R-3. Install Transcritical CO_2 Supermarket Systems in Place of High-GWP Systems

GHG Mitigation Potential

Up to a 99.9 percent reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Climate resilience benefits vary by climate; in cooler and more dry climates, a CO_2 transcritical system can be at parity or more energy efficient than conventional direct expansion systems. 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 CO_2 transcritical systems. Whereas direct expansion systems typically use a high-GWP refrigerant, CO_2 transcritical systems use CO_2, which has a GWP of 1 and a lower leakage rate than typical conventional direct expansion systems. By reducing annual leak rates and replacing high-GWP refrigerants with CO_2, these systems result in a reduction of potential direct GHG emissions. CO_2 transcritical systems operate at high pressures but otherwise operate similarly to conventional direct expansion systems. Typically, the charge size of these systems is comparable to conventional direct expansion systems. CO_2 transcritical systems work most efficiently in cooler climates; but can also be used in warmer climates (Belusko et al. 2019; U.S. EPA 2019). Transcritical CO_2 systems can be used in all California climate zones given California's latest building codes require the use of specialized equipment to ensure that energy penalties are minimized.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Transcritical CO_2 supermarket systems carry a high initial cost over traditional systems. However, CO_2 systems have a lower operating cost, mainly due to the cost of CO_2 being much lower than the cost of conventional refrigerants.

Expanded Mitigation Options

Measure is a subset of Measure R-1, *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, which should be selected for increased GHG reductions in supermarket refrigerant systems.

GHG Reduction Formula

$$A = \frac{(E \times G \times \mathbf{B}) - (D \times F \times C)}{D \times F \times C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	0–99.9	%	Calculated
User Inputs				
B	Equipment charge size of CO_2 transcritical system	[ ]	kg	user input
Constants, Assumptions, and Available Defaults				
C	Equipment charge size of conventional direct expansion system	1,633	kg	U.S. EPA 2019
D	Annual leak rate of conventional direct expansion system	25	%	U.S. EPA 2013
E	Annual leak rate of CO_2 transcritical system	15	%	U.S. EPA 2019
F	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007
G	GWP of alternative refrigerant (CO_2)	1	unitless	IPCC 2007

Further explanation of key variables:

- (B) – The equipment charge size is the total quantity of refrigerant installed in refrigeration or A/C equipment.
- (C) – 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.
- (D and E) – Based on industry data, the average annual leak rates for the given equipment type are provided. This includes operational and servicing leak rates for the equipment throughout the year. Leak rates are provided as averages and may vary with specific systems.
- (F and G) – 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 99.9 percent.

Example GHG Reduction Quantification

The user reduces high-GWP emissions by replacing a conventional direct expansion system with a CO_2 transcritical system in a supermarket. In this example, the conventional direct expansion system refrigerant is R-404A, which has a GWP of 3,922 (G), and a charge size of 1,633 kg (D). The charge size for a CO_2 transcritical system is also 1,633 kg (B) and it has a 15 percent leak rate (F). Implementation of this project would reduce GHG emissions from the refrigeration system at this supermarket by 99.9 percent.

$$A = \frac{(15\% \times 1 \times \mathbf{1{,}633\ kg}) - (25\% \times 3{,}922 \times 1{,}633\ kg)}{25\% \times 3{,}922 \times 1{,}633\ kg} = -99.9\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure could achieve energy and fuel savings. Depending on the climate in which a CO_2 transcritical system is installed, energy efficiency can show improvements up to 10 percent (U.S. EPA 2019). These improvements decrease, or become negative, in warmer and more humid climates (U.S. EPA 2019; Belusko et al. 2019). Note that, unlike the GHG reduction formula, the energy savings cannot be precisely quantified using a predictive formula for the purposes of this methodology.

Sources

- Belusko, M., R. Liddle, A. Alemu, E. Halawa, and F. Bruno. 2019. *Performance Evaluation of a CO_2 Refrigeration System Enhanced with a Dew Point Cooler*. Energies 12, 1079. March. Available: https://www.mdpi.com/1996-1073/12/6/1079. Accessed: May 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
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