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Energy Assessment of Convenience Stores

Part 1: Survey of Convenience Store Equipment and Opportunities

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ABSTRACT

Convenience stores have among the highest energy density of any commercial building type because of considerable refrigeration, lighting, and space conditioning loads, coupled with long operating hours. Many utilities have commercial energy efficiency incentive programs with offerings for convenience stores already, but there are opportunities for further savings. In this report, the first of a two-part effort, surveys of convenience stores are undertaken to understand the equipment used, the variation in equipment between stores, and the opportunities for energy savings. A high-level assessment of 24 stores shows the similarities and differences between store configurations, which may present opportunities for replicable programs, but also barriers as different owners have different brand and format requirements. In addition, two stores are investigated in detail, and will be included in a detailed monitoring in the second phase of this project. This effort will help utilities identify opportunities to grow and improve efficiency, peak demand reduction, and demand response options.

Keywords
Energy efficiency
Refrigeration
Space conditioning
Lighting
Commercial buildings
Convenience store

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INTRODUCTION AND BACKGROUND

Introduction

Convenience stores are a unique building type, as the indoor spaces are often brightly-lit, contain large windows, frequently-opened doors, and house large refrigeration loads. This combination of building characteristics adds up to high energy consumption and potential opportunities for savings.

This report is the first in a two-part effort to examine energy efficiency and demand response opportunities in convenience stores. The overall project is intended to examine high-level trends of the industry, as well as detailed surveys of specific convenience stores. The focus of the project is on refrigeration, HVAC, and lighting technologies. This report is the first of two phases which will take place over 2017 and 2018. In this report, industry trends, end-use energy consumption, and energy efficiency opportunities are explored for convenience stores. In the second phase of this effort, data collection from field sites will provide an in-depth profile of end-use energy and demand, which will allow for EPRI to identify opportunities for savings.

Convenience stores are categorized in the North American Industry Classification System (NAICS).[1] The two following categories apply:

- Convenience Stores: "This industry comprises establishments known as convenience stores or food marts (except those with fuel pumps) primarily engaged in retailing a limited line of goods that generally includes milk, bread, soda, and snacks."
- Gas Stations with Convenience Stores: "This industry comprises establishments engaged in retailing automotive fuels (e.g., diesel fuel, gasohol, gasoline) in combination with convenience store or food mart items. These establishments can either be in a convenience store (i.e., food mart) setting or a gasoline station setting. These establishments may also provide automotive repair services."

Convenience stores can be expected to have variations on a set of typical loads:

- Refrigeration: A range of refrigeration equipment will be present, depending upon the extent of food sales and service at the store. In some cases, stand-alone equipment may be the only refrigeration equipment, but in many stores there are walk-in coolers and/or remote-condensing merchandisers, as well as some back-of-house refrigeration equipment for food preparation. There also may be miscellaneous refrigeration equipment, such as refrigerated food preparation tables, condiment coolers, ice makers and others.

[1] http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

- HVAC: In convenience stores, heating, ventilation, and air-conditioning (HVAC) will generally be accomplished by packaged-rooftop or split direct expansion (DX) systems. Space heating maybe provided by a heat pump, electric resistance, or natural gas furnace. For space heating, approximately 64% of stores are electric-only and therefore use an electric space heating option; natural gas is present in about 36% of convenience stores in the U.S. The number of heat pumps in the EIA Commercial Building Energy Consumption Survey (CBECS)[2] food retail category (which also includes grocery stores) is not statistically significant. Depending upon the size and layout of the convenience store, one or multiple HVAC systems may be used to provide space conditioning and fresh air ventilation.

- Lighting: There is an indoor and outdoor lighting component to every convenience store. For interior, most convenience stores have a drop ceiling with 2x4 troffers densely configured throughout the store. Since product sales are a significant driver for convenience store design, lighting levels are high as in most retail applications. Some stores may also have track lighting or can lighting to accent or highlight specific areas. There is also lighting in refrigeration equipment, typically built into the frame or door. Walk-in coolers or freezers will also have special lighting fixtures rated for cold conditions. For the exterior, a convenience store with a gas station will have a significant lighting load for the canopy. The canopy generally has ceiling mounted lights and may also have spot lights pointing at the pumps. The convenience store typically has exterior signage, generally in the form of a road sign, canopy wrap-around lighting, and a sign on the building which are generally backlit. In addition, the general parking area is usually lit with pole mounted fixtures and building mounted fixtures. All of these specific applications make for a diverse set of lighting requirements for a convenience store.

- Other Appliances: Convenience stores typically also include a variety of other appliances, including water heating, coffee machines, fountain drinks, microwaves and other small cooking appliances, hot food displays, and ice cream machines.

- Gas Service: Many convenience stores also serve as gas stations and contain pumping and sales equipment for gas service. The gas service industry is highly specialized and will not be examined in-depth within this study.

According to the 2012 CBECS survey, there are 131,000 convenience stores (with and without gas stations) in the United States, totaling 470 million square feet. The median store size is 3,000 square feet, median operating hours are 119 per week, and 28 years is the median building age. The energy consumption of these stores varies with age, region and size. Convenience stores are mostly electric: of approximately 131,000 convenience stores connected to the electrical grid in the 2012 CBECS survey, about 48,000 (36.6%) used natural gas. Table 1-1 and Table 1-2 show the electricity and natural gas end-use data for convenience stores. The per-square-foot electricity consumption is among the highest of any commercial end use. Much like supermarkets, the high density of refrigeration loads which are maintained at all hours of the year are a major factor in driving this high energy density.

[2] https://www.eia.gov/consumption/commercial/data/2012/

Table 1-1
Electricity End-Use Data for Convenience Stores (CBECS 2012)

Number of Buildings Using Electricity:		131,000
Total Floorspace:		470 million sq. ft.
Floorspace per Building:		3,600 sq. ft.
Total Electricity Used:		27 billion kWh
Electricity Used:	Total	203,000 kWh per building
	Mean:	56.4 kWh per sq. ft.
	25th percentile:	34.8 kWh per sq. ft.
	50th percentile:	63 kWh per sq. ft.
	75th percentile:	100 kWh per sq. ft.

Table 1-2
Natural Gas End-Use Data for Convenience Stores (CBECS 2012)

Number of Buildings Using Natural Gas		48,000
Total Floorspace:		154 million sq. ft.
Floorspace per Building:		3,200 sq. ft.
Total Natural Gas Usage		10 billion cubic ft.
Natural Gas Usage	Total	215,000 cubic ft. per building
	Mean:	66.4 cubic ft. per sq. ft.
	25th percentile:	18.3 cubic ft. per sq. ft.
	50th percentile:	46.4 cubic ft. per sq. ft.
	75th percentile:	118.3 cubic ft. per sq. ft.

The energy consumption breakdown is shown in Figure 1-1, showing the electric-only consumption and all-fuels consumption. The breakdown below does not include gasoline equipment. Considering the “all-fuel” breakdown, 79% of all energy consumption is used for refrigeration, lighting and heating.

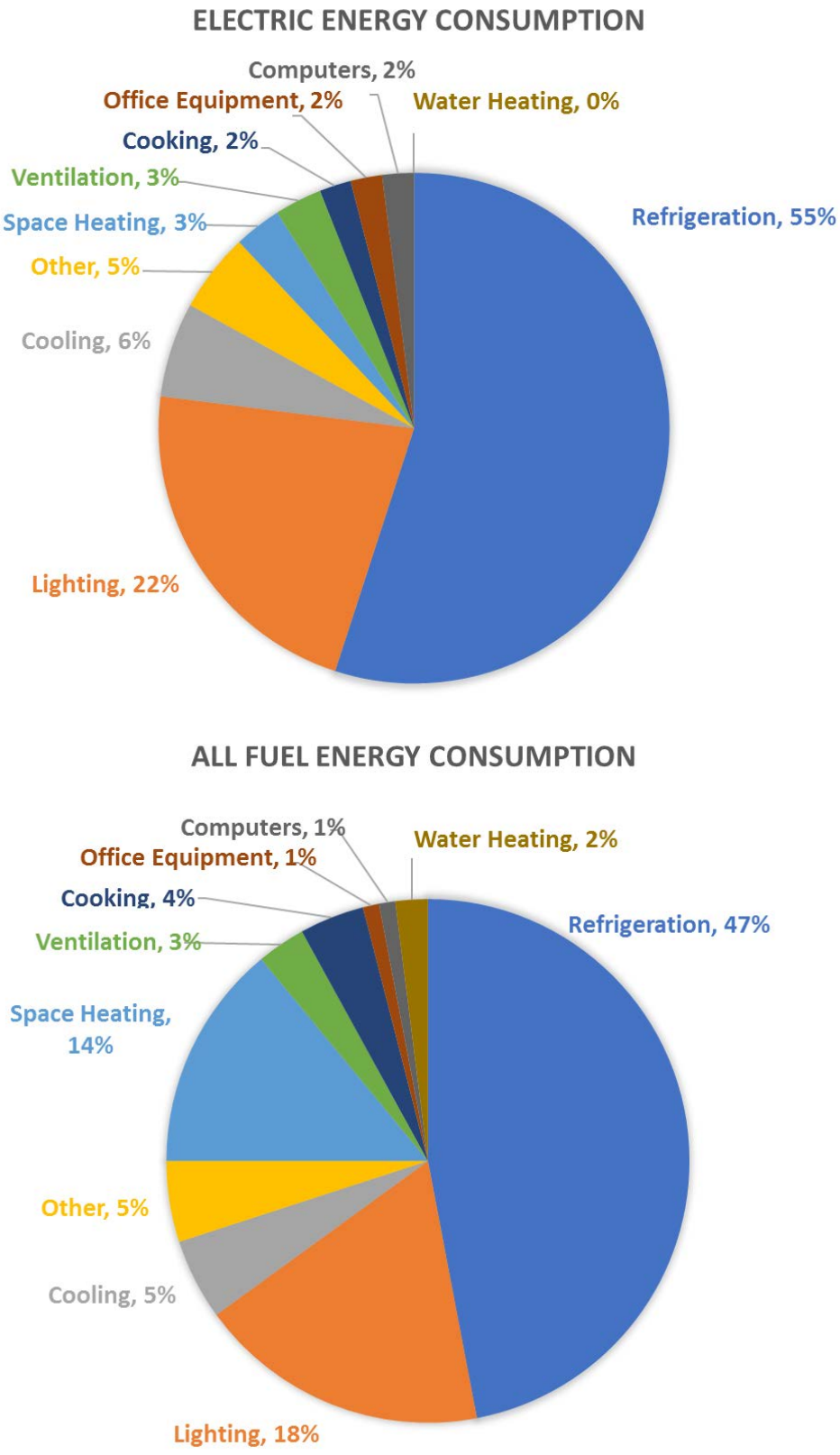

Figure 1-1
Energy Consumption Breakdown for Convenience Stores (CBECS)

Example Existing Utility Programs

One of the objectives of this work is to identify new opportunities for efficiency and demand programs. Many utilities already have incentive programs that can be applied in convenience stores, and some market directly to convenience stores for energy efficiency. Most often the incentives are for technologies that can fit in many categories. In some cases, convenience stores and grocery stores are grouped together. A review of three well-established programs shows a wide range of options available for energy efficiency, including numerous standard offerings. Three utilities from different regions of the country are shown here as examples.

Utility A provides incentives through a prescribed incentive form for commercial customers. For convenience stores, this utility markets high-efficiency lighting in troffers and signs, daylighting controls, high-efficiency HVAC, anti-sweat heater control for refrigeration, EC motors, fan control, head pressure control, efficient case lighting, ENERGY STAR equipment, heat pump water heaters, and other measures. This utility also has some food preparation incentives, including ovens, holding cabinets and ventilation hoods. Some specific measures include:

- Lighting: A per-Watt-saved incentive that is at one level without controls, or a higher incentive level with controls. The "without controls" rate is in the range of $0.15-0.20/watt reduced, compared with $0.25-0.30/watt for "with controls". A slight additional benefit is given for ENERGY STAR or DesignLights Consortium certified LEDs. Also, occupancy sensors, daylighting controls, photocells, and clocks all pay an additional incentive per watt under control.

- HVAC: For unitary or split air conditioners or heat pumps, incentives are available based on the SEER or EER/IEER of the equipment, in the range of $20+ per ton with the incentive scaling linearly with SEER or EER. As an example, a 5-ton system with a 18 SEER would qualify for $60/ton, or $300 total. Other incentives are available in related areas, including window films, electronically commutated motors, and air-side economizers, on a case-by-case basis. Heat pump water heaters also may qualify for between $100-150 per unit.

- Refrigeration: Refrigeration incentives are available for a set of pre-determined items. Anti-sweat heater controls, DLC-rated LED lights, lighting controls and new doors on cases are all incentivized per-linear-foot of case, in the range of $8-25/linear foot (except doors, which are in the range of $250-300/linear foot). ENERGY STAR refrigerators and freezers can receive incentives of up to $400/unit. Floating head pressure control incentives are in the range of $30-40 per HP. Ice makers can be incentivized based on the nominal kWh/100 lbs. of ice, in the range of $100-150 per kWh/100 lbs.

Utility B lists popular measures in the same three categories. In refrigeration, anti-sweat heater controls, ENERGY STAR freezers, and efficient case lighting are listed as most popular. Interior lighting retrofits to LEDs and occupancy sensors for lower-traffic areas (like bathrooms and offices) are also listed. And, high-EER heat pump systems and HVAC controls are listed in the HVAC category. They also have standard incentives for steam cookers and holding cabinets. Some of the specific incentives within the standard measure list include:

- Lighting: Lamp and fixture replacements for interior lighting to LED replacements, from approximately $5 to $105 per unit depending on wattage. In the case of converting linear fluorescents to LED or efficient fluorescents incentives range from $1-10 per lamp. Exterior

lighting replacing HID, incandescent or CFL with LED for about $10-110 per unit. Occupancy sensing and lighting sensor ranging from $10-50 per unit.

- HVAC: Most HVAC incentives subject to custom review and paid on a per-kWh-saved basis. Heat pump water heaters to replace electric resistance commercial water heaters in a range of sizes – for convenience stores, approximately $1,000 per unit
- Refrigeration: Freezers from non-ENERGY STAR to ENERGY STAR, based on internal volume and door type, from $30-450 per unit. Also, anti-sweat heater control for approximately $75/unit. Other equipment may be submitted for review.

Utility C, grouping convenience stores and grocery stores together, recommends lighting replacements to low-wattage linear fluorescent and LED screw-in lights, LED case lighting and occupancy sensors. They also recommend advanced HVAC control, including economizer control and intelligent ventilation control, refrigerator door automatic closers and seals, and anti-sweat heat controls for refrigeration equipment. This utility also has a wide range of food preparation incentives, focusing on ENERGY STAR appliances. Some of their prescribed measures in lighting, HVAC and refrigeration include:

- Lighting: LED troffers are incentivized up to about $40/troffer, and exterior LED fixtures are incentivized about $50-200 per fixture. Low-wattage T8 lamps are also incentivized about $1-2 per lamp. Accent and directional type lights can be incentivized in the range of $5-20 per fixture.
- HVAC: An incentive is available for ENERGY STAR water heaters of $300/unit. Economizer controls for A/C units are incentivized in the range of $20/ton and demand-control ventilation in the range of $100-200/ton depending on sensors and configuration.
- Refrigeration: ENERGY STAR refrigerators and freezers are incentivized based on internal volume and door type in the range of $40-500 per unit, while remote-condensing system refrigerated display cases are incentivized to be high-efficiency models in the range of $50-200 per linear foot. Anti-sweat heaters are incentivized in the range of $25/linear foot and door auto-closers at about $75 each.

2
CONVENIENCE STORE EQUIPMENT

In Part 1 of this project, two survey efforts were undertaken to understand the equipment and electrical load in convenience stores: an in-depth review of two recent-construction (approximately 2015) stores in Texas, and an informal survey of 24 convenience stores in Tennessee. The two stores that were studied in-depth in Texas are expected to be monitored beginning in Winter 2017-18 and utilized in Part 2 of this project.

Detailed Case Study: Texas Host Sites

This report includes a case study of two convenience stores located in Texas. These stores are approximately 5,000 square feet and include refrigerated beverages and a separate beer cooler, packaged foods, hot food and gasoline sales. The stores are part of an effort to examine current practice in convenience stores, as well as potential modifications to help improve energy efficiency and reduce peak demand. The EPRI team visited the stores in the summer of 2017 to survey existing equipment and plan for data monitoring equipment to be installed; equipment installation is expected to take place in December 2017. These two stores were selected because they are nearly identical. It is expected that in the continuation of this research, the team will work to improve the performance of one store via controls changes and monitor the other as a baseline. The following sections describe the existing equipment in the stores.

Refrigeration Equipment Overview

The host convenience stores have a variety of refrigeration loads. The refrigeration equipment includes walk-in coolers and freezers with remote condensers, merchandisers with remote condensers, and stand-alone packaged equipment. There is refrigerated display equipment as well as back-of-house equipment. Figure 2-1 is a photograph of the roof of one of the host stores showing the array of refrigeration condensing units and three rooftop air conditioners for HVAC.

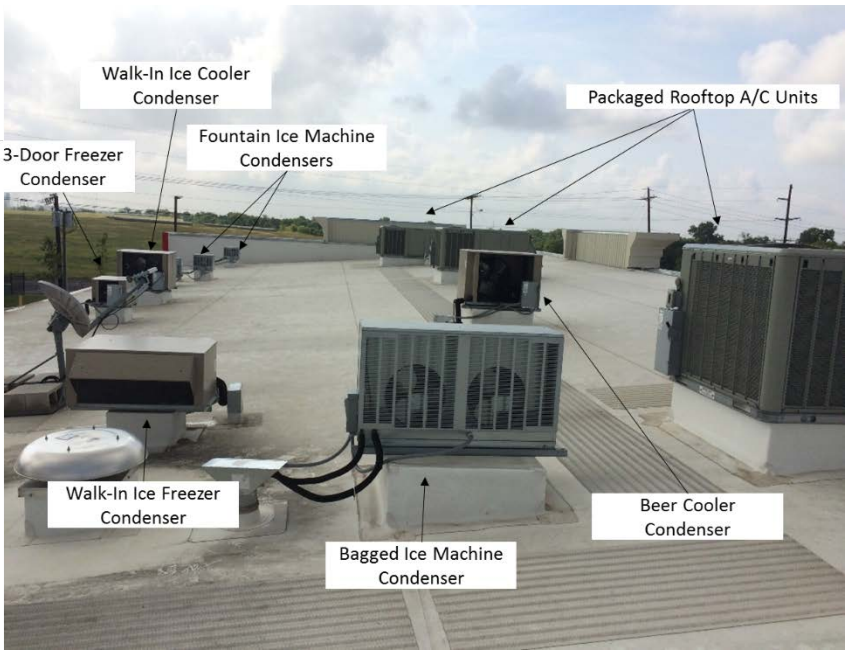

Figure 2-1
Locations of rooftop condensing units

Walk-in Coolers and Freezers

Each of the stores features two walk-in coolers and one walk-in freezer. One cooler contains non-alcoholic beverages, and the other contains beer. The walk-in freezer is used for bagged ice. Adjacent to the non-alcoholic beverage container is a freezer display case which also uses a remote condenser but is front-loaded, not a walk-in. This freezer is installed in a recessed wall area. Figure 2-2 shows the refrigerated and freezer display cases in one of the convenience stores in Texas.

Figure 2-2
Configuration of refrigerated and freezer display cases

The approximate dimensions of the walk-in refrigerators are 25’x10’ and 21’x10’. The freezer, adjacent to the smaller refrigerator, is approximately 8’x6’. The equipment is described here.

The walk-in coolers each contain two ceiling-hung, horizontal evaporator fans. The beverage walk-in uses a nominal 4-horsepower compressor while the beer cooler has a nominal 3-horsepower compressor. The fan coils are each rated for 13,500 Btu/h at 25°F saturated suction temperature (a typical level for refrigeration loads). The fan coils, and the doors to the beer cooler and ice freezer, are shown in Figure 2-3. The beer fridge temperature set-point is 42°F, the refrigerator set-point 34°F, and the ice cooler set-point -3°F.

Figure 2-3
Walk-in cooler layout

The equipment that is in use in the walk-ins is described in Table 2-1. The walk-ins have doors made by Anthony Door Company using anti-sweat heaters with nominal 2.84-amp circuits. The coolers are controlled using Johnson Controls A419 temperature controllers.

Table 2-1
Walk-In Cooler and Freezer Equipment

Application	Type	Count	Manufacturer /Brand	Model	Nominal Size	Refriger-ant	Notes
Beverage Walk-In	Conden-sing Unit	1	Heatcraft	MOH040X63CFMT	4HP Comp.	R404A	-25F- +30F evap. range
Beer Walk-In	Conden-sing Unit	1	Heatcraft	*MOH032X63CFMT*	3HP Comp.	R404A	-25F- +30F evap. range
Ice Freezer	Conden-sing Unit	1	Heatcraft	*MOH025X63CFM*	2HP Comp.	R404A	-25F- +30F evap. range
Beverage and Beer Walk Ins	Evapora-tor	2 per walk-in, 4 total	Heatcraft Larkin	*LCA6135BEMC6NTB*	13,500 Btu/h @ 25F SST	R404A	Axial side-discharge
Ice Freezer	Evapora-tor	1	Heatcraft	*TLF090BE*	10,800 Btu/h @ -20F SST	R404A	Vertical intake side discharge

Misc. Remote-Condenser Equipment

Apart from the walk-in coolers and freezers there are several other refrigeration systems with remote condensers. The freezer display case pictured in Figure 2-2 is one of these additional miscellaneous refrigeration systems. Of the three island merchandizers in the store, one (an open self-serve deli display) has a remote condenser, while the other two are stand-alone. Other systems in this category include ice makers, one for bagged ice and two for beverage fountain displays, each of which has a remote condensing unit.

Table 2-2
Other Remote-Condenser Refrigeration Equipment

Application	Type	Count	Manufacturer	Model	Nominal Size	Refrig.	Notes
Frozen Food Display	Condensing Unit	1	Zero Zone - Heatcraft	*MOH014L63C*	1-1/2 HP	R404A	Low-Temp. -30°F-0°F
Frozen Food Display	3-Door Freezer	1	Zero Zone - Heatcraft	3RMZC24	4,455 Btu/h	R404A	1,740 W defrost 1x per day; 230W anti-sweat heaters
Self-Serve Deli	Condensing Unit	1	Master-Bilt	MHHZ0191b	2HP	R404A	
Self-Serve Deli	Island Merchandiser	1	Federal	IMSS-60R-2		R404A	40°F Nominal Temp
Bagged Ice Maker	Air-Cooled Condenser	1	Hoshizaki	URC-22F	26,500 Btu/h heat reject.	R404A	Fan Coil Only
Bagged Ice Maker	Ice Machine	1	Hoshizaki	KM1601SRH	Up to 1531 lbs/day ice	R404A	Comp./evap unit
Fountain Ice Maker	Air-Cooled Condenser	2	Hoshizaki	URC-5F	4,900 Btu/h heat reject.	R404A	Fan Coil Only
Fountain Ice Maker	Ice Machine	2	Hoshizaki	FD-650MRH-C	Up to 650 lbs/day ice	R404A	Comp./evap unit

Figure 2-4
Two types of island merchandisers: a sandwich display with remote condenser (left) and two self-contained freezers (right)

Finally, there are self-contained pieces of equipment in the store, with condensing unit packaged with the display as a single unit. Two of the island merchandizers, both chest-style glass-door freezers, are located on the store floor. There are also refrigeration units in the frozen yogurt dispensers, condiment refrigerators, two back-of-house, steel-door vertical freezes, and a refrigerated sandwich preparation table.

Table 2-3
Self-Contained Refrigeration Equipment

Application	Type	Count	Manufacturer	Model	Nominal Size	Refrig.	Notes
Frozen yogurt dispenser	Packaged	1	Stoelting	F231-ADA	12,000 Btu/h	R404A	
Condiment refrigerator	Packaged	2	APW Wyott	CW-3	1/3 HP	R134a	
Back-of-House Freezers	Vertical 2-Door	2	True	T-49F	¾ HP	R404A	-10°F nominal temp.
Refrigerated Prep Table	2-Door Sandwich Prep Unit	1	True	TSSU-48-18M-B	1/3 HP	R134a	33-41°F nominal temp.
Island Merchandiser	Chest Freezer Merchandiser	2	AHT	Malta 185(-)L AD		R404A	Nominal 9.6 kWh/day

HVAC Equipment Overview

The HVAC system at the host convenience store consist of three packaged rooftop air-conditioners with electric resistance heat. Each packaged rooftop unit (RTU) provides space conditioning and fresh air ventilation to a portion of the convenience store. Each of the RTUs is controlled independently by a simple thermostat and an indoor temperature reading at the return ductwork of each unit. The simple thermostats are set at approximately 72°F during the cooling season. Figure 2-5 shows the HVAC equipment and thermostats at one of the host convenience stores. The packaged HVAC systems are located on the roof, while the thermostats are located in the back office of the store.

Figure 2-5
HVAC Equipment at Host Convience Store

A detailed description of the HVAC equipment, layout, and control is provided in Table 2-4. The packaged RTUs at the host convenience stores are typical baseline systems for their year of manufacture and installation, which was approximately 2015. At the host convenience stores, the RTUs are a mix of 6-ton and 7.5-ton units. On average, the total nominal space cooling for one

of the host convenience stores is 20 tons. The rated efficiency of the RTU for space cooling is at the federal minimum requirement for their year of manufacture and installation, an 11.2 EER and corresponding 12.6 IEER. The Energy Efficiency Ratio (EER) is a metric used to characterize full-load cooling at 95°F, while the Integrated Energy Efficiency Ratio (IEER) is a cooling metric for part-load operation. The packaged RTUs utilize R-410A refrigerant, which is the most common refrigerant for split and packaged air conditioning units.

Table 2-4
Description of HVAC System at Host Convenience Store

Equipment Configuration	3 x Packaged Rooftop Units (RTUs)
Equipment Type	Air-Conditioner with Electric Heat
Total Space Cooling Nominal Size	20 tons
Rated Efficiency of Equipment	11.2 EER; 12.6 IEER
Refrigerant in HVAC Equipment	R-410A
Ventilation Strategy	Fixed Rate Ventilation through Outdoor Air Damper of Each RTU
Ductwork Layout of HVAC System	2 RTUs primarily dedicated to Open Retail Space. 1 RTU covering Retail, Office, Storage, and Restroom Space.
HVAC Controller	Simple Thermostat for Each RTU. Housed in central location (office space).
Control Strategy	Satisfy Setpoint Temperature Reading at Return of Each RTU.

At the host convenience stores, each RTU conditions a portion of the building. Two of the RTUs primarily condition the open retail space as well as a small kitchen, while the third RTU conditions an office, storage space, restrooms, and a small portion of the retail space. The RTUs at the host convenience stores are controlled independently by separate thermostats for space conditioning. An indoor temperature sensor at the return ductwork of each RTU provides each thermostat with a suitable reading for controlling the space conditioning of each RTU. Each RTU supplies a portion of the required outdoor air ventilation for the occupied space through a fixed outdoor air damper.

Lighting

The host stores being examined were constructed with LED products, but that is not the case for all of the stores of this chain in the region. Around the country, many convenience stores have already upgraded some or all of their lighting to LED due to the large energy savings potential and fast payback. In most cases, LED lighting is a prescriptive rebate in utility energy efficiency programs.

A convenience store has a wide array of lighting products. The stores in this case study have at least 23 different light fixtures on the premises. Table 2-5details the primary lighting products used in these stores.

Table 2-5
Lighting products used in example convenience stores

Application	Type	Mount	Manufacturer/ Brand	Model	Notes
General Interior Lighting	LED	Lay-In	CREE	LED-CR24-40L	Architectural Troffer
General Interior Lighting	LED	Wall Washer	CREE	CRI4-40-L	
General Interior Lighting	LED	Recessed	CREE	LR6-18L-40K	Can Lighting
Walk-in Cooler Lighting	LED	Surface	CREE	WS4-59L-40K	Wet Location
Exterior Canopy	LED	Recessed	Beta	CAN-228-PS-RM	Low profile, canopy light
Streetlight	LED	Pole	Beta	STR-LWY-3ME	Ledway Streetlight
Exterior Wall Pack	LED	Wall Pack	CREE	XSPW-A-O-3-M	LED Trapezoid Wall Pack

Looking specifically at the lighting layouts in these stores, there are several observations to make. First, the stores have LED troffers, not LED tubes that have been retrofitted for fluorescent tubes. LED troffers guarantees driver compatibility and typically provide maximum lifespan for the LEDs as well as better optics. Another observation is the usage of can lighting over some of the drink stations and counter spaces. Can lights are often used to provide a spot or accent of light for hands-on tasks, such as, in this case, preparation of food and drinks. When specifying LED can lighting, it is important to utilize directional LED lamps instead of omni-directional LED lamps that lose light in or above the reflector.

Figure 2-6
LED lighting in the main retail space

The walk-in cooler space had special LED products that are Ingress Protection (IP) rated for wet locations. LED fixtures operate more efficiently in cold spaces whereas fluorescent lights dim significantly when cold, making LED an attractive technology for cold storage spaces.

Figure 2-7
Freezer LED Light

The site visit occurred during the day so the outdoor lighting was controlled to be off. However, as seen in the pictures below, the site had LED streetlights for the parking areas and LED canopy lights at the fuel stations.

Figure 2-8
LED Area Lighting

Another common strategy that many gas stations are employing is LED streetlighting fixtures to light up the area between the canopy and the store. This is to provide more visibility for pedestrians walking between the store and their car. Figure 2-9 shows that the area lights are mounted at an angle to better cover the full space. While these fixtures are mounted at an angle, there are LED fixtures designed to be mounted flat with special lensing to distribute light over a greater distance. A design such as this would limit the uplight and glare that contributes to light pollution that can disrupt neighbors, particularly in residential areas. However, due to the increased cost of such lensing for reducing uplight, many store owners may be tempted to purchase unlensed LED lights which may contribute to light pollution.

Figure 2-9
Angled LED area lights highlighted in red

Looking at the canopy lights, this store used 8 rows of 4 canopy LED that are flush mounted into the ceiling. As expected, the canopy LEDs are off during the day, due to the use of a photocell.

Figure 2-10
Flush-mounted LED canopy lights

Overall, the stores display high-efficiency LED lighting throughout. The exterior lights were off during the day due to the use of a photocell. There is opportunity for increased energy saving through the use of lighting controls. Since this store is open 24/7, additional exterior lighting savings could be realized using step dimming motion sensors. For example, from 12 am to 5 am, the lights could step down to 30% power and then jump up to full on when motion is detected.

Motion controls could also be used indoors in rooms that are irregularly occupied such as bathrooms, closets, freezers, and offices.

Informal Survey: Tennessee Sites

In addition to the host sites, an informal survey of 24 convenience stores in Knoxville, Tennessee, was conducted. A brief summary of the sites is shown in Table 2-6. The purpose of this survey was to capture the range of configurations that are present in convenience stores, which vary across brands, layouts and locations. The survey conducted here is not intended to be a statistically-significant representation, but rather to help understand the similarities and differences that may be observed when trying to apply a savings approach across the industry.

Table 2-6
Summary of Surveyed Sites

Store	Brand	Type	Attached Restaurant?
Store #1	Brand A	Gas Station	Yes
Store #2	Brand B	Pharmacy	No
Store #3	Brand C	Pharmacy	No
Store #4	Brand D	Gas Station	No
Store #5	Brand E	Gas Station	No
Store #6	Brand A	Gas Station	Yes
Store #7	Brand B	Pharmacy	No
Store #8	Brand F	Gas Station	No
Store #9	Brand D	Gas Station	No
Store #10	Brand G	General Conv. Store	No
Store #11	Brand H	Gas Station	Yes
Store #12	Brand I	Gas Station	No
Store #13	Brand J	Gas Station	Yes
Store #14	Brand A	Gas Station	Yes
Store #15	Brand K	Gas Station	No
Store #16	Brand I	Gas Station	No
Store #17	Brand A	Gas Station	No
Store #18	Brand D	Gas Station	No
Store #19	Brand B	Pharmacy	No
Store #20	Brand E	Gas Station	No
Store #21	Brand B	Pharmacy	No
Store #22	Brand L	Gas Station	Yes
Store #23	Brand H	Gas Station	No
Store #24	Brand D	Gas Station	No

Refrigeration Equipment

The store survey revealed differences in the overall approach to refrigeration among different stores. Within brands, stores typically follow a formula which may vary slightly from store-to-store. Figure 2-11 shows the total count of doors of each type: refrigeration and freezer, walk-in and stand-alone.

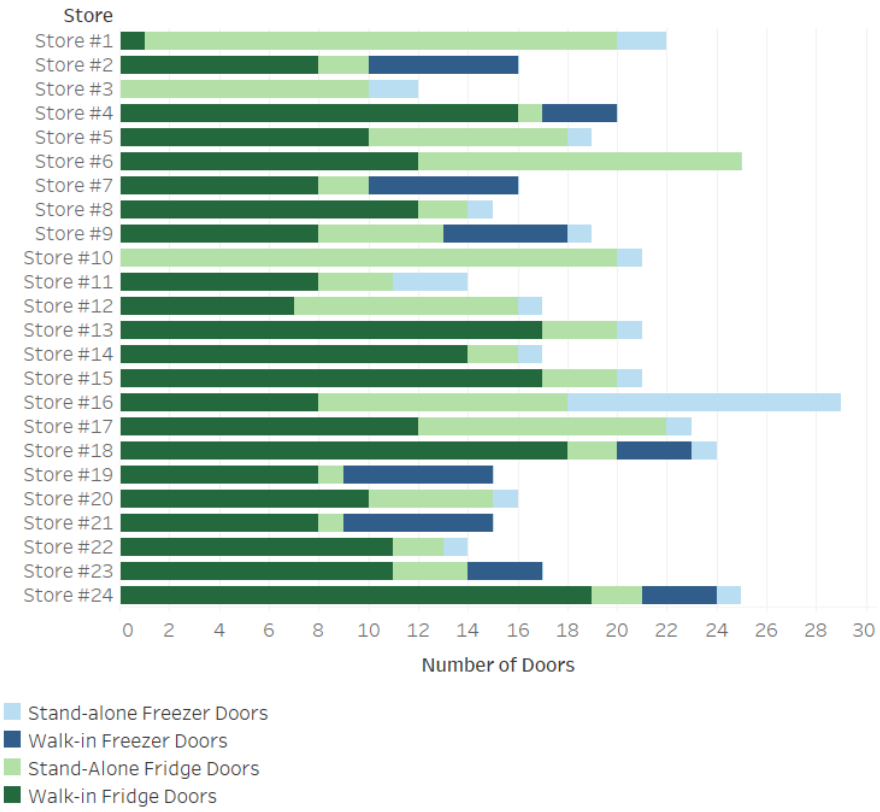

Figure 2-11
Distribution of refrigeration equipment observed in an informal survey

Of the 24 stores surveyed, 22 were found to have walk-in cooler displays, with a range from 7 to 19 doors of display space. Far fewer had walk-in freezers: only 9 stores had walk-in freezers, with 3 to 6 doors each. Stand-alone equipment was found to vary as well. The stores that had no walk-ins relied on stand-alone refrigeration equipment, with one using four stand-alone refrigerators (two each two-door and three-door models) and one two-door freezer; the other had approximately 18 doors of refrigerated stand-alone packages and a small chest freezer.

Among stores that did have walk-ins, most also had some stand-alone equipment throughout the store. Stores had between 2 and 11 stand-alone refrigeration units, most with doors, and most stores had one to two stand-alone freezer units, all with doors. 7 stores did not have stand-alone freezers. All but one store had at least one freezer of some kind. The primary findings in this area are that refrigeration space generally outnumbers freezer space by a wide margin, and in many stores walk-in refrigeration is around half of the total refrigeration space.

Lighting Equipment

The survey of local convenience stores revealed several interesting findings regarding lighting. Fifteen of the eighteen gas stations had LED canopy lighting. Interestingly, 6 out of 18 either did not use photocell control (or their photocell not functioning properly, indicated by the canopy lights operation during the day). Most of the refrigeration doors used LED lighting, but several still used fluorescent and some even had T12 fluorescent. Most of the stores used fluorescent troffer lighting which is still prevalent throughout the country. One of the large chains had switched to LED troffers which requires a significant initial investment but can payback quickly

due to high usage patterns of convenience stores. Overall, the small sampling of convenience stores in the area showed that there is a large potential for energy savings by switching to LED lighting.

Table 2-7
Summary of Lighting Equipment

Store	Canopy Lighting	Photocell Control?	Lot Lighting	Exterior/ Façade Lighting	Indoor Troffer Lighting	Refrigerator Lighting
Store #1	LED	N	LED	LED	LED	LED
Store #2	N/A	N/A	HID	HID	LED/Fluorescent	LED
Store #3	N/A	N/A	HID	HID	Fluorescent	Fluorescent
Store #4	LED	Y	HID	Induction	Fluorescent	LED
Store #5	HID	Y	HID	Halogen	Fluorescent	LED
Store #6	LED	Y	LED	LED	LED	LED
Store #7	N/A	N/A	HID	HID	LED/Fluorescent	LED
Store #8	LED	Y	HID	N/A	Fluorescent	Fluorescent
Store #9	LED	Y	N/A	LED/Induction	Fluorescent	Fluorescent
Store #10	N/A	N/A	HID	HID	Fluorescent	LED
Store #11	LED	N	LED	HID	Fluorescent	LED
Store #12	HID	Y	LED	Halogen	Fluorescent	LED
Store #13	LED	Y	LED	HID	Fluorescent/HID	LED/Fluorescent
Store #14	LED	Y	LED	LED	LED	LED
Store #15	LED	Y	LED	N/A	Fluorescent	LED
Store #16	LED	N	HID	Fluorescent	LED	LED
Store #17	LED	Y	N/A	HID	LED	LED/Fluorescent
Store #18	LED	Y	LED	Fluorescent/HID	Fluorescent/HID	LED
Store #19	N/A	N/A	HID	HID	LED/Fluorescent	LED
Store #20	HID	N	HID	Fluorescent	Fluorescent	Fluorescent
Store #21	N/A	N/A	HID	HID	LED/Fluorescent	LED
Store #22	LED	Y	HID	Fluorescent	Fluorescent	LED
Store #23	LED	N	HID	Fluorescent	Fluorescent	Fluorescent
Store #24	LED	N	HID	HID	Fluorescent	LED/Fluorescent

HVAC Equipment

The informal survey of HVAC equipment at the Tennessee convenience stores demonstrated a mixture of equipment type and quantity. For HVAC equipment type, 19 stores contained packaged, rooftop systems, while 7 stores utilized split systems. Two of the convenience stores in the survey utilized both a packaged, rooftop unit and a split system for space conditioning. Of the 24 stores included in the survey, 22 of the stores had multiple HVAC systems. Based on this informal survey, a common HVAC configuration in convenience stores appears to be multiple packaged, rooftop units.

Table 2-8
Total Count of A/C Systems from Informal Survey of Tennessee Convenience Stores

Store	Packaged Rooftop	Split
Store #1	2	0
Store #2	4	0
Store #3	3	0
Store #4	0	3
Store #5	1	1
Store #6	3	0
Store #7	3	0
Store #8	0	3
Store #9	0	3
Store #10	2	0
Store #11	1	0
Store #12	1	2
Store #13	2	0
Store #14	4	0
Store #15	2	0
Store #16	1	0
Store #17	2	0
Store #18	0	4
Store #19	4	0
Store #20	2	0
Store #21	4	0
Store #22	2	0
Store #23	3	0
Store #24	0	4

3
EQUIPMENT ENERGY AND DEMAND CONSIDERATIONS

This chapter examines energy implications, changing efficiency standards, and energy efficiency opportunities for each of three primary end-uses at convenience stores: refrigeration, HVAC, and lighting.

Refrigeration

Energy Implications

The factors driving efficiency of refrigeration equipment include the temperatures of the space being refrigerated, the heat rejection temperature, internal loading (product to be cooled, lighting, etc.), external loading (door openings, ambient air infiltration), equipment construction and insulation, defrosting and the refrigerant being used.

The heat rejection temperature is in part determined by the location of the condenser. The two main configurations encountered in refrigeration equipment are remote condensing and packaged (or stand-alone) equipment. Packaged equipment has all of the refrigeration equipment including the heat rejection equipment indoors. Much like a domestic refrigerator, heat is removed from inside of a refrigerated area, and rejected to the outside, generally in a conditioned space. The heat rejection of the refrigeration equipment becomes sensible load for the air conditioning system. This can be beneficial or detrimental depending on season and climate. For remote-condensing systems, the condenser and often the compressor are outside. This means the heat rejection of the system is to the outdoors. This heat rejection equipment does not directly impact the space conditioning load unlike packaged equipment. The trade-off is that this equipment is exposed to outdoor temperatures, and therefore the capacity and the efficiency of the equipment will vary with ambient temperature much like an air conditioner. Where packaged equipment would be expected to have a relatively flat load profile which varies mostly with customer or employee interactions, remote-condensing equipment's load profile will also vary with weather. It is important to note that both systems' performance is connected to weather; it is a direct effect for systems with outdoor condensers, where the impact is passed through the heating and air conditioning equipment for packaged equipment with indoor condensers.

Most of the refrigeration equipment in the Texas case study stores examined here use R404A refrigerant, which has a high global warming potential (GWP) of 3,940 and is subject to some rule changes from the U.S. Environmental Protection Agency's (EPA's) Significant New Alternatives Policy (SNAP) program. In particular, the EPA SNAP rulings numbered 20 and 21 effectively prohibit R404A for the following convenience store-related applications and dates[3]:

- New refrigerated food processing and dispensing equipment, as of January 1, 2021
- Retrofits into remote condensing units, as of July 20, 2016

[3] https://www.epa.gov/snap/snap-regulations

- New remote condensing units as of January 1, 2018
- Retrofits into stand-alone refrigeration units as of July 20, 2016
- New stand-alone medium temperature refrigeration units (applies to both R404A and R134a) as of January 1, 2019 (for systems smaller than 2,200 Btu/h) or January 1, 2020 (for systems 2,200 Btu/h or larger)
- New stand-alone low temperature units, as of January 1, 2020

While R404A is familiar and inexpensive, it is not particularly efficient, especially in refrigerating (medium temperature) applications. A number of existing options are more efficient, such as R448A (GWP: 1386) and R449A (GWP: 1397) for condensing unit applications, or R290 (propane, GWP: 5) for self-contained equipment. Since propane is flammable, it is limited to use in systems with a small refrigerant charge; however, self-contained systems using R290 refrigerant are already available in many applications.

Standards Changes

It should be noted that the efficiency rules and regulations surrounding some categories of refrigeration equipment have changed or are changing, and convenience stores will be impacted. There are two primary categories where changes have happened or will happen:

The U.S. Department of Energy (DOE) has changed the allowable energy consumption for many pieces of equipment including display cases, merchandizers and storage cabinets. The DOE's changed ruling, described in Federal Register 10 CFR Part 431 Volume 79 Number 60, describes new energy consumption thresholds for these pieces of equipment. The standard lists a maximum daily energy consumption, and applies to self-contained and remote-condensing equipment. The new efficiency thresholds, required for all equipment manufactured or imported starting on March 27, 2017, are aggressive and for some categories approach a 70% reduction in the allowable energy consumption of the equipment.

Another separate change applies to walk-in cooler and freezer equipment. This standard change, described in Federal Register 10 CFR Part 431 Volume 82 Number 130, has gone through a litigation and negotiation period, with a resolution reached in 2017. The result is new standards for efficiency of walk-in cooler and freezer equipment (with an internal floor space of 3,000 ft^2 or less). The equipment will have to satisfy a minimum Annual Walk-In Energy Factor (AWEF) rating, which is a standardized ratio of annual delivered capacity divided by annual energy consumption. The new standard requires compliance for systems manufactured starting in January, 2020. The new standard presents a significant increase in the required efficiency of the systems over the existing baseline.

Both of the above rule changes are imposed upon equipment manufacturers, with the intent that the burden is not placed upon the organization buying the equipment. While the change to display cases and other equipment has already become law, meaning many utilities will now consider this equipment "baseline" technology, the walk-in cooler changes do not take effect until 2020, and there may be opportunities to provide incentives for improvements ahead-of-schedule.

Energy Efficiency Opportunities

There are a number of energy conservation measures that can be taken in refrigeration equipment, including hardware and control changes. Some of the controls changes that can be used to improve performance are described here. This list is not intended to be exhaustive, and some of the changes may be incorporated in order to meet the energy standards discussed in the above section. This section refers to recommendations contained in the U.S. EPA Refrigeration Roadmap[4].

For packaged equipment, ENERGY STAR offers an option for quickly discerning efficient equipment[5]. Because of the 2017 changes to the federal efficiency standards in this category, the ENERGY STAR efficiency limits also changed. Figure 3-1 shows the allowable daily energy consumption for ENERGY STAR vertical and horizontal refrigerators and freezers. For reference the new federal maximum daily consumption value is also shown for two representative categories: vertical transparent door refrigerators and freezers (shown with dotted lines).

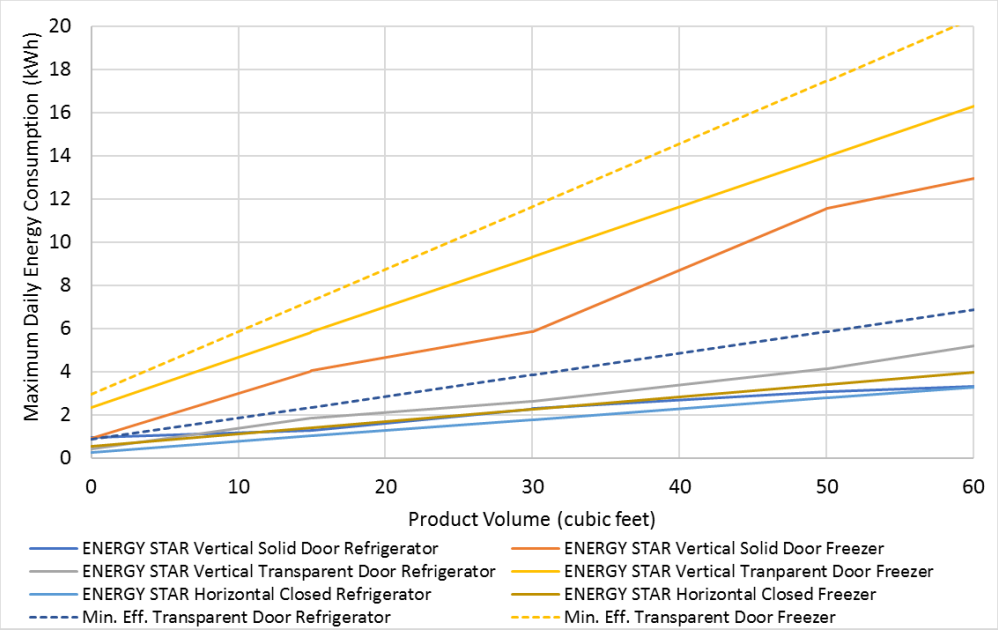

Figure 3-1
Maximum Daily Energy Consumption vs. Volume for ENERGY STAR Cases

Floating Head Pressure: Conventional control of many types of refrigeration equipment involves a fixed or minimum head pressure; when the ambient temperature drops, the condensing pressure of the refrigeration equipment remains constant or remains at or above some minimum level. However, significant energy savings are possible if the system can be controlled to "follow" ambient temperature, allowing condensing temperature to decrease as outdoor

[4] https://www.epa.gov/sites/production/files/documents/refrigerationroadmap.pdf

[5] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_refrigerators_freezers/key_product_criteria

temperatures decrease. This requires better control: the condenser fans must be able to vary speed, an electronic expansion valve may be needed, and a variable speed compressor can help further improve performance. Floating head pressure control is required in some cases; for example, California supermarkets require a minimum condensing temperature of 70°F or lower, where a typical minimum for a fixed system would be 105°F. Floating head pressure provides savings when outdoor temperatures are lower, and therefore savings are a function of climate. Each reduction of 10°F of head pressure can produce a 10-20% reduction in system power for a given delivered capacity.

Defrost Control: Refrigeration systems require defrost to remove ice that forms on coils and surfaces. This is usually done at a pre-set schedule and for a fixed duration. However, with sensing and intelligent control, defrost can be reduced to the frequency and duration required to productively melt and remove the water. Refrigeration energy savings of around 9% have been observed for frozen cabinets in field trials.

Set-Point Controls: The set-point of refrigeration equipment is generally dictated by food safety and quality, and in many cases, store or chain standards. However, in some cases the set-points can be adjusted upwards without adversely affecting the food quality or safety. Adjusting the set-point upwards by 2°F can produce savings of 3-5% for each refrigerated end-use. In the case of demand response applications, there may be the opportunity to "pre-cool" some refrigeration loads, to allow a load shed during peak periods.

Lighting Control: The lighting inside refrigeration displays and walk-ins has two energy impacts: the direct energy consumption of the light, and the energy required for the refrigeration equipment to remove the heat from the lights. Modern lighting technologies can yield substantial reduction in energy consumption, particularly with LED technology. However, newer technologies can be more sensitive to humidity in refrigerated chambers, requiring the use of more rugged designs. By controlling the lighting based on occupancy which senses customer movement nearby, the energy consumption associated with refrigeration lighting can be reduced by up to 40%. This measure provides straightforward energy savings, but must be balanced with appearance standards.

HVAC

Energy Implications

The energy usage of the HVAC system at a convenience store is dependent upon the weather and associated thermal loads. Unique considerations for the space conditioning load at the host convenience stores include outdoor air exchanges, usage of glass for exterior walls and doors, and unique internal loads. The host convenience stores were constructed with two entrances for customers, an automatic primary entrance and a secondary manual door on the side of the building. Approximately one third of the retail space in the host convenience stores consisted of a glass or transparent exterior surface. The impact of the glass exterior surface on the thermal load is dependent upon the building orientation and shading. The host convenience stores have an outside canopy just beyond the exterior wall consisting primarily of glass, but the canopy is not connected to the building and thus offers limited shading to the glass surface. The internal heat loads for the HVAC system include stand-alone refrigeration equipment, food warmers, food preparation equipment in the kitchen, and occupants.

Standards Changes

The federal minimum efficiency standards for packaged space conditioning equipment are changing in two manners beginning in 2018. First, the defining efficiency metric is switching from EER to IEER. Second, the federal minimum efficiency requirement is increasing in both 2018 and 2023 from previous efficiency levels. Federal minimum efficiency requirements for space conditioning equipment is dependent upon the HVAC configuration (packaged or split) and the nominal size. As an example, Table 3-1 provides a summary of the changing space cooling efficiency landscape for packaged air-conditioning equipment 6 to 10 tons with electric resistance heat. The table provides the federal minimum efficiency requirement (either EER or IEER) for a given timeframe, and a general corresponding efficiency (either EER or IEER) for currently available products at the federal minimum level. For example, in the "Pre-2018" timeframe the federal minimum efficiency requirement was 11.2 EER, which generally corresponds to a 12.5 IEER in currently available packaged air-conditioners of 6 to 10 tons.

Table 3-1
Efficiency Changes for 6 to 10 ton Packaged Air-Conditioner with Electric Heat

Effective Year	Space Cooling Efficiency Rating	
	Federal Minimum Requirement	Corresponding Efficiency in Available Products
Pre-2018	11.2 EER	12.5 IEER
2018 – 2023	12.9 IEER	11.7 EER
2023	14.8 IEER	12.2 EER

Energy Efficiency Opportunities

Multiple advanced technologies could be considered for potential energy efficiency improvement in the HVAC system of convenience stores. Figure 3-2 provides a summary of advanced HVAC technologies, which could be implemented into a packaged RTU for potential efficiency improvements. For each of the five technologies listed, there is an available technology in the market for both retrofit (modifying existing RTU) and replacement (replacing RTU) applications. A light description of these advanced HVAC technologies for RTUs is provided here. However, further details of these technologies may be found in two previous publications on Retrofit Space Conditioning Technologies (#3002008239) and Variable Capacity Rooftop Units (#3002001380).

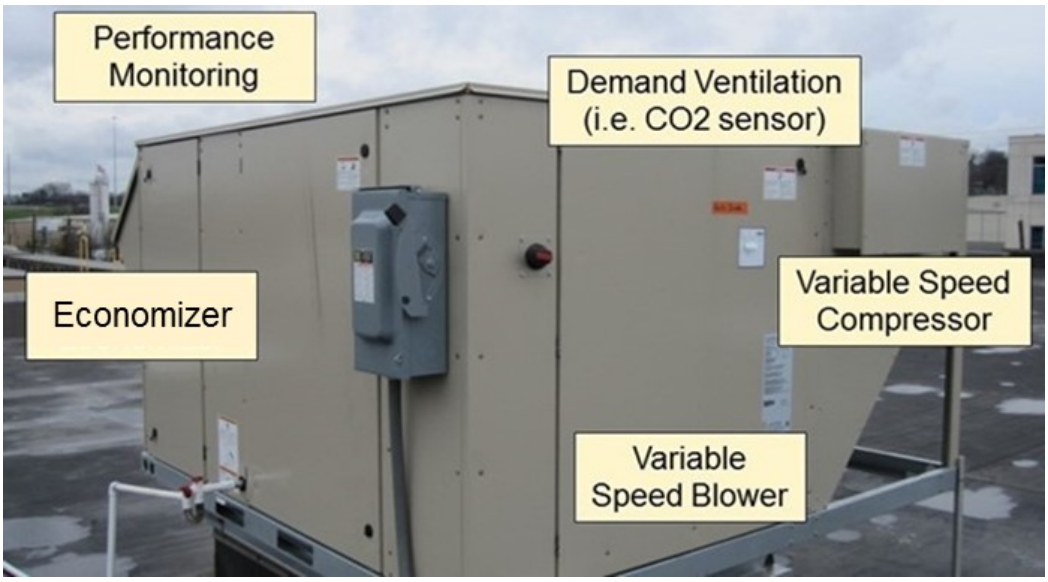

Figure 3-2
Advanced Performance Options for Packaged Rooftop Units

Advanced HVAC technologies that may be implemented for RTUs in convenience stores include performance monitoring, heat pumps, economizers, variable speed blowers, variable speed compressors, and demand ventilation. Performance monitoring refers to real-time monitoring of the HVAC performance, which allows for a user to potentially identify and resolve issues and optimize equipment operation. An economizer refers to an outdoor air damper within the RTU, which allows for cool outside air to condition the occupied space when conditions are favorable. Variable speed blower refers to modulation of the indoor airflow in response to the thermal load or ventilation demand of the occupied space. Variable speed compressor refers to modulation of the cooling output in response to the thermal load of the space. Combined, a variable speed blower and compressor provide variable capacity, which offers potential efficiency improvement through load matching and part-load operation. Finally, demand ventilation refers to utilizing a CO2 sensor to satisfy the actual fresh air demand of the occupied space, as opposed to providing a fixed, predetermined rate.

Table 3-2 provides a comparison of the HVAC equipment or strategy at the host convenience store along with the advanced technology option. Each of the identified HVAC areas offers a potential opportunity for improving the efficiency or performance of the HVAC system. For the host convenience stores, the packaged RTUs were manufactured and installed in 2015, and thus an advanced retrofit technology likely offers the most effective option for energy efficiency and improved performance. At the host site, one potentially effective option for the improving the HVAC system performance is integrated and intelligent control of the three packaged RTUs. Currently, the RTUs at the host convenience store are controlled independently, and the power demand of each RTU is approximately 7 kW during operation. Independent control of each RTU could result in all three RTUs operating simultaneously, resulting in a total RTU power demand exceeding 20 kW. Integrated control of the RTUs could allow for reduced power demand by limiting the number of RTUs in operation and improved efficiency by reducing cycling of the RTUs. Limiting and reducing the total HVAC power demand offers a potential benefit to the electrical grid and for the customer's demand charge.

Table 3-2
Comparison of HVAC at Host Convenience Store and Advanced Alterative

	Host Site	Advanced Option
Outdoor Air / Ventilation Equipment	Fixed Outdoor Air Damper with RTU	Digital Outdoor Air Damper with Economizer Option
Ventilation Strategy	Fixed Rate	Demand Ventilation
Compressor Modulation	1-Speed; ON-OFF	Variable Speed; Match Load
Indoor Blower Modulation	1-Speed; ON-OFF	Variable Speed; Control Ventilation Rates
Space Conditioning Control Equipment	Simple Thermostat	Integrated, Intelligent Control
Space Conditioning Control Strategy	3 Indoor Setpoints for Each RTU	Match Building Load; Control for Peak Demand
Performance Monitoring	None	Real-time Monitoring for Performance or Fault Detection

Lighting

Energy Implications

When thinking about which measures to target in a convenience store, it is also important to note if the store is open 24 hours a day or not. 24-hour stores can achieve faster payback through energy savings with LED technology since the operating hours are high. Furthermore, the lighting load shape of a convenience store can vary greatly depending on whether the store is a gas station or not. Stores with a gas station will have a much larger lighting load due to the necessary outdoor lighting. Canopy lighting is usually the first lighting technology to target for increased efficiency. When considering the indoor lighting of a convenience store, it is also important to consider the desired lighting levels. Some stores may seek to improve light levels during a lighting retrofit in which case LED technology can provide higher lighting output while saving at least 30-40% energy consumption over existing fluorescent. Many convenience store owners are not receptive to lowering light levels, which is a barrier for dimmable LED products. However, there are many benefits of having dimmable LEDs even in convenience stores as is discussed in the next section.

Energy Efficiency Opportunities

Upgrading lighting from fluorescent or HID to LED is a simple and easy way to gain cost-effective energy savings with fast payback. With the long operating time for lighting in a convenience store, the payback period shortens due to the long life of LEDs which reduces maintenance calls. LED installation will reduce the primary lighting load by approximately 50%, but further savings can be achieved by incorporating natural light, daylighting, lighting controls, and monitoring. These strategies can be more expensive, but if partnered with the LED installation, installation costs can be reduced. Each of these strategies is discussed in more detail below.

Natural Light and Daylighting: One method of energy savings for lighting is to incorporate natural daylight when possible. This can take several form factors including floor to ceiling windows on one or more sides of the building, skylights, clearstories, or solar tubes. Using

daylight reduces the need for electric lighting and also can provide increased visual comfort. LEED certification has several points it awards for buildings that have access to the outside views and for the use of natural light in a space.

The key to the proper implementation of daylighting is having a flexible LED technology that actively dims the light levels in response to the incoming natural light. This is primarily important for the fixtures located nearest the windows. The fixtures in the back of the store may not receive any direct sunlight and thus would not need to be dimmed with the daylight. Since stores are also open at night, it is important for the electric lighting to be able to provide full illumination when necessary. There are several control systems that use either DALI, 0-10V, or some proprietary control system to dim lights with input from photosensors located throughout the space. One important consideration when designed a store with this technology is to not dim the LEDs too fast where light fluctuation is noticeable or irritating.

Daylighting strategies can be applied to the main convenience store building but also to the canopy. EPRI observed several gas station canopies that used the outer row of lights during a cloudy day to provide additional light under the canopy. The light had minimal impact and consumed unnecessary power. Implementing sky lights at a few locations in the canopy roof could provide extra light in the middle of a large canopy that may be darker than desired during the day.

Lighting Controls and Monitoring: Lighting controls refers to a range of technologies and strategies. These include occupancy sensing, dimming, scheduling, monitoring/tracking, demand response, and remote control. Lighting control systems can be connected to the internet or use only local connectivity. Control systems connected to the internet generally allow store owners or regional managers to pull energy reports on lighting consumption. Some control systems may also integrate HVAC, in which case additional energy data could be obtained. Energy reports can be an insightful tool to view trends across all stores in a region to identify inefficiencies such as lights left on overnight in areas where they were supposed to be off. Using the scheduling feature of control systems, efficient control strategies such as these can be automated.

Monitoring or tracking in the world of lighting controls refers to a technology that records the path that customers take throughout a store. The data is captured through light sensors or through low-resolution cameras and then advanced analytics are applied to plot the flow of customers. This data can be very insightful to floor designers to know what items attract the most interest. Using tracking analytics, store managers can improve product placement which often leads to increased sales. Several large retail stores have tested this technology and a few are implementing some version of this technology throughout their stores.

4
SUMMARY AND FUTURE WORK

The convenience store sector presents opportunities for energy and demand reduction that are repeatable across all regions, as many stores have comparable end-use equipment and follow similar trends for equipment usage. While many utilities have efficiency programs that are applicable to convenience stores, there may be opportunities for more and better engagement in this sector. The three primary load areas for convenience stores are refrigeration, lighting and HVAC.

Many convenience stores are all-electric, but heat pump technology is rarely used in these buildings. Instead, the majority of space heating in all-electric stores is through electric resistance heat. Thus there is a huge potential for adoption of heat pump technology in many climates. Some other improvements in space conditioning can be realized through economizers, variable speed compressors or blowers, and demand ventilation. Integrating controls to a central control system may allow opportunities to control for peak demand, adjust thermostat schedules and manage run-time among multiple units.

Refrigeration loads make up a large portion of the energy consumption, and also present opportunities for improvement. Many utilities already incentivize to use ENERGY STAR equipment where appropriate and install LED case lighting. Floating head pressure control is well-known, but less commonly incentivized. Control improvements may also provide both energy and demand savings in refrigeration: permanent set-point changes can improve efficiency if the product is over-cooled, and pre-cooling may allow load profile shaping and/or peak demand management. Also, defrost control and anti-sweat heater control can both provide efficiency benefits as well as reducing peak demand impact (particularly if included in a building-wide control strategy).

Convenience stores have among the highest energy intensity of any commercial building category, because of dense refrigeration, lighting and HVAC loads and long hours. There are also considerable opportunities for energy savings and efficiency improvements. The load profile of a store may also be adjustable to allow for reduced demand during utility peak periods. With refrigeration loads, there may be the potential for load shifting and demand response via thermal storage or set-point changes (pre-cooling). The air conditioning and lighting loads may similarly be able to vary to some degree. Many stores have 24/7 indoor lighting which could be improved with daylighting when appropriate. Similarly, multiple air conditioners may be better-controlled through intelligent whole-building control rather than individual thermostats.

In lighting, many stores have already moved to LED in some applications, such as canopy lighting, for easy energy savings. However, many stores have not completed a full conversion to all LED lighting. Some stores have outdoor lights which are on 24 hours per day, and present an easy opportunity for savings. The use of daylighting in the store can provide deeper energy savings, particularly if dimmable LEDs and photosensors are used to maintain lighting power at the lowest level to satisfy illumination standards for the store.

There are a number of research questions related to convenience stores, some of which will be addressed in the 2018 continuation of this work. The research questions include:

- What is the impact of packaged refrigeration equipment compared with remote condensing equipment on whole building energy and load shape? Is the optimal configuration region-specific?
- What savings can be achieved using centralized, integrated control systems?
- How can utilities achieve better participation?
- Are there combined technology packages for convenience stores that merit specific program consideration by utilities?
- How much load can be shifted or shed in convenience stores without disrupting operation?

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