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 CO₂.

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

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Global Warming Potential (GWP)</th>
<th>Saturated Liquid Density, p (kg/m³)</th>
<th>Liquid Constant Pressure Heat Coefficient, cp (kJ/kgK)</th>
<th>Vapor Constant Pressure Heat Coefficient, cp (kJ/kgK)</th>
<th>Enthalpy of Vaporization (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R134a</td>
<td>1301</td>
<td>1207</td>
<td>1.426</td>
<td>0.881</td>
<td>234.7</td>
</tr>
<tr>
<td>R513a</td>
<td>573</td>
<td>1134</td>
<td>2.742</td>
<td>2.036</td>
<td>440.1</td>
</tr>
<tr>
<td>R290</td>
<td>3</td>
<td>1394</td>
<td>1.412</td>
<td>0.881</td>
<td>194.8</td>
</tr>
</tbody>
</table>

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

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.

Energy Consumption by Component

Power Consumption by Component

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