Performance Assessment of High-Efficiency Refrigerated Display Cases With Low Global Warming Potential Refrigerants

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All photos and figures by Alexander Bulk, NREL

Objective

Evaluate daily energy savings of high-efficiency medium-temperature (MT) reach-in refrigerated display cases utilizing environmentally friendly refrigerants under realistic operating conditions

Background

- Self-contained MT refrigerator display cases see widespread use in convenience stores, restaurants, and small supermarkets.
- Significant attention has been given to energy-efficient remote and low-temperature (LT) refrigeration. However, little research has investigated energy use by MT self-contained cases other than to verify compliance with standards.
- In 2020, Congress and the U.S. Environmental Protection Agency initiated a phase-down of units using hydrofluorocarbon (HFC) refrigerants with high global warming potential (GWP). GWP is the ratio of heat stored in one metric ton of a substance to the same amount of CO_2.

Properties of Selected Refrigerants

Two cases with alternative refrigerants were evaluated against a case containing traditional HFC R134a refrigerant (baseline case):

Refrigerant	Global Warming Potential (GWP)	Saturated Liquid Density, ρ @ 25°C (kg/m3)	Liquid Constant Pressure Heat Coefficient, cp @ 25°C (kJ/kgK)	Vapor Constant Pressure Heat Coefficient, cp @ 25°C (kJ/kgK)	Enthalpy of Vaporization (kJ/kg)
R134a	1301	1207	1.426	0.851	234.7
R513a	573	492	2.742	2.036	440.1
R290	3	1134	1.412	0.881	194.8

Energy-Efficient Features of Display Cases

- **Energy-Efficient (EE) Case A:** Closest matching model containing hydrocarbon R290 (high-purity propane), ***energy-efficient lighting, heat exchanger fan motors, and improved insulation***
- **EE Case B:** Same model case as the baseline containing R513a (Hydrofluoroolefin drop-in replacement to R134a) with ***energy-efficient upgrades including efficient lighting, oversized evaporator, and condenser heat exchangers***

Display Case Specifications

Case	Refrigerant	V/Hz/Ph	CCMS-Rated Energy (kWh/day)	Defrost Cycle Frequency	Rated Cooling Output (Btu/h)	Rated Current (A)
Baseline	R134a	115/60/1	6.24	24 hours	2,600	13.8
EE Case A	R290	115/60/1	4.90	none	4,716	9.3
EE Case B	R513a	115/60/1	Unavailable	12 hours	Unavailable	Unavailable

Case	GWP	Volumetric Capacity (ft³)	Default Cut-In Temp (°F)	Default Cut-Out Temp (°F)	Evaporator Fan Cycling
Baseline	1300	48.29	32	40	Continuous
EE Case A	<4	49.15	33	38	1 min every 6 min
EE Case B	573	48.29	32	40	With compressor cycling

Experimental Design

Display Case Selection Criteria

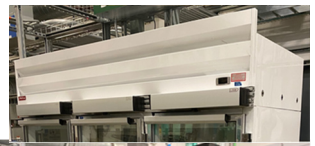
Selected from a U.S. Department of Energy database of commercially available refrigerators that contained the closest specifications based on:

1. Equivalent overall merchandizing volume and configuration (5 deck/4 shelf, 6-ft length)
2. Discharge air temperatures (medium temperature)
3. Components wiring (all on 115V/3Ph/60Hz)
4. Number of glass doors (3)
5. An equal number of compressors/condensing units (1, ½ HP)
6. Close internal dimensions.

Experimental Procedure

- Followed ASHRAE 72-2018 method of test where applicable
- 24-hour experiments in controlled environmental chamber
- Measured total power, sub-component power, refrigerant and air temperatures, product temperatures, and mass of condensate
- Door actuators used to replicate customer traffic and door openings over an 8-hour period.

Environmental chamber



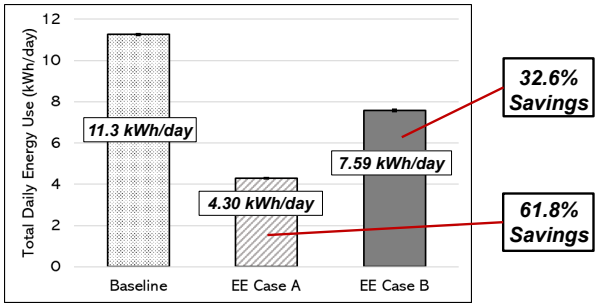
Door actuators

Refrigerator cases inside environmental chamber: Baseline (left), EE Case A (right)

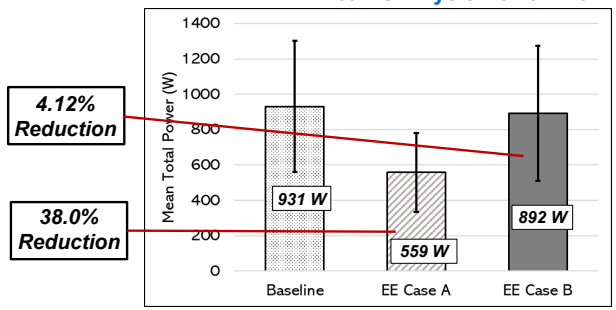
Findings

Energy error bars indicate standard deviation across repeated 24-hour evaluations. Power error bars indicate standard deviation across compressor operation.

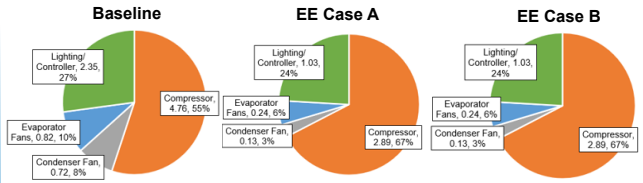
Total Mean Daily Energy



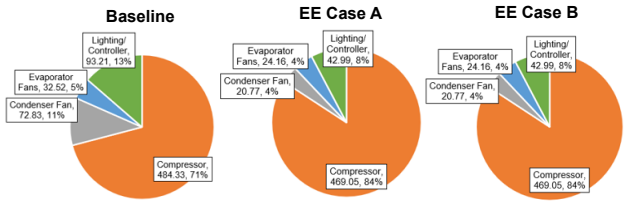
Mean On-Cycle Power Draw



Energy Consumption by Component



Power Consumption by Component



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