$346,000**

Energy Use Intensities by End Use

Energy modeling was an integral part of the design process for the Centennial Walmart project, enabling the design team to verify that the EEMs selected would achieve the energy savings target. Walmart also used modeled savings to screen EEMs based on their economic returns.

To assess whole-building savings, three energy models were created: an ASHRAE 90.1-2007 baseline model, a pre-retrofit baseline model, and a post-retrofit model (see Table 2).

The ASHRAE 90.1-2007 baseline model is minimally code compliant—it represents how the store would be built and operated if constructed to the minimum requirements of ASHRAE Standard 90.1-2007.

The pre-retrofit baseline model reflects the implementation of the Walmart Existing Building Optimization Program before the energy retrofit measures were installed. This is a retro-commissioning program for HVAC and refrigeration systems that is intended to identify and correct mechanical issues commonly encountered in Walmart stores. Both pre-retrofit and post-retrofit models were calibrated against data collected from electricity submeters and utility bills.

Table 3 shows a comparison of ASHRAE 90.1-2007 baseline, pre-retrofit, and post-retrofit model input assumptions for the building envelope.

Table 4 (page 6) shows the interior lighting and electrical plug loads assumed for each model. Although pre-retrofit installed lighting power density was much lower than code minimum, differences were minor between pre- and post-retrofit; also, the plug loads were assumed to be the same for all three models, because EEMs were not installed to control this end use.

Table 2. Energy Models Used by Walmart

Model	Intent	Annual EUI (kBtu/ft^2)
ASHRAE 90.1-2007 Baseline	Represents a building that meets Walmart's needs and is built according to the prescriptive specifications of ASHRAE Standards 90.1-2007 and 62.1-2007.	139
Pre-Retrofit Baseline	Represents the Centennial Walmart before the CBP energy-saving retrofit work was undertaken. The building has lower lighting power density and a more efficient mechanical system than the ASHRAE 90.1 baseline building.	113
Post-Retrofit	Represents the Centennial Walmart with all energy-saving retrofit work completed and operating as intended.	92

Table 3. Comparison of Energy Models

	ASHRAE 90.1-2007 Baseline	Pre-Retrofit Baseline	Post-Retrofit
Roof	Insulation entirely above deck, R-20 continuous insulation, U-0.048		
Walls, Above Grade	Steel-framed R-13 batt + R-7.5 c.i., U-0.064	12-in. thick concrete block wall, Solid grouted U-0.52	
Slab-on-grade	Unheated slab, F-0.73		
Vertical glazing	None		
Skylight	U-0.69, Solar heat gain coefficient-0.39	U-0.54, Solar heat gain coefficient-0.40	
Skylight % of roof	3.85%		
Opaque doors	Nonswinging, U-0.50		

Table 4. Assumed Interior Lighting and Electrical Plug Loads

Zone	Zone Area (ft²)	Interior Lighting (W/ft²)			Plug Loads (W/ft²)		
		ASHRAE 90.1-2007	Pre-Retrofit	Post-Retrofit	ASHRAE 90.1-2007	Pre-Retrofit	Post-Retrofit
Garden West	1,259	1.70	0.48		–		
Garden East	7,643	1.70	0.59		0.07		
Fish/Pets		1.70	0.76		0.64		
Merchandise West	49,656	1.70	1.03	0.97	0.04		
Interior Pharmacy	2,730	1.70	0.82		4.26		
Merchandise East	55,916	1.70	1.06	1.02	0.48		
Back Offices	10,516	1.10	0.58	0.52	2.23		
Auto Center	6,899	1.90	0.58		1.94		
Vestibule West	1,020	0.50	0.27		–		
Vision Center	1,804	1.70	1.40		0.99		
Front Tenants	4,614	1.70	0.61		2.20		
McDonalds Dining	1,704	2.10	1.81		38.49		
Grocery Sales	37,384	1.70	0.39	0.35	0.05		
Receiving Racks	13,757	0.80	0.43		0.85		
Vestibule East	1,764	0.50	0.18		2.65		
Service Deli	4,956	1.20	0.45		8.37		
Stockroom East	5,923	0.80	0.15		–		
Stockroom West	3,100	0.80	0.19		–		
Total	**213,052**	**1.56**	**0.77**	**0.73**	**1.02**		

The ASHRAE 90.1-2007 baseline model used a variable air volume system served by a chiller and boiler in some zones and packaged single-zone equipment served by direct expansion cooling and natural gas furnaces in others, consistent with 90.1-2007 guidance. In the pre-retrofit and post-retrofit models, all zones were served by packaged single-zone rooftop equipment.

Expected Annual Energy Cost Savings by End Use

Table 5 shows estimated energy cost savings[5] resulting from all CBP retrofits, by building end use:

Table 5. Modeled Retrofit Cost Savings by End Use Versus Pre-Retrofit

End Use	Electricity Savings ($/year)	Natural Gas Savings ($/year)	Total ($/year)
Heating	$0	$19,800	$19,800
Cooling	$3,800	$–	$3,800
Interior Lighting	$9,500	$–	$9,500
Exterior Lighting	$14,400	$–	$14,400
Interior Equipment	$0	$–	$0
Pumps	$(3,200)	$–	$(3,200)
Fans	$(900)	$–	$(900)
Water Heater	$0	$–	$0
Refrigeration	$22,700	$–	$22,700
Heat Rejection	$500	$–	$500
Total	**$46,800**	**$19,800**	**$66,600**

[5] Virtual energy cost based on actual utility rates used at the Centennial store: electricity: $0.091/kwh, natural gas: $0.7107/therm. Savings were calculated using two calibrated energy models: one representing pre-retrofit operation and the second representing post-retrofit operation. Walmart's standard HVAC and refrigeration retro-commissioning process was performed before the retrofits were implemented and is reflected in the pre-retrofit model results.

Expected Annual Energy Savings by End Use

All end-use savings are derived from a comparison of the post-retrofit model results against the ASHRAE 90.1-2007 and pre-retrofit baseline models (see Table 6). Therefore, the results reflect the combined savings of all implemented EEMs and how they interacted across various end uses. Negative savings indicate increased energy use.

Table 6. Post-Retrofit Savings by End Use

End Use	Versus ASHRAE 90.1-2007		Versus Pre-Retrofit	
	Electricity Savings (kWh/year)	Natural Gas Savings (Therms/year)	Electricity Savings (kWh/year)	Natural Gas Savings (Therms/year)
Heating	–	3,700	–	27,800
Cooling	140,600	–	40,700	–
Interior Lighting	1,731,800	–	100,800	–
Exterior Lighting	397,300	–	159,200	–
Interior Equipment	–	–	2,400	–
Heat Reclaim Pump	(35,200)	–	(35,200)	–
Fans	254,700	–	(11,000)	–
Pumps	56,400	–	–	–
Heat Rejection	2,000	–	–	–
Water Heater	4	–	–	–
Refrigeration	257,100	–	245,600	–
Condenser	7,200	–	5,300	–
Total	**2,811,900**	**3,700**	**507,800**	**27,800**

Expected Annual Energy Use Intensity by End Use

All end-use savings are derived from a comparison of the post-retrofit model against the ASHRAE 90.1-2007 baseline model and pre-retrofit baseline model (see Table 7). Therefore, the results reflect the combined savings of all implemented EEMs and how they interacted across various end uses.

Table 7. End-Use Energy Comparison

End Use	ASHRAE 90.1-2007 Baseline Annual EUI (kBtu/ft^2)	Pre-Retrofit Baseline		Post-Retrofit		
		Annual EUI (kBtu/ft^2)	Savings Versus ASHRAE Baseline (%)	Annual EUI (kBtu/ft^2)	Savings Versus ASHRAE Baseline (%)	Savings Versus Pre-Retrofit Baseline (%)
Heating	24	35	(48%)	22	7%	37%
Cooling	6.6	5.0	24%	4.4	34%	13%
Interior Lighting	44	18	60%	16	63%	9%
Exterior Lighting	6.9	3.1	55%	0.6	92%	81%
Interior Equipment	21	21	0%	21	0%	0%
Fans	8.5	4.3	50%	4.5	48%	(4%)
Pumps	0.9	–	100%	0.6	33%	–
Water Heater	2.5	2.5	0%	2.5	0%	0%
Refrigeration	23	23	1%	19	18%	17%
Heat Rejection	1.6	1.6	2%	1.5	7%	5%
Total	**139**	**114**	**19%**	**92**	**34%**	**19%**

Lessons Learned

This section highlights key lessons from the Walmart Centennial CBP retrofit project.

Lighting

- The interior lighting EEMs were the most cost effective to implement. They included:
  - Replace metal halide fixtures with highly efficient LED fixtures in selected areas of the store.
  - Delamp fixtures along the perimeter of the general merchandise zone perimeter while maintaining bright walls and well-lighted signage.
  - Turn off garden center lights during the daytime.
  - Install occupancy sensors in the back-of-house areas to turn off lights when spaces are unoccupied.
- With the lighting power density reduction, heating energy can increase. From a source energy perspective, this tradeoff is still beneficial. To counteract the increased heating energy consumed at the site, refrigeration waste heat was recovered to preheat ventilation air and doors were added to the open medium-temperature cases.
- Exterior lighting provided a large reduction in energy use and is a self-contained measure that does not interact with other end uses.

Walmart is expected to save an estimated $12,000/yr from its parking lot LED retrofit. *Photo by Dennis Schroeder, NREL 32772*

Heat Reclaim

- Significant waste heat can be reclaimed from the refrigeration system and used to warm ventilation air during the winter by 20°–30°F over outdoor conditions.
- Parasitic pumping energy can be significant when glycol is used to transfer heat from the refrigeration system to air handling units, and care should be taken to minimize the pumping pressure drop in the heat recovery loop. The pump should be controlled by a variable frequency drive to provide either variable or multispeed control to match the heating load with the heat supply. A variable frequency drive is also helpful to set the correct speed during commissioning when simple constant-speed control is used.
- Implementation costs can be appreciable when significant modifications of airside systems are required to add a heat recovery coil. The economics of refrigeration heat recovery are likely to improve significantly when incorporated as an integral design element, rather than implemented as a retrofit.
- For how-to guidance on heat reclaim system performance and design, consult the *DOE Refrigeration Playbook: Heat Reclaim*.

Walmart used evaporative cooling for rooftop condensers and ventilation air to save energy during the summer. *Photo by Dennis Schroeder, NREL*

Evaporative Cooling

- Control should be integrated within the existing building automation system, which should be used to enable evaporative cooling based on the system's own OAT sensor. If evaporative cooling units are controlled using their own onboard OAT sensors, those sensors must be carefully placed and shielded to ensure proper control. Control issues can arise with low-cost thermostats and sensors. Proper control of the evaporative cooling units as a function of OAT should be verified.
- The system should be properly commissioned and the airflow tested and balanced to identify and correct deficiencies from installation and startup.
- Broken outdoor air dampers and or actuators should be replaced to ensure they modulate from minimum position to full open based on an economizer call.
- Regular preventative maintenance is critical to maintain system functionality and energy savings. For example, direct evaporative cooling of RTU condensers will cause more dirt to accumulate on the condenser coil, evaporative media, and sump. Sump float valves also need regular adjustment. Proper winterization is needed because freezing can destroy components such as submersible pumps. A hard copy of the operations and maintenance guide should be provided in a placed inside the RTU cabinet in its own folder location and a digital copy should be provided to the building owner/manager.

- Attention must be paid to setting and maintaining bleed water control (needed to refresh the sump water over time. Otherwise, significant water waste or inadequate bleed, which can shorten system component life and degrade effectiveness, may occur.

- Indirect evaporative cooling of ventilation air allows the economizer OAT high limit to be raised by 5°–7°F above typical return air temperatures, leading to additional energy savings.

Refrigeration

- Refrigeration EEMs reduced the refrigeration energy use *and* the heating energy use in the sales area.

- Gathering information about case credits (the impact of refrigerated cases on the energy balance of the sales area), anti-condensate heater power, and controls from vendors to build the model with DOE's EnergyPlus modeling software proved challenging. Consequently, some assumptions had to be made about operating conditions, which meant that the modeling team needed a high level of refrigeration expertise. Fortunately, the team had access to refrigeration data from multiple years of operation. These data allowed the team to test its assumptions and improve the quality of its modeling efforts.

- There is currently no published definition of a code-compliant baseline supermarket refrigeration system (analogous to ASHRAE Standard 90.1 Appendix G) that can be used to benchmark energy savings. NREL is currently developing such a definition, called *A Supermarket Refrigeration Baseline for Benchmarking Energy Performance*. Pre-retrofit baseline data were used to calibrate the refrigeration system in the code-compliant baseline model to provide a clear and accurate comparison for calculating retrofit energy savings.

Adding doors and LED lights to medium temperature cases saves refrigeration energy and keeps refrigerated aisles more comfortable. *Photo by Dennis Schroeder, NREL*

- Retrofitting doors on open medium-temperature cases requires additional work to account for the lower refrigeration loads post-retrofit, including downsizing of the thermostatic expansion valves, evaporator pressure regulators, and suction risers. See the Better Buildings Alliance's *Guide for the Retrofitting of Open Refrigerated Display Cases with Doors* for more information about this topic.

The red pump delivers waste heat from the refrigeration system to warm up ventilation air in the winter. *Photo by Dennis Schroeder, NREL 32768*

Customer Experience

- EEMs that could negatively affect the user experience were not permitted. In all cases, before considering an EEM implementation, its potential effect on customer experience had to be thoroughly researched.

- For example, reducing plug loads by means of occupancy sensors for electrical products in the sales area, or exterior lighting recommendations that involved reducing illumination in the parking lot, were eliminated from consideration.

General Considerations

- In a retail environment, retrofit measures are generally pursued and installed individually; they are not developed as an integrated set of drawings and specifications. This approach may cause companies to miss opportunities to improve the economics of more expensive measures by combining them with EEMs that provide a quick return on investment. Utility incentives should also be investigated as a means to lower first costs.

- Selecting a qualified contractor that has experience with the new systems being installed is also important.

U.S. DEPARTMENT OF ENERGY
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For more information, visit:
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DOE/GO-102015-4629 • March 2015

Prepared by the National Renewable Energy Laboratory (NREL), a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. NREL is operated by the Alliance for Sustainable Energy, LLC.