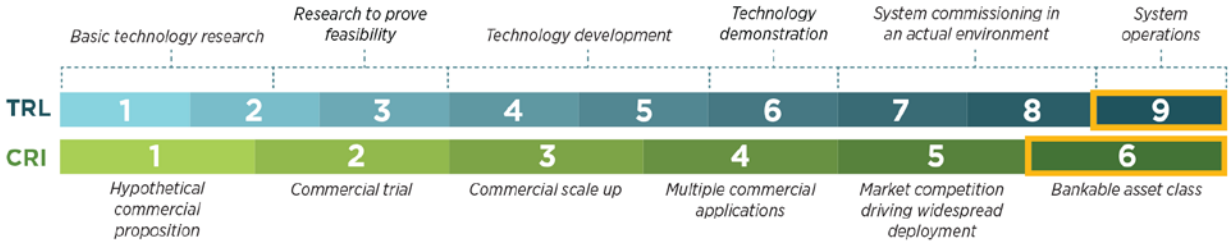
Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector Commercial Refrigeration Equipment Product Category Automatic Commercial Ice Makers Last Updated 11/30/2018	 *Figure 1: Automatic commercial ice maker*

Product Category Overview

Automatic commercial ice makers (ACIMs) consist of a refrigeration system and an ice-making section, and they are used to store and dispense ice. They are typically used in the food service, food preservation, hotel, and healthcare industries. Efficiency improvement opportunities for all refrigeration systems include improvements in compressor technologies, replacements of evaporator and condenser fan shaded pole motors with electronically commutated motors, efficient fan blades, etc. Energy efficiency measures specific to ACIMs include improved ice harvesting controls, optimal evaporator design, and improved water pumping efficiency.

Characterization at a Glance



Product Category Characterization

Energy Benefits

Compressors in ACIMs account for roughly half their energy use. Provided that physical size or noise constraints are not inhibiting factors, the use of high-efficiency compressors is a viable efficiency measure for significant energy savings. Further, variable-speed or dual-capacity compressors allow part-load operation for the compressor when the ACIM is generating ice at less than full capacity, which can also translate to substantial energy savings.

Thermal cycling of the evaporator has an impact on compressor energy use. Reducing the thermal mass of the evaporator can achieve a reduction of compressor energy use during the freeze cycle.

Reducing meltage during ice harvesting can reduce ACIM energy use by preserving more ice per harvest. This can be achieved with reduction of the time the ice is on the evaporator during harvest (through

mechanical or other methods), or by using smooth evaporator surfaces that allow the ice to slide out of the cube cells.

Non-Energy Benefits

The use of more efficient ice makers reduces heat generation to the ambient environment. Further, installing timers on ice makers and shifting ice production to off-peak electricity hours reduces electricity costs for businesses and shifts noise to those off-peak hours, when businesses are generally not operational.

Product Category Differentiation

ACIMs can be categorized based on their configuration (ice making head, self-contained units with storage bin, and remote-condensing units), condenser cooling medium (air- or water-cooled), capacity, and ice-making process (continuous or batch).

Ice-making heads do not include a storage bin or dispenser and need to be paired with one. Self-contained units include all the refrigeration system components in one assembly while remote-condensing units have the condensing unit separate (typically with access to outside air) from the ice freezing and harvesting equipment

Air-cooled condensing units are used in the vast majority of ACIMs, and are typically cheaper than water-cooled ACIMs, which consume significant amounts of water, but have better heat transfer capabilities than air-cooled ACIMs.

With regard to the ice-making mechanism, the batch process alternates the freezing and harvesting periods to generate cube ice, whereas the continuous process combines freezing and harvesting to make flake or nugget ice.

Installation Pathway and Dependencies

When purchasing and installing an ACIM, apart from space and ventilation considerations, a water supply and floor drain is generally required. Further, sometimes ACIMs do not include a cord and plug and are hardwired to the building's electrical system, so professional installation by an electrician may be needed.

In spaces where ambient temperatures are high (i.e. above 25^{o} C), or spaces with poor air ventilation, a water-cooled ACIM may be preferable. If opting for a water-cooled ACIM, water use (and associated expenses) may be significant.

Remote-condensing ACIMs tend to be larger (and with higher ice-making capacities) than self-contained ACIMs. Remote condensing units also require refrigeration lines between the condenser and the ice-producing machine, which can be costly. However, remote units are quieter than self-contained ones.

Certain energy efficiency measures (e.g. installing a high efficiency compressor or replacing a shaded pole condenser fan motor with a more efficient electronically commutated motor) can be implemented as a retrofit and included in new purchases. However, other measures, such as the redesign of the evaporator, are not applicable to retrofits of existing units. A more common efficiency measure is to replace an older unit with a newer Energy Star-rated ACIM.

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Hoshizaki	KM-1900SAJ	Ice-making head, air-cooled, batch	Energy Star rated Stackable unit Stainless steel evaporator 1,675 lbs ice/day* 3.9 kWh/100 lbs ice*
ATOSA	YR280-AP-161	Self-contained, air-cooled, batch	Energy Star rated Propane (R290) refrigerant 236 lbs ice/day* 6.1 kWh/100 lbs ice*
Follett	HCF1410RBS	Remote-condensing, air-cooled, continuous	Energy Star rated Allows ice machine to be installed up to 75 ft away from dispenser 1156 lbs ice/day* 3.26 kWh/100 lbs ice*
Manitowoc	IDT1500N-261	Remote-condensing, air-cooled, batch	Energy Star rated Removable evaporator; programmable ice production cycles; acoustical ice thickness sensor 1435 lbs ice/day* 3.9 kWh/100 lbs ice*

*Based on Energy Star certified products database

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
N/A	Empirical data Effect of improvement in compressor efficiency to overall ACIM energy use.	Average percentage ACIM energy use reduction equal to 57% of the percentage of compressor energy use reduction	[1]
California, USA	Field Study Measurement of energy use reduction from replacing a baseline ACIM with an Energy Star model.	A 34% reduction in electricity consumption was measured.	[2]
N/A	Empirical data Reduction of the evaporator's thermal mass by a factor of 2 compared to standard designs.	A 5% overall reduction in ACIM energy use can be achieved	[3]
N/A	Empirical data Reduction of meltage during harvest by 50% compared to standard meltage rates.	A 4% overall reduction in ACIM energy use can be achieved	[3]

References

[1] U.S. Department of Energy, "Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Technical Support Document: Automatic Commercial Ice Makers," DOE, Washington, DC, December 2014.

[2] A. Karas, D. Cowen and D. Fisher, "Ice Machine Field Study: Energy and Water Saving with Ice Machine Upgrade and Load Shifting," PG&E, San Francisco, CA, Sep 2011.

[3] Navigant Consulting, Inc., "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration," U.S. Department of Energy, 2009.

Technology Sector
Refrigeration

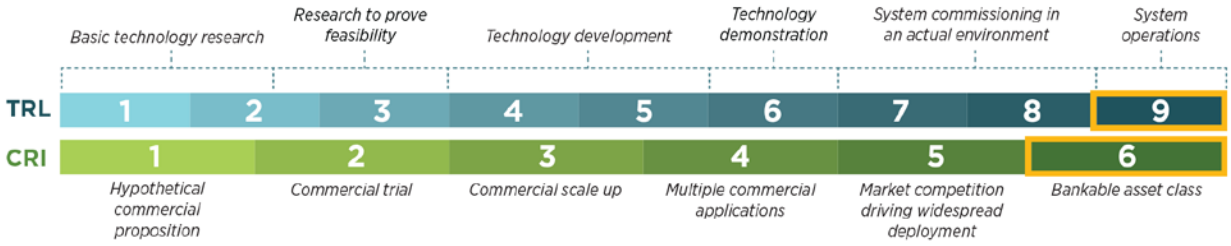
Product Category
Closed, Remote-Condensing Commercial Refrigerators and Freezers

Last Updated
12/14/2018

Figure 1: Closed, remote-condensing service over counter (left), and horizontal remote-condensing closed merchandiser (right)

Product Category Overview
Closed, remote-condensing refrigeration equipment has transparent or solid (opaque) doors and drawers and includes an evaporator fan. It does not include a condenser and compressor, which are sold separately and located remotely. Equipment with glass doors is typically used in food-sales applications, while equipment with solid doors is generally used in food-service applications. This equipment is available in multiple configurations, including vertical and horizontal. Energy savings opportunities include efficient evaporator fan motors and fan blades, insulation improvements, efficient lighting, improved transparent doors (where applicable), and anti-sweat heater controls.

Characterization at a Glance



Product Category Characterization

Energy Benefits
Light emmitting diode (LED) lighting fixtures have high efficacies, very low heat generation, and better directionality than comparable fluorescent systems. Additional savings can be achieved when LED lighting is coupled with occupancy sensors, which reduce or turn off lighting during periods of inactivity around the refrigerated unit.

Efficient evaporator fan motors, and in particular electronically commutated motors (ECMs), offer significant energy savings opportunities for all commercial refrigeration equipment.

Equipment with transparent doors has lower thermal resistance compared to units with solid, insulated doors. To improve visibility of the products to consumers, refrigerators and freezers with transparent doors include a heating element that reduces condensation from forming on the outside glass. These heating elements are called anti-sweat heaters and may run continuously. The units can be made more

energy efficient by improving the door's insulation value and including anti-sweat heater controls, which sense relative humidity and turn on the heating element only when needed.

Non-Energy Benefits

Energy efficient refrigeration equipment may lead to improved ambient humidity and temperature levels for commercial spaces with a high density of refrigeration equipment (e.g. supermarkets and grocery stores). Additionally, improved light directionality and better control of light systems in display cases with LEDs may increase product visibility and consumer preference.

Product Category Differentiation

Refrigeration equipment with doors is generally more efficient compared to equipment without, while equipment with solid insulated doors and drawers is more efficient compared to equipment with transparent, glass doors. Closed refrigeration equipment with transparent doors is typically used for displaying merchandise, while equipment with solid doors is more often used in food preparation and food storage applications. Although open and closed display cases are not traditionally used interchangeably, utilities are now offering incentives to encourage replacement of open, multideck display cases with closed ones of equal or smaller size [1].

Installation Pathway and Dependencies

Remote-condensing commercial refrigeration equipment uses an external condensing unit that is typically situated in either a machine room or an outdoor store location. This equipment is more suitable for new construction applications. Compared to self-contained units, it's more costly and time-consuming to install and connect the refrigerated case to the remote condensing unit. However it's easier to perform preventative maintenance measures (such as cleaning the condenser coil) for remote-condensing units than self-contained units. Remote condensing equipment has more storage and display capacity per unit of volume and is more suitable for applications where noise and high temperatures need to be controlled. The choice between self-contained and remote-condensing units depends on the building's constraints and operating objectives.

Energy efficiency measures for commercial refrigeration equipment are generally applicable for both new units as well as for retrofits of existing equipment [2]. Note that retrofits or replacements of refrigerated units leading to load reductions could be served by the existing remote condensing unit, especially for the case where the condensing unit serves more than one refrigerated unit. However, in the case of a dedicated condensing unit serving one refrigerated case that has a significant load reduction of 50% or more, certain measures should be employed in order to better match the refrigeration load with the condensing unit. See [2] for more information.

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Zero Zone	1RHCC30	Vertical closed display case with transparent doors	LED Lighting ECM evaporator fan motor 32.3 ft^2 display area* 2.84 kWh/day estimated daily energy use*
Hussman	RL-1-M-GE	Vertical refrigerator display case with transparent doors (1 door)	LED lighting 30.9 ft^2 display area* 2.14 kWh/day estimated daily energy use*
Glastender	LP24	Back bar cabinet	LED lighting 24” width 3.32 ft^2 display area* 0.59 kWh/day estimated daily energy use*
Glastender	LPT48	4-door pass-through back bar cabinet	LED lighting 48” width 13.26 ft^2 display area* 1.79 kWh/day estimated daily energy use*

**per Dept. of Energy’s Compliance Certification Management System*

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
N/A	Empirical data Evaporator fan motor. Compared shaded pole and permanent split capacitor motor performance to ECM performance (wattage & efficiency).	Reported 20% efficiency/45 watts for shaded pole motors, 29% efficiency/31 Watts for permanent split capacitor motors, and 66% efficiency/13.6 Watts for ECMs.	[3]
N/A	Empirical data High performance doors. Comparison of the power used by anti-sweat heaters in standard doors vs. high performance (low-emissivity) doors.	A 50% reduction (from 180 Watts to 90 Watts) in anti-sweat heater power was assumed per door when high performance doors were used in closed transparent freezers and ice cream freezers.	[3]
Eugene, Oregon, USA	Field Test Lighting occupancy sensors. Assessed the effect of occupancy sensors in a commercial refrigeration unit with LED lighting.	Occupancy sensors resulted in an overall 30.7% reduction in energy use compared to the same system without occupancy sensors.	[4]

References

[1] Pacific Gas and Electric Company, "Refrigeration Rebate Catalog," July 2018. [Online]. Available: https://tinyurl.com/y7fvklob. [Accessed 30 October 2018].

[2] Navigant Consulting, Inc., "Guide for the Retrofitting of Open Refrigerated Display Cases with Doors," Department of Energy, Washington, DC, November 2012.

[3] U.S. Department of Energy, "Technical Support Document: Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment," 2014. [Online]. Available: https://www.regulations.gov/docket?D=EERE-2010-BT-STD-0003. [Accessed 01 November 2018].

[4] Pacific Northwest National Laboratory, "Demonstration Assessment of LED Freezer Case Lighting," U.S. Department of Energy, Washington, DC, 2009.

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector
Refrigeration

Product Category
Closed, Self-Contained Commercial Refrigerators and Freezers

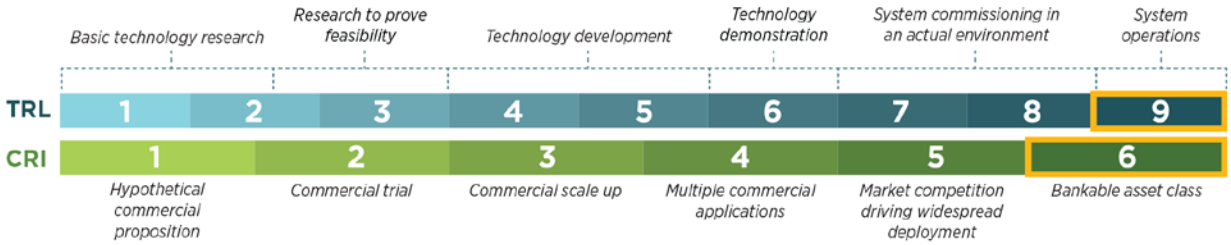
Last Updated
12/14/2018

Figure 1: Vertical closed refrigerators with solid doors (left) and transparent doors (right)

Product Category Overview

Closed, self-contained refrigeration equipment has transparent or solid (opaque) doors and drawers, and includes a complete refrigeration system, including a condenser, compressor, and evaporator. Equipment with glass doors is typically used in food-sales applications, while equipment with solid doors is generally used in food-service applications. This equipment is available in multiple configurations, including vertical, and horizontal configurations. Energy savings opportunities include high-efficiency compressors and fan motors, insulation improvements, efficient lighting, improved transparent doors (where applicable), anti-sweat heater controls.

Characterization at a Glance



Product Category Characterization

Energy Benefits

Light emmitting diode (LED) lighting fixtures have high efficacies, very low heat generation, and better directionality than comparable fluorescent systems. Additional savings can be achieved when LED lighting is coupled with occupancy sensors, which reduce or turn off lighting during periods of inactivity around the refrigerated unit.

Efficient evaporator fan and condenser fan motors, and in particular electronically commutated motors (ECMs) offer significant energy savings opportunities for all commercial refrigeration equipment. Efficient ECM compressor motors, efficient compressor technologies (e.g., scroll compressors) and

variable speed compressors can achieve significant energy savings in all self-contained refrigeration units.

Equipment with transparent doors has lower thermal resistance compared to units with solid, insulated doors. To improve visibility of the displayed products by consumers, refrigerators and freezers with transparent doors include a heating element that reduces condensation from forming on the outside glass. These heating elements are called anti-sweat heaters, which may run continuously. An effective energy efficiency measure is to improve the door's insulation value, and to include anti-sweat heater controls, which sense relative humidity and turn on the heating element only when needed.

Non-Energy Benefits

Energy efficient refrigeration equipment may lead to improved ambient humidity and temperature levels for commercial spaces with a high density of refrigeration equipment (e.g., supermarkets and grocery stores). Also, improved light directionality and better control of light systems in display cases with LEDs may increase product visibility and consumer preference.

Product Category Differentiation

Refrigeration equipment with doors is generally more efficient compared to equipment without, while equipment with solid insulated doors and drawers is more efficient compared to equipment with transparent, glass doors. Closed refrigeration equipment with transparent doors is typically used for displaying merchandise to consumers, while equipment with solid doors is more often used in food preparation and food storage applications. Although open and closed display cases are not traditionally used interchangeably, utilities are now offering incentives to encourage replacement of open, multideck display cases by closed ones of equal or smaller size [1].

Installation Pathway and Dependencies

Self-contained refrigeration equipment are standalone units that can be easily installed by plugging into a power outlet with little to no technical setup. They are also easily relocated in different locations, if desired. On the other hand, self-contained units have lower storage and display capacity, make more noise and can lead to higher ambient temperatures than comparable remote-condensing units (especially in kitchen areas, where temperatures are already elevated). Therefore, the choice between self-contained and remote-condensing units depends on the needs of each building's constraints and operating objectives. Energy efficiency measures for commercial refrigeration equipment are generally applicable for both new units as well as for retrofits of existing equipment [2].

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Beverage-Air	UCR20HC	Undercounter refrigerator with solid doors	• Self-closing door • Propane (R290 refrigerant) • 2.28 ft^3 storage capacity* • 0.48 kWh/day energy use*
Turbo Air	TGM-5R-N6	Counter top merchandiser with transparent doors	• LED interior lighting • Low- E glass door • 4.16 ft^3 storage capacity* • 0.6 kWh/day energy use*
True	TMC-58-HC	One sided solid horizontal milk cooler	• 58” width • Propane (R290 refrigerant) • 19.94 ft^3 storage capacity* • 1.17 kWh/day energy use*
Hoshizaki	HR24A	Undercounter solid door refrigerator	• Self-closing door • R-600a (isobutane) refrigerant • 3.7 ft^3 storage capacity* • 0.49 kWh/day energy use*

*per Dept. of Energy’s Compliance Certification Management System

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
N/A	Empirical data Evaporator fan motor Compared shaded pole and permanent split capacitor motor performance to ECM performance (wattage & efficiency)	Reported 20% efficiency/45 watts for shaded pole motors, 29% efficiency/31 Watts for permanent split capacitor motors, and 66% efficiency/13.6 Watts for ECMs	[3]
N/A	Empirical data High performance doors Comparison of the power used by anti-sweat heaters in standard doors vs. high performance (low-emissivity) doors	A 50% reduction (from 180 Watts to 90 Watts) in anti-sweat heater power was assumed per door when high performance doors were used in closed transparent freezers and ice cream freezers	[3]
Eugene, Oregon, USA	Field Test Lighting occupancy sensors Assessed the effect of occupancy sensors in a commercial refrigeration unit with LED lighting	Occupancy sensors resulted in an overall 30.7% reduction in energy use compared to the same system without occupancy sensors.	[4]

References

[1] Pacific Gas and Electric Company, "Refrigeration Rebate Catalog," July 2018. [Online]. Available: https://tinyurl.com/y7fvklob. [Accessed 30 October 2018].

[2] Navigant Consulting, Inc., "Guide for the Retrofitting of Open Refrigerated Display Cases with Doors," Department of Energy, Washington, DC, November 2012.

[3] U.S. Department of Energy, "Technical Support Document: Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment," 2014. [Online]. Available: https://www.regulations.gov/docket?D=EERE-2010-BT-STD-0003. [Accessed 01 November 2018].

[4] Pacific Northwest National Laboratory, "Demonstration Assessment of LED Freezer Case Lighting," U.S. Department of Energy, Washington, DC, 2009.

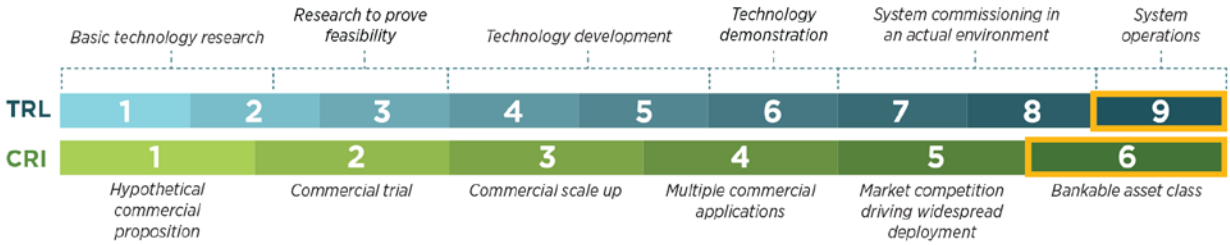
Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector Refrigeration Product Category Open, Remote-Condensing Commercial Refrigerators and Freezers Last Updated 11/16/2018	 *Figure 1: Open, remote-condensing merchandise display case*

Product Category Overview

Open remote-condensing refrigeration equipment does not include doors or drawers, allowing for easier access to refrigerated products. The equipment does include an evaporator fan but does not include a condenser and compressor, which are sold separately and located remotely. This equipment is typically used in large supermarket applications and is available mostly in vertical configurations. Energy savings opportunities include efficient evaporator fan motors and fan blades, efficient lighting, improved air curtain design, and the use of night curtains.

Characterization at a Glance



Product Category Characterization

Energy Benefits

Light emmitting diode (LED) lighting fixtures have high efficacies, very low heat generation, and better directionality than comparable fluorescent systems. Additional savings can be achieved when LED lighting is coupled with occupancy sensors, which reduce or turn off lighting during periods of inactivity around the refrigerated unit.

Efficient evaporator fan motors, and in particular electronically commutated motors (ECMs), offer significant energy savings for all commercial refrigeration equipment.

Specific energy savings measures include night curtains and air curtains. Night curtains reduce the amount of cooled air lost during night hours or when the commercial space is not open for service. Air curtains are created by circulating an effective curtain of air between the cooled area of the display case

and the outside ambient air, thus reducing warm air infiltration and helping maintain desired humidity levels inside the display case.

Non-Energy Benefits

Energy efficient open refrigeration equipment may lead to improved ambient humidity and temperature levels for commercial spaces with a high density of refrigeration equipment (e.g. supermarkets and grocery stores). Improved light directionality and better control of light systems in display cases with LEDs may also increase product visibility and consumer preference.

Product Category Differentiation

Open commercial refrigerators have better marketability than closed units (i.e. refrigerators with glass doors) because the displayed merchandise is more easily accessible and visible to consumers. However, open refrigeration equipment is also significantly less energy efficient compared to equivalent closed equipment. Although open and closed display cases are not traditionally used interchangeably, utilities are now offering incentives to encourage replacement of open, multideck display cases with closed ones of equal or smaller size. [1]

Installation Pathway and Dependencies

Remote-condensing commercial refrigeration equipment is more suitable for new construction applications as it uses an external condensing unit that is typically situated in either a machine room or an outdoor store location. Compared to the setup for self-contained units, installing and connecting refrigerated cases to remote condensing units is costly and time-consuming. However it is more difficult to perform preventative maintenance measures on self-contained units (e.g. cleaning the condenser coil) compared to maintaining the remote condensing unit. Remote condensing equipment has more storage and display capacity per unit of volume and is more suitable for applications where noise and high temperatures need to be controlled. The choice between self-contained and remote-condensing units depends on the building's constraints and operating objectives. Energy efficiency measures for commercial refrigeration equipment are generally applicable for both new units as well as retrofits of existing equipment [2]. Note that retrofits or replacements of refrigerated units leading to load reductions could be served by the existing remote condensing unit, especially for the case where the condensing unit serves more than one refrigerated unit. However, in the case of a dedicated condensing unit serving one refrigerated case that has a significant load reduction of 50% or more, certain measures should be employed in order to better match the refrigeration load with the condensing unit. See [2] for more information.

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Zero Zone	ORMC82(L/M/H)-M	Vertical open display case with multiple decks	• ECM evaporator fan • LED Lighting • In 4',6',8'12' configurations
Hussman	ID5SM6	Vertical open merchandiser for dairy/meat applications	• LED lighting • 6 ft width • 25.8 ft2 display area • 14.91 kWh/day estimated daily energy use*
Piper	R-GNG-HPRO-3-R-GEP-LED	Vertical open merchandiser	• LED lighting • 3 ft width • 19.7 ft2 display area • 8.25 kWh/day estimated daily energy use*
Hussman	ID5NL4	Vertical open merchandiser for dairy/meat applications	• LED lighting • 12 ft width • 55.2 ft2 display area • 32.3 kWh/day estimated daily energy use*

*per Dept. of Energy's Compliance Certification Management System

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
N/A	Empirical data Evaporator fan motor Compared shaded pole and permanent split capacitor motor performance to ECM performance (wattage & efficiency)	Reported 20% efficiency/45 watts for shaded pole motors, 29% efficiency/31 Watts for permanent split capacitor motors, and 66% efficiency/13.6 Watts for ECMs.	[3]
Irwindale, California, USA	Field Test Night curtains Evaluated the effect of night curtains on compressor performance	A 36% reduction in compressor power was achieved when night curtains were used for 6 hours (midnight to 6 a.m.) daily.	[4]
Eugene, Oregon, USA	Field Test Lighting occupancy sensors Assessed the effect of occupancy sensors in a commercial refrigeration unit with LED lighting	Occupancy sensors resulted in an overall 30.7% reduction in energy use compared to the same system without occupancy sensors.	[5]

References

[1] Pacific Gas and Electric Company, "Refrigeration Rebate Catalog," July 2018. [Online]. Available: https://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/refrigeration_catalog_final.pdf. [Accessed Oct. 30, 2018].

[2] Navigant Consulting, Inc., "Guide for the Retrofitting of Open Refrigerated Display Cases with Doors," Department of Energy, Washington, DC, November 2012.

[3] U.S. Department of Energy, "Technical Support Document: Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment," 2014. [Online]. Available: https://www.regulations.gov/docket?D=EERE-2010-BT-STD-0003. [Accessed Nov. 1, 2018].

[4] Southern California Edison Refrigeration Technology and Test Center, "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case," Southern California Edison, Rancho Cucamonga, CA, 1997.

[5] Pacific Northwest National Laboratory, "Demonstration Assessment of LED Freezer Case Lighting," U.S. Department of Energy, Washington, DC, 2009.

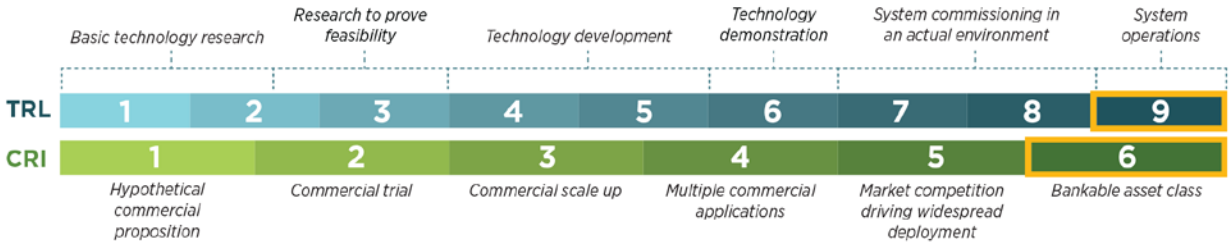
Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector Refrigeration Product Category Open, Self-Contained Commercial Refrigerators and Freezers Last Updated 11/16/2018	 *Figure 1: Open horizontal and open upright merchandise display case.*

Product Category Overview

Open, self-contained refrigeration equipment does not have doors or drawers, allowing easier access to refrigerated products. This is a complete refrigeration system, including a condenser, compressor, and evaporator. This equipment is typically used in food sales applications and is available in vertical, semivertical, or horizontal configurations. Energy savings opportunities include high-efficiency compressors and fan motors, efficient lighting, improved air curtain design, and the use of night curtains.

Characterization at a Glance



Product Category Characterization

Energy Benefits

Light emmitting diode (LED) lighting fixtures have high efficacies, very low heat generation, and better directionality than comparable fluorescent systems. Additional savings can be achieved when LED lighting is coupled with occupancy sensors, which reduce or turn off lighting during periods of inactivity around the refrigerated unit.

Efficient evaporator fan and condenser fan motors, and in particular electronically commutated motors (ECMs) offer significant energy savings opportunities for all commercial refrigeration equipment. Efficient ECM compressor motors, efficient compressor technologies (e.g. scroll compressors) and variable speed compressors can achieve significant energy savings in self-contained refrigeration units.

Specific energy savings measures include night curtains and air curtains. Night curtains reduce the amount of cooled air lost during night hours, or when the commercial space is not open for service. Air curtains are created by circulating an effective curtain of air between the cooled area of the display case and the outside ambient air, thus reducing warm air infiltration, and helping maintain desired humidity levels inside the display case.

Non-Energy Benefits

Energy efficient open refrigeration equipment may lead to improved ambient humidity and temperature levels for commercial spaces with high density of refrigeration equipment (e.g., supermarkets and grocery stores). Improved light directionality and better control of light systems in display cases with LEDs may also increase product visibility and consumer preference.

Product Category Differentiation

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Installation Pathway and Dependencies

Self-contained refrigeration equipment are standalone units that can be easily installed by being plugged into a power outlet with little to no technical setup. They are also easily relocated if desired. However, self-contained units have lower storage and display capacity, make more noise, and can lead to higher ambient temperatures than comparable remote-condensing units (especially in kitchen areas, where temperatures are already elevated). Therefore, the choice between self-contained and remote-condensing units depends on the building's constraints and the operating objectives. Energy efficiency measures for commercial refrigeration equipment are generally applicable for both new units as well as for retrofits of existing equipment [2].

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
True	TAC-14GS-LD	Vertical open display case	• Configuration • LED lighting • 5.38 ft^2 display area* • 10.03 kWh/day energy use*
Turbo Air	TOM-50LW-N	Horizontal open air curtain display case.	• Configuration • Self-cleaning condenser • Propane (R290) refrigerant • 9.81 ft^3 capacity
Beverage-Air	VM7	Vertical open display case	• Includes night curtain • 9.32 ft^2 display area* • 8.98 kWh/day energy use*
Hussman	Q2-SSM-6S	Semivertical open display case	• 6 ft width • LED lighting • 20 ft^2 display area* • 16.14 kWh/day energy use*

*per Dept. of Energy's Compliance Certification Management System

Quantification of Performance

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N/A	Empirical data Evaporator fan motor Compared shaded pole and permanent split capacitor motor performance to ECM performance (wattage & efficiency)	Reported 20% efficiency/45 watts for shaded pole motors, 29% efficiency/31 Watts for permanent split capacitor motors, and 66% efficiency/13.6 Watts for ECMs.	[2]
Irwindale, California, USA	Field Test Night curtains Evaluated the effect of night curtains on compressor performance	A 36% reduction in compressor power was achieved when night curtains were used for 6 hours (midnight to 6 a.m.) daily.	[3]
Eugene, Oregon, USA	Field Test Lighting occupancy sensors Assessed the effect of occupancy sensors in a commercial refrigeration unit with LED lighting	Occupancy sensors resulted in an overall 30.7% reduction in energy use compared to the same system without occupancy sensors.	[4]

References

[1] Pacific Gas and Electric Company, "Refrigeration Rebate Catalog," July 2018. [Online]. Available: https://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/refrigeration_catalog_final.pdf. [Accessed Oct. 30, 2018].

[2] U.S. Department of Energy, "Technical Support Document: Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment," 2014. [Online]. Available: https://www.regulations.gov/docket?D=EERE-2010-BT-STD-0003. [Accessed Nov. 1, 2018].

[3] Southern California Edison Refrigeration Technology and Test Center, "Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case," Southern California Edison, Rancho Cucamonga, CA, 1997.

[4] Pacific Northwest National Laboratory, "Demonstration Assessment of LED Freezer Case Lighting," U.S. Department of Energy, Washington, DC, 2009.

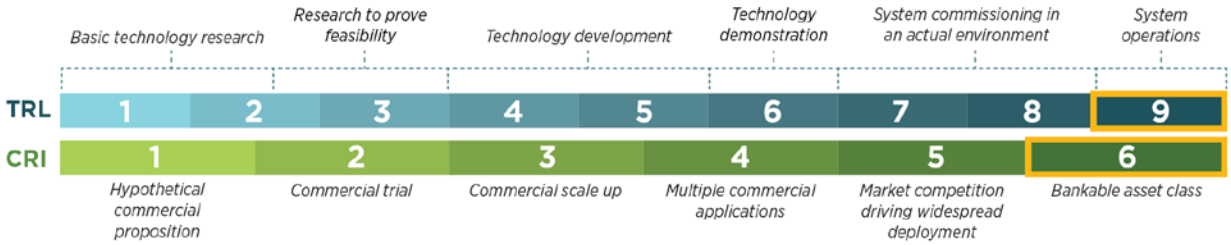
Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector Commercial Refrigeration Equipment Product Category Refrigerated Beverage Vending Machines Last Updated 12/14/2018	 *Figure 1: Automatic beverage vending machine*

Product Category Overview

Beverage vending machines (BVMs) are upright, self-contained refrigerated cases which can quickly reduce the temperature of their contents (pull-down). They are generally used in the commercial sector (e.g. offices, hotels, education, healthcare, public locations) to store and dispense refrigerated packaged beverages on payment. Efficiency improvement opportunities include typical refrigeration system measures (insulation, efficient lighting, efficient fan motors and compressors, improved fan motor controls, etc.) as well proximity sensors and controls that reduce lighting and raise the cooling set point when the space is unoccupied.

Characterization at a Glance



Product Category Characterization

Energy Benefits

BVMs typically include lighting to showcase merchandise in equipment with transparent displays or to illuminate exterior signs in equipment with opaque fronts. Efficient lighting reduces energy use and heat generation, which reduces the cooling load for the BVM when lighting is located inside the refrigerated space. Light-emitting diode (LED) lighting provides energy efficiency and better directionality and is becoming the norm in BVMs currently available in the market.

The compressor accounts for roughly 50% of vending machine energy use. High efficiency scroll or reciprocating compressors as well as variable speed controls can significantly reduce compressor and BVM energy consumption.

Proximity sensors and controls can significantly reduce BVM energy use by turning off lighting and reducing the holding temperature set point when the surrounding area is not occupied for a specific time duration (typically about 15 minutes or more).

Non-Energy Benefits

Improved light directionality and better control of light systems in BVMs with LEDs may increase product visibility and consumer preference. Also, the use of non-hydrofluorocarbon refrigerants such as propane (R290) may lower the climate change impact of BVMs.

Product Category Differentiation

BVMs can be categorized based on the door type (transparent or opaque), the beverage storage system (shelves or stacks), the cooling mechanism (fully cooled or zone cooled), and the types of products stored and sold (bottles and cans, other products, or combination thereof).

BVMs with transparent fronts are fully cooled, whereas opaque BVMs, which store merchandise in stacks, are typically zone-cooled. This means that cool air from the evaporator is directed primarily towards the lower part of the BVM in order to refrigerate the items that will be dispensed first. This method reduces the energy consumption of the BVM, compared to fully-cooled BVMs.

Installation Pathway and Dependencies

For the most part BVMs are purchased directly from the manufacturer by soft drink bottling companies and often owned by those companies. BVMs are easily installed, with installation costs estimated at about $100 [1]. In addition, BVMs typically come with a 5-year warranty. Failures in the refrigeration system past the warranty period are generally managed and addressed by the bottling company by replacing the failed component.

Due to the market and ownership structure of BVMs, energy efficiency measures are more applicable to new units. However certain energy efficiency measures (e.g. installation of proximity sensors and controls) may be performed in retrofits.

List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Sanden Vendo America, Inc.	GF9AH	Glass front for indoor use	• Energy Star rated • LED lighting • 3.81 kWh/day* • 38.54 ft^3 refrigerated volume*
Royal Vendors	GIII 550	Opaque front for indoor/outdoor use	• Energy Star rated • Optional CO_2 refrigerant • 2.83 kWh/day* • 19.49 ft^3 refrigerated volume*
Crane	DN5800-4	Glass front for indoor use	• Energy Star rated • LED lighting • 3.95 kWh/day* • 35.84 ft^3 refrigerated volume*
Sanden Vendo America, Inc.	821-HC	Opaque front for indoor/outdoor use	• Energy Star rated • Propane (R290) refrigerant • 3.55 kWh/day* • 30.5 ft^3 refrigerated volume*

*Based on Energy Star certified products database

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
N/A	Empirical data Comparison of evaporator fan motor technologies. Baseline technology: Shaded-pole motor.	Efficiency of shaded pole motors is 15-17%. Efficiency of permanent split capacitor motors is 40-43%. Efficiency of electronically commutated motors is 70-72%.	[1]
N/A	Simulated data Evaluation of the effect of vacuum insulated panels (compared to no vacuum).	Use of a vacuum insulated panel with an R-value of 30 reduces BVM energy use by 10%.	[2]
N/A	Modeling – empirical data.	Hermetic compressors using propane (R290) compared to tetrafluorothane (R134a) can be 15% more efficient.	[1]
N/A	Empirical data Comparison of the energy use of BVMs with the use of proximity sensors and controls.	Proximity sensors and controls with the ability to regulate lighting and cooling loads in BVMs can reduce BVM energy use by 20%.	[2]

References

[1] Navigant Consulting, Inc., "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration," U.S. Department of Energy, 2009.

[2] U.S. Department of Energy, "Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Technical Support Document: Refrigerated Bottled or Canned Beverage Vending Machines," DOE, Washington, DC, August .

Product Characterization Report
California Energy Product Evaluation (Cal-EPE) Hub

Technology Sector
Commercial Refrigeration Equipment

Product Category
Walk-In Refrigerators and Freezers

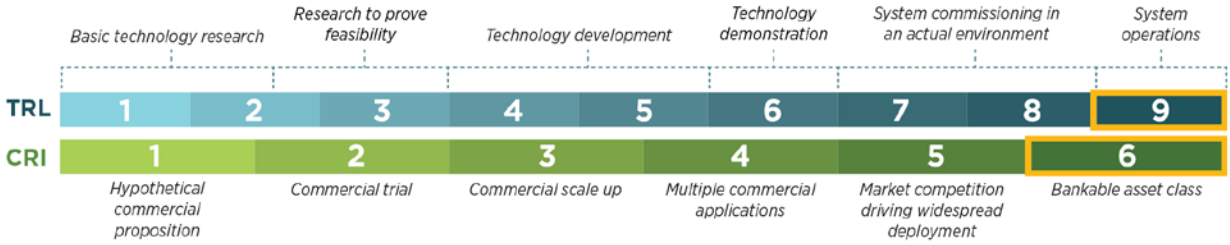
Last Updated
12/14/2018

Figure 1: Indoor walk-in cooler box

Product Category Overview

Walk-in coolers and freezers (WICFs) are large, insulated refrigeration systems that allow people to enter through access doors. They are typically custom made from insulated panels with steel or aluminum exteriors, doors, and a blower-refrigeration system that maintains temperature conditions inside the conditioned space. Self-contained walk-ins are generally found in systems less than 3 hp, while remote-condensing units are used in systems greater than 3 hp. Efficiency measures for walk-ins can result from improvements in the refrigeration system (e.g. compressor, motors, fans), system improvements (e.g. defrost controls, refrigerant conditions), and floor, wall, and door insulation.

Characterization at a Glance



Product Category Characterization

Energy Benefits

Typically evaporator fans operate continuously at full speed. Controls for evaporator fans reduce WICF energy use by allowing the fan to operate at lower speeds or cycle on and off when the compressor is off.

In large WICFs, doors tend to remain open to allow frequent loading and unloading. To reduce heat infiltration to the refrigerated box, strip curtains are installed at the opening of the WICF. Installing automatic door closers produces a similar result while also decreasing ambient air infiltration.

Low temperature WICFs generally have an electric resistance heating element for defrost. Hot gas defrost essentially reverses the refrigeration cycle and, as a result, hot gas from the compressor is directed to the evaporator, melting the ice on the coil. This method is more energy efficient than electric defrost but does require a control mechanism between the compressor and the coil.

Non-Energy Benefits

Energy efficient WICFs that are able to regulate ice buildup on the evaporator coil can reduce burden on the compressor and may extend its lifetime.

Product Category Differentiation

Self-contained (packaged) systems include the condensing unit, evaporator, and controls in a package. The evaporator is located inside or has air ducted to the refrigerated unit, and the condensing unit is located on the wall or the roof of the refrigerated unit (but inside the building). In remote-condensing (split) systems, which tend to be larger, the condensing unit is generally located outside the building. The latter configuration allows heat from the condensing unit to be rejected outdoors.

Installation Pathway and Dependencies

Panels, doors, and refrigeration systems in WICFs are typically sold separately and assembled and installed onsite by refrigeration contractors. Certain energy efficiency measures—such as hot gas and adaptive defrost—are more applicable for new systems because they require additional labor and components (e.g. a new refrigerant plumbing system) between the evaporator and the condensing unit. Other efficiency measures, such as replacements of evaporator fan motors with more efficient technologies (e.g. electrically commutated motors [ECM]), are applicable to both retrofit and new purchases. Condensing units have roughly half the lifetime of the refrigerated box, so replacements with more efficient refrigeration systems can occur during retrofits. With regard to the refrigerated box, doors are replaced more often due to wear and tear, thereby providing opportunities for efficiency improvements through better insulation, curtains, and auto-closing mechanisms.

Product Characterization Report
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List of Products

Table 1: Summary of manufacturers and products for the product category.

Manufacturer	Model	Type	Differentiating Feature
Copeland	XFAM-010Z-TFC	Outdoor condensing unit	• Scroll compressor • Air cooled condenser • 12 AWEF • 0.125 HP condenser fan motor
Refplus	IEZ-15001H1	Indoor condensing unit	• Scroll compressor • Air cooled condenser • 8.16 AWEF • 0.5 HP condenser fan motor
Hussman/Krack	KR24G-074-EAK	Unit Cooler	• Fan ECM • 2 fans • Hot gas defrost
Refplus	LVH-3600	Unit Cooler	• Low air, blow through • 0.25 HP evaporator fan motor • Hot gas defrost

Quantification of Performance

A literature search was conducted and a sample of published study results are summarized in Table 2.

Table 2: Summary of results from literature review

Location	Application	Results	Reference
California, USA	Experimental Effect of strip curtains on energy use.	Strip curtains may reduce WICF energy consumption by 9%.	[1]
California, USA	Experimental Effect of auto door closers on energy use.	Auto-door may reduce WICF energy consumption by 8%.	[1]
N/A	Empirical data Efficiency of ECM compared to permanent split capacitor motor for condenser fan.	Condenser fan ECMs had 75% efficiency, compared to permanent split capacitor motors with 50% efficiency.	[2]
N/A	Empirical data Energy use of evaporator fan control options compared to single speed fans without controls.	For a 50% speed reduction in variable speed fans, an 80% energy use reduction was assumed, compared to single speed fans running without controls.	[2]

References

[1] Davis Energy Group, Energy Solutions, "Analysis of Standards Options for Walk-in Coolers (Refrigerators) and Freezers," PG&E, May 2004.

[2] Department of Energy, "Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Walk-In Coolers and Walk-In Freezers," 2017.