REFRIGERANT LEAKAGE ASSESSMENT

STAFF REPORT OF THE EFFICIENCY MAINE TRUST

Submitted to the Joint Standing Committee on Environment and Natural Resources

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1. Background

In June 2021, the Maine State Legislature enacted LD 226 – *An Act To Limit the Use of Hydrofluorocarbons to Fight Climate Change*. The bill provided for the phaseout of the use of the most environmentally-damaging hydrofluorocarbons (HFCs) in certain products and equipment for specified air conditioning, refrigeration, foam or aerosol propellant uses.

During public hearings for the bill, the Joint Standing Committee on Environment and Natural Resources (ENR) heard concerns about mechanical, design, installation, and servicing issues associated with some of these same products and equipment that, regardless of the refrigerants used in those products and equipment, are and will continue to leak refrigerants. Although not addressed in LD 226, the ENR Committee remained concerned about the issues posed by such leakage and expressed interest in further discussion of potential solutions to the problem.

On June 2, 2021, the ENR Committee Chairs sent a letter to the Efficiency Maine Trust (the Trust), requesting that it conduct a review of refrigerant leakage issues and options for addressing those issues. It requested that the Trust address the possibility of imposing a fee upon refrigerants, or equipment or products containing refrigerants, to fund a new program that supports proper installation, repair, or servicing of products or equipment that are or have the potential to leak refrigerants. The Committee asked the Trust to report back in early 2022 regarding any findings or recommendations from that review. This report reflects the results of the Trust's assessment.

2. Review of Leakage Issues

The Trust would first like to preface that is it very difficult and expensive to study refrigerant leakage. Therefore, there is very little primary research on refrigerant leakage and leak rates. The process of evacuating a system, weighing its refrigerant content, and then recharging refrigerant back into the system often releases some of that refrigerant into the atmosphere and holds the risk of introducing problems to the system that may not have existed before. Since 2006, there have been only three primary studies (published in 2009, 2014, and 2015) from which the Intergovernmental Panel on Climate Change (IPCC) has been able to update their stationary HVAC and refrigeration leak rate estimates in 2019.[1]

The Trust hired Cadmus Group, LLC (Cadmus) to estimate the volumetric and equivalent CO_2 (CO_2e) impact of refrigerant leakage in Maine. To estimate leakage, Cadmus inventoried the residential and commercial building stock in Maine, built assumptions of refrigerant charge

[1] Intergovernmental Panel on Climate Change. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3: Industrial Processes and Product Use.

based on building type and equipment assumptions, and applied a variation of annual leak rate estimates. Cadmus performed the following steps:

- Conducted a literature review on Maine building stock, refrigerant types, quantities, and leakage rates, including the 2015 residential baseline study[2] and commercial metering study;[3]
- Reviewed the Trust's energy efficiency program data on residential and commercial HVAC and refrigeration measures;
- Reviewed residential census data[4] and 2018 SMR Research data on commercial and industrial (C&I) building types, quantities, and total area in Maine;
- Compiled normalized average refrigeration unit data (i.e., average refrigeration compressor horsepower per building square foot) using data from the Northwest Energy Efficiency Alliance (NEEA) Commercial Building Stock Assessment (CBSA) conducted by Cadmus, as the regions included in the CBSA have similar climate zones to Maine;
- Estimated the approximate refrigerant volume associated with typical refrigeration system horsepower values to develop a normalized ratio of refrigerant volume per square foot for each commercial and industrial building type;
- Estimated the total quantity of refrigerant in Maine by multiplying this ratio by the total square footage of applicable building types; and
- Applied leakage rates associated with each refrigerant end use based on the 2019 IPCC estimates.

In Table 1 below, annual estimated refrigerant leakage in Maine is broken down by equipment type. Annual impact ranges from approximately 61,500 tons CO_2e to 171,500 tons CO_2e. Approximately 91% of estimated leakage is derived from the commercial sector. Commercial refrigeration experiences the highest leak rates, while packaged HVAC sees lower leakage, but a larger prevalence in Maine's commercial building stock.

[2] 2015-Maine-Residential-Baseline-Study-Report-NMR.pdf (efficiencymaine.com)
[3] 2015-Commercial-Building-Interval-Meter-Data-Analytics-Study.pdf (efficiencymaine.com)
[4] MAINE: 2020 Census

***Table 1.** Annual Refrigerant Leakage Estimates in High and Low Scenarios*

Sector	Equipment Type (assumed refrigerant)	Estimated Total In-Use Refrigerant, tons CO_2e	High Estimate		Low Estimate	
			Annual Leakage Rate, %	Annual Refrigerant Leakage, tons CO_2e	Annual Leakage Rate, %	Annual Refrigerant Leakage, tons CO_2e
Residential	Refrigerators/ Freezers (R-134a)	281,882	0.20%	564	0.10%	282
	Heat Pumps (R-410a)	320,383	3.00%	9,611	1.00%	3,204
	Window ACs (R-410a)	1,248,649	0.20%	2,497	0.10%	1,249
	Central ACs (R-410a)	74,723	3.00%	2,242	1.00%	747
	Total	**1,925,637**	**0.77%**	**14,914**	**0.28%**	**5,482**
C&I	Refrigerated Reach-ins (R-134a)	5	3.00%	0.14	1.00%	0.05
	Packaged HVAC[a] (R-410a)	2,126,370	6.00%	127,582	2.00%	42,527
	Compressors[b] (R-410a)	178,621	15.00%	26,793	7.00%	12,503
	Condensers[b] (R-410a)	14,481	15.00%	2,172	7.00%	1,014
	Total	**2,319,477**	**6.75%**	**156,548**	**2.42%**	**56,045**
Total		**4,245,114**	**4.04%**	**171,462**	**1.45%**	**61,526**

[a] Packaged HVAC includes chillers, unitary DX, and other packaged equipment primarily used for space conditioning.
[b] Compressors and condensers reflect primarily commercial refrigeration equipment in grocery applications (~70%) and other split systems used for space conditioning.

In the Trust's Residential Heat Pump survey, the incidence of repairs for refrigerant leakage was 2% of all installations.[5] When heat pumps do leak, the range of charge lost can be minimal to 100% of charge. Assuming the midpoint of 50% of charge leaked, 2% of installations leaking 50% of their charge is a 1% leak rate (0.02 x 0.5 = 0.01). A 1% to 3% leak rate is applied to residential heat pumps in this calculation.

Variable Refrigerant Flow (VRF) systems are not separated from other HVAC equipment in this calculation. However, a 2015 German study which studied commercial multisplits and VRFs separately from chillers and other air conditioning, concluded that the annual leak rate of VRFs and multisplits is 3.8%.[6]

Very high commercial refrigeration leak rates are an indicator of frequent system failure. While the Trust only sees a small portion of the refrigeration industry in Maine, the Trust has not seen a high incidence of system failure in commercial refrigeration equipment. A 7% to 15% leak rate, aligned with the IPCC estimates, is applied to compressors and condensers in this calculation.

[5] Initial unpublished results as part of an ongoing Residential Heat Pump Evaluation.
[6] Intergovernmental Panel on Climate Change. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 3: Industrial Processes and Product Use.

3. Options for Addressing Leakage Issues

Programs addressing refrigerant leakage exist at the state level in California and Vermont in the form of leak reporting and servicing of leaky commercial equipment. At the federal level, the U.S. Environmental Protection Agency (USEPA) runs a voluntary reporting program known as GreenChill.

California

California Air Resources Board (CARB) was the first state agency to implement a refrigerant management program in 2009. CARB's regulatory strategy consists of registration, leak detection and repair, reporting, retrofitting, and servicing of large stationary commercial refrigeration systems. This program's key concerns about refrigerants are focused on appliances that pass their estimated useful life. They added that the larger a system is, the more likely it is to leak.

CARB's program had difficulties with size classifications, data gathering, and making sure contractors/servicers follow the regulations that come with servicing refrigeration systems. For instance, many contractors will collect multiple refrigerant types in the same vessel and dispose of them rather than capturing them on their own so they can be recycled or reused elsewhere. It was also difficult for small businesses because they are not as knowledgeable about the challenges and cost of the process. CARB noted that the program typically has a strong understanding about what various participating companies are doing in terms of refrigerant management, but they are lacking data and visibility into what service technicians are doing. They recommended incorporating more involvement from service technicians and additional training into future program designs, but also noted that it would be challenging to ask small contractors to take on the financial burden of complying with rigorous procedures. CARB recommends revamping the USEPA refrigerant training.

Vermont

As of 2020, Efficiency Vermont (EVT) operates the Refrigerant Leak Detection and Repair program for large commercial systems. This program provides rebates for 80% of leak detection and repair costs up to twice annually per site. EVT noted that contractor training is a high priority, but has been challenging to implement. They are developing a leak-tight installation contractor program for heat pump systems and a checklist of installation best practices. Eventually the checklist will need to be submitted as part of a rebate application.

USEPA

USEPA launched its nationwide GreenChill program in 2007. Participation in this program is voluntary and involves annual reporting of new refrigerant charges. Hannaford Bros. (Hannaford), headquartered in Scarborough, Maine, was one of ten founding partners of the program. In 2009 and 2014, Hannaford was recognized by GreenChill for 'superior' goal

achievement in emissions reduction. GreenChill noted in February 2022 that Hannaford stores continue to report below-average leak rates in their systems. [7] In 2019, individual Hannaford stores in North Berwick, ME and Turner, ME were awarded platinum certifications. Platinum is awarded for systems with the lowest charge and emission rate of HFCs or with only low-global warming potential (GWP) refrigerants.

As of 2019, there were an estimated 220 partner stores in Maine participating in GreenChill. According to the USEPA, approximately 63% of GreenChill partners reduced emissions in 2019 compared to their baseline year. Rather than contractor training, GreenChill attributes these successes to proactive leak detection and implementation of the newest leak detection technologies. The remaining 37% of partners reported that emissions either increased or stayed the same, demonstrating the inherent challenges associated with refrigerant leak management, even with strong awareness of the potential for leakage and the support of a government program.

The Trust was not able to determine the effectiveness of the aforementioned programs. None of the programs shared cost data with the Trust. It is also difficult to quantify accurate benefits, as there is little research to support a baseline leak rate for avoided emissions that is relevant to today. There is also no research to support the proposition that additional training is guaranteed to reduce the incidence of refrigerant leaks.

Maine

The Trust currently addresses heat pump and VRF leakage issues through training and certification requirements for Registered Residential Vendors (RRVs) and Qualified Partners (QPs).

All of the Trust's participating RRVs are required to follow the heat pump installation checklist for installations rebated through the residential and low-income programs. This checklist requires a pressure test (a process used to identify leaks in a heat pump system) as well as tightening of all flare connections to the manufacturer's torque specifications. Additionally, all RRVs installing heat pumps are required to obtain a minimum of two certifications that cover refrigerant management and testing, including the manufacturer's training for pressure testing and the USEPA Section 608 Refrigerant Handling Certificate.

For installers participating in the Trust's commercial and industrial programs, QPs are required to follow all manufacturer installation procedures for heat pump and VRF systems. This includes testing for refrigerant leaks and ensuring that all piping connections are optimally tightened. VRF systems are first tested for leaks with dry nitrogen (elemental N_2 gas) over a 24-hour period before the system is charged with refrigerant. This verifies the integrity of the pipe fittings through which leakage can occur. ZoomLock fittings have become a popular and effective connection fitting, and installers are encouraged to use them. Additionally, all QPs

[7] 2022. GreenChill Partner Spotlight: Hannaford (epa.gov)

installing heat pumps or VRF systems are required to complete the manufacturer's product training and obtain the USEPA Section 608 Refrigerant Handling Certificate.

4. Recommendations

Refrigerant leakage is difficult to detect and state leakage programs are challenging and expensive to run. Programs can also be burdensome to small businesses, who do not have dedicated environmental or sustainability staff. A voluntary program is available at the federal level in which many Maine stores already participate and for which Hannaford was a founding member. The Trust does not recommend the creation of a state refrigerant leakage reduction program, but rather that the State of Maine support federal regulations around training and the industry-wide transition to low-GWP refrigerants.

The following summarizes the USEPA's current regulations which were extended to ozone-depleting substances (ODSs) substitutes in 2016 and upheld in 2020 revisions:[8]

- Anyone removing refrigerant from a refrigeration or air-conditioning appliance must evacuate refrigerant to a set level using certified refrigerant recovery equipment before servicing or disposing of the appliance;
- The final disposer (such as scrap recyclers or landfills) of small appliances, like refrigerators and window air conditioners, must ensure and document that refrigerant is recovered;
- All used refrigerant must be reclaimed to industry purity standards before it can be sold to another appliance owner; and
- Anyone purchasing refrigerant for use in a stationary appliance or handling refrigerants (such as air-conditioning and refrigeration service technicians) must be section 608-certified.

The USEPA Section 608 license requires technicians involved in maintenance, service, repair, and disposal of heat pump equipment to pass a written test on the following topics:

- Environmental impacts of chlorofluorocarbon (CHC), hydrochlorofluorocarbon (HCFC), and hydrofluorocarbon (HFC) refrigerants;
- Clean Air Act Section 608 regulations and the Montreal Protocol;
- Refrigerant states, gauges, and leak detection;
- Refrigerant recovery techniques and requirements; and
- Safety guidelines and requirements

This test must be administered by a certification program approved by the USEPA.

[8] Revised Section 608 Refrigerant Management Regulations | US EPA

On May 6, 2021, the USEPA enacted the Significant New Alternatives Policy (SNAP) Program Final Rule 23, which went into effect on June 7th, 2021. The purpose of the federal SNAP Program is to evaluate alternative refrigerants for commercialized end use based on the following criteria: atmospheric impacts, exposure assessments, toxicity, flammability, and other environmental impacts including ecotoxicity and air quality. Based on these criteria, the SNAP Program designates alternative substances for HVAC into the following categories: Acceptable, Acceptable subject to use conditions, Acceptable subject to narrowed use limits, and Unacceptable. This rule designated the refrigerants R-32 (GWP 675), R-452B (GWP 700), R454A (GWP 240), and R-454B (GWP 470) for use in residential and light commercial split systems as Acceptable subject to use conditions.[9] Currently, R-410A (GWP 2,088) is the most common refrigerant.

On January 1, 2021, new SNAP regulations also came into place for household refrigeration. No new equipment may be charged with R-134A (GWP 1,430). Acceptable low-GWP substitutes include R450A (GWP 601) and R-513A (GWP 630).[10]

The transition to low-GWP refrigerants is already underway in the commercial HVAC and refrigeration industries. Several original equipment manufacturers (OEMs) are transitioning commercial refrigeration equipment to use natural and low-GWP refrigerants, such as CO_2 (GWP 1), R-448A (GWP 1,387), and R-449A (GWP 1,400). In 2019, R-448A/R-449A represented over 8.4% of installed refrigerants in GreenChill's partner stores,[11] up from 3.2% in 2018.[12] Albertson's/Safeway, represented by Shaw's stores in Maine, as well as Whole Foods Market and 7-Eleven convenience stores, have received Honeywell's 2021 Solstice Award for the implementation of R-448A in their refrigeration systems. There are also many chillers commercially available today which use R-513A (GWP 630) and R-515B (GWP 287) as opposed to R-410A and R-134A. Danfoss, an equipment distributor with three Maine locations, has received Honeywell's 2021 Solstice Award for implementing R-515B. [13]

In other HVAC equipment including heat pumps, OEMs plan to transition to R-32 and R-454B in upcoming years. The largest regulatory barrier to installing these low-GWP substitutes is their slight flammability (ASHRAE's A2L classification), which is not permissible by the building codes of most states. The State of Maine can revise its current building codes to be friendly towards low-GWP refrigerants to assist HVAC and refrigeration industries in this transition.

In Table 2, changing refrigerant assumptions from high-GWP to low-GWP, while keeping leak rate assumptions constant, reduces annual refrigerant emissions by 131,243 tons CO_2e (76.5% decrease) in the high leakage scenario, and by 45,422 tons CO_2e (73.8% decrease) in the low

[9] Overview of SNAP | US EPA
[10] Refrigerant changeover from HFC R134a to HFC/HFO R450a & R513a. Date: (emerson.com)
[11] 2020. GreenChill Annual Recognition Event (epa.gov)
[12] 2019. GreenChill Recognition Event (epa.gov)
[13] Honeywell Unveils Inaugural Solstice Award Recognizing Adoption Of Sustainable Refrigerants

leakage scenario. There is no evidence that running a refrigerant program nor imposing a fee on refrigerants would have an impact close to this.

***Table 2:** Annual Refrigerant Leakage Estimates with Alternative Low-GWP Refrigerants*

Sector	Equipment Type (assumed refrigerant)	Estimated Total In-Use Refrigerant, tons CO_2e	High Estimate		Low Estimate	
			Annual Leakage Rate, %	Annual Refrigerant Leakage, tons CO_2e	Annual Leakage Rate, %	Annual Refrigerant Leakage, tons CO_2e
Residential	Refrigerators/ Freezers (R-450a)	119,258	0.20%	239	0.10%	119
	Heat Pumps (R-454b)	71,503	3.00%	2,145	1.00%	715
	Window ACs (R-454b)	278,674	0.20%	557	0.10%	279
	Central ACs (R-454b)	16,677	3.00%	500	1.00%	167
	Total	**486,111**	**0.71%**	**3,441**	**0.26%**	**1,280**
C&I	Refrigerated Reach-ins (R-450a)	2	3.00%	0.06	1.00%	0.02
	Packaged HVAC[a] (R-515b)	292,274	6.00%	17,536	2.00%	5,845
	Compressors[b] (R-448a)	118,653	15.00%	17,798	7.00%	8,306
	Condensers[b] (R-448a)	9,620	15.00%	1,443	7.00%	673
	Total	**420,548**	**8.75%**	**36,777**	**3.53%**	**14,825**
Total		**906,660**	**4.44%**	**40,219**	**1.78%**	**16,104**

[a] Packaged HVAC includes chillers, unitary DX, and other packaged equipment primarily used for space conditioning.
[b] Compressors and condensers reflect primarily commercial refrigeration equipment in grocery applications (~70%) and other split systems used for space conditioning.

Even further into the future, equipment innovation will replace low-GWP refrigerants with ultra-low GWP and natural refrigerants. The Trust does not recommend state action beyond supporting federal regulation and industry movements. Updating state building codes will enable the transition to lower GWP substitutes to occur in Maine.