Researchers look to carbon dioxide as a more environmentally friendly refrigerant gas

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In an indoor research area, Brian Fricke preps display cases for refrigeration.

Keeping food fresh is no easy feat. Trials of transporting ice over long distances and the hazards of systems that rely on toxic gases riddle the pages of refrigeration history. And although cooling science has come a long way in the past two centuries, modern refrigeration has an environmental cost that poses new challenges.

By experimenting with CO_2 refrigerant systems and new refrigerant molecules, however, Brian Fricke, a researcher at the Department of Energy's Oak Ridge National Laboratory, looks to mediate and minimize conventional refrigeration's environmental footprint.

"Each supermarket has a lot of refrigerant in its system—two to four thousand pounds—and about 20 percent of that leaks out every year. That's a lot of greenhouse gas into the atmosphere," said Fricke, who works in ORNL's Buildings Technologies Research and Integration Center, a DOE user facility.

That's especially true of hydrofluorocarbons, or HFCs, the most common refrigerant cooling supermarket display cases in the United States today. HFCs followed a phase-out of their chlorofluorocarbon precursor when scientists in the 1970s traced chlorine breaking down ozone in the upper atmosphere to chlorofluorocarbons refrigerants being used at the time—chlorofluorocarbons were designed as a "safety refrigerant" and served as a substitute for toxic refrigerant gases such as ammonia and sulfur dioxide.

While HFCs don't destroy ozone, they are a strong greenhouse gas.

"The typical HFC example you see in a supermarket system is called R404A. It has a GWP of about 3,900," Fricke said.

GWP is the global warming potential of a molecule, or the molecule's ability to act as a greenhouse gas. By definition CO_2 has a GWP of one, making R404A almost 4,000 times as potent as CO_2.

"Compared with the refrigerants we're using right now, CO_2 is much less of a greenhouse gas than R404A," Fricke said.

In his lab, Fricke is installing a refrigeration system that uses solely CO_2. As a refrigerant, CO_2 is nearly ideal because it is nonflammable, nontoxic, doesn't affect the ozone and has a low GWP. CO_2 isn't perfect though.

Due to the thermodynamic properties as well as the operating pressures and temperatures involved in refrigeration, CO_2 really only works well in cold climates, where it can be efficiently cooled by outside air. In warmer climates such as the southern United States, it's more difficult to cool CO_2 and more energy is required to operate the refrigeration system.

The tests Fricke conducts tackle this problem. One option he suggests is a cascade system, which in addition to using CO_2 also incorporates a traditional refrigerant such as R404A. R404A is efficiently cooled by warm outside air and can then be used to cool the CO_2. While R404A has a large GWP, a cascade system restricts it to a mechanical room in the back of a supermarket where leakage risk is small and less R404A is required.

"In warmer climates, CO_2 uses more energy, but it doesn't have anywhere near the environmental impact of leaking refrigerant," Fricke said, adding, "If you're using CO_2 in the refrigeration system, that's CO_2 confined in the refrigeration cycle and not in the atmosphere. So that's CO_2 that you've pulled out of the atmosphere, and it's not contributing to global warming as a greenhouse gas."

In addition to investigating CO_2's refrigeration qualities, Fricke has also partnered with Honeywell Inc. to study another replacement refrigerant for R404A that, unlike CO_2, could be used in an R404A system. To add another jumble to the refrigerant-naming-mix, the refrigerant Fricke is working on with Honeywell is a hydrofluoroolefin, or a HFO, called N40.

HFOs initially have a GWP of four, only slightly higher than that of

CO_2. But HFOs are mildly flammable and require mixing with other substances, which creates a HFO blend and raises the GWP to about 1,300.

Still, that's significantly less than R404A's GWP of 3,900, and N40 has the advantage of being able to simply replace R404A in the same refrigeration system. For supermarkets looking to be more green that don't have the resources to install a whole new CO_2 system, N40 can be an attractive alternative.

Besides having a lower GWP, N40 is more efficient than R404A. Following tests where Fricke compared R404A and N40 under various temperatures in the same refrigerant system, Fricke found that N40 increased the efficiency of the system by around 10 percent.

"It would be nice to have a refrigerant that could replace R404A that would perform the same or better and also have a lower GWP. That's the intent of N40, to be a replacement of R404A," Fricke said.

With the University of Maryland, Fricke has helped design a software tool called Life Cycle Climate Performance (LCCP), too. Essentially, LCCP calculates the CO_2 equivalent emissions over the entire operating lifetime of a refrigeration system.

The software takes into account the CO_2 emissions related to all aspects of refrigeration: manufacture, transport, assembly, maintenance, electricity usage, refrigerant leakage, teardown, recycling, and so on. LCCP even takes into account the emissions associated with making a part within the refrigeration system, Fricke said. By considering these factors, buyers can consider environmental factors more easily. The ultimate goal, Fricke said, would be to use LCCP as a global tool to study regional differences in refrigeration. The United States could be compared with Japan, or Europe with India, he said.

In fact, Europe might be setting the standard for refrigeration, Fricke said. Already there are around 1,300 CO_2 refrigeration systems throughout Europe. The United States trails with only three, one each in Illinois, Maine and New York. The United States is likely to follow Europe's lead though, Fricke said.

"CO_2 is only going to get more and more popular as time goes by," Fricke said, adding, "Food preservation is something essential to our well-being. It's a big energy user and big producer of greenhouse gases. I think it's important to try to make these systems more efficient and produce less environmental impact."

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