2017 issue #3

LEARN SERIES

latest news from HFA

Refrigeration System Energy Comparison in Small Format Stores

A Case Study by Greg Schluterman, PE & Miguel L. Purdy, PE

REFRIGERATION SYSTEM ENERGY COMPARISON IN SMALL FORMAT STORES

A CASE STUDY BY GREG SCHLUTERMAN, PE & MIGUEL L. PURDY, PE

Every bit of energy savings counts when it comes to small format and food retail stores.

From the fueling stations outside to the refrigeration units inside, these stores use a lot of energy. That energy adds up to a good chunk of change for most store owners. Curbing consumption can help, but finding the best way to do that isn't always easy.
One potential way to save energy is through the refrigeration system used for the store's coolers. There are two main types of systems currently used: the conventional refrigeration condensing unit system and the small rack refrigeration system. A recent study examined the energy consumption of both types of systems located in two different yet nearly identical stores.

So which saves more energy, a conventional system or a small rack system?

That was the question posed for the case study by Greg Schluterman, PE, and Miguel Purdy, PE, of HFA. The study compared two small-format refrigeration systems – one conventional, one small rack – to determine which would be more energy efficient over time.

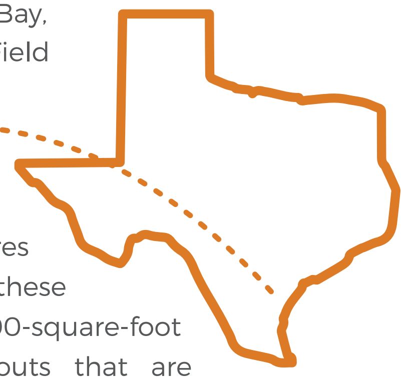
Schluterman and Purdy conducted the case study using data collected in 2015 by Greg Sandford, an employee at Hussmann Protocol, the company that manufactured the small rack system used in one of the stores involved in the study.

The goal was to learn three things from this project: the energy use of a conventional system, the energy use of a small rack system and how they compare.

To accomplish this, the study set parameters and used store locations that were as similar as possible.

Let's take a trip to Corpus Christi

Corpus Christi, Texas, lies on the Gulf of Mexico a little more than halfway between Houston and the Texas-Mexico border. Leopard Street is located a couple of miles off Nueces Bay, while Holly Road and Rodd Field Road lie close to Corpus Christi Bay.



Two Stripes convenience stores are situated on these streets. These 7,000-square-foot stores contain layouts that are mirror images of each other. Because of their locations – about 10 miles apart, both inland about the same distance, yet both near the ocean – they also share similar traffic patterns and climate. In fact, these nearly identical stores have only one major difference – one store uses a conventional refrigeration system, while the other uses a small rack system.

Stripes stores number in the hundreds but are contained mainly to south Texas. Up until 2014, all of the stores were outfitted with conventional condensing unit systems for refrigeration, including the Corpus Christi store built in 2013. However, a Corpus Christi store built in 2014 included a small rack system for its refrigeration needs. Both stores had the latest technology for the time. Stripes stores have their own prepared food, so they tend to have more refrigeration requirements than stores that don't offer such products.

The two stores became the subjects of the study that began in December 2014 and lasted through the following year.

What are their similarites?

The stores had identical, though reversed, footprints. When combined with the stores' similar locations, the identical footprints eliminated building design and climate as major factors that could alter the study's results. The one factor not eliminated was store sales, which could determine how often the cooler doors were opened and closed. That information was not available to HFA.

The equipment the systems powered was also similar. Both systems powered **medium-temperature equipment** (0-34 degrees, generally coolers) and **low-temperature equipment** (below zero, generally freezers). The low-temperature equipment required mechanical defrost systems, but defrost systems were also included in the stores' beer coolers, which ran on medium-temperature equipment.

The capacity of these systems, while not exact, was very close. **The medium-temperature equipment in the conventional system's store had a capacity of 10.5 tons** and included beer and drink coolers. **The low-temperature equipment there had a capacity of about 3 tons** and powered the store's freezers. That was a **total capacity of about 13.5 tons.**

The capacity for the small rack system, which powered similar coolers and freezers, was only slightly different. **The medium-temperature capacity was about 10.75 tons,** while **the low-temperature equipment had a capacity of about 3.2 tons. That's a total capacity of 13.95 tons,** less than half a ton more than the conventional system.

This all factored into the data used by Greg Schluterman and Miguel Purdy for the case study.

Why does it matter?

Why does it matter which type of system is used? That's the big question this study attempts to answer.

The systems in this case study serve as examples of those typical of small-format stores. While these examples are specifically for convenience stores, they apply to food retail stores as well. The potential cost savings between systems is important because such systems account for so much of a store's electricity consumption.

According to the U.S. Small Business Administration's website[1], **refrigeration typically accounts for 35-60% of the electricity consumption** in grocery stores, convenience stores and restaurants.

What are their differences?

The conventional system also has a limitation eliminated in the small rack system. The conventional condensing unit system has a single suction temperature coming out of the condensing unit, whereas the rack system has the capability to use multiple suction temperatures in the same system.

In other words, each unit in the conventional system can produce a certain pressure that keeps the temperature the same, and it can do that for more than one cooler per unit. However, all of the coolers on that one unit have to run at the same temperature. So if one unit has a beer cooler running slightly below freezing, then all of the coolers on that unit will run slightly below freezing unless an additional pressure regulating valve is installed on the cooler. A different unit would have to be used to run a soft-drink cooler slightly above freezing.

The small rack system, however, can produce more than one suction pressure per unit. This means that several coolers attached to that unit can run at different temperatures. One unit could power a beer cooler slightly below freezing and a soft-drink cooler slightly above more efficiently.

The systems also share differences on how they share compressors. The conventional system's condensing units can only work with one load at a time, whereas the small rack system contains more compressors and can share loads on the compressors it uses. When a lower load is needed, the small rack system can share the energy load among a portion of the compressors and save others from needing to run. The conventional system has to use individual compressors for each load, no matter how big or small the energy consumption.

In addition, the ability to share capacity among compressors means the small rack system has a built-in redundancy. If one compressor fails, the others can share the load and take over as backup.

[1]https://www.sba.gov/managing-business/running-business/energy-efficiency/energy-efficient-upgrades/refrigeration

ABOUT THE SYSTEMS

Before continuing, let's delve into the heart of the systems in these two Stripes stores to find out exactly how they work.

The conventional system is comprised mostly of Trenton condensing units and evaporator coils. Evaporator coil power on the store's freezer and beer cooler is supplied by the eight separate condensing units of the conventional system. The evaporator coils on the other coolers are supplied by the building's regular electrical system. The coils on the low-temperature equipment have electronically commutated fan motors and an electric mechanical defrost system. Amperage was taken at each condensing unit.

The small rack system uses a Hussmann Protocol unit with Krack brand evaporator coils, which power the walk-in freezers. However, the evaporator coils are powered separately from the Protocol unit. The amperage was taken on the Protocol unit, which meant the amperage for the freezers' and beer cooler's evaporator coils had to be added to the Protocol unit readings.

In order to get the calculations correct, the manufacturer of the evaporator coils provided the rated power for the units in operation. The "effective" amps were calculated by taking that rated power and dividing it by the listed voltage. The result was added to the amperage for the Hussmann Protocol unit.

In addition, the evaporator coils in the small rack system have electronically commutated fan motors, and the system's defrost is achieved using hot gas with electric pan heaters. These used extra power not included in the data, so those measurements were added later. The evaporator coil's fan and defrost power on the conventional system was included in the data.

The Data Collection

The amperage data was collected over two time periods. The first took place from December 2014 to June 2015. The second took place from September to December 2015. Nothing was downloaded for May, July or August in 2015, leaving gaps in the overall data. Other small gaps were created due to rollover in the data logger and during collection of the data.

The data logger had a 29-day capacity that rolled over. So while data was collected continuously on the logger, after 29 days, the logger would begin recording over the first day's data, and so on. There were a few times during the study when the logger rolled over before the data could be collected and downloaded.
In addition, downloading the data meant removing the logger from the site without backup available. That meant that during the week or so the data was being downloaded from the logger, no data was collected. The loggers were pulled at the same time from both stores to retrieve data.

During the 29 days of information gathering, the system assumed that everything pulled the same amperage. That information was used to determine the amount of amperage used per day, week, month and year.

Initial findings

The data showed some interesting patterns. The colder months clearly showed the biggest energy savings. On average, the small rack system showed 25-30% energy savings during the winter months compared with the conventional system.

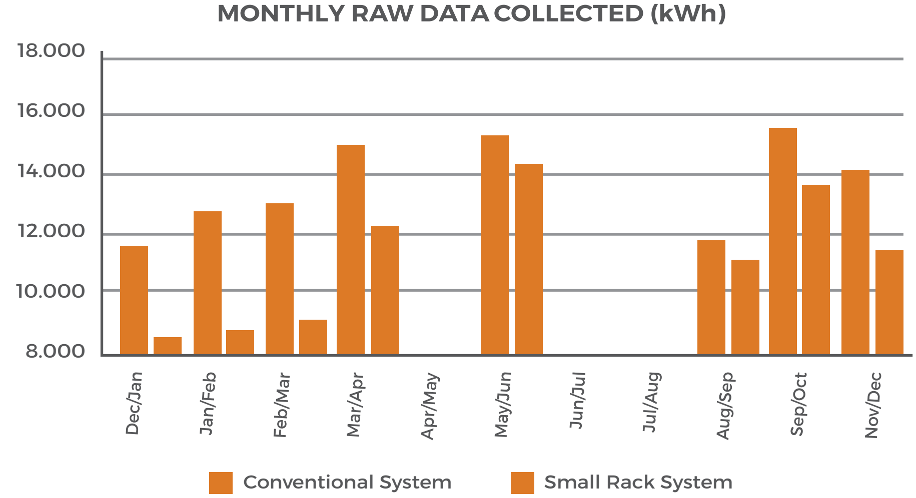
Those savings dropped significantly during the warmer months. By summer, the savings had declined to just 5-10% over the conventional system.

The average annual energy savings, based on the raw data, was 18.3% for the small rack system when compared with the conventional system's energy use.

As previously stated, winter months showed a much larger gap in energy savings compared with summer months. For example, the gap between the conventional and small rack systems was nearly 3,200kWh from Dec. 6, 2014, to Jan. 5, 2015. However, the gap from Aug. 31, 2015, to September 21, 2015, was less than 600kWh. The difference was also less than 1,000kWh from May to June, but was more than 3,800kWh from February to March, a savings of 30.1%. That compares to the August-September savings of only 5.2%.

An overall comparison of the total raw data showed the conventional system used 108,724kWh in power, whereas the small rack system used 88,797kWh, a savings of 18.3%.

MONTHLY RAW DATA COLLECTED (kWh)



*Each month's data for the small rack system includes 547 kWh of power from fans and pan heaters.

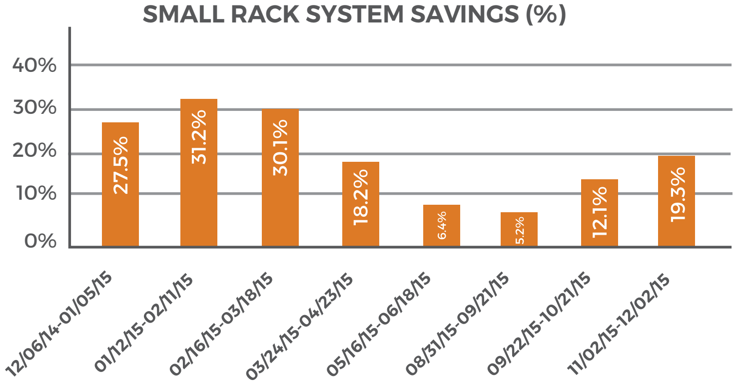
Calibration

Before an accurate model could be achieved, the system had to undergo calibration using the knowns and unknowns for the systems.

An annual energy cost savings model was created using Trane Trace 700 software and the average utility rate in Texas of $0.0816 per kWh.[2]

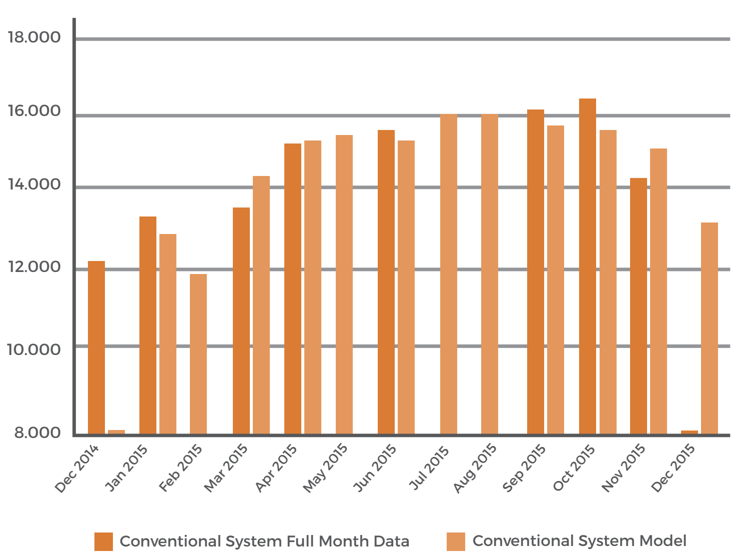
The conventional system offered several known factors and a few unknown ones during the calibration process. The known factors included the vault temperature, outer space temperature, evaporator coil fan energy, condensing unit energy and efficiency, insulation values, defrost heater size, defrost schedule and the area's 2015 weather data.

SMALL RACK SYSTEM SAVINGS (%)



The biggest unknown was the infiltration to the coolers. This could be determined by actual store sales, but that data was not available for the case study. The best approach to determine the infiltration was to match the monthly energy consumption data to output data generated from a computer model.

CONVENTIONAL SYSTEM RAW DATA VS. MODEL DATA (kWh)

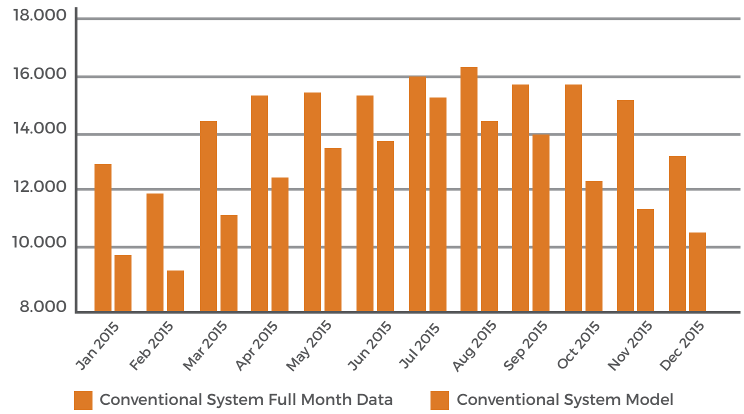


[2]The average rate was obtained from the Department of Energy Statistics and Analysis

The infiltration rate for the coolers and freezers was held constant between the two locations in order to make an accurate comparison. It assumed the sales between the two stores was roughly the same.

The maintenance costs or other outside factors are excluded.

MODEL COMPARISON OF SYSTEMS (kWh)



Once all the factors had been determined, a computer model was created based on the raw data to determine the energy differences between the two systems each month. The model was able to show what the savings would be for the missing months.

Though the model's savings numbers were slightly different, the pattern remained the same. Like the raw data, the computer model showed an average savings for the small rack system of 25% during the winter and 5% during the summer. The model predicted an average annual savings of 16.4%, which was only 1.9% from the raw data's same figure.

THE BOTTOM LINE

The study concluded that in the warm, humid climate of Corpus Christie, Texas, the small rack system had annual energy savings of more than 16%. The study also showed the savings were higher in the cooler months, when the small rack system's variability increased in efficiency as energy demands declined in cooler months.

Such findings may vary in different climates, but the small rack system showed promise based on the Corpus Christi study. Further investigation could confirm these trends in other climate zones.

HFA
Creative Solutions
Meaningful Places

Bentonville · Boston · Fort Worth · Mexico City
479.273.7780
hfa-ae.com

Greg Schluterman, PE
greg.schulterman@hfa-ae.com

Miguel L. Purdy, PE
miguel.purdy@hfa-ae.com