R-2. Install Secondary Loop and/or Cascade Supermarket Systems in Place of Direct Expansion Systems

GHG Mitigation Potential

100%

Up to a 100% reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased energy efficiency in refrigeration systems can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

Non-applicable

Measure Description

This measure replaces conventional direct expansion systems in supermarkets with indirect systems such as secondary loop and cascade systems. Currently, direct expansion systems are the most used refrigeration system type in supermarkets in the U.S. (U.S. EPA 2016). Whereas direct expansion systems circulate one refrigerant from the machinery room out to the store and back to the machinery room, indirect systems employ a primary and secondary refrigerant or heat transfer fluid (U.S. EPA 2016, 2019). In secondary loop systems, the primary refrigerant remains in the machine room and cools the secondary fluid, which is then pumped throughout the store to cool products. Another type of indirect system is a cascade system, which contains two refrigeration systems that share a common heat exchanger. These systems often use HFCs, NH_3, or hydrocarbons as the primary refrigerant. Often water mixed with glycol is used as the secondary heat transfer fluid in secondary loop systems; CO_2 is often used as the second refrigerant in cascades. By either confining HFCs to the machinery room as the primary refrigerant or removing HFCs entirely (as in NH_3 and hydrocarbon systems), these systems require significantly lower refrigerant charge and have lower leak rates than conventional direct expansion systems (U.S. EPA 2013a, 2019). Decreasing the refrigerant charge and leak rates results in a reduction of potential direct GHG emissions.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

While both secondary loop and cascade supermarket systems have a higher initial cost over traditional systems, minimized costs associated with rechanging systems due to reduced leakage and energy efficiency improvements may provide a net cost savings over the lifetime of the systems.

Expanded Mitigation Options

Pair with Measure R-1, *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, for increased GHG reductions in supermarket refrigerant systems.

GHG Reduction Formula

$$A = \frac{[(B \times F \times H)+(C \times F \times I)] - (D \times E \times G)}{D \times E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	0–100	%	calculated
User Inputs				
B	Equipment charge size of secondary loop and/or cascade system	[ ]	kg	user input
C	Equipment charge size of secondary refrigerant in secondary loop and/or cascade system	[ ]	kg	user input
Constants, Assumptions, and Available Defaults				
D	Equipment charge size of conventional direct expansion system	1,633	kg	U.S. EPA 2013a
E	Annual leak rate of conventional direct expansion system	25	%	U.S. EPA 2013b
F	Annual leak rate of secondary loop and/or cascade system	5–15	%	U.S. EPA 2013a
G	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018
H	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018
I	GWP of refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018

Further explanation of key variables:

- (B) – The equipment charge size is the total quantity of the primary refrigerant installed in refrigeration or A/C equipment.
- (C) – The equipment charge size is the total quantity of the secondary refrigerant installed in refrigeration or A/C equipment.
- (D) – Based on industry data, the equipment charge size of a conventional direct expansion system is 1,633 kg. If the user can provide a project-specific value, they should replace the default conventional direct expansion system charge size in the GHG reduction formula.
- (E and F) – Based on industry data, the average annual leak rates for the given equipment type, including operational and servicing leak rates for the equipment

throughout the year. Leak rates are provided as averages and may vary with specific systems.

- (G, H, and I) – The GWP of the refrigerant measures the contribution to global warming from the release of one unit of the given refrigerant relative to CO_2 on a 100-year time horizon. The GWP of common refrigerants and alternatives is provided in Table R-1.1 in Appendix C.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 100 percent.

Example GHG Reduction Quantification

The user reduces high-GWP refrigerant emissions by replacing a conventional direct expansion system in a supermarket with a secondary loop system. In this example, the conventional direct expansion system refrigerant is R-404A, which has a GWP of 3,922 (G). The direct expansion system equipment charge size of 1,633 kg (D) is assumed. The charge size for the primary refrigerant (R-407A) in the secondary loop system is 1,145 kg (B) and the GWP is 2,107 (H). The charge size for the heat transfer fluid refrigerant using water is 1,145 kg (C) with a GWP of 0 (I). Implementation of this project would reduce GHG emissions from the refrigeration system at this supermarket by 77 percent.

$$A = \frac{((1{,}145\text{ kg} \times 15\% \times 2{,}107) + (1{,}145\text{ kg} \times 15\% \times 0)) - (1{,}633\text{ kg} \times 25\% \times 3{,}922)}{(1{,}633\text{ kg} \times 25\% \times 3{,}922)} = -77\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure could achieve energy savings. While historically secondary loop and/or cascade systems have reduced energy efficiency, the past 15 years of development have resulted in energy efficiency improvements ranging from 0.5 percent to 35 percent compared to conventional direct expansion systems (U.S. EPA 2013a; Pan et al. 2020). Note that this range of values is a historical average and that, unlike the GHG reduction formula, the energy savings cannot be precisely quantified using a predictive formula for the purposes of this methodology.

Sources

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