NAVIGANT

# AHRI Project 8018 Final Report

## Review of Refrigerant Management Programs

**Prepared for:**

AHRI
AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

we make life better™

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## Acronyms, Abbreviations, and Definitions

| | |
|---|---|
| AB | California Assembly Bill |
| ABNT | Associação Brasileira de Normas Técnicas |
| ABRAVA | Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento |
| AC | Air Conditioner |
| AEHA | Association for Electric Home Appliances |
| AHRI | Air-Conditioning, Heating, and Refrigeration Institute |
| APCD | Air Pollution Control Districts |
| ARA | Australian Refrigeration Association |
| ARC | Australian Refrigeration Council |
| AREMA | Air-Conditioning and Refrigeration Equipment Manufacturers Association |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| AUD | Australian Dollar |
| CAA | U.S. Clean Air Act |
| CAD | Canadian Dollar |
| CARB | California Air Resource Board |
| CFC | Chlorofluorocarbon |
| CONAMA | Conselho Nacional do Meio Ambiente |
| $CO_2e$ | Carbon Dioxide equivalent |
| CSLB | California Contractors State License Board |
| CSP | Refrigerant Management Canada Collection Service Provider |
| DECC | U.K. Department of Energy and Climate Change |
| DEFRA | U.K. Department for Environment, Food & Rural Affairs |
| DG CLIMA | EU Directorate-General for Climate Action |
| DOT | U.S. Department of Transportation |
| EC | European Commission |
| EEA | European Environment Agency |
| EOL | End-of-Life |
| EPA | U.S. Environmental Protection Agency |
| EPR | Extended Producer Responsibility |
| EU | European Union |

| | |
|---|---|
| F Gas | Fluorinated gases (see definitions table below) |
| FAQ | Frequently Asked Questions |
| GHG | Greenhouse Gas |
| GWP | Global Warming Potential |
| HCFC | Hydrochlorofluorocarbon |
| HFC | Hydrofluorocarbon |
| HRAI | The Heating, Refrigeration and Air Conditioning Institute of Canada |
| HVAC/R | Heating, Ventilation, Air Conditioning, and Refrigeration |
| IBAMA | Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais |
| IMI | U.K. Institute of the Motor Industry |
| IOR | Institute of Refrigeration |
| ISO | International Organization for Standardization |
| JARC | Japan Auto Recycling Promotion Center |
| JARP | Japan Auto Recycling Partnership |
| JAVADA | Japan Vocational Ability Development Association |
| JSRAE | Japan Society of Refrigeration and Air Conditioning Engineers |
| KHK | High Pressure Gas Safety Institute of Japan |
| MAC/MVAC | Mobile/(Motor Vehicle) Air Conditioner |
| MMA | Ministério do Meio Ambiente |
| METI | Japan Ministry of Economy Trade and Industry |
| $MMTCO_2e$ | Million Metric Tons of $CO_2$ Equivalent |
| MOE | Japan Ministry of the Environment |
| NAP | Canada National Action Plan |
| ODS | Ozone Depleting Substance |
| OEM | Original Equipment Manufacturers |
| OEMA | Organizações Estaduais e Municipais de Meio Ambiente |
| PBH | Programa Brasileiro de Eliminação de HCFCs |
| PG&E | Pacific Gas and Electric Company |
| PROZON | Comitê Interministerial para a Proteção da Camada de Ozônio |
| PMS | AHRI Project Monitoring Subcommittee |
| PSS | Product Stewardship Scheme |
| RA | Refrigerants Australia |

| | |
|---|---|
| RAD | EPA Responsible Appliance Disposal Partnership |
| RCR | Japan Refrigerant Recycling Promotion and Technology Center |
| RCRA | Resource Conservation and Recovery Act |
| RF | Refrigerator/Freezer |
| RMC | Refrigerant Management Canada |
| RMP | California's Refrigerant Management Program |
| RRA | Refrigerant Reclaim Australia |
| SCAQMD | Southern California Air Quality Management District |
| SCE | Southern California Edison |
| SGG | Synthetic Greenhouse Gas |
| SNAP | Significant New Alternatives Program |
| TV | Television |
| U.K. | United Kingdom |
| UN | United Nations |
| U.S. | United States |

Navigant defines the following terminology related to refrigerant management to ensure consistency and clarity throughout this report.

| | |
|---|---|
| F Gas[1] | Fluorinated Gases - a term used predominantly in the European Union, and upon which regulations are based. Primarily used as substitutes for ozone-depleting substances, such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons which are being phased out under the Montreal Protocol and EU legislation. |
| Recovery | Extraction of refrigerant from a system |
| Reuse | Recovery, temporary storage, and recharging of refrigerant from the same system |
| Recycle | Recovery and limited cleaning of refrigerant (physical filtration e.g. oil separation, water removal), which may return to original system or a different system. Cleaning may occur on-site with the appropriate equipment. |
| Reclaim | Recovery and extensive reprocessing of refrigerant to virgin specifications as stipulated by industry standards. Because specialized machinery is required, reclamation does not occur on-site. |

[1] See: http://ec.europa.eu/clima/policies/f-gas/index_en.htm

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## Executive Summary

Around the world, many different regulations and programs exist to abate refrigerant emissions and promote refrigerant recycling. Unfortunately, it is very difficult to measure the enforcement rigor and effectiveness of these programs. Unlike other environmentally deleterious emissions, refrigerants are typically colorless and odorless, making violations (e.g. venting) easy to conceal and hard to track.

The processes and approaches to manage refrigerant vary widely around the world. Some jurisdictions, such as Australia, Japan, and the European Union (EU), rely on robust regulatory frameworks that control refrigerant from cradle to grave. Others, such as Canada and the United States (U.S.) pair voluntary programs with less comprehensive regulations. These approaches are informed by a wide range of factors, including as cultural, climate, and market differences.

This report aims to provide clarity and insights on seven primary jurisdictions: Australia, Canada, California, the EU, Japan, the United Kingdom (U.K.), and the U.S. The report also includes a high-level review of activities in China and Brazil. The focus areas of research included characterizing the current processes for original equipment manufacturers (OEMs), contractors, end users, and reclaimers to handle refrigerants, how refrigerant recycling happens, where it happens, and the amount of refrigerants ultimately destroyed.

The objective of this project is to characterize refrigerant management and recycling programs implemented in key regions of the world, evaluate their effectiveness, and determine best practices as they relate to the U.S. refrigerant landscape.

Navigant conducted a literature review and interviewed key personnel in the target jurisdictions to develop the detailed content of this report. Research covered the regulations, roles and responsibilities, funding sources, incentive and enforcement mechanisms, performance, refrigerant recovery, tracking and reporting, outreach, training, and flow of refrigerant in the nine jurisdictions.

### *Research Summary*

Table 1 briefly summarizes the key characteristics of each of the target jurisdictions.

**Table 1. Summary of Target Jurisdictions**

| | Covered Refrigerants | Covered Industries | Recovery Rate (%) | Returnable Canisters |
|---|---|---|---|---|
| **Australia** | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | 35-61% | Mandatory |
| – Regulation-driven, industry-sponsored and administered **mandatory** recovery and destruction paired with import, trade, and use controls<br>– Strict import/manufacture licensing and reporting requirements for all covered refrigerants (both bulk and pre-charged equipment)<br>– Strict buying and selling controls mandate handling licenses based on competencies<br>– Regulations for refrigerant handling and use based on industry standards and codes of practice<br>– Product stewardship scheme (PSS), which extends responsibility for end-of-life (EOL) product management to producers and importers, is **funded by import levies** on all Ozone Depleting Substances (ODS) & Synthetic Greenhouse Gases (SGG); **built upon existing distribution channels**<br>– Refrigerants Reclaim Australia (RRA) governs PSS and provides rebates for recovered refrigerants<br>– Regulations require **detailed tracking, reporting**, and licensing | | | | |
| **Canada** | CFC, HCFC, *HFC*[A] | Stationary Equipment, *Domestic Appliances*, *Vehicles* [B] | Not tracked | Mandatory |
| – Regulation-driven, industry-sponsored and administered **voluntary** recovery and destruction program based on extended producers responsibility (EPR)<br>– EPR, similar to PSS, is **funded by levies charged to by the manufacturers/suppliers to their customers and passed down supply chain.**<br>– Refrigerant Management Canada (RMC) is an EPR program formed and administered by The Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI<br>– RMC facilitates recovery, shipment, and destruction of ODS from **stationary HVAC/R equipment** | | | | |
| **EU** | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | See U.K. for proxy | Mandatory |
| – Strict regulation with **aggressive phase outs of and import controls on ODS and high Global Warming Potential (GWP)** refrigerants. **Member nations must develop, implement, and enforce local legislation** based on European Commission regulations.<br>– Regulations **mandate service & equipment bans**, minimum training and certification requirements<br>– Regulations **require industry to report to European Environment Agency** (EEA), which publishes annual reports on refrigerant management activities | | | | |

| | Covered Refrigerants | Covered Industries | Recovery Rate (%) | Returnable Canisters |
|---|---|---|---|---|
| **Japan** | CFC, HCFC, *HFC*[C] | Stationary Equipment, Domestic Appliances, Vehicles | 30%[D] | Not found |
| – Strong regulatory framework that is supported by industry through trade groups, innovative collection and recycling techniques, and a **strong culture of environmental protection**<br>– Refrigerant management **costs shared by consumers (with fees) and industry**<br>– Refrigerant management varies by sector:<br>o Domestic appliances and motor vehicle EOL management built on PSS<br>o Commercial equipment subject to robust auditing and reporting<br>– Regulations enable **detailed tracking of product** to EOL | | | | |
| **U.K.** | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | See Table 2-17 | Mandatory |
| – Strong regulatory framework that is driven by the European Commission and **implemented by industry groups, municipalities, and end users**<br>– Refrigerant management **varies by sector**:<br>o Appliance refrigerant management built on appliance PSS<br>o Stationary equipment refrigerant managed with maintenance, recordkeeping requirements<br>– Funding is varied; **consumers do not pay fees for appliance disposal**<br>– Tracking, reporting, and licensing dictated by European Commission regulations<br>– **Robust EU-wide training resources** to encourage best practices | | | | |
| **U.S.** | CFC, HCFC, *HFC*[A] | Stationary Equipment, *Domestic Appliances*, Vehicles | Not tracked | Not Mandatory |
| – Regulatory framework **focused on ODS with phasedown**, venting prohibitions, and certification requirements. No national collection, destruction services, but some **voluntary programs** exist.<br>– Refrigerant management costs borne by market<br>– **Voluntary programs demonstrate above-industry-average performance** (e.g. GreenChill Partnership with food retailers, Responsible Appliance Disposal [RAD] Partnership) | | | | |
| **California** | CFC, HCFC, HFC | Stationary Equipment | ~80%. See Table 2-26 | Not Mandatory; Deposits for "small cans" |
| – Strict regulatory framework "phase in" focused on large stationary refrigeration and **includes HFCs**<br>– Regulations **require robust record keeping**, maintenance best practices, and technician licensing<br>– Annual fees fund program implementation, including enforcement<br>– **Tracking, reporting, leak inspection, and leak repair requirements exceed federal regulations** | | | | |

[A] Venting of HFCs is illegal in these jurisdictions; however, regulations/programs do not explicitly focus on HFCs.
[B] Venting is illegal in these applications/jurisdictions; however, programs do not focus on these applications.
[C] Japan recently enacted regulations to expand focus to include HFCs.
[D] Estimate for commercial equipment

## *Program Effectiveness*

Effectiveness of refrigerant management programs is difficult to evaluate in a consistent fashion because of the wide variability in program implementation. Details such as reporting, recordkeeping, and handling requirements have a profound impact on each jurisdictions' ability to track refrigerant through the supply chain. Furthermore, the breadth of the regulations (i.e. affected industries) dictate how much of the refrigerant market is covered. Australia, for example, has relatively comprehensive data from across industries as a result of robust regulations and detailed refrigerant tracking through its supply chain. Such tracking is more straightforward there than in other jurisdictions because Australia does not manufacture any refrigerants, requires all importers to hold import license, and requires all businesses that handle refrigerant to report activity to the government. Similarly, California's annual reporting requirements outlined in the Refrigerant Management Program (RMP) enable the California Air Resource Board (CARB) to estimate leak and recovery rates. Conversely, because Canada tracks only some refrigerant imports and relies upon a voluntary program that is limited to the stationary HVAC/R industry, it is very difficult to evaluate rigorously program success. Lastly, because industry often considers refrigerant manufacture, import, sale, and use proprietary information, limited public data exists. Despite this challenge, Navigant captured as much data as possible. The following list summarizes insights from each jurisdictions' data. See Table 2 for a summary of the key supporting data by jurisdiction.

- Japan destroys the highest tonnage of refrigerants on a yearly basis, destroying more refrigerant than most other programs have since their inception. Japan has also seen a 1.8x increase in annual refrigerant recovered from commercial equipment since 2006.
- Australia's RRA recovers between 35 and 61% of refrigerant, which is almost all destroyed. Unlike reclaimed or recycled refrigerant, this locks in substantial emissions abatement.
- Of reviewed programs, the U.K. has the highest reported rate of recovery, but it is unclear how well this compares to other programs who do not report recovery rates. Note that California pairs these estimates with internal data to estimate California's similarly high recovery rates.
- California's "Small Can" regulations has pushed "small can" recovery to 70-80%, making California a clear leader over the rest of the U.S.
- The EPA's GreenChill and Responsible Appliance Disposal (RAD) Partnerships also exhibit substantially above average performance; however, this data is self-reported and may overstate performance.
- EU regulation excludes domestic destruction or reclamation companies from reporting requirements. Additionally, because of confidentiality concerns, the European Environment Agency EEA limits the public release of refrigerant destruction and reclamation activity. Thus, the low destruction and reclamation rates reported below are likely very large underestimates.
- Canada requires very limited tracking, making it impossible to quantify effectiveness.

**Table 2. Summary of Researched Effectiveness Data**

| Jurisdiction | Effectiveness Data |
|---|---|
| Japan | – Commercial equipment refrigerant collected in **FY14: 3,731 metric tons**<br>– Motor vehicle refrigerant collected in **FY14: 772 metric tons**<br>– Household appliance refrigerant collected in **2013: 2025 metric tons** |
| Australia | – Recovery rate estimates: **35-61%**<br>– Total refrigerant recovered: **4,600 metric tons**<br>– Percentage of recovered refrigerant destroyed by RRA: **92%** |
| U.K. | – Recovery rate estimates: **65-92% (varies by end-use)** |
| EU[A] | – Percentage of ODS destroyed in 2013: **~4%**<br>– Percentage of F-gas reclaimed in 2013: **1%** |
| Canada | – Total refrigerant destroyed through 2015: **3,100 metric tons** |
| California | – Recovery rate estimates: **80% for "large equipment"**<br>– Recovery rate of "small cans": **70-80% (four year average)**<br>– See Table 2-25 detailed recovery rate estimates by sector/equipment type (0-85%). |
| U.S. | – GreenChill Partner average refrigerant leak rate: **13% (vs. industry average of 25%)**<br>– Refrigerant recovered by RAD Partners in 2013: **~170 metric tons** |

[A] Note: EU reporting limited to producers and importers of ODS and F-gas and excludes "domestic" reclaimers or destroyers. Thus, estimates are too low.

## *Best Practices*

As public opinion and regulatory bodies increase their focus on, and prioritization of, environmental stewardship, U.S. refrigerant management practices will need to improve. As AHRI develops a strategy to improve U.S. refrigerant management, Navigant recommends that AHRI consider the best practices of other key jurisdictions. Navigant recognizes that not all of these characteristics will or should map directly to a U.S. based program; instead, Navigant believes that these considerations will help AHRI develop the most appropriate program for the U.S.

See Table 3 for seventeen best practices, irrespective of their direct applicability to the U.S.

**Table 3: Best Practices for Consideration in the United States**

| Originating Program | Best Practice Advantages | Consideration for U.S. |
|---|---|---|
| Australia | **Comprehensive product stewardship scheme that is built upon existing distribution channels minimizes cost burden** on industry; friction for contractors, who are "perhaps the most important stakeholder"[2] | Nationwide program built upon existing distribution channels will minimize cost burden on industry. |
| Australia | Inclusion of all synthetic refrigerants (CFCs, HCFCs, HFCs) in phase down & regulatory requirements has created consistent market incentives for better refrigerant management | Meaningful GHG emissions abatement must target ODS and HFCs with high-GWP. |
| Australia | **Robust recordkeeping from point of entry to destruction** (despite one major exception) makes accurate emissions tracking very achievable | While costly, robust recordkeeping creates industry-wide accountability from contractors to international producers. |
| California | **Robust maintenance and servicing requirements** for major refrigerant charges has served as **educational tool to industry and promoted best practices.** | Strong maintenance and service requirements save end users money. Building requirements around this benefit will increase compliance. |
| California | Utility energy efficiency programs successfully capture large volumes of appliances. This enables easy refrigerant/resource management | Non-traditional vectors, such as utility programs, can serve as consumer-facing entry points for domestic appliance refrigerant management. |
| California/ Australia | *California:* Moving away from disposable small refrigerant cans sets **reusable canister precedent (**despite limited volumes of recoverable refrigerant from small cans). | Mandatory small can deposits greatly increases recycling rate. |
| | *Australia:* **Banning disposable cylinders was pivotal in improving refrigerant management.** Returning cylinders for refills supports the ethos that refrigerants are not a commodity but a specialized good and encourages refrigerant return for destruction. | Programs and policies should shift perception of refrigerants from a commodity to a specialized and environmentally damaging good. |
| European Union | Robust reporting requirements **respect industry confidentiality** concerns but enable EU to publish detailed refrigerant flow data. | Ensuring industry-appropriate confidentiality will encourage industry to support recordkeeping requirements. |
| European Union | **Collaborative training and best practice development proven to reduce leak rates** (REAL Skills, Zero, etc.). EC committed to developing easy-to-use, robust, and thorough documentation for industry. | Leverage existing international research, training material to improve industry best practices. |

[2] Interview with Greg Picker.

| Originating Program | Best Practice Advantages | Consideration for U.S. |
|---|---|---|
| Japan | **Industry-specific** refrigerant management **programs built upon current product EOL infrastructure** with opportunities for innovation, **competition between product stewardship schemes.** | Nationwide program should respect differences between refrigerant-using industries. |
| Japan/ United Kingdom | Japan: Fees for motor vehicle EOL management (including refrigerants) charged **at time of purchase**. This greatly encourages compliance.<br>United Kingdom: No explicit cost to consumers for appliance disposal—instead manufacturers incur cost as part of operations and **build costs into retail prices.** | Capturing funding for refrigerant management up front (through explicit fees or increased retail price) incentives consumers to handle products responsibly at end of life. Any program that funds operation by collecting fees at end of life may disincentivize full compliance. |
| United Kingdom | **Multiple product stewardship schemes** encourage competition, low cost EOL management. | Nationwide program with competing implementations can foster innovation, low cost best practices. |
| United Kingdom | Societal norms that value environmental stewardship have made REALSkills certifications popular. | As environmental stewardship grows more important to consumers and governments, members of transparent and well-publicized refrigerant management program will continue to gain popularity. |
| United States | **Voluntary programs (e.g. GreenChill, RAD) exhibit above-industry-average performance** and marketing benefits to partners | Cite marketing benefits, cost savings to encourage industry to support voluntary programs or mandatory regulations. If well designed, either can abate emissions and benefit end-users. |

### *Recommendations*

Through our research, Navigant has identified the eight best practices from other jurisdictions that are valuable as starting points for development of a comprehensive refrigerant management program in the U.S. Based on these attributes, AHRI can develop a construct for improved refrigerant management that helps achieve global climate goals while maintaining key characteristics that are important to AHRI member organizations. The recommendations in Table 4 (numbered for identification only, not to indicate priority) represent valuable components to a broader program that will require involvement across industry and government to execute successfully:

**Table 4: Recommendations**

| | |
|---|---|
| **1** | Strengthen national regulations to include HFCs.<br>– **Outcome:** levels the playing field for industry with less confusion in the marketplace. Reduced negative environmental impact by targeting all major high GWP refrigerants instead of high ODS refrigerants only. |
| **2** | Charge end users of refrigerant-containing equipment for any necessary costs associated with refrigerant management **up front** (as opposed to at end-of-refrigerant or -equipment life). Standardize costs across sectors so that individual manufacturers do not gain an unfair advantage.<br>– **Outcome:** Up-front fees minimize EOL product management friction and noncompliance. End users enjoy no benefit by ignoring regulations—they have "pre-paid" the costs associated with responsible product management. |
| **3** | Ensure tracking and reporting requirements are balanced against the additional costs and benefits of tracking and reporting, while still maintaining confidentiality where needed (i.e., in cases where manufacturers consider the data to be valuable intellectual property).<br>– **Outcome:** Tracking reinforces industry and regulatory accountability. |
| **4** | Model maintenance regulations after voluntary partnerships (e.g. GreenChill, RAD).<br>– **Outcome:** Portraying refrigerant management as a cost saver to equipment owners greatly improves participation and performance. Our interviews suggest that involvement with environmental stewardship programs can improve brand perception. |
| **5** | Develop and implement regulations at appropriate speed for industry.<br>– **Outcome:** Overambitious phase outs, recycling requirements, or service bans can drive undesirable behavior (e.g. venting, unlicensed operator recovery). |
| **6** | Leverage a broad range of sources (e.g. other governments, industry groups, research, training programs, etc.) that have more experience with comprehensive refrigerant management.<br>– **Outcome**: Tapping robust international subject matter expertise will minimize duplicating effort and expedite the development of a U.S.-specific program. |
| **7** | Promote unified, actionable, and application-specific education and training programs.<br>– **Outcome:** Robust education and training programs unlock meaningful savings by boosting compliance and efficacy within the context of current regulations. |
| **8** | Work proactively with responsible regulators (e.g. EPA, state agencies) to ensure all parties are fully enforcing existing regulations.<br>– **Outcome:** Industry supported regulations and enforcement levels the playing field, improves national environmental stewardship, and improves compliance and efficacy of current regulations. |

While comprehensive refrigerant management will require a thorough development process to outline the most appropriate policies for the U.S., we can learn valuable lessons from the successes and failures

in other jurisdictions. The key advantages and recommendations reviewed here represent a starting point for development of a comprehensive approach.

# 1. Introduction

## *1.1 Background*

In recent years, concerns have grown regarding the high global warming potential (GWP) of common fluorocarbon refrigerants, increasing scrutiny of how manufacturers and HVAC service technicians manage fluorocarbon refrigerants. As the industry transitions to lower-GWP alternative refrigerants for new equipment, there remains a large installed base of equipment using conventional refrigerants. The industry's management of these systems and their refrigerants plays a major role in mitigating potential negative environmental impacts.

Many countries now have programs in place to recycle and manage refrigerants to reduce atmospheric impacts. These programs vary in design, including approaches to enforcement, with varying degrees of success. Many programs were implemented as a mechanism for reducing the use of ozone depleting substances (ODS); some of these countries are now looking at options for expanding the programs' scopes to include some or all of the high-GWP, ODS replacements.

There are many regulations and programs requiring refrigerant emission minimization and refrigerant recycling worldwide. However, it is not always clear how well these regulations and refrigerant management programs are enforced and how successful they are. This report aims to provide clarity and insights on this topic, including characterizing the current processes for original equipment manufacturers (OEMs), contractors, end users and reclaimers to handle refrigerants, how refrigerant recycling happens, where it happens, and the amount of refrigerants ultimately destroyed.

## *1.2 Objective*

The objective of this project is to characterize refrigerant management and recycling programs implemented in key regions of the world, evaluate their effectiveness, and determine best practices as they relate to the U.S. refrigerant landscape.

## *1.3 Scope*

The project focuses on refrigerant containment and recycling activities in Australia, Canada, California, the European Union, Japan, the United Kingdom (U.K.), and the United States (U.S.). The report also includes a high-level review of activities in China and Brazil.

## *1.4 Approach*

Navigant conducted a literature review and interviewed key personnel in the target jurisdictions to develop the detailed content of this report. Research covered the regulations, roles and responsibilities, funding sources, incentive and enforcement mechanisms, performance, refrigerant recovery, tracking and reporting, outreach, training, and flow of refrigerant in the nine jurisdictions. Figure 1-1 illustrates the steps Navigant took in developing this report.


**Figure 1-1. Project Methodology**

In collaboration with AHRI Project Monitoring Subcommittee (PMS), Navigant selected seven jurisdictions for primary research: *Australia, Canada, European Union (EU), Japan, the United States (U.S.), the United Kingdom (U.K.), and California*, and two jurisdictions for a high level overview: *China and Brazil*. After developing a strong foundation for each jurisdiction, Navigant conducted interviews to confirm foundational research as well as address key questions about program successes and challenges. Table 1-1 lists the contacts and primary sources for each jurisdiction. See Appendix B for valuable secondary sources that provide additional detail on international refrigerant management

**Table 1-1. Select Sources and Interviewees**

| Jurisdiction | Contacts | Sources | Report Section |
|---|---|---|---|
| Australia | Gregory Picker | Dept. of the Environment; Australian Refrigerant Council; Refrigerant Reclaim Australia | 2.2 |
| Canada | April Heeley<br>Warren Heeley | Environment Canada; Refrigerant Management Canada | 2.3 |
| EU | N/A | European Commission; European Environment Agency | 2.4 |
| Japan | Rep. of AEHA | Ministry of the Environment; Ministry of Economy, Trade, and Industry | 2.5 |
| U.K. | Prof. Graeme Maidment | European Commission, European Environment Agency; Dept. for Environment, Food & Rural Affairs; Institute of Refrigeration; Environment Agency; realskills | 2.6 |
| U.S. | Luke Hall-Jordan | U.S. Environmental Protection Agency (EPA) | 2.7 |
| California | Pamela Gupta | U.S. EPA, California Air Resources Board (ARB) | 2.8 |
| *Brazil* | N/A | Ministério do Meio Ambiente (MMA); Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais (IBAMA); Multilateral Fund | 3.1 |
| *China* | N/A | Ministry of Environmental Protection, National People's Congress of the People' Republic of China, The State Council of the People's Republic of China | 3.2 |

# 2. Findings for Primary Target Jurisdictions

## *2.1 Overview*

Table 2-1 summarizes key findings from the research, including which refrigerants are regulated or included and the industries that participate (either voluntarily or by law) in the in the jurisdictions' management program. Table 2-1 also summarizes known recovery rates and the use of returnable canisters.

**Table 2-1. Summary of Target Jurisdictions**

| | Covered Refrigerants | Covered Industries | Recovery Rate (%) | Returnable Canisters |
|---|---|---|---|---|
| **Primary Jurisdictions** | | | | |
| Australia | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | 35-61% | Mandatory |
| Canada | CFC, HCFC, *HFC*[A] | Stationary Equipment, *Domestic Appliances*, *Vehicles* [B] | Not tracked | Mandatory |
| EU | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | See U.K. for proxy | Mandatory |
| Japan | CFC, HCFC, *HFC*[C] | Stationary Equipment, Domestic Appliances, Vehicles | 30%[D] | Not found |
| U.K. | CFC, HCFC, HFC | Stationary Equipment, Domestic Appliances, Vehicles | See Table 2-17 for estimates | Mandatory |
| U.S. | CFC, HCFC, *HFC*[A] | Stationary Equipment, *Domestic Appliances*, Vehicles | Not tracked | Not Mandatory |
| California | CFC, HCFC, HFC | Stationary Equipment | ~80%. See Table 2-26 | Not Mandatory; Deposits for small cans |
| **Secondary Jurisdictions (high-level review only)** | | | | |
| *Brazil* | *CFC, HCFC* | *Stationary Equipment, Domestic Appliances* | *Unknown* | *Mandatory for specific ref.* |
| *China* | *CFC* | *Stationary Equipment, Domestic Appliances, Vehicles* | *Unknown* | *Unknown* |

[A] Venting of HFCs is illegal in these jurisdictions; however, regulations/programs do not explicitly focus on HFCs.
[B] Venting is illegal in these applications/jurisdictions; however, programs do not focus on these applications.
[C] Japan recently enacted regulations to expand current focus from CFCs, HCFCs to HFCs.
[D] Estimate for commercial equipment

## *2.2 Australia*

### 2.2.1 Summary

Australia does not manufacture any synthetic refrigerants. Instead, all refrigerants are imported in bulk or pre-charged in imported equipment. Additionally, ~90% of air conditioning & refrigeration equipment is imported. Australia requires importers (both bulk and pre-charged equipment) to have a license from the Federal Government. One of the standard license conditions is that importers must participate in an approved product stewardship scheme. Product stewardship schemes are a policy approach that distributes responsible end-of-life product management between producers, sellers, and users of covered products. As the only authorized product stewardship scheme, Refrigerants Reclaim Australia (RRA) uses the collected fees to manage the downstream (i.e. post-consumer) costs of refrigerant destruction. Because RRA exclusively handles refrigerant destruction, private firms take responsibility for reclaiming refrigerants. Authorization, licensing, and training is handled by Australian Refrigeration Council (ARC), while bulk collection, transport and destruction is handled by RRA. Technicians can charge customers for the costs associated with recovering refrigerant while also receiving a rebate for returning refrigerant to wholesalers. Once a wholesaler accumulates enough refrigerant, they contact RRA to arrange bulk collection and transport to RRA's plasma arc destruction facility.[3]

Figure 2-1 outlines the flow of refrigerant through Australia's refrigerant management program from refrigerant import to destruction. The figure represents bulk refrigerant flow in Australia. Typical sources of this refrigerant are stationary HVAC/R equipment (residential, commercial, and industrial). Motor vehicle refrigerants and domestic appliance refrigerants are captured after end user has disposed of a product.

[3] Interview with Greg Picker.

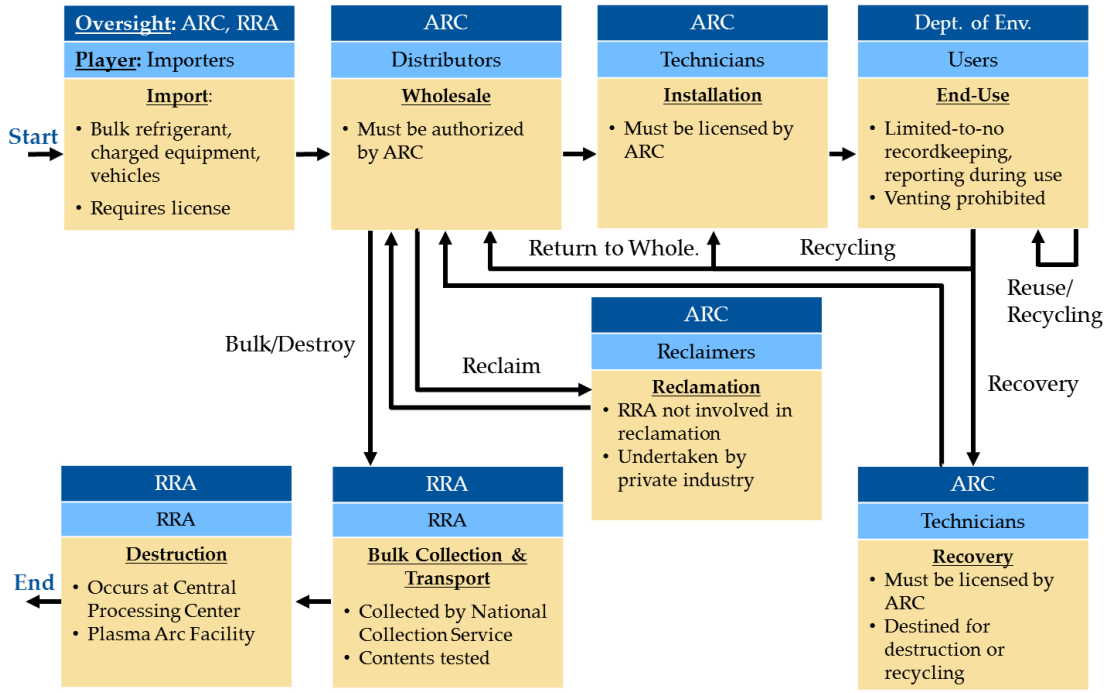



**Figure 2-1. Australia's Refrigerant Management Process**

Table 2-2 summarizes the key characteristics of Australia's programs.

**Table 2-2. Summary of Australia's Programs[4]**

| **Program Type/Characterization** |
|---|
| Regulation-driven, industry-sponsored and administered recovery and destruction program paired with import, trade, and use controls |
| **Funding Source** |
| – Import levies for all ODS and synthetic greenhouse gas (SGG) refrigerants (in bulk and pre-charged in equipment) paid to RRA to fund the product stewardship scheme (rebates, bulk collection, destruction)<br>– RRA sets its own levies and rebates<br>– Small importers (<100 kg) pay flat fee, while large importers pay per kg ($2.00 (AUD)/kg)[5]<br>– All importers pay $0.165 (AUD)/kg (SGG) or $3.00 (AUD)/ODP kg (for ODS) to federal government used to cover government costs and industry development fund.[6] |

[4] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015 and Interview with Greg Picker.
[5] Ibid.
[6] Australia Department of the Environment. "Technical Analysis Report." October 2015. Accessed October 2015. Link

**Incentives & Enforcement Mechanisms**

- RRA provides rebates for the return of recovered refrigerant
- Minimum rebate $5 (AUD)/kg. Wholesalers can offer higher rebates at their own cost[7]
- Wholesalers receive $15 (AUD)/kg[8]
- Avoidable venting is an offense with strict penalties for unauthorized discharge
- Maximum penalties for breaches to the Ozone Acts and supporting regulations range from $1,700 to $425,000 (AUD)[9]

**Summary Description[10]**

With **strong regulatory backing**, RRA recovers, reclaims, destroys, and tracks surplus refrigerants by:

- Interfacing with government to ensure industry understands regulations
- Helping contractors comply at "reasonable burden and cost"
- Providing rebates for collected refrigerants
- Operating a national collection and destruction service
- Conducting educational and promotional campaigns for industry

Concurrently, private industry reclaims phased down refrigerants when economically advantageous[11]

**Program Performance[12]**

- More than 4,600 metric tons recovered and destroyed since inception
- 468 metric tons recovered in 2012 (CFCs 6%, HFCs 40%, HCFCs 35%)
- 556 metric tons destroyed in 2012
- $4.6M (AUD) provided in rebates provided in 2012 to contractors and wholesalers
- 900+ companies contribute to RRA program
- Winner of three awards:
    - UN Environment Program Montreal Protocol Implementers Award
    - U.S. EPA Climate Protection Award
    - U.S. EPA Stratospheric Ozone Protection Award

**Recovery[13]**

- RRA estimates recovery between 35% and 61% of available volume
- Department of Environment estimates that 80% of refrigerant from split systems is correctly recovered; however, this is likely an overestimate.

[7] Ibid. Note: based on 2011 report and we were unable to confirm.
[8] Ibid. Note: based on 2011 report and we were unable to confirm.
[9] Australian Refrigeration Council. "Fact Sheet 11." Accessed August 2015.
[10] Refrigerant Reclaim Australia. "our role." Accessed August 2015. Link
[11] Interview with Greg Picker.
[12] Refrigerant Reclaim Australia. "Annual Report 2011/12." Accessed August 2015.
[13] Refrigerant Reclaim Australia. "program performance." Accessed August 2015. Link and RRA "Annual Report 2011/12."

**Tracking/Reporting Mechanisms**

- Tracking and reporting are a major part of Australia's refrigerant management program.
- Refrigerant is tracked through every transaction from import to destruction with the following exception: Little to no recordkeeping and tracking is required when refrigerants are installed

**Outreach/Involvement**

Outreach is considered a shared responsibility between industry groups such as ARC, RA, RRA, and Air-Conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA)

**Training**[14]

ARC facilitates training for aspiring technicians by:

- outlining the requirements for licensure,
- listing the registered training organizations on its website
- providing comprehensive training frequently asked questions (FAQs) and "FactSheets"

Technical colleges and other training organizations prepare technicians for ARC certification

**Reusable Canisters**

- Reusable canisters are mandatory. Interviewees pitch this as a cornerstone component in their program and that it should be considered pivotal in driving successful refrigerant management worldwide.
- Illegal to import, sell, or use disposable canisters

See Appendix A for details on relevant regulations.

Figure 2-3 summarizes the roles and responsibilities of relevant Australian organizations.

**Australian Parliament**

- Passed regulations controlling the manufacture, import, export, and end-use of ODS and SGG

**Australian Refrigeration Council (ARC)**

- Industry body appointed in 2005:[15] administers refrigeration and air conditioning aspects of the regulations, including granting refrigerant handling license and refrigerant trading authorizations, and conducting audits on behalf of the Department of the Environment

[14] ARC. "Frequently Asked Questions." Accessed August 2015. Link
[15] ARC. "About ARC." Accessed August 2015. Link

**Refrigerants Australia (RA)**

- Member of ARC
- Primary industry interface with government
- Covers vast majority of industry, representing
  - 90% of all synthetic refrigerant imported and sold in Australia
  - 90% wholesalers
  - main contractors organization
- Excludes those entities that promote the use of hydrocarbons as direct "drop-ins" for retrofit without OEM approval)

**Other Industry Groups**

- Air-Conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA)
  - Industry group for equipment manufacturers[16]
- Other smaller industry groups represent other interests

**Importers**

- Passed regulations controlling the manufacture, import, export, and end-use of ODS and SGG

**Technicians**

- Earn and maintain Australia-wide licensing (includes payment to ARC). If contractor buys refrigerant, he must also obtain a trading authorization (also ARC).

**Figure 2-2: Australia's Roles and Responsibilities**

### 2.2.2 Program Structure

Australia's refrigerant management program was born from deep industry and government collaboration. RA, created in 1987, works with the Australian Government to manage ODS and SGG issues. One aspect of this collaboration was the development of industry programs, including Refrigerants Reclaim Australia (RRA) and the Australian Refrigeration Council (ARC), both of which came directly from RA.

RRA, formed in 1993, aimed "to create an industry-wide recovery program that met all government and international obligations for all parties; that provided an outlet for all recovered refrigerant; (and) that shared the cost burden (of refrigerant management) across the whole industry."[17] Industry was motivated by what they felt was fragmented, inconsistent, and conflicting state and territory regulations. Originally, this program was voluntary, but became compulsory after Parliament passed the 1995 Ozone Acts. Importers joined as a way to control the volume of available refrigerant in the economy.

The original Ozone Act was enacted in 1989, laying the groundwork for future ODS regulation. Originally, PSS membership was voluntary for bulk gases; however, in 2004 the regulations mandated that PSS membership was required for an import license. RRA manages the only PSS, making it the default choice for importers. Members pay RRA for a license to import refrigerant to Australia. RRA uses

[16] AREMA. "About AREMA." Accessed September 2015. Link

[17] Refrigerant Reclaim Australia. "why was rra created?" Accessed August 2015. Link.

the collected fees to incentivize refrigerant recycling (e.g. with rebates), to operate a national collection service and central processing center, and to conduct educational and promotional campaigns.

Australia relies on robust licensing to manage refrigerant flow throughout the economy. Licensing covers 1) importers of bulk and pre-charged equipment with ODSs and SGGs, 2) businesses and individuals who acquire, possess, or dispose of fluorocarbon refrigerant, and 3) individuals who handle refrigerant or work on refrigeration and AC equipment. Importers apply for import licenses through the Department of the Environment. Licensing costs ~$15,000 AUD, last for two years, and require importer to submit quarter reports on refrigerant-related activities. Phase out quotas for HCFCs dictate the availability of HCFC import licenses, limiting the number of parties that can import HCFCs refrigerant importing. Businesses and individuals apply for trading authorizations and handling licenses through ARC, which was appointed by Australia's Minister for the Environment and Water Resources. Licensing costs range from $137 AUD to $442 AUD and last for two years. [18]

RA, RRA, ARC, AREMA, other industry groups, and the Department of the Environment work together to promote refrigerant management best practices and develop refrigerant management regulations. For example, RRA's board is made up of: importers of bulk refrigerant, importers of equipment containing refrigerant, wholesaler and distributors of refrigerant, and contractors from the commercial and automotive sector.

Backed by this strong regulatory framework, these organizations oversee the import, transportation, charging, recycling, and disposal of Australia's refrigerants.

Figure 2-3 summarizes the relationships between parties responsible for refrigerant management in Australia.

[18] Australian Government Department of the Environment. "Refrigeration and air conditioning." Accessed October 2015. Link and "Controlled Substances License to import SGGs" Accessed October 2015. Link

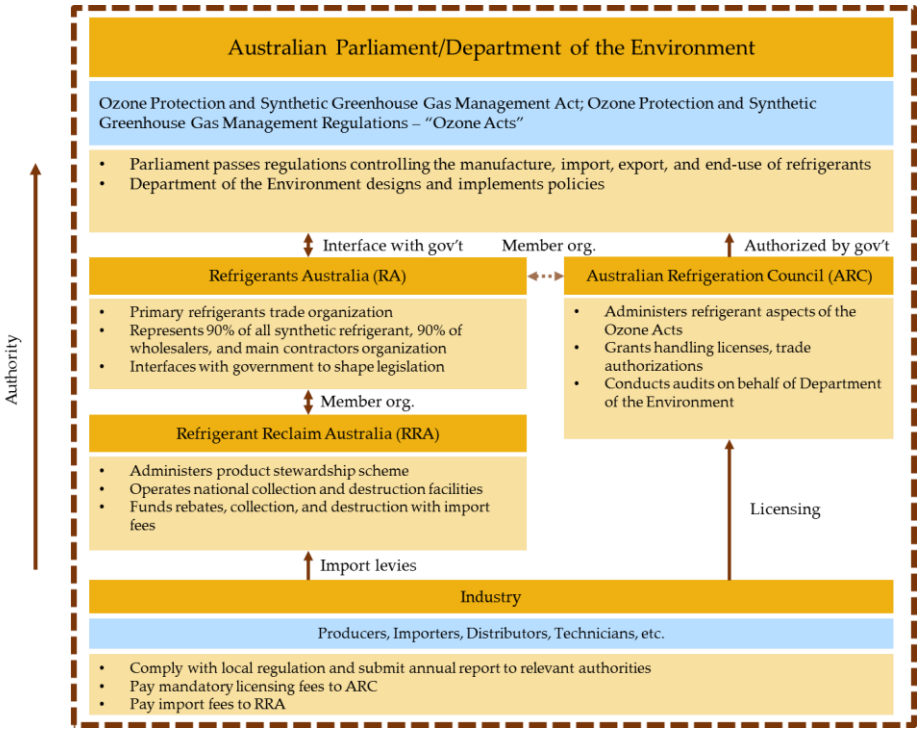



**Figure 2-3. Australia's Regulatory and Enforcement Framework**

### 2.2.3 Effectiveness Data

Australia's current regulatory framework mandates robust recordkeeping on the import, sale, transfer, and disposal of refrigerant, thus, robust effectiveness data exists on refrigerant management. See the figures below for more data on refrigerant flow in Australia.

In addition to the government-collected data, RRA rigorously tracks all refrigerant that enters the product stewardship scheme. See Figure 2-4, Figure 2-5, Figure 2-6 and Table 2-3 for the most recent data on RRA's recovery and destruction activity.

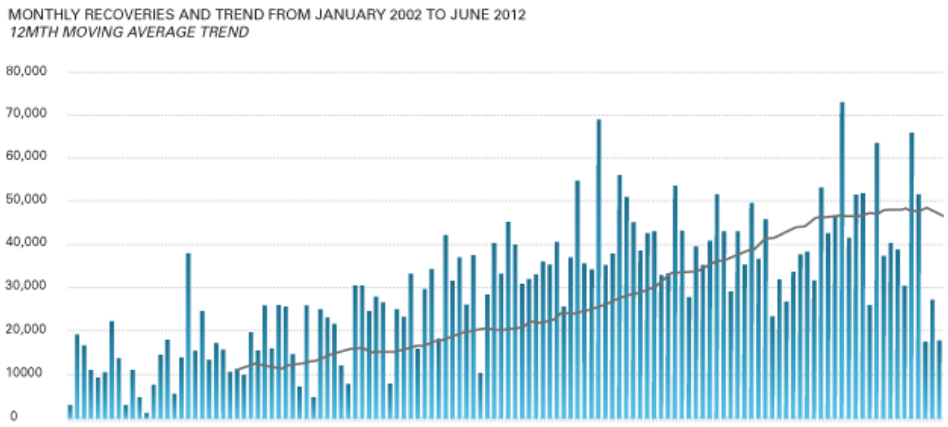



**Figure 2-4. RRA Monthly Recovery of Refrigerant (kg) (January 2002 – June 2012)[19]**

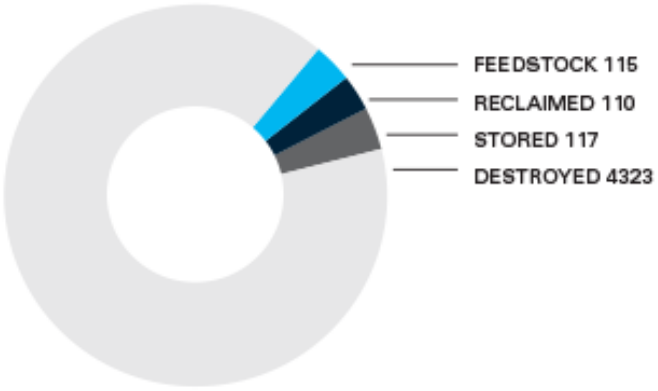



**Figure 2-5. RRA Process Activity for Recovered Refrigerant (metric tons) (1993-2012)[20]**

[19] Refrigerant Reclaim Australia. "program performance." Accessed August 2015. Link
[20] Ibid.

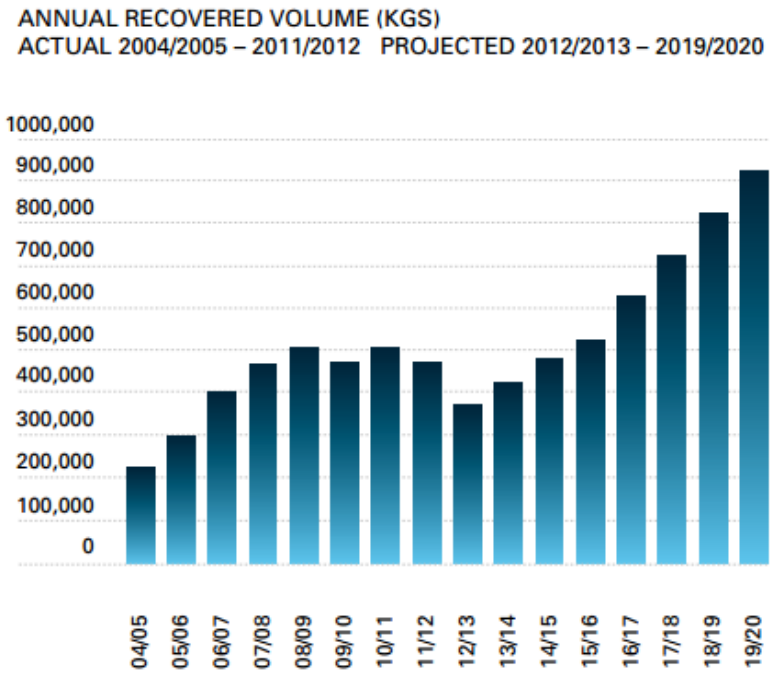



**Figure 2-6. RRA Actual and Projected (kg) (2012/2013 – 2019/2020) Annual Recovered Volume[21]**

**Table 2-3. Refrigerant Recovery Estimates from RRA[22]**

| Applications for New Refrigerant | (Metric Tons) | |
|---|---|---|
| OEM | 600 | |
| New Installations | 1400 | |
| Automotive Service | 900 | |
| Commercial/Industrial/Domestic Service | 1700 | |
| **Total Sales** | **4600** | |
| **Available for Recovery** | **Range of Estimations** | |
| Automotive Service | 300 | 400 |
| Commercial/Industrial/Domestic Service | 400 | 600 |
| EOL Vehicles | 190 | 240 |
| EOL AC | 470 | 680 |
| EOL Commercial | 300 | 300 |
| Available for Recovery | 1660 | 2220 |
| Amount Retained for Reuse | -880 | -880 |

[21] Refrigerant Reclaim Australia. "Annual Report 2011/12." Accessed August 2015.
[22] Refrigerant Reclaim Australia. "program performance." Accessed August 2015. Link

| Applications for New Refrigerant | (Metric Tons) | |
|---|---|---|
| Amount Available to be Returned | 780 | 1340 |
| Amount Returned to RRA | -475 | -475 |
| Balance Available for Recovery | 305 | 865 |
| **Percentage Recovery** | **-61.1** | **-35.5** |

### 2.2.4 Key Findings

Table 2-4 summarizes the key successes and challenges of Australia's refrigerant management program.

**Table 2-4. Successes and Challenges of Australia's Refrigerant Management Programs**

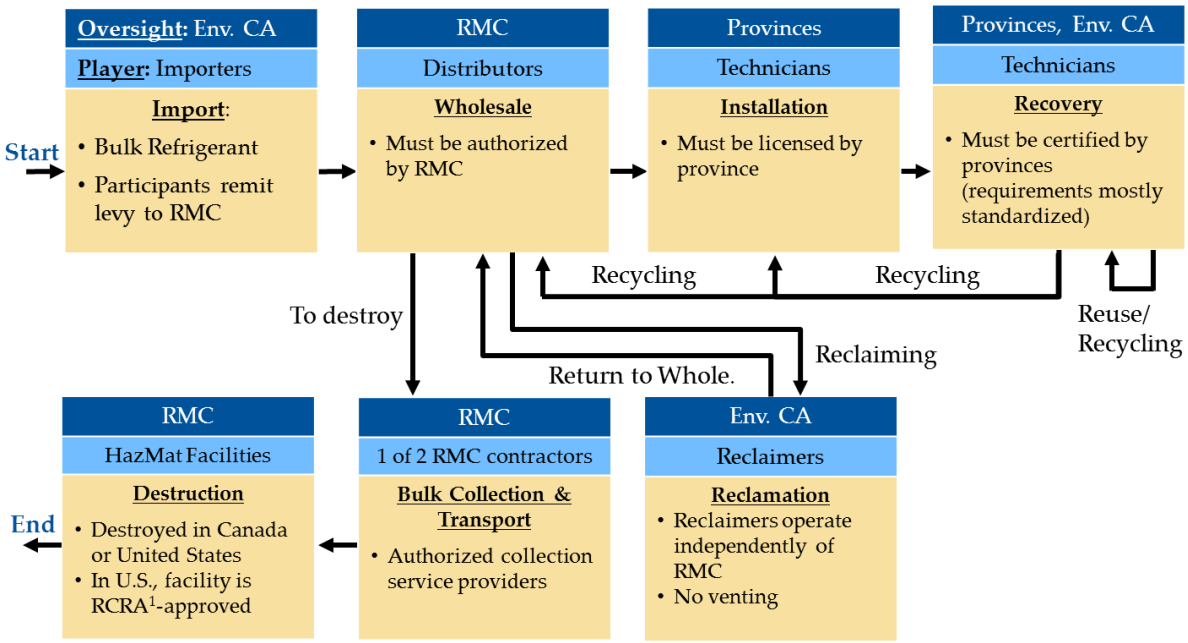
| Key Successes | Key Challenges |
|---|---|
| Large membership base for RRA (900+ members) | Utilization of a single organization/system raises concerns and complaints of anti-competitiveness |
| Sophisticated investing has enabled RRA to generate large funding reserve ($50M+ AUD) | Aggressive phase-out regulations and costly alternatives encourage contractors to retain and reuse impure or contaminated recovered HFCs |
| PSS was developed by industry; originally voluntary | High cost of destruction services may disincentivize proper EOL management |
| Industry-government collaboration | Costs incentivizes counterfeit refrigerants |
| Design changes to equipment are shifting industry to hydrocarbon refrigerants for most domestic appliances/equipment | Very low-GWP refrigerants will not require RRA's collection and disposal infrastructure, resulting in a major loss in funding |
| Inclusion of all synthetic refrigerants (CFCs, HCFCs, HFCs) has leveled playing field | RRA focuses on destruction; leaves reclamation to industry, where recordkeeping, compliance may be lower |
| Robust recordkeeping requirements enable very close tracking of program performance | Carbon pricing (recently repealed) discouraged good behavior by drastically increasing the price of synthetic refrigerants; reuse of un-reclaimed, out-of-spec refrigerant became more common |
| Awards for execution by UN, U.S. EPA | Phase down is causing industry to stockpile R-22 (~30% of recovered R-22; ~50% during carbon taxation period) |
| Built upon existing distribution channels | Phase down and carbon pricing decreased motor vehicle compliance |
| | Recovery from domestic equipment still very low |
| | Lack of maintenance and EOL reporting requirements is the major data/performance gap |
| | No mandatory leak testing |

## *2.3 Canada*

### 2.3.1 Summary

Refrigerant flow in Canada is very similar the U.S. (see section 2.7). While federal regulations set specific requirements, (e.g. no venting), the provinces set regulations on the proper handling of refrigerants. Users can opt to handle refrigerant however they choose as long as they comply with the federal and provincial regulations. The major distinguishing feature of refrigerant flow in Canada is an industry-backed voluntary product stewardship scheme for stationary HVAC/R refrigerants. This scheme requires refrigerant manufacturers to remit levies to Refrigerant Management Canada (RMC), which are used to manage surplus refrigerants when they reach end-of-life (EOL). Once technicians recover refrigerant, they can return refrigerant to authorized wholesalers at no cost. These wholesalers then coordinate with an RMC Collection Service Provider (CSP) who aggregates, tests, and transports the surplus refrigerant to approved destruction facilities in Canada and the U.S. RMC has made unsuccessful attempts to expand the program beyond ODS refrigerants and stationary HVAC/R equipment; however, the appliance and automotive industries have pushed back, claiming that they handle refrigerant properly. Because RMC is voluntary, they do not have the authority to compel these industries to contribute to the program. RMC anticipates that it will accept HFCs starting in 2016.

Figure 2-7 outlines the flow of refrigerant through Canada's refrigerant management programs from refrigerant import to destruction. Note that Canada does not manufacture any synthetic refrigerants.




[1] Resource Conservation and Recovery Act (RCRA)

**Figure 2-7. Canada's Refrigerant Management Process**

Figure 2-7 encompasses bulk refrigerant flow in Canada. RMC is funded by levies on bulk imports and covers stationary HVAC/R equipment. Other refrigerant sources may use RMC at additional cost. No

national program exists to collect domestic appliance or motor vehicle refrigerant. Once collected, domestic appliance and motor vehicle refrigerants are typically managed outside of RMC.

Table 2-5 summarizes the key characteristics of Canada's programs.

**Table 2-5. Summary of Canada's Programs[23]**

| **Program Type/Characterization** |
|---|
| Regulation-driven, but not mandated, industry-sponsored and administered voluntary recovery and destruction program based on extended producer responsibility |
| **Funding Source[24]** |
| Levies remitted by participating manufacturers, importers, and reclaimers to RMC and ultimately passed down to end-users ($3.5 CAD/kg) at discretion of wholesalers and contractors. |
| **Incentives & Enforcement Mechanisms[25]** |
| – RMC covers the cost of shipping refrigerant from wholesalers to collection service providers, analysis, consolidation, and storage by the collection service provider, shipping to the destruction facility, and destruction.<br>– Fines depend on entity that breach the relevant regulations and the severity of the breach. Appendix E for a summary of fines.<br>– Illegal imports very well policed as refrigerants are controlled substances that require licensing[26] |
| **Summary Description[27]** |
| With strong regulatory backing, RMC facilitates the recovery, shipment, destruction, and tracking of refrigerants from stationary HVAC/R equipment covered under Environment Canada's regulation by:<br>– Setting levies for refrigerant recovery<br>– Authorizing wholesalers who accept refrigerant from contractors<br>– Requiring strict labeling and recordkeeping by wholesalers<br>– Approving collection service providers (CSP) (currently two)<br>– Collecting monthly activity reports to track refrigerant movement, destruction, and program success<br>– Accepting refrigerant from collection service providers for destruction at RCRA approved hazardous waste facilities |

[23] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015 and Interview with April and Warren Heeley.
[24] Interview with April Heeley.
[25] Refrigerant Management Canada. "The Program." Accessed August 2015. Link
[26] Interview with April Heeley.
[27] Ibid.

**Program Performance**[28]

- 371,500 kg/year of surplus refrigerant collected and destroyed (2011)
- Winner of "Best-of-the-Best Stratospheric Ozone Protection Award" by the U.S. EPA (2007)
- Membership in voluntary RMC program represents 95% of marketplace
- In 2007, average cost to dispose 1 kg of ODS $11.50 CAD

**Recovery**[29]

- RMC does not track recovery percentage or reclamation rates
- Success is measured in total amount of destroyed ODS refrigerant
- 322,000 kg collected in 2010 (estimated)
- 3.1M kg destroyed through 2015 (estimated)

**Tracking/Reporting Mechanisms**

- Tracking begins when contractor returns refrigerant to wholesaler
- Refrigerant is tracked through destruction
- CSP and destruction facilities no longer subject to RMC-sponsored annual audits because regulations (e.g. RCRA) mandate similar reporting, which RMC now uses.

**Outreach/Involvement**[30]

- Limited advertisements, brochures – "minimally successful"
- RMC model doesn't require extensive outreach – "most contractors don't know who we are"
- RMC develops relationships with wholesalers who input refrigerant into RMC's program
- Environment Canada developed a "Guide for the Implementation of a Halocarbon Recovery Program for Domestic Appliances" to help municipalities develop recovery programs
- Appliance retirement programs are "plugged through standard advertising channels"

**Training**[31]

- Trade qualification requirements differ by province
- Regulations drive minimum training requirements for contractors
- Contractors have to go to trade school, need to apprentice, receive license from provincial government
- Technical colleges, other service providers offer trade qualification schooling
- Most provinces require environmental awareness proficiency to purchase, trade, or work with refrigerants
- HRAI acts as federal administrator for environmental awareness course; offers course when needed

[28] Interview with April Heeley; Refrigerant Management Canada. "RMC Annual Report 2011." 2011. Accessed August 2015 and ICF International. "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015

[29] Interview with April Heeley

[30] Ibid.

[31] Interview with Warren Heeley

**Reusable Canisters**

- Refrigerant recycling operates with refillable containers that are typically owned by the wholesaler or the contractor.
- RMC's Collection Service Providers aim to return containers within one month

See Appendix E for details on relevant regulations.

Figure 2-8 summarizes the roles and responsibilities of relevant Canadian organizations.

**Government**

- Passed regulation controlling "the import, export, manufacture, use, sale and offer for sale of ozone-depleting substances" [32]

**Refrigerant Management Canada (RMC)**

- Collects levies from manufacturers, importers, and reclaimers of refrigerant through individual agreements with each company (ultimately passed on to end users) to fund collection, analysis, storage, and destruction of refrigerants
- Approves collection service providers, established program guidelines and environmental audits, and tracks program performance[33]

**Environment Canada**

- Administers the regulations, including inspecting equipment, auditing records, and fining violators
- Enforcement action uncommon

**Heating, Refrigeration & Air Conditioning Institute of Canada (HRAI)**

- At the request of Environment Canada, founded and developed Refrigerant Management Canada. Not-for-profit industry trade group for HVAC/R.
- Partners with Environment Canada to develop and offer training for technicians. [34]
- Administer ODS environmental awareness training by harmonizing across provinces, offering training when needed

**Individual Provinces**

- Responsible for defining requirements of, and issuing Trade Certification of Qualifications to, technicians
- Responsible for restricting emissions and mandating recovery
- Example programs include municipally-run domestic appliance recycling.

**Figure 2-8: Canada's Roles and Responsibilities**

[32] Environment Canada. "Fact Sheet: Federal Halocarbon Regulations, 2003" Accessed August 2015. Link
[33] Interview. Refrigerant Management Canada. Accessed August 2015. Link
[34] Refrigerant Management Canada. "HRAI." Accessed August 2015. Link

### 2.3.2 Program Structure

An early signatory of the Montreal Protocol, Canada has robust regulatory requirements to minimize the environmental impact of ODS refrigerants. Canada's regulations address ODS phase down, venting of refrigerants, and certification and reporting requirements. In Canada, refrigerant management is end-use specific. While venting refrigerants is illegal, no national programs exist to handle the collection of refrigerants from motor vehicles or domestic appliances. Bulk refrigerant from commercial and residential equipment is collected nationally through a voluntary industry-sponsored program. This program is modeled as a product stewardship scheme, known in Canada as an extender producer responsibility program (EPR), which was developed and administered by HRAI.

HRAI, in response to a request from the Canadian government, formed RMC to recover unwanted refrigerant on top of the industry's current recovery supply chain. Currently, RMC covers CFC and HCFC refrigerants from commercial and residential stationary refrigeration and AC equipment. Refrigerant manufacturers remit a levy to RMC, which is then passed along the retail chain to end-users. This levy covers the costs of collection, transportation, storage, and destruction of the surplus refrigerants.

RMC's program addresses surplus refrigerants. Therefore, once a refrigerant in stationary equipment has reached EOL, a certified technician recovers the refrigerant and returns it to a wholesaler (some provinces have instituted mandatory take-back laws) to begin the destruction process. Once wholesalers collect sufficient quantities of refrigerant, they contact RMC's Collection Service Providers (CSP). The CSP are contracted by RMC to test refrigerant, bulk and store refrigerant, and prepare refrigerant for shipment to a disposal facility. RMC operates 12 ISO trucks, which transport refrigerants from each CSP to the disposal facilities. Both the CSP and disposal facilities (rotary kilns) keep detailed records for annual audits. [35]

Figure 2-9 summarizes the relationships between parties responsible for refrigerant management in Canada.

[35] Interview with April Heeley.

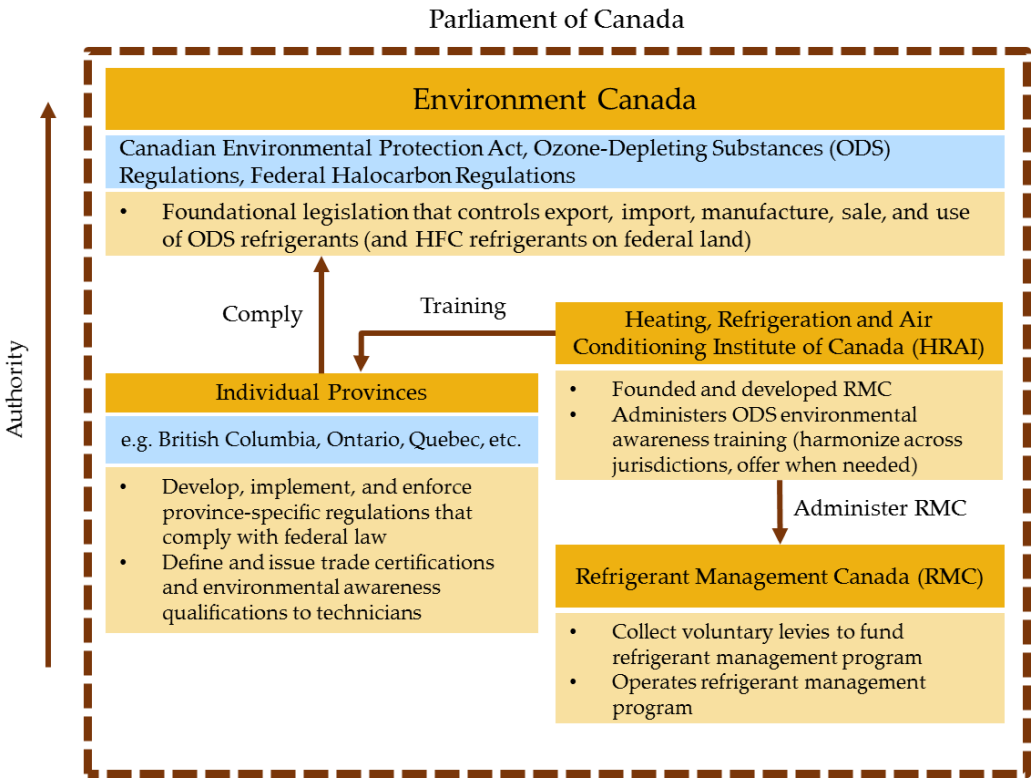



**Figure 2-9. Canada's Regulatory and Enforcement Framework**

### 2.3.3 Effectiveness Data

RMC does not track recovery rate, as they feel reported data would be unrealistic since it is difficult to determine the number, remaining life, and charge of systems operating (a value that is fundamental to calculating recovery rate).[36] Instead, RMC determines success by absolute ODS and GHG emission reductions equated to pounds of ODS destroyed. RMC does publish total refrigerant collected and destroyed. RMC also does not track reclamation rates, which has also proven to help reduce emissions. See Table 2-6 for 2003-2007 data. To date, RMC estimates that they have destroyed 3.1M kg of ODS. Without a strong basis for estimating total refrigerant in circulation, it is difficult to estimate a recovery rate.

[36] Ibid.

**Table 2-6: Canada's Bulk ODS Collected by Year (2003-2007)[37]**

| ODS Type | Kilograms Collected (Non-ODP Weighted) | | | | |
|---|---|---|---|---|---|
| | 2003 | 2004 | 2005 | 2006 | 2007 |
| CFC-11 and CFC-12 | 74,246 | 162,975 | 225,659 | 212,160 | 214,400 |
| HCFC-22 | - | 92,385 | 100,612 | 99,840 | 105,600 |

Canada reports very few major enforcement actions under the refrigerant management regulations.

One example, albeit a limited one, of a public enforcement action is from 2011. Environment Canada investigated and charged Gestion Alexis Dionne Inc. with illegally importing approximately 120,000 kg of R-22. The company agreed to forfeit the 70,000 kg of seized refrigerant, and the president agreed to pay $4,500 (CAD) to the Environmental Damages Fund. Relative to the $1 million (CAD) market value of the seized refrigerant, this fine is very small.[38]

### 2.3.4 Key Findings

Table 2-7 summarizes the successes and challenges of Canada's refrigerant management program.

**Table 2-7. Successes and Challenges of Canada's Refrigerant Management Programs**

| Key Successes | Key Challenges |
|---|---|
| Industry funded and managed | Includes refrigerant from stationary HVAC/R industry only |
| High participation rate (95%) | Automotive and appliance industries have ignored attempts to join voluntary program |
| Built on existing infrastructure—"contractors don't know who we are"[39] | Phase-out of HCFCs is reducing funding source |
| Very low industry burden | Voluntary program with no regulatory backdrop to prevent free riders |
| "Vibrant supply chain (reclamation, destruction) for refrigerant end-of-life"[40] | Excludes HFCs, which can have high GWPs |

[37] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[38] Environment Canada. "Record seizure of more than $1 million of a toxic substance imported illegally." March 2011. Accessed September 2015. Link
[39] Interview with April Heeley.
[40] Ibid.

| Key Successes |
| --- |
| ODS Environmental Awareness course required to practice refrigerant management |

| Key Challenges |
| --- |
| Domestic destruction capacity cannot handle RMC's needs, thus some refrigerant travels 1,000s of km for destruction at U.S. facilities. |
| Inter-country transport of ODS can be slow and costly |
| Limited-to-no tracking of total stock of refrigerant |
| Refrigerant in pre-charged equipment is not tracked |
| Reclamation rates not tracked |

## *2.4 European Union*

### 2.4.1 Summary

Because refrigerant management varies by member states see Figure 2-20 for the UK's refrigerant management process as an example of EU refrigerant management flow.

Table 2-8 summarizes the key characteristics of the European Union's programs.

**Table 2-8. Summary of European Union Programs**

| Summary Description |
| --- |
| Detailed international regulatory framework that:<br>– Phases down ODS and Fluorinated greenhouse gas (F gas) production, import, and use<br>– Includes service & equipment bans<br>– Requires annual reporting to EU<br>– Mandates minimum training and certification requirements<br>– Covers domestic appliances, mobile ACs, and commercial equipment<br>– Requires member states to develop and enforce regulations that comply with the framework |
| **Program Type/Characterization** |
| Strict regulation with aggressive phase outs and import controls of ODS and high GWP refrigerants. Member nations develop, implement, and enforce local legislation that must comply with European Commission regulation. |
| **Funding Source** |
| Varies by member state. No fees paid directly to European Commission or European Environment Agency. |

| Incentives and Enforcement Mechanisms |
|---|
| Varies by member state. All member state laws must comply with and enforce European Commission's HFC, ODS phase down and regulatory policies. |
| **Program Performance** |
| No information at this time. See U.K. (section 2.6) for proxy. |
| **Recovery** |
| – Destruction of newly included substances under ODS regs. not subject to reporting obligations<br>– Destruction of some ODS public; however, others not public because of confidentiality concerns<br>– Destruction of F-gas not public because of confidentiality concerns (est. below 1% of net supply)<br>– Reclamation of F-gas reported by importers and producers only (est. below 1% of net supply)<br>– Production, import, export, and destruction of ODS provided below[41] |
| **Outreach/Involvement** |
| – Both the Directorate-General for Climate Action and the European Environment Agency have robust websites with informational pamphlets, FAQs targeted at affected stakeholders, summary of legislation, required reporting and service practices, links to other relevant agencies, relevant contacts in member states, etc. [42]<br>– Varies by member state. See Table 2-16 for information on the Institute of Refrigeration's REAL skills, REAL zero, and REAL alternatives publicly available resources |
| **Tracking/Reporting Mechanisms** |
| – Annual reporting to EEA and DG CLIMA dictated by EC 517/2014, EC 1005/2009<br>– On-site recordkeeping dictated by EC 517/2014, EC 1005/2009<br>– Annual data is aggregated to protect confidentiality of reporting parties (e.g. producers, importers, etc.)<br>– Implementations vary by member states |
| **Training** |
| Varies by member state. See Table 2-16 for information on the Institute of Refrigeration's REAL skills, REAL zero, and REAL alternatives publicly available resources |
| **Reusable Canisters** |
| Varies by member state |

See Appendix A for details on relevant regulations.

Figure 2-10 summarizes the roles and responsibilities of relevant EU organizations.

European Commission

[41] EEA. "Ozone-depleting substances 2013." September 2014. Accessed August 2015.
[42] EC Climate Action. "Competent Authorities in Member States." May 2015. Accessed August 2015.

- Propose legislation (e.g. all EC Directives); enforce European law; oversees Directorate-General for Climate Action[43]

**Directorate-General for Climate Action (DG CLIMA):**

- Formulates and implements climate polices and strategies (including ODS regulations)
- Administers HFC Registry and F-gas Registry where individuals and companies must request HFC quota and report HFC activity as mandated by EC 517/2014[44]

**European Environment Agency (EEA)**

- Collects, archives, checks, and aggregates data for annual ozone-depleting substances and fluorinated greenhouse gases reports
- Also supports companies obligated to report with reporting procedure and technical questions. [45]

**Figure 2-10: European Union's Roles and Responsibilities**

### 2.4.2 Program Structure

As a coalition of member states, the European Union is unique in its refrigerant management approach. The European Commission develops and enacts legislation that member states must enforce. The European Union takes four major approaches to refrigerant management: aggressive phase out schedules for ODS and F-gases, application-specific maximum GWP requirements, technician certification requirements, and robust reporting and maintenance requirements.

While each member state may take a different approach to refrigerant management, all states must meet minimum threshold of EC legislative requirements. Refrigerant management varies by sector. Stationary equipment, domestic appliances, and motor vehicle refrigerants all reach destruction in different ways with different levels of success.

Figure 2-11 summarizes the relationships between parties responsible for refrigerant management in the EU.

[43] EC. "About the European Commission." Accessed August 2015. Link
[44] EC. "What we do." Accessed August 2015. Link
[45] EEA. "Fluorinated greenhouse gases 2013" and "Ozone-depleting substances 2013." September 2014. Accessed August 2015.

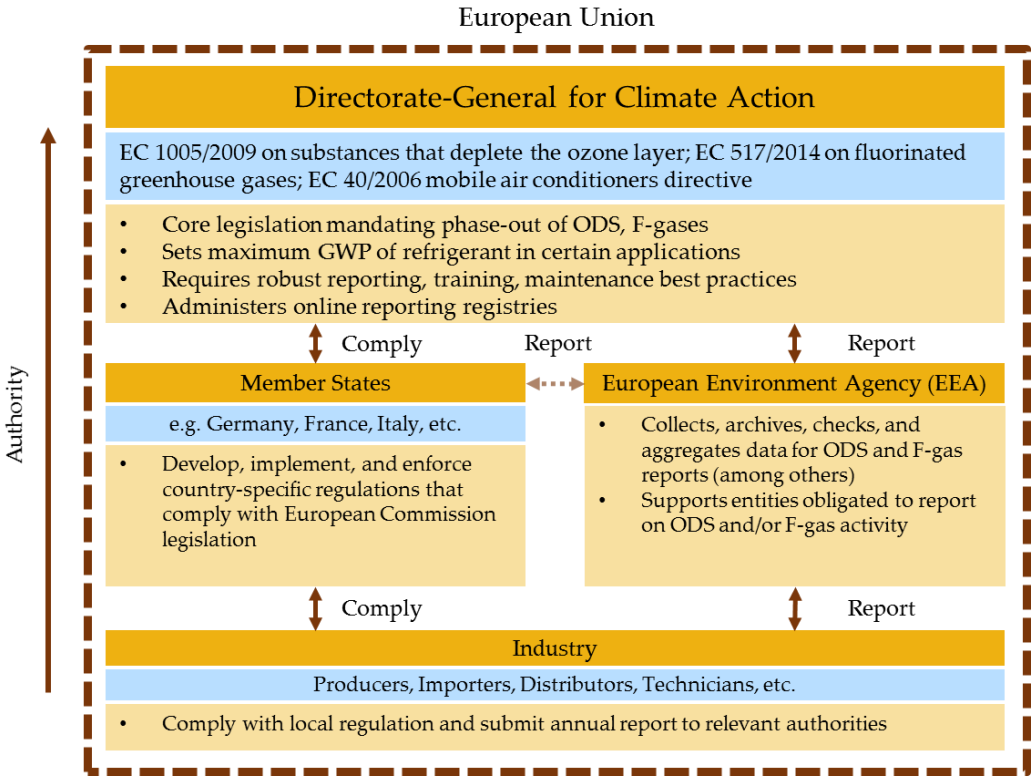



**Figure 2-11. European Union's Regulatory and Enforcement Landscape**

See Section 2.6 for details on U.K. refrigerant management.

### 2.4.3 Effectiveness Data

While the EU mandates robust reporting to the EEA, limited data exist on the overall effectiveness of refrigerant management in the EU. In an attempt to protect confidential information, the EEA publishes aggregated data only when more than three corporate groups report on specific refrigerant activity. Due to confidentiality concerns, the EEA did not report on the destruction of F-gases in 2013. Because the expanded F-gas regulations were adopted in 2014 and apply beginning January 1, 2015, most detailed data focuses on ODS substances. Lastly, the F-gas regulations require only producers and importers to report on reclamation and destruction activities, thus specialized "domestic" reclamation or destruction companies are not covered by current reporting requirements. Table 2-9 presents the most recent EEA data on ODS activities in the EU.

**Table 2-9. EU Production, Import, Export, Destruction, and Consumption of Controlled Substances 2008-2013 (metric tons)[46]**

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| Production | 228,679.988 | 158,964.698 | 192,701.432 | 185,012.855 | 171,421.433 | 163,664.494 |

[46] EEA. "Ozone-depleting substances 2013" September 2014. Accessed August 2015.

| | | | | | | |
|---|---|---|---|---|---|---|
| For feedstock use in EU | 143,882.204 | 155,279.160 | 166,676.115 | 176,348.903 | 163,305.811 | 155,041.750 |
| For other uses | 84,797.784 | 3,685.538 | 26,025.317 | 8,663.952 | 8,115.622 | 8,501.483 |
| Import | 14,047.129 | 13,488.668 | 8,879.960 | 9,615.495 | 9,455.048 | 8,501.483 |
| Export | 45,889.870 | 30,584.610 | 22,306.714 | 16,025.203 | 14,321.337 | 11,622.477 |
| Destruction | 20,965.473 | 15,696.544 | 10,537.109 | 6,015.862 | 2,,844.209 | 5,883.409 |
| Consumption | 25,603.340 | 11,314.252 | -1,680.472 | -2,918.315 | 32.509 | -3,513.702 |

Note: these data include ODS that are used for non-refrigeration applications

Table 2-10 summarizes the limited reclamation data reported by the EEA. The EEA notes that "the reported amounts cannot fully reflect complete EU activities due to the scope of the reporting obligation: only producers and importers are obliged to report on reclamation, destruction and own feedstock use."[47]

Instead, the EEA estimates that in 2013 producers and importers destroyed less than 1% of the net supply of F gases.

**Table 2-10. EU Producer and Importer Reclamation of F-gases, 2007-2013[48]**

| Unit | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|
| Metric Ton | 417 | 398 | 177 | 326 | 508 | 487 | 484 |
| % of net supply (ton basis) | 0.5% | 0.4% | 0.2% | 0.4% | 0.6% | 0.6% | 0.6% |

Table 2-11 summarizes ICF International's estimate on both the quantity and recovery efficiency of refrigerant in systems at EOL.[49]

**Table 2-11. ICF International Estimated Refrigerant Recovery Potential from Refrigeration/AC Equipment at EOL in the European Union**

| End-Use | Refrigerant Remaining at EOL | | Refrigerant Technically Recoverable at EOL | Total Potential Refrigerant Recovered at EOL | |
|---|---|---|---|---|---|
| | EU-15 [B] | EU-12 [A] | | EU-15 [B] | EU-12 [A] |
| Small Commercial | 90% | 80% | 90% | 81% | 72% |
| Medium/Large Commercial | 70% | 60% | 95% | 67% | 57% |

[47] EEA. "Fluorinated greenhouse gases 2013" September 2014. Accessed August 2015.
[48] Ibid.
[49] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.

| | | | | | |
|---|---|---|---|---|---|
| Industrial Refrigeration | 60% | 50% | 95% | 57% | 48% |
| Small Stationary | 90% | 80% | 90% | 81% | 72% |
| Large Stationary (Chillers) | 80% | 70% | 95% | 76% | 67% |

Source: ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." [50]

[A] EU-12: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, United Kingdom

[B] EU-15: EU-12 plus Austria, Finland, Sweden

### 2.4.4 Key Findings

Table 2-12 summarizes the successes and challenges of the EU's refrigerant management program.

**Table 2-12. Success and Challenges of EU Refrigerant Management**

| Key Successes | Key Challenges |
|---|---|
| Training and best practices developed and shared by consortium of institutions (REAL Alternatives, REAL Zero, REAL Skills) | Reporting requirements do not cover specialty reclaimers and destroyers, thereby omitting portions of the market |
| Regulatory framework enables member states to develop customized solutions to regulations | Variability of member state programs results in variable compliance levels |
| Annual publications respect industry confidentiality concerns | Confidentiality needs make full reporting difficult |
| EU regulatory bodies offer detailed information for stakeholders | |
| Robust reporting requirements improve accountability | |

## *2.5 Japan*

### 2.5.1 Summary

Refrigerant flow in Japan is highly end-use specific. Similar to Australia and the UK, Japan relies on extended producer responsibilities programs to enforce refrigerant management. Unlike these other jurisdictions, however, Japan also mandates robust raw material recycling (similar to California for appliances, but more comprehensive). Thus, refrigerant management is almost always paired with the same infrastructure used to disassemble, recycle, and dispose of products at EOL.

[50] Ibid.

Figure 2-12, Figure 2-13, and Figure 2-14 outline the flow of refrigerant through Japan's refrigerant management programs for home appliances, motor vehicles, and commercial equipment, respectively.

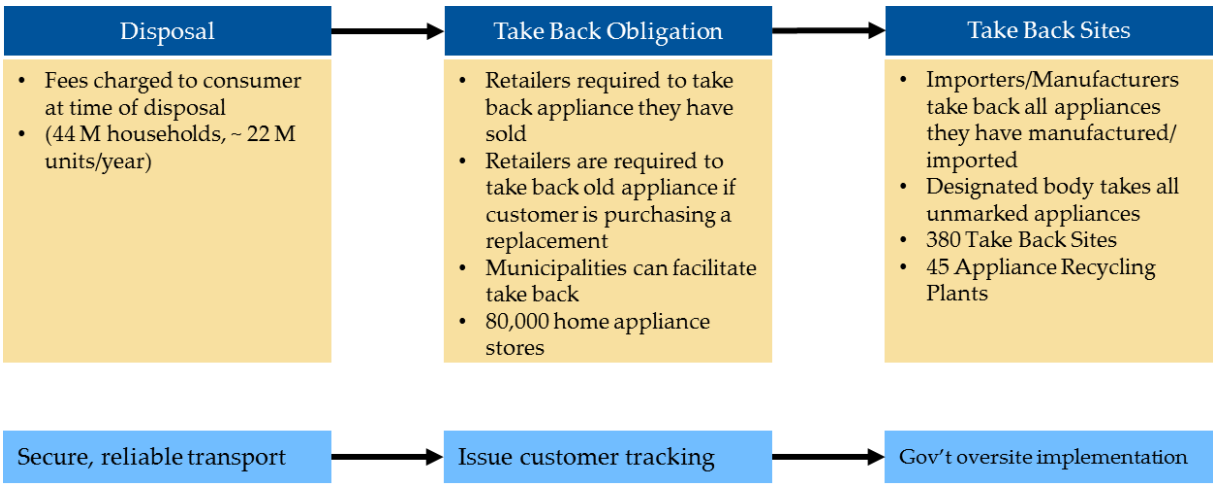



**Figure 2-12. Japan Ministry of Economy Trade and Industry -Adapted Home Appliance Recycling Diagram[51]**

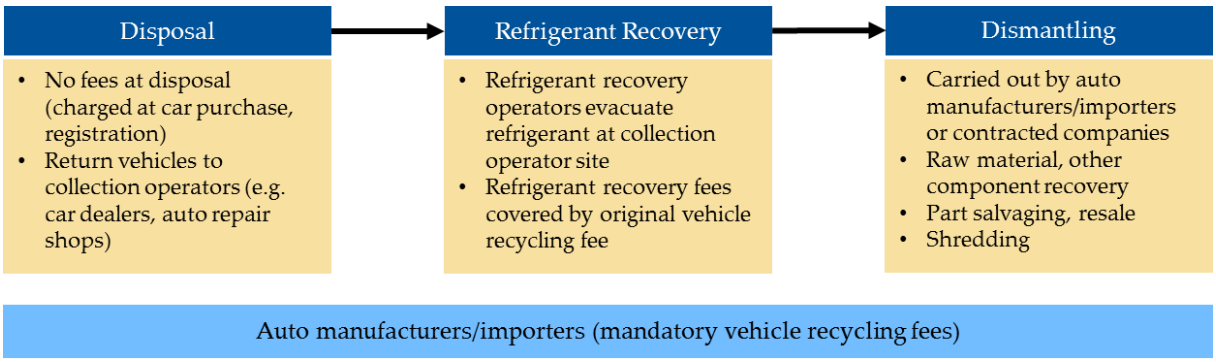
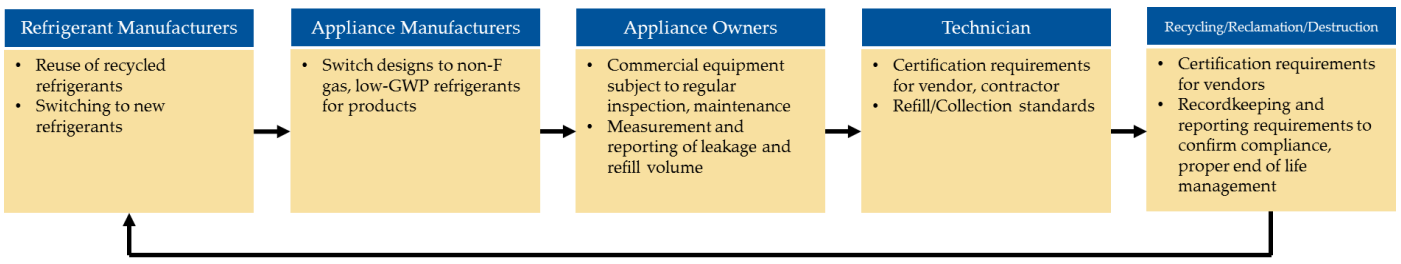



**Figure 2-13. Japan Ministry of Environment-Developed Vehicle Recycling Diagram[52]**




[51] METI. "Home Appliance Recycling Law." Accessed August 2015. Link

[52] Ministry of Environment (MOE). "Law for the Recycling of End-of-Life Vehicles (End-of-Life Vehicle Recycling Law)." Accessed August 2015.

**Figure 2-14. Overview of Japan's Refrigerant Management Based on Newly Enacted Fluorocarbons Emission Control Law[53]**

Table 2-13 summarizes the key characteristics of Japan's programs.

**Table 2-13. Summary of Japan Programs[54]**

| **Summary Description** |
|---|
| Strict regulatory framework, which covers domestic appliances, bulk refrigerant from commercial equipment, and mobile ACs<br>– Regulations and refrigerant flow differ by sector, but end-users typically pay fees associated with management.<br>– Note that for motor vehicle ACs, fees (which cover refrigerant recovery AND vehicle recycling) are charged at time of purchase, greatly increasing recovery rates.<br>– Law mandates reporting, licensed technicians, "extended producer responsibility."<br>o Appliance industry has responded with "Group A & B"<br>o Motor vehicle industry has responded with Japan Auto Recycling Partnership (JARP)<br>o Commercial equipment not subject to extended producer responsibility requirements, instead robust auditing/reporting requirements ensure proper refrigerant management |
| **Program Type/Characterization** |
| Strong regulatory framework that is supported by industry through trade groups, innovative collection and recycling techniques, and a strong culture of environmental protection |
| **Funding Source[55]** |

[53] Tsukada, Toshihiko. "Overview of the Fluorocarbons Emission Control Law." July 2015. Accessed September 2015.
[54] Interview with Rep. of AEHA. ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[55] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.

- Fees paid by end user at end of refrigerant life (e.g. in 2008, ~$40 (USD) for domestic refrigerator, ~$25 for AC).
- Recovery operators pay fees to destruction operators; however, recovery operators may pass fees along to consumers. Fee covers recovery, transportation, and destruction.
- Fees may not cover total costs of end-of-life product and refrigerant management, thus manufacturers must decide how they want to cope with this discrepancy. Either they pass some or all of these costs along to consumers with increased prices or they shoulder some or all the uncovered costs.[56]
- Consumer pays vehicle recycling fee at time of purchase ($60-$160 per vehicle, of which ~$18 is used for fluorocarbon removal and destruction).
- Capital costs for vehicle recycling/MAC recovery $130+ million and was born by manufacturers and importers.
- Operating costs of vehicle recycling/MAC recovery shared equally by manufacturers and end users.

**Incentives and Enforcement Mechanisms**

- Dumping domestic appliances is illegal and punishable with imprisonment and fine (max of $90,000).[57]
- +1,000 on-site inspections of fluorocarbon recovery operators are carried out annually.
- Public perception drives private companies to destroy refrigerant instead of reclaim it.

**Program Performance[58]**

- 90% of disposed appliances are handled through retailers.[59]
- METI estimates that 22-23 million domestic appliances (RF/AC/TV/Washers) are disposed of annually, but only ~11 million were collected through proper channels.
- 4,470 metric tons of refrigerant was destroyed in FY2013.[60]

**Recovery**

[56] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.
[57] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[58] Ibid.
[59] Ibid.
[60] Ministry of Economy, Trade and Industry (METI). "Results of the Amount of Destroyed Fluorocarbons Pursuant to the Law for Ensuring the Implementation, Recovery and Destruction of Fluorocarbons Concerning Specified Products of FY2013." Accessed August 2015. Link

- Domestic appliance refrigerant recovery estimated at 30% by volume[61]
- 1,800 metric tons of refrigerant recovered from domestic appliances in 2014[62]
- 1,241 metric tons of refrigerant recovered from domestic appliances was destroyed in 2014
- Commercial equipment refrigerant recovery estimated at 30% by volume (2006 estimate)
- Approximately 4,495 metric tons of refrigerant recovered from commercial equipment in 2014. This represents a 1.8x increase over 2006.[63]

**Outreach/Involvement**

- Outreach is mostly undertaken by industry organizations such as the Association for Electric Home Appliances (AEHA) and Refrigerant Recycling Promotion and Technology Center (RCR).
- Local prefectural governments also involved in outreach.

**Tracking/Reporting Mechanisms**

- Home Appliances Recycling Coupon allows end-user and government to track location and fate of appliance.
- Recovery/destruction operators maintain records that are submitted annually.
- End users of commercial equipment must keep refrigerant removal receipt.
- Japan Automobile Recycling Promotion Center (JARC) tracks vehicle disposal with robust online system.

**Training**

- Regulations require that collection and recycling of refrigerants are done by, or under the supervision of, professionals with sufficient knowledge and experience.
- Local prefectural governments offer training, enforce certification requirements and certify contractors.
- Both industry organizations and prefectures offer training.
- A number of certifications from different industry organizations meet the standards, including:
    - HVAC Engineer certification by JSRAE (Japan Society of Refrigeration and Air Conditioning Engineers)
    - High Pressure Gas Manufacturing Safety Supervisor - Refrigeration certification by High Pressure Gas Safety Institute of Japan (KHK)
    - High Pressure Gas Manufacturing Safety Supervisor (non-refrigeration) by KHK plus 5 years of relevant experience
    - Refrigeration and Air Conditioning Equipment Engineer certification by Japan Vocational Ability Development Association (JAVADA)
    - Refrigerant Collection Engineer certification by RCR

[61] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015; Interview with.
[62] Interview; Ministry of Economy, Trade and Industry (METI). "Results of the Amount of Destroyed Fluorocarbons Pursuant to the Law for Ensuring the Implementation, Recovery and Destruction of Fluorocarbons Concerning Specified Products of FY2013." Accessed August 2015. Link
[63] Navigant estimate based on Interview with representative of AEHA.

**Reusable Canisters**

No information at this time

See Appendix E for details on relevant regulations.
Figure 2-15 summarizes the roles and responsibilities of relevant Japanese organizations.

**Federal Government**

- **Ministry of the Environment (MOE):** Share responsibility with METI to inspect retailers, manufactures, and importers, and to publicly disseminate data on program performance
- **Ministry of Economy, Trade and Industry (METI):** Share responsibility with MOE to inspect retailers, manufactures, and importers, and to publicly disseminate data on program performance

**Association for Electric Home Appliances (AEHA)**

- Recycle appliances of unknown manufacturer or importers
- Recycle appliances on behalf of small- and medium-sized manufacturers or importers (by request)
- Collect appliances from municipalities or residents that are difficult to transfer
- Funded by consumer fees

**Japan Auto Recycling Partnership (JARP)**

- Established by auto industry – ensures vehicle disposal meets End-of-Life Vehicle Recycling Law
- Directly engages with refrigerant recovery firms to improve performance

**Retailers**

- Obligated to accept all units they sold and all old units disposed of at the time of replacement
- Charge consumers costs associated with transportation and recycling
- Issue tracking documentation

**Manufacturers/Importers**

Required to recycle appliances, vehicles, and charged refrigerant

**Appliances: Group A & B (Ecology Net and R-Station)**

- Created by manufacturers/importers to meet requirements of Home Appliance Recycling Law
- Run designated appliance collection sites
- Manages transport and recycling of appliances
- Distributes costs to manufacturers based on makeup of recycled equipment
- Operate appliance recycling plants where foam and refrigerant are recovered
- Send refrigerants to nearest destruction facility (R-22 occasionally reclaimed)

**Motor Vehicles**

- Send refrigerants to nearest destruction facility (R-22 occasionally reclaimed)

**Commercial Equipment**

- Send refrigerants to nearest destruction facility (R-22 occasionally reclaimed)

**Prefectures/Municipalities**

- Enforce certification requirements and certify contractors
- Offer training for contractors (jointly or in parallel to industry ogranizations0
- Support appliance collection among small retailers (those that are too small to transport appliances)
- Charge consumers costs associated with transportation and recycling
- Issue tracking documentation

**End-User**

- Return appliances to approved collector (retailer, municipality, designated collection site)
- Pay relevant fees to cover transportation through destruction
- Commercial equipment end users must retain fluorocarbon receipt certifications
- Bear costs of refrigerant collection and vehicle recycling at time of vehicle purchase

**Recovery Operators**

- Licensed by prefecture government
- Required to keep records that are submitted annually

**Destruction Operators**

- Comply with standards and regulations related to destruction
- Submit annual reports to relevant ministers

**Figure 2-15: Japan's Roles and Responsibilities**

### 2.5.2 Program Structure

As a signatory of the Montreal Protocol, Japan is obligated to implement regulations to protect the stratospheric ozone layer. Furthermore, a culture of environmental stewardship and waste minimization has further propelled Japan to the forefront of refrigerant management.

Japan's refrigerant management programs are driven by four major initiatives: 1) Japanese law mandates product stewardship schemes for domestic appliances, 2) Japanese law mandates product stewardship schemes for motor vehicles, 3) Japanese law sets strict servicing and recordkeeping requirements for commercial refrigeration applications, and 4) Japanese law prohibits venting of refrigerants.

Each regulated sector has addressed these requirements differently. Domestic appliance manufacturers and importers developed two competing product stewardship schemes, which manufacturers and importers can choose between. At the end-of-life, users are charged for the costs associated with recovering, transporting, disassembling, destroying or recycling raw materials and refrigerants. Ideally, this dual scheme structure promotes competition between the end-of-life contractors, keeping down costs. While very little recordkeeping is required during the life of an appliance, retailers and other entities that take end-of-life appliances from consumers must generate a report for the consumer, which can be used to track the appliance through final processing.

Motor vehicle manufacturers and importers also developed a product stewardship scheme; however, unlike the domestic appliance scheme, the fees associated with end-of-life management are paid **up front** when customers purchase a vehicle. These fees cover all end-of-life management, including raw

material recycling and refrigerant removal and destruction. Additionally, recovery operators are incentivized to recover refrigerant, as they receive payment if recovered refrigerant/MAC exceeds a pre-set threshold. Recordkeeping and licensing is also a key piece of MAC refrigerant management, as licensing and annual reporting is required for all recovery operators.

Commercial refrigeration equipment is not subject to a product stewardship scheme; however, Japan mandates strict certifications for technicians as well as recordkeeping by equipment owners. All refrigerants must be destroyed at permitted facilities, and users cover the costs associated with end-of-life refrigerant management.

All of these approaches stem from the overarching federal requirements that prohibit the venting of refrigerants and dumping of recyclable raw materials.

Figure 2-16 summarizes the relationships between parties responsible for refrigerant management in Japan.

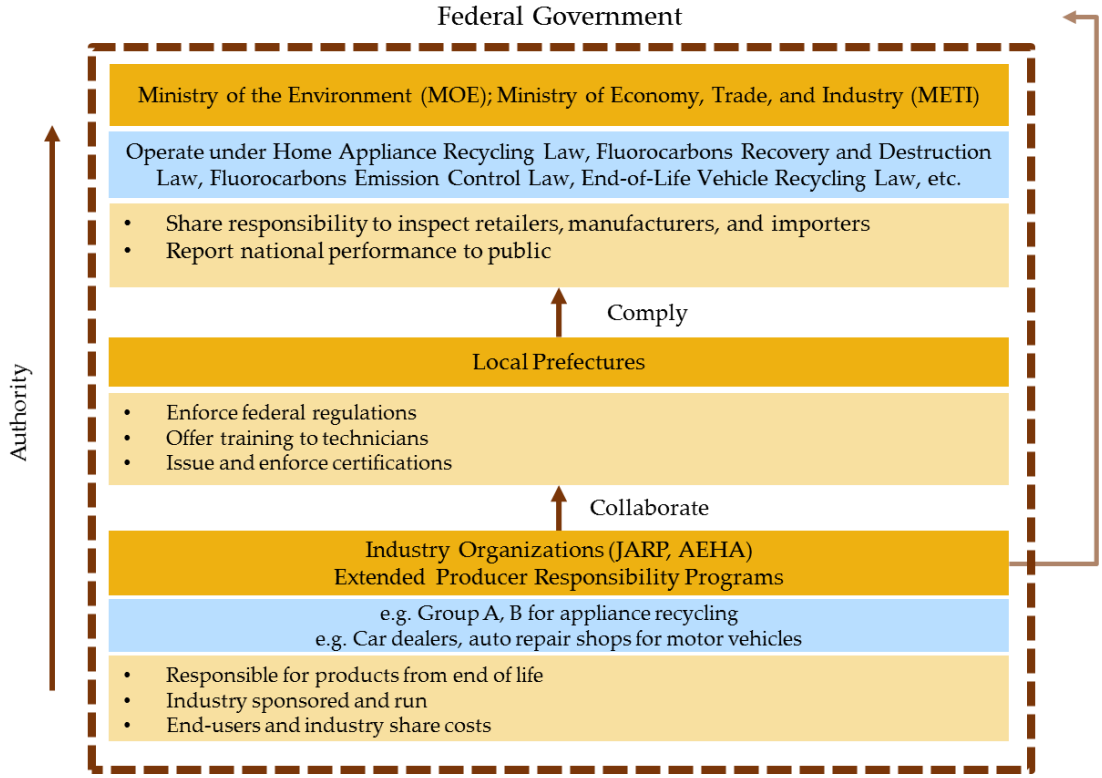



**Figure 2-16. Japan's Regulatory and Enforcement Landscape**

### 2.5.3 Effectiveness Data

Japan's current regulatory framework mandates robust reporting requirements, which Japan recently expanded through the Fluorocarbons Emission Control Law (2015 – see Appendix A.4 for additional

detail). This section includes available data on refrigerant recovery and destruction by sector. For additional data on unit recovery and costs, see Appendix H.

Due to societal pressures, most refrigerant that is recovered is destroyed, permanently mitigating negative environmental impacts. The three primary regulations are viewed with differing levels of success. Prior to the 2005 End-of-Life Vehicle Recycling Law, 220,000 vehicles were dumped illegally. By 2007, illegal dumping dropped to 35,000 per year.[64] For appliances, recovered refrigerant represents approximately 30% of available volume and recovered appliances represent approximately 50% of end-of-life products. For commercial equipment, enhanced regulations for have not materially increased the percentage of recovered refrigerant prior to the 2007 regulations. Hope exists, however, that the most recent Fluorocarbons Emission Control Law will improve performance, as HFCs are more heavily regulated.

Table 2-14 summarizes METI's most recent press release on refrigerant destruction in FY2014. Figure 2-17 and Figure 2-18 present total refrigerant recovered from domestic appliances (2001-2013, 2014 estimated), and commercial equipment (2002-2013, 2014 estimated). Figure 2-19 presents historical motor vehicle refrigerant recovery data for 2002-2006.

**Table 2-14. Aggregate Amount of Fluorocarbons Destroyed from Commercial Equipment and Motor Vehicle ACs in Japan, FY2014 (kg)[65]**

| | CFC | HCFC | HFC | Total |
|---|---|---|---|---|
| Storage of fluorocarbons at the beginning of FY2013 | 11,394 | 113,696 | 60,142 | 185,233 |
| Class 1 (commercial refrigerators and air conditioners) | 141,756 | 2,294,215 | 1,295,174 | 3,731,146 |
| Class 2 (vehicle air conditioners) | 11,768 | - | 760,379 | 772,147 |
| Total amount of recovered fluorocarbons | 153,524 | 2,294,215 | 2,055,553 | 4,503,292 |
| **Amount of destroyed fluorocarbons** | **155,295** | **2,305,098** | **2,034,403** | **4,494,796** |
| Storage amount of fluorocarbons at the end of FY2013 | 9,624 | 102,814 | 81,292 | 193,729 |

[64] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[65] Adapted from METI Press Release. Accessed August 2015. Link

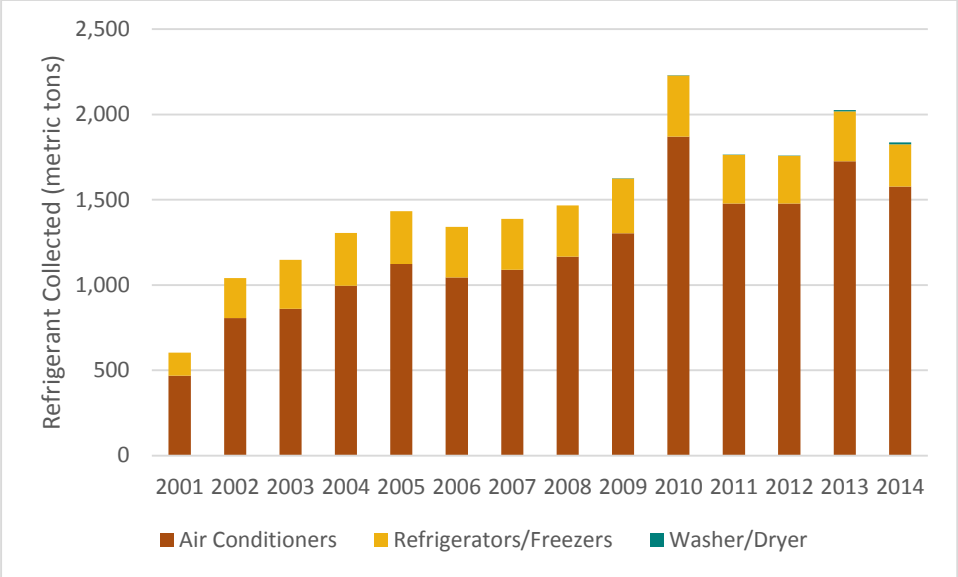



**Figure 2-17. Fluorocarbons Collected from Household Appliances in Japan, 2001-2014[66]**

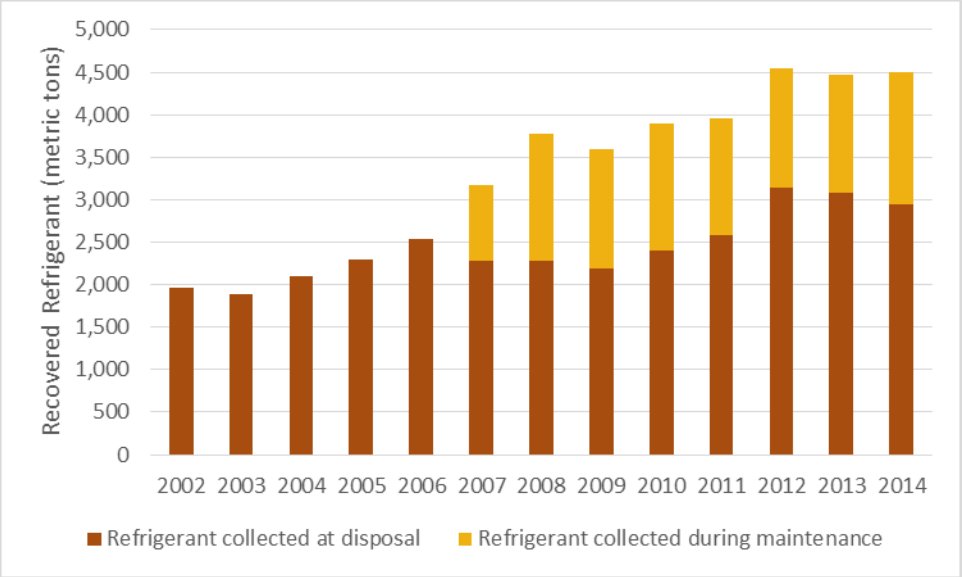



**Figure 2-18. Quantity of Refrigerant Recovered from Commercial Equipment in Japan, 2001-2014[67]**

[66] Interview with representative of AEHA. Note: 2014 data based on Navigant estimate.
[67] Interview with representative of AEHA Note: 2014 data based on Navigant estimate.

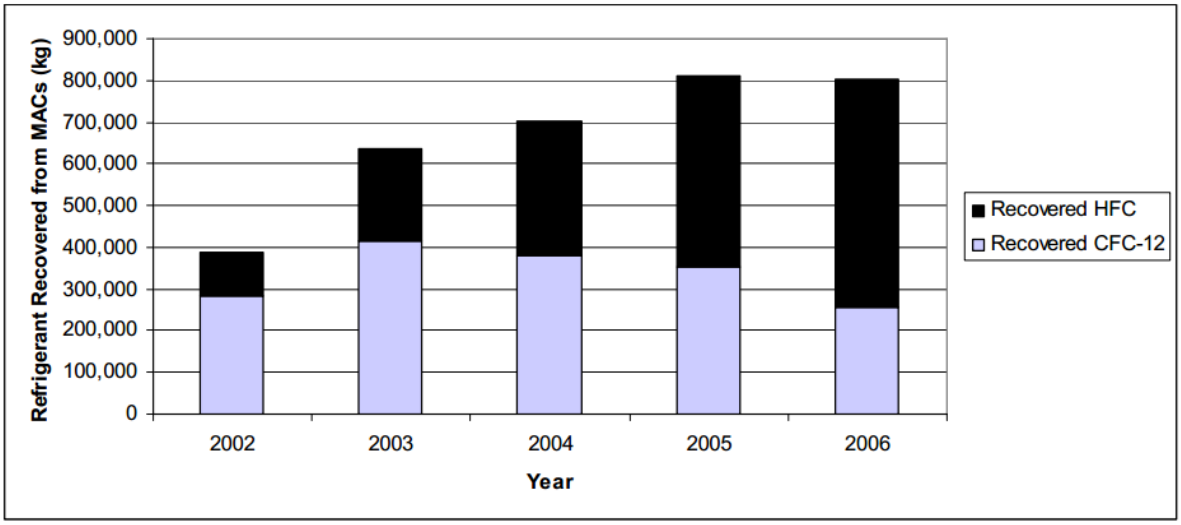



**Figure 2-19. Quantity of Refrigerant Recovered from MACs (kg) in Japan, 2002-2006[68]**

### 2.5.4 Key Findings

Table 2-15 summarizes the successes and challenges of Japan's refrigerant management program.

**Table 2-15: Successes and Challenges of Japan's Refrigerant Management Programs**

| Key Successes | Key Challenges |
|---|---|
| Motor vehicle refrigerant recycling hugely successful because recycling fees charged at vehicle purchase | Fees for proper appliance and commercial-equipment disposal at end-of-life results in some noncompliance |
| Environmental education and public perception encourages responsible refrigerant management | While a leader in appliance recycling, only 30% of available refrigerant is recovered from domestic appliances |
| Industry heavily involved in developing strategies for compliance, best practices | Limited to no public reporting requirements for Group A & B performance decreases public accountability |
| Industry accommodates mandatory recycling regulation with innovative and competitive product stewardship schemes | Recovery of commercial-equipment refrigerant (~30%) lags other jurisdictions |
| Strong regulatory framework for ODS refrigerants helps guide management | Full regulatory framework only recently extended to HFCs |

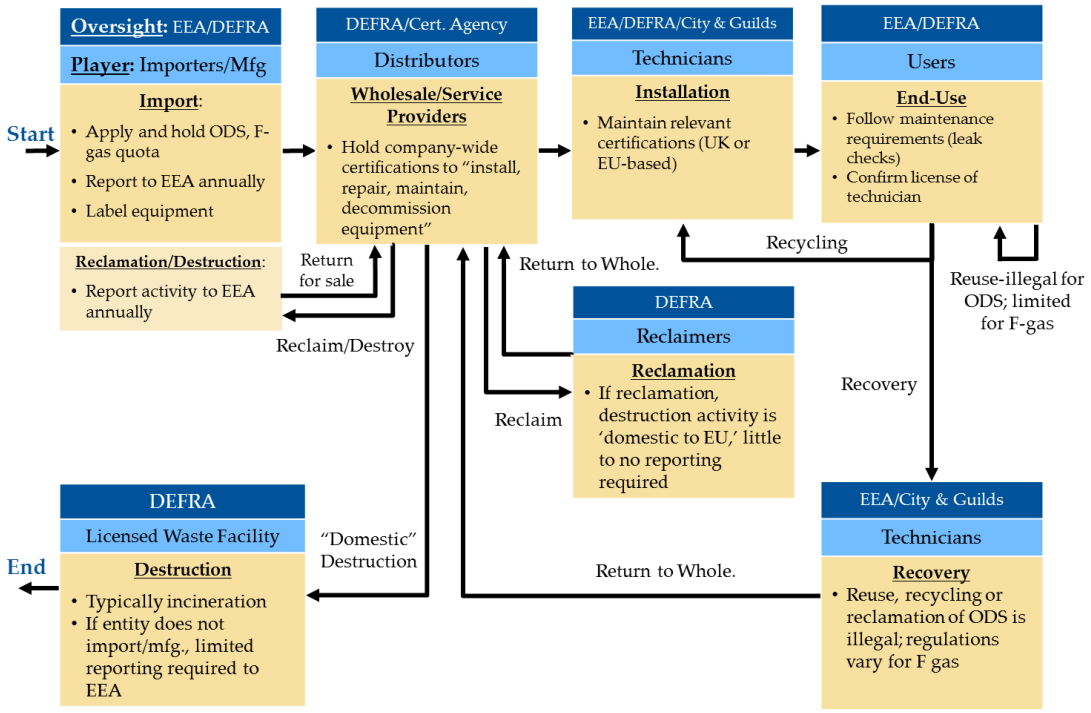
[68] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.

## *2.6 United Kingdom*

### 2.6.1 Summary

Refrigerant flow in the U.K. must meet the requirements of the European Commission's regulations. Thus, a major aspect of refrigerant management in the U.K. centers on reporting refrigerant trade, use, and destruction to the European Environment Agency. The EU has banned the reuse or reclamation of all ODS refrigerants, so technicians must send all recovered ODS for destruction. As the F gas phase-down progresses, F gas reuse and reclamation will also be limited (see Appendix A.5 for details on F gas regulations). Refrigerant flow varies based on end-use: domestic appliance and motor vehicle refrigerant is typically captured prior to product dismantling, and stationary equipment refrigerant is captured on-site prior to decommissioning. See Section 2.6.2 for more details on sector-specific refrigerant flow in the U.K.

Figure 2-20 outlines the flow of refrigerant through the UK's refrigerant management programs from refrigerant manufacturing or import to destruction.




Note: Encompasses bulk refrigerant flow in the U.K. Typical sources of this refrigerant are stationary HVAC/R equipment (residential, commercial, and industrial). Motor vehicle refrigerant and domestic appliance refrigerant are typically captured after disposal. Once captured, refrigerant follows same flow noted above.

**Figure 2-20. U.K. Refrigerant Management Process**

Table 2-16 summarizes the key characteristics of the U.K.'s programs.

**Table 2-16. Summary of U.K. Programs[69]**

| **Summary Description** |
|---|
| Strong international and federal regulatory backing paired with:<br>– Extended producer responsibility for appliances<br>– Maintenance, recordkeeping requirements for stationary equipment |
| **Program Type/Characterization** |
| Strong regulatory framework that is driven by EU and implemented by industry groups, municipalities, and end users. |
| **Funding Source** |
| – General funding for environmental agencies come from Department for Environment, Food & Rural Affairs (DEFRA), licensing fees, and local governments. Funding not necessarily for refrigerant recovery<br>– Consumers do not pay fees for disposal of old appliances<br>– Municipal Designated Collection Facilities (DCF) receive funding from municipal taxes<br>– Compliance Schemes must pay large licensing fee to Environment Agency |
| **Incentives & Enforcement Mechanisms** |
| – Heavy penalties for deliberate release of ODS<br>– Appliance pickup/drop off is free to end users |
| **Program Performance** |
| – DEFRA estimates that 90% of EOL refrigerators are sent to recyclers.[70]<br>– REAL Zero claims an average 44% reduction in leakage rate for equipment owners who completed training[71] |
| **Recovery** |
| – ICF International estimates range from 60% to 92% depending on end-use. See Table 2-17 for disaggregated recovery rate estimates. |

[69] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015 and Interview with Professor Graeme Maidment
[70] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[71] realskills europe. "questions about the programme." August 2014. Accessed September 2015. Link

**Outreach/Involvement**

- Responsibility distributed between technician's associates, U.K. government, and EU
- Robust material on Department of the Environment's website[72]
- "Consortium of educational institutions, teaching, membership and research organisations"[73] developed **REAL Alternatives, REAL Zero, and REAL Skills** to provide multi-lingual resources on best practices for alternative refrigerants and refrigerant management.
    - Includes opportunity for additional accreditation on top of legal requirements
    - Includes case studies
    - REAL Zero training includes guides on leak testing, common leaks, design practices, contractor and equipment owner responsibility, and logs and emissions calculators
    - REAL Alternatives training includes detailed modules on alternative refrigerant safety, system design, containment and leak detection, maintenance and repair, retrofitting, legal obligations, financial and environmental impacts, tools for conducting site surveys
    - Navigant believes this is the most robust and publicly available resource on refrigerant management best practices

**Tracking/Reporting Mechanisms**

Robust reporting requirements based on EU regulations

- Recordkeeping and maintenance requirements for companies that operate or service F gas-containing equipment include:
    - Using trained technicians
    - Labeling equipment (same requirements as manufacturers and importers see Regulation (EC) No 517/2014 in Appendix A.3 below)
    - Performing leak checks (See Table 4-9 for mandatory leak check schedule)
    - Installing leak detection system for equipment containing "F gas equivalent to more than 500 ($MMTCO_2e$)"[74]
    - Keeping records for 5 years and make them available to government upon request
- Reporting requirements for importers, and producers of more than 100 $MMTCO_2e$:[75]
    - "Produced or imported to the EU
    - Placed on the market in the EU
    - Sold for use as feedstock
    - Recycled, reclaimed, destroyed
    - Held in stocks at the end of the year
    - Authorized a non-EU manufacturer to pre-charge into equipment imported to the EU"

[72] U.K. Department for Environment. "F gas: guidance for users, producers, and traders." December 2014. Accessed September 2015. Link
[73] realskills europe. "About the project partners." July 2015. Accessed September 2015. Link
[74] U.K. Department for Environment. "F gas: guidance for users, producers, and traders." December 2014. Accessed September 2015. Link
[75] U.K. Department for Environment. "Guidance – HFC producers and importers: get and transfer EU quotas." December 2014. Accessed September 2015. Link

| Training |
| --- |
| – City & Guilds, other certifications required to handle refrigerants<br>– Taught at technical colleges, other accredited institutions<br>– REAL Skills certification offered on top of minimum legal requirement |
| **Reusable Canisters** |
| Required by EU regulation |

See Appendix A for details on relevant regulations.

Figure 2-21 summarizes the roles and responsibilities of relevant U.K. organizations. See Section 2.4.1 for governing European Union bodies.

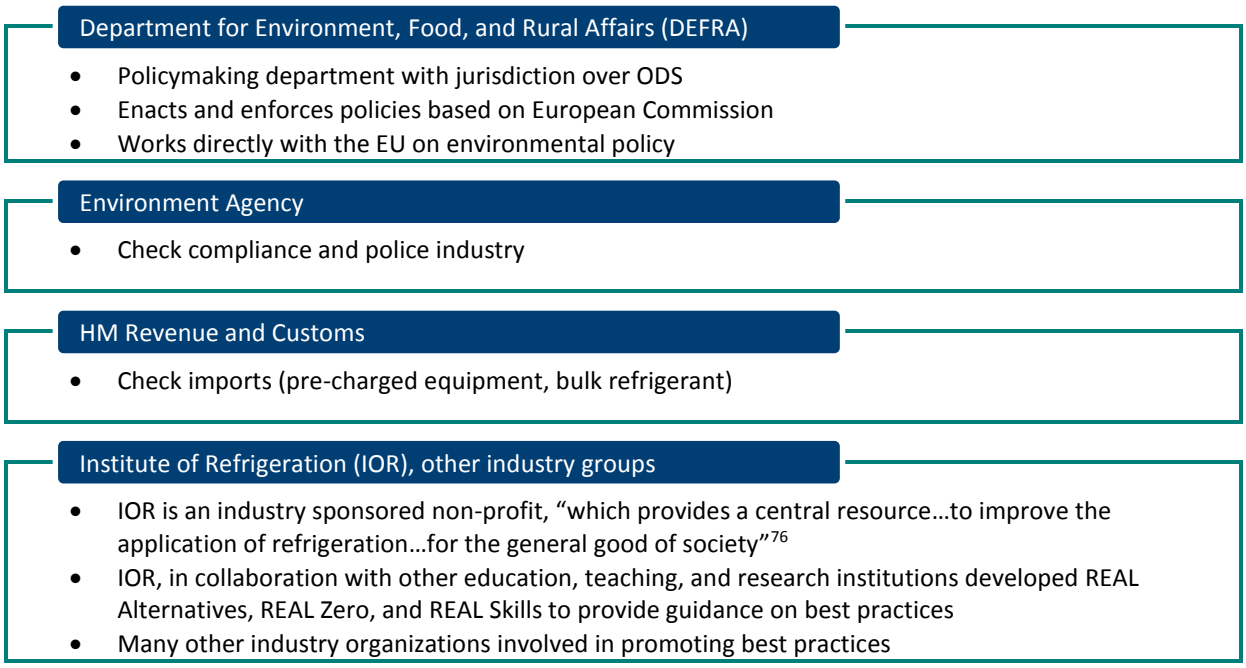



**Figure 2-21: U.K. Roles and Responsibilities**

### 2.6.2 Program Structure

As a signatory of the Montreal Protocol, the United Kingdom is obligated to implement regulations to protect the stratospheric ozone layer. Furthermore as an EU member state, the United Kingdom is obligated to comply with all European Commission regulations.

The U.K. addresses this obligation by prohibiting the emissions of ODS and F gases and prescribing reporting, recordkeeping, and certification requirements. These obligations, costs, and strategies vary by

[76] Institute of Refrigeration. "About the Institute of Refrigeration." Accessed September 2015. Link and Interview with Professor Graeme Maidment

end-use. Domestic appliances require limited reporting and recordkeeping by consumers, but require manufacturers to implement extended producer responsibility programs—better known as "compliance schemes."[77]

As of 2008, there were approximately 18 compliance schemes in the UK. Each scheme is responsible for disposing of appliances in proportion to its members' market share. The costs of the schemes are shouldered by manufacturers. Additionally, municipal governments run over 1,400 designated collection sites where consumers can drop off EOL appliances at no charge. Retailers also run collection programs, which take back EOL appliances at the sale of a new one. [78]

Bulk refrigerant and motor vehicles do not enjoy the same centralized EOL program. Instead, equipment owners take responsibility to properly evacuate and decommission commercial refrigeration equipment. Similar to the U.S. prior to motor vehicle destruction, refrigerants must be properly evacuated.

Unlike appliance refrigerant management, bulk refrigerant and stationary-equipment refrigerant is managed with obligatory scheduled maintenance and leak checks. These checks must be performed by certified technicians, and both the business and the service company must keep records for five years.

Import and production of ODS or F gas is closely tracked by the EEA. Additionally, any service provider that employs technicians to work on HVAC/R equipment must register and certify with one of three EU-wide certification entities. Similarly, technicians must earn UK-based certifications from one of a number of industry or governmental bodies. By tightly regulating the supply of ODS and F gas refrigerants and the qualifications of technicians, the U.K. strives to abide by the EU regulations.

Figure 2-22 summarizes the relationships between parties responsible for refrigerant management in the U.K.

[77] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[78] Ibid.

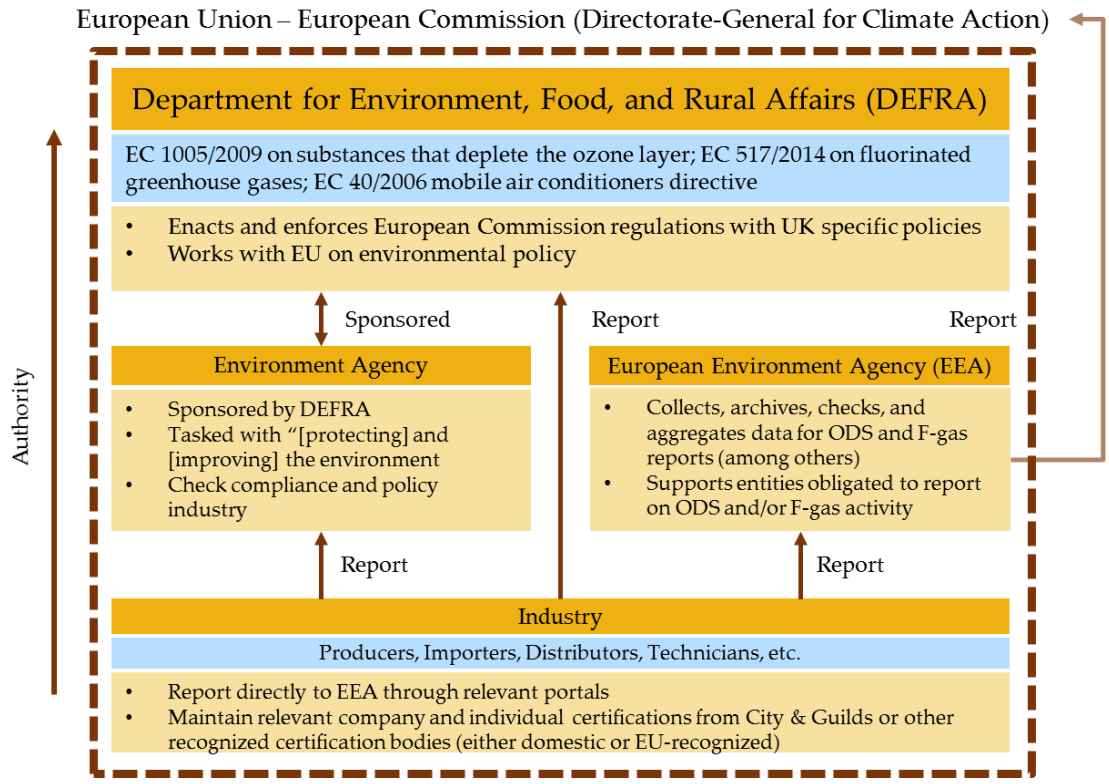



**Figure 2-22. United Kingdom's Regulatory and Enforcement Landscape**

### 2.6.3 Effectiveness Data

Estimates of refrigerant recovery in the U.K. vary widely. In 2011, the Department of Energy and Climate Change (DECC) hired ICF International to update the existing national refrigerant inventory model. ICF International collected and aggregated recovery rates from a number of primary and secondary sources. See Table 2-17 for a summary of these data.

Assuming these estimates are accurate, the U.K. likely leads refrigerant recovery worldwide. Anecdotal evidence and other industry experts suggest that these values are overestimated.

**Table 2-17. ICF International Estimated Recovery Rate by End-Use for the U.K.[79]**

| End-Use | Recovery Rate |
|---|---|
| Domestic Refrigeration | 65% |
| Small Hermetic Stand-Alone Refrigeration Units | 60% |
| Condensing Units | 85% |

[79] ICF International, "Development of the GHG Refrigeration and Air Conditioning Model." December 2011. Accessed August 2015. Adapted to report recovery rate instead of disposal loss rate.

| End-Use | Recovery Rate |
|---|---|
| Centralized Supermarket Refrigeration Systems | 92% |
| Industrial Systems | 85% |
| Small Stationary Air Conditioning | 70% |
| Medium Stationary Air Conditioning | 70% |
| Large Stationary Air Conditioning (Chillers) | 80% |
| Heat Pumps | 65% |
| Light Duty Mobile Air Conditioning | 70% |
| Other Mobile Air Conditioning | 70% |

### 2.6.4 Key Findings

Table 2-18 summarizes the successes and challenges of the U.K.'s refrigerant management program.

**Table 2-18: Successes and Challenges of U.K. Refrigerant Management Programs**

| Key Successes | Key Challenges |
|---|---|
| No direct cost to consumer for appliance disposal | Unregulated export of refrigerators and freezers, which may not be disposed of as responsibly as domestic destruction (not believed to be significant) |
| Collaborative teaching approach: REAL Skills, REAL Zero, REAL Alternatives | Appliance recycling infrastructure was not ready for foam regulations; hurt appliance recycling market |
| Robust recordkeeping requirements | No national programs for motor vehicle recycling |
| Strict supply-side controls drives technology adoption, market behavior | No industry-run bulk collection, reclamation, destruction service |
| Multiple product stewardship schemes promote competition | |

## *2.7 United States*

### 2.7.1 Summary

Refrigerant management in the U.S. is highly application specific. While venting of refrigerants from motor vehicles, domestic appliances, and commercial equipment is illegal, the refrigerant management approach for each sector is unique. Further complicating refrigerant management, the U.S. has developed and implemented a large regulatory framework for ODS but few regulations for the recovery and management of alternative refrigerants. The U.S. EPA does review and approve alternative

refrigerants through the Significant New Alternatives Policy (SNAP) based on "a comparative risk framework."[80] See Appendix J for more information about the SNAP program.

Figure 2-23 outlines the flow of refrigerant through the U.S.'s refrigerant management programs from refrigerant manufacturing or import to destruction.

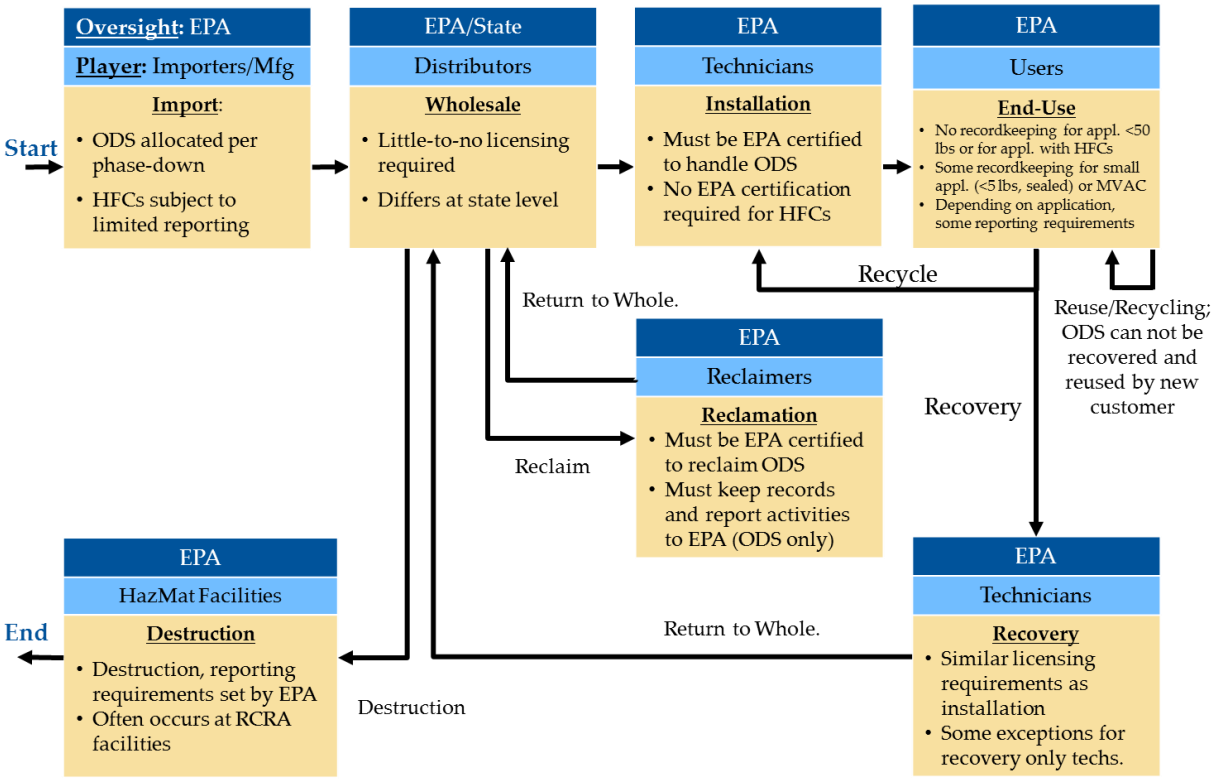



**Figure 2-23. U.S. Refrigerant Management Process**

Figure 2-23 encompasses bulk refrigerant flow in the U.S. Typical sources are stationary HVAC/R equipment (residential, commercial, and industrial). Motor vehicle refrigerant and domestic appliance refrigerant are typically captured after end user has disposed of a product.

Table 2-19 summarizes the key characteristics of the U.S.'s programs.

[80] EPA. "Overview of SNAP." Updated September 30, 2015. Accessed October 2015. Link

**Table 2-19: Summary of U.S. Programs[81]**

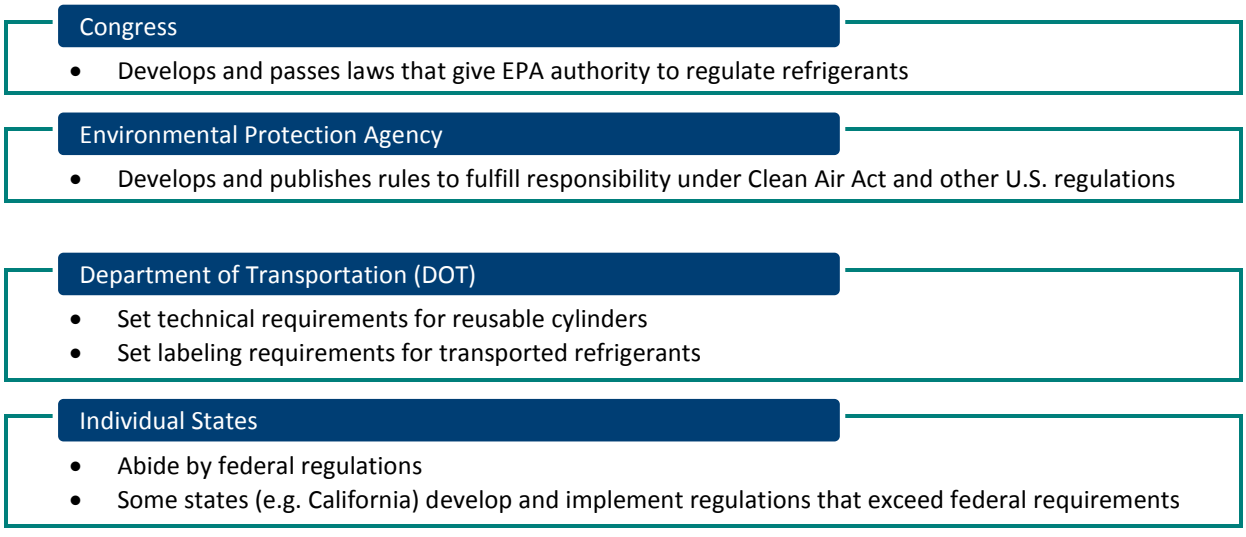
| **Summary Description** |
|---|
| The U.S. relies on market compliance of a large and complex regulatory framework to manage refrigerants. Framework covers: Phasedown of ODS, venting, certification of technicians, certification of recovery equipment, repair of leaking systems, disposal requirements, and recordkeeping. Additionally, two voluntary partnerships exist for refrigerant management:<br>– GreenChill:[82] Reporting, benchmarking, recognition, and technology program for supermarkets with large refrigeration equipment<br>– Responsible Appliance Disposal (RAD):[83] Reporting, marketing program for utility, manufacturer, retail, and state partners that take back used appliances |
| **Program Type/Characterization** |
| Regulatory framework focused on ODS with phasedown, venting prohibitions, and technician certification requirements. No national collection, destruction services. Some voluntary programs exist. |
| **Funding Source** |
| No funding source. Market bears the cost of refrigerant management. |
| **Incentives & Enforcement Mechanisms** |
| – No explicit incentives. Phasedown of ODS creates natural market incentive mechanism for more responsible recovery, reclamation, and reuse of ODS.<br>– Intentional venting is illegal and carries strict fines (currently $37,500 per incident)[84]<br>– Enforcement of some requirements (i.e. venting prohibition) is very difficult, as burden of proof is high and violations can be easily concealed<br>– See Section 2.7.3 for details on recent enforcement actions |
| **Program Performance[85]** |
| – Lack of ubiquitous reporting requirements prevents tracking of program performance<br>– GreenChill partnership represents 30% of supermarkets nationally<br>– RAD provides marketing benefits and is popular with partners |
| **Recovery** |
| Not tracked. EPA does require reclaimers of ODS refrigerants to report activities annually. See Figure 2-26 for a summary of 2013 refrigerant reclamation. |
| **Outreach/Involvement** |

[81] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015 and Interview with Luke Hall-Jordan.
[82] EPA. "GreenChill Partnerships." Accessed August 2015. Link
[83] EPA. "RAD Partners and Affiliates." Accessed August 2015. Link
[84] Interview with Luke Hall-Jordan.
[85] Ibid.

| |
|---|
| – Robust FAQ, summary documentation, and factsheets on EPA's website<br>– EPA-sponsored partnerships with industry (GreenChill, RAD) both provide a forum for best practices and recognition of high performing partners |
| **Tracking/Reporting Mechanisms** |
| – EPA requires annual reporting, clear labeling and recordkeeping by technicians, equipment owners, and destruction facilities (specifically for ODS)<br>– Exemptions exist for low charge |
| **Training** |
| – EPA does not mandate training, instead, requires technicians to pass a test that covers:<br>o Basics of recovery<br>o Environmental ramifications of leakage<br>o Legal requirements<br>– Technician certification required for ODS refrigerants<br>o Three categories of certification<br>– Technician certification not required for SGG refrigerants[86] |
| **Reusable Canisters** |
| Not required. Canisters are subject to DOT regulations |

See Appendix A for details on relevant regulations.

Figure 2-24 summarizes the roles and responsibilities of relevant U.S. organizations.




[86] EPA. "Homeowners FAQ." Accessed August 2015. Link

**Equipment Manufacturers, Importers, and Exporters**

- Receive ODS allocation
- Cannot manufacture equipment with R-22 or R-142b after January 1, 2010
- Cannot import equipment containing R-22, R-142b
- Can sell domestically or export uncharged appliances designed for HCFCS without refrigerant to Article 5 countries
- Label equipment that contains or is manufactured with ODS with warning[87]

**Technicians**

- Cannot knowingly vent or otherwise release refrigerant into the environment during maintenance, servicing, repair or disposal of an appliance (applies to ODS and substitutes)
- Maintain EPA certification to buy ODS or service ODS-containing equipment
- No EPA certification to buy or service HFC-containing equipment
- If involved in disposal, must follow EPA's Safe Disposal Requirements[88]
- Can recycle ODS refrigerants (remove from system, clean (minimally), and replace in same system or other systems owned by the same person/company)
- Can send ODS to reclaimers for thorough cleaning and resale[89]

**Figure 2-24: U.S. Roles and Responsibilities**

### 2.7.2 Program Structure

As a signatory of the Montreal Protocol, the U.S. is obligated to implement regulations to protect the stratospheric ozone layer. The U.S. addresses this obligation by prohibiting the emissions of ODS and prescribing reporting, recordkeeping, and certification requirements. Unlike Japan, or the UK; however, the U.S. does not mandate a product stewardship scheme, extended producer responsibility program, or an industry-sponsored management program. Instead, the U.S. places the burden of responsibility on all industry participants to comply with the regulations in whatever manner they choose.

For domestic appliances and mobile air conditioning systems (i.e. motor vehicles), the regulations stipulate that the final handler of the appliance (e.g. scrap yard, recycling facility) must retain records that all refrigerants were removed legally. For large commercial equipment (>50 lbs. of charge), both the equipment owner and the technician who services or decommissions the system must retain records.

Additionally, while the regulations prevent intentional venting of ODS and alternative SGGs such as HFCs, Section 608 of the Clean Air Act focuses heavily on ODS requirements. For example, the sale of ODS is restricted to licensed technicians, while the sale of HFCs is open to the public.

The U.S. maintains less rigorous recordkeeping and reporting requirements than other surveyed jurisdictions. All parties involved in ODS transactions are obligated to keep records at sale; however, there are exemptions for charges under 50 lbs. Additionally, reporting is limited to reclamation facilities.

[87] EPA. "Equipment Manufacturers, Importers, and Exporters FAQ." Accessed August 2015. Link
[88] EPA. "Complying With The Section 608 Refrigerant Recycling Rule." Accessed August 2015. Link
[89] EPA. "Technicians and Contractors FAQ." Accessed August 2015. Link

Well-received voluntary refrigerant management partnerships exist: notably EPA's GreenChill and Responsible Appliance Disposal (RAD). GreenChill works with food retailers (e.g. supermarkets) to promote servicing and maintenance best practices and higher performing technologies (e.g. lower leak rates). Additionally, the GreenChill program recognizes partners who set and achieve aggressive leak reduction targets.

Figure 2-25 summarizes the relationships between parties responsible for refrigerant management.

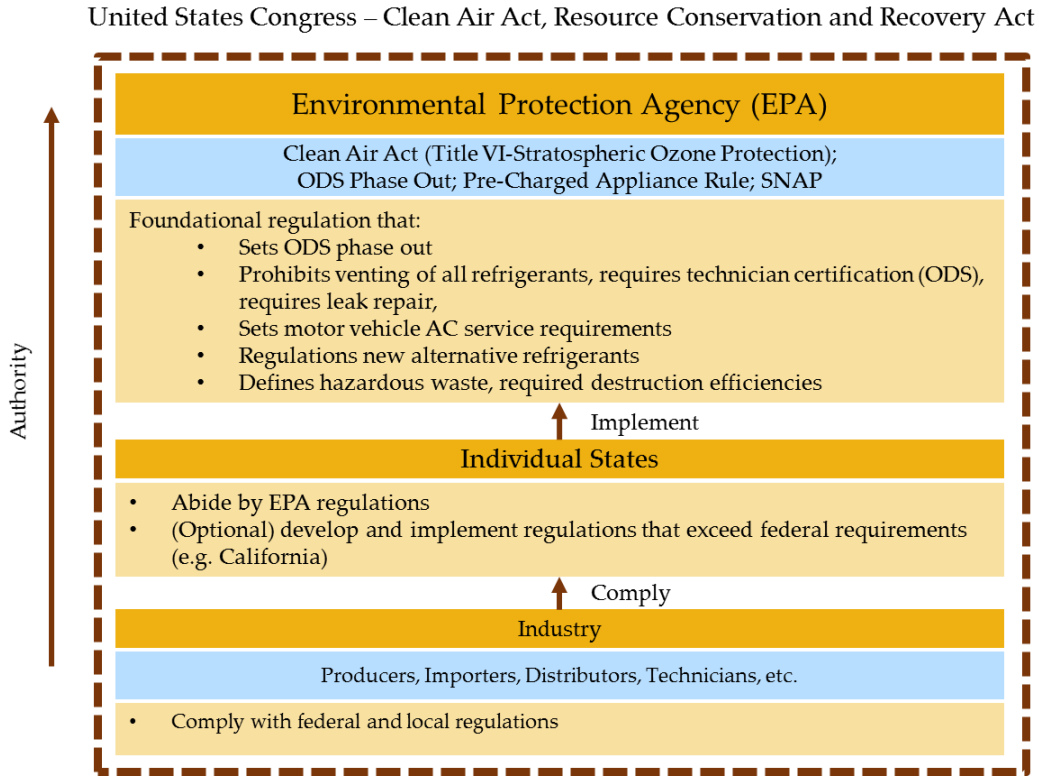
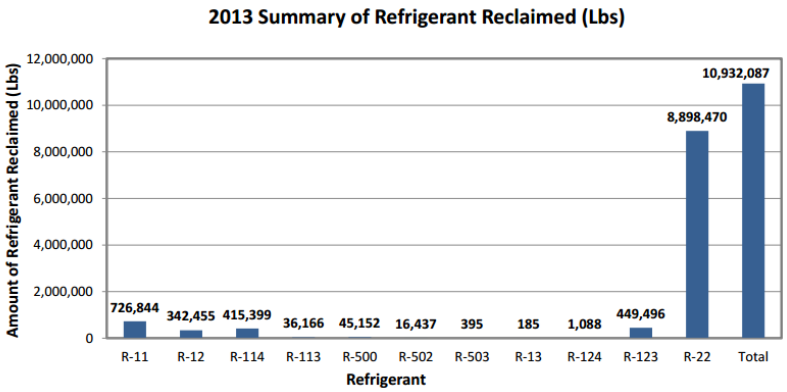



**Figure 2-25. U.S. Regulatory and Enforcement Landscape**

### 2.7.3 Effectiveness Data

EPA's current regulatory framework prevents EPA from collecting detailed and accurate data on the effectiveness of mandatory refrigerant management. However, the EPA does collect data on ODS refrigerant reclamation, which is found in Figure 2-26 (excludes HFC reclamation due to EPA's reporting requirements).




| 2013 Reclamation Totals (Lbs) | |
|---|---|
| R-11 | 726,844 |
| R-12 | 342,455 |
| R-114 | 415,399 |
| R-113 | 36,166 |
| R-500 | 45,152 |
| R-502 | 16,437 |
| R-503 | 395 |
| R-124 | 1,088 |
| R-123 | 449,496 |
| R-13 | 185 |
| R-22 | 8,898,470 |
| Total | 10,932,087 |

**Figure 2-26. EPA Summary of Refrigerant Reclaimed in 2013[90]**

EPA's GreenChill and RAD partnerships include voluntary reporting from members. Table 2-20 presents EPA's estimates of avoided emissions from the GreenChill partnership. Figure 2-27 shows self-reported data from GreenChill and Figure 2-28 shows self-reported data from RAD. These data show the value in developing a program with well understood economic and marketing implications and the resulting improvements in refrigerant management.

**Table 2-20: EPA GreenChill Partnerships Annual Emissions Avoided[91]**

| Units | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| ODP Metric Tons | 45 | 45 | 49 | 49 | 64 |
| MMTCO$_2$e (ODS & HFCs) | 2.99 | 3.32 | 3.76 | 4.00 | 6.21 |
| MMTCO$_2$e (HFCs only) | 1.53 | 1.85 | 2.15 | 2.38 | 4.12 |

[90] EPA. "Summary of Refrigerant Reclaimed for 2013 (lbs.)." Accessed August 2015.
[91] EPA. "GreenChill Progress Report 2011." Accessed August 2015.

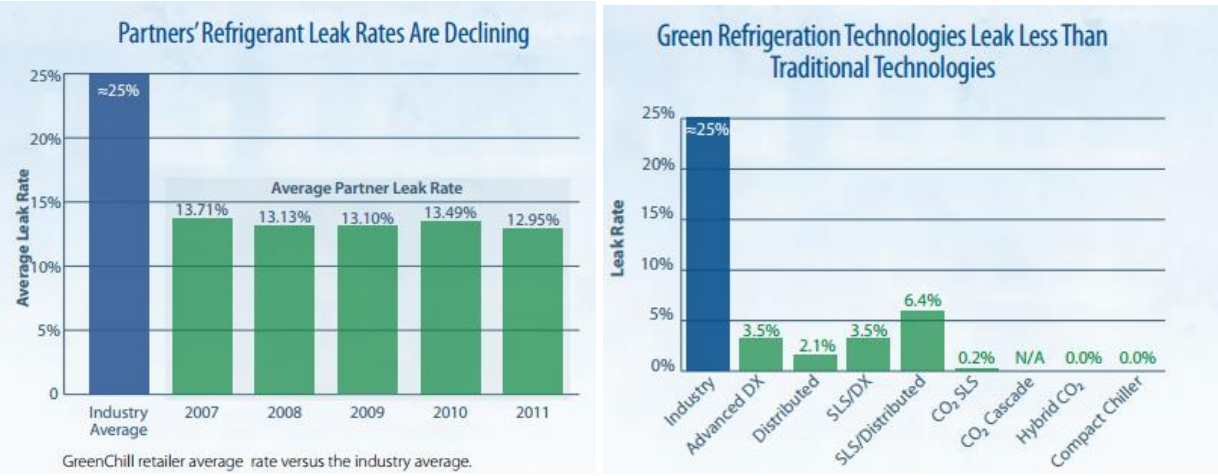



**Figure 2-27. GreenChill Partners' Refrigerant Leak Rate[92] and Promoted Technology Leak Rates[93]**

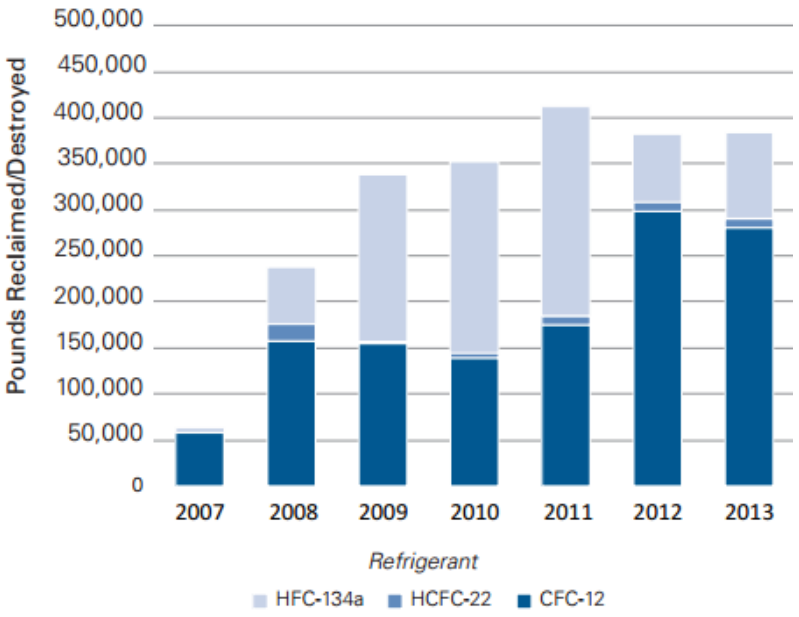



**Figure 2-28. Refrigerants Recovered by EPA RAD Partners, 2007-2013[94]**

According to ICF, very limited data exists on the sale and use of "small can" refrigerant cylinders; however, ICF estimates that approximately 6 million "small can" cylinders are sold in the U.S. annually.[95] ICF estimates that more than 90% of these cylinders are disposable. Low recycling rates of

[92] Ibid.
[93] Ibid. Leak rates reported are for stores that have been operational for at least one year. SLS = secondary lop system; DX = Direct expansion.
[94] EPA RAD. "2013 Annual Report." 2013. Accessed September 2015.
[95] Anecdotally, EPA thinks that this is an exceedingly low estimate. Additional data is unavailable

disposable cylinders suggest that while illegal, most residual refrigerant in disposable cylinders is vented prior to raw material recycling.[96]

Because refrigerant management in the U.S. is driven by regulation, enforcement actions may serve as a proxy for effectiveness. Some recent and notable EPA enforcement actions include a $531,000 fine for DuPont (1/8/15) for the improper maintenance and repair of two large refrigeration units; a $110,000 penalty for Metal Dynamics (10/16/14) for allegedly releasing ODS into the environment; and a $335,000 fine for Costco (9/3/14) for failing "to promptly repair refrigeration equipment leaks… [and] to keep adequate records of servicing."[97]

### 2.7.4 Key Findings

While limited data exist on the entire U.S. refrigerant management market, Table 2-21 shows a number of key successes and challenges Navigant identified based on conversations with interviewees and GreenChill and RAD literature.

**Table 2-21. Successes and Challenges of U.S. Refrigerant Management Programs**

| Key Successes | Key Challenges |
|---|---|
| Voluntary partnership programs see substantially improved performance over industry average | Inconsistent framework (ODS vs. HFCs) creates confusion, non-compliance in marketplace |
| GreenChill represents 30% of supermarkets | Difficult to convince "small players" to comply |
| Voluntary program partners enjoy marketing and economic benefits to participation | Limited attention on technician competency |
| ODS phase out has resulted in more responsible use of ODS | Limited resources constrain EPA from pursuing enforcement |
| Utility programs focused on appliance efficiency also a vector for responsible refrigerant recovery | |

## *2.8 California*

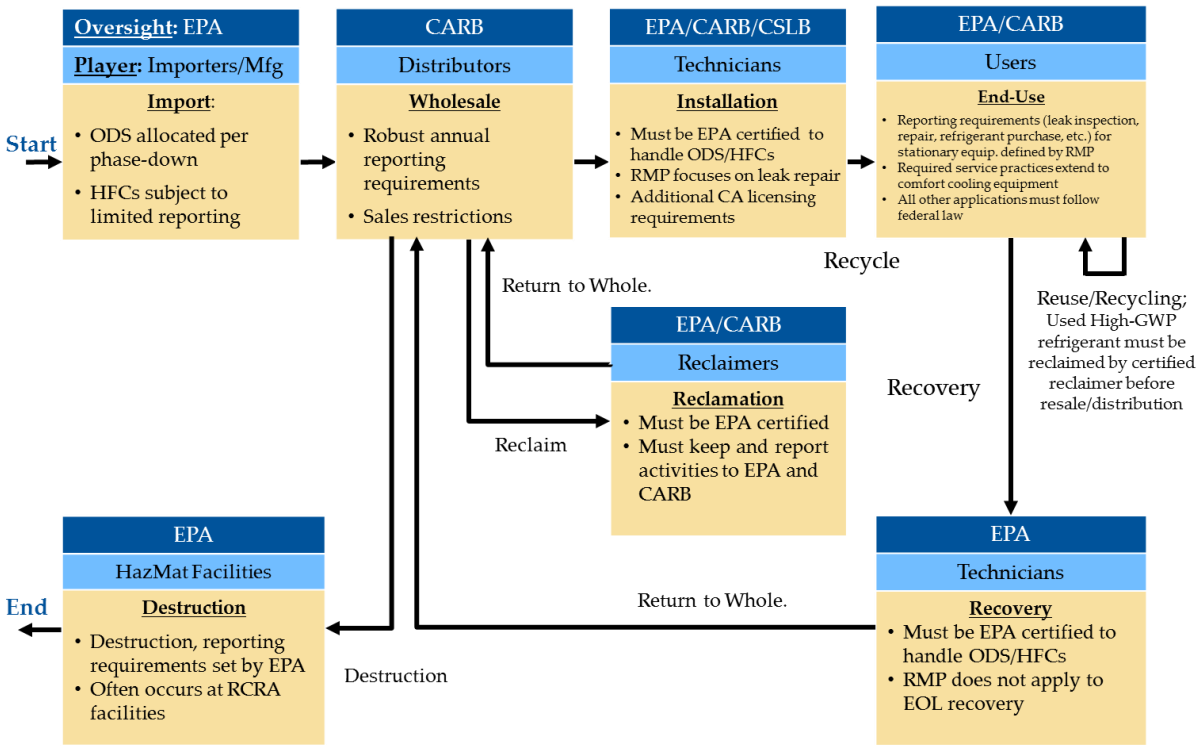
### 2.8.1 Summary

Refrigerant flow in California does not differ materially from the rest of the U.S. Instead, California manages refrigerant by mandating more robust inspection, maintenance, and recordkeeping requirements for stationary refrigeration systems. Notably, these requirements do not extend to domestic appliances or motor vehicles. These sectors must comply with national non-venting

[96] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.
[97] EPA. "Enforcement Actions under Title VI of the Clean Air Act." Accessed August 2015. Link

regulations. Lastly, unlike federal requirements, California regulations apply to both ODS and HFC refrigerants.

Figure 2-29 outlines the flow of refrigerant through California's refrigerant management programs from refrigerant manufacturing or import to destruction.




Note: Encompasses bulk refrigerant flow in California regulated by Refrigerant Management Program (RMP). Motor vehicle refrigerant and domestic appliance refrigerant are typically captured after end user has disposed of a product. Once captured, refrigerant follows same flow noted above.

**Figure 2-29. California's Refrigerant Management Process**

Table 2-22 summarizes the key characteristics of California's programs.

**Table 2-22. Summary of California Programs[98]**

| **Summary Description** |
|---|
| Robust regulatory framework that enforces high-GWP (>150 GWP) refrigerant management best practices at large stationary refrigeration sites by:<br>– Mandating annual reporting, on-site recordkeeping, continuous monitoring and inspection, and rapid leak repair for business with large refrigerant charges<br>– Mandating annual reporting and detailed recordkeeping for wholesalers and distributors<br>– Prescribing federal and state licensing for HVAC/R technicians<br>– Penalizing noncompliance with harsh financial penalties |
| **Program Type/Characterization** |
| Strict regulatory framework with ratcheting implementation of registration and reporting requirements (2011-2016) that requires robust record keeping, maintenance best practices, technician licensing, and compliance with both state and federal regulation |
| **Funding Source** |
| – Annual operating fees for users of large commercial and industrial refrigeration (not comfort cooling) equipment<br>– Fee depends on amount of charged refrigerant ($170 to $370; see Table 2-23)<br>– Fees are deposited into the California Air Pollution Control Fund, with the goal of funding implementation, enforcement, and reporting activities[99] |
| **Incentives & Enforcement Mechanisms[100]** |
| – Enforcement is the primary incentive mechanism<br>– Operational savings for large commercial and industrial systems drives leak prevention<br>– Phase down of ODS creates scarcity, which incentivizes responsible refrigerant management<br>– CARB AB 32 Cap-and-Trade program credits ODS destruction as sellable credits on the offset market. This encourages system owners to undertake proper refrigerant recovery at the equipment EOL and producers to destroy unwanted refrigerant to achieve offset credits<br>– Utility energy efficiency programs for domestic appliances offer rebates and free pickup, which is a key driver of responsible refrigerant management in residential equipment.<br>– Regulations enforced with site visits, inspections, recordkeeping requirements and varying fines and potential for imprisonment.[101] |

[98] Interview with Pamela Gupta and comments from CARB.
[99] CARB. "Refrigerant Management Program Question and Answer Guidance Document." November 2013. Accessed August 2015. and Interview Notes
[100] Interview Notes
[101] Sections 42400 through 52405 of the California Health and Safety Code. Accessed August 2015. Link

**Program Performance**

- CARB feels that RMP is generally well received, with high levels of compliance for larger facilities covered by RMP
- Domestic appliances and residential HVAC compliance is not tracked, and thus much harder to gauge.
- The "Small Can" regulations focused on do-it-yourself motor vehicle refrigerant service has resulted in a 70-80% return rate for small cans. While the original goal of 90% was not met, we assume performance is much better than the rest of the U.S.
- See Section 2.8.3 for details on effectiveness data.

**Recovery**[102]

- Strong regulations and robust infrastructure make appliance recycling common in California. Approximately 85% of appliances are handled by Certified Appliance Recyclers, while 15% are handled through utility programs by dedicated appliance recyclers. It is hard to quantify the small number of appliances that are disposed of illegally.
- Nationally, disposable cylinder metal recycling is estimated between 15% and 100%, suggesting that refrigerant recovery from disposable cylinders is low.
- Recovery of refrigerant from small cans is low because of the small amount of refrigerant remaining in the average recycled can (less than 2% of original charge).
- For large-equipment (containing 200+ lbs.), CARB estimates a refrigerant recovery rate of 80%
- Estimates range by end-use (85% for smaller refrigeration units and 92% for larger centralized supermarket systems). See Table 2-25 for detailed recovery rate estimates.

**Tracking/Reporting Mechanisms**

- Robust tracking and reporting requirements. See Table 2-23 and Table 2-24 for tracking requirements for businesses, wholesalers, distributors, and reclaimers.
- No reporting requirements for domestic appliances or mobile ACs other than EPA end-of-life requirements

**Outreach/Involvement**

The California ARB provides robust and easy-to-read documentation online, including pamphlets (Refrigerant Best Management Practices), FAQs targeted at affected stakeholders (businesses with refrigeration systems, service technicians and contractors, refrigerant distributors and wholesalers, and refrigerant reclaimers), summaries of legislation, required reporting and service practices, and links to other relevant agencies.

**Training**

HVAC and refrigeration contractors are required to complete and renew relevant licensing, including U.S. EPA certification. Training is responsibility of contractor. Apprenticeship requirements vary by industry.

[102] Interview; ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.

**Reusable Canisters**

- See Section 2.7 for details on U.S. requirements. Refrigerant service typically occurs with non-reusable canisters.
- Mobile Vehicle AC regulation requires 'do-it-yourselfers' to use small cans (2 ounces to 2 lbs.), which must be returned in 90 days for recycling

See Appendix A for details on relevant regulations.

Figure 2-30 summarizes the roles and responsibilities of relevant Californian organizations.

**CA Environmental Protection Agency**

- Reports to Governor; has responsibility "to restore, protect, and enhance the environment, to ensure public health, environmental quality and economic vitality;"[103] supports policy development[104]

**California Air Resources Board (ARB)**

- Part of the California Environmental Protection Agency; approved RMP regulation
- Enforces RMP in conjunction with Air Pollution Districts[105]

**Air Pollution Control Districts (APCD)**

- "Establishes and enforces air pollution regulation … to attain and maintain all state and federal ambient air quality standards"[106]
- Provides permits for stationary sources of pollution
- Implements transportation control measures
- Regulated pollution sources vary by district. See Rule 1415 in Section 4.2A.7 above.

**California State Licensing Board (CSLB)**

- Responsible for licensing and regulating state's construction industry
- Licensing covers Warm-Air Heating, Ventilation and Air-Conditioning Contractor (C-20) and Refrigeration Contractors (C-38)[107]

[103] Ibid.
[104] California EPA. "About Us." Accessed August 2015. Link
[105] California EPA ARB. "Organization of the California Air Resources Board." July 2015. Accessed August 2015. Link
[106] Ibid.
[107] Department of Consumer Affairs Contractors State License Board (Link) and CARB "Refrigerant Management Program (RMP) Technicians and Contractors." Accessed August 2015. Link

**California Department of Toxic Substances Control**

- Assembly Bill 227 (2004)
- "Established a certification program for individuals and business that process major appliances for scrap"[108]
- If unit has not been evacuated and is ready to be scraped, only a Certified Appliance Recycler (CAR) may remove refrigerants

**CA Utilities**

- Per direction of California Public Utilities Commission, California utilities offer residential customers incentives (free pickup, financial incentive) to recycle working refrigerators.[109]
- Contract with recyclers to dismantle refrigerator and recover refrigerants before destruction.

**Figure 2-30: California's Roles and Responsibilities**

### 2.8.2 Program Structure

California's regulatory and enforcement landscape builds upon U.S. federal regulations. The California ARB, a unit of the Environmental Protection Agency, approves and enforces statewide refrigerant regulation. Concurrently, 35 air pollution districts work with the Air Resource Board to design, implement, and enforce both statewide and district-specific regulation. Lastly, California's State Licensing Board ensures that contractors are properly licensed and qualified to perform HVAC/R work.

California's RMP is intended to "reduce leaks from large commercial and industrial refrigeration systems."[110] This is accomplished through a number of system inspecting, leak monitoring, leak repair, recordkeeping requirements, and annual reporting requirements. See Table 2-23 and Table 2-24 for details of RMP requirements.

RMP covers all facilities with refrigeration systems containing more than 50 pounds of high-GWP refrigerant but excludes systems used exclusively for comfort cooling. Note that dual-use systems (used for both refrigeration and comfort cooling) are included in the RMP requirements. RMP considers all ozone-depleting substances, regardless of GWP, and all refrigerants with a 100-year GWP 150+ as a high-GWP refrigerant.[111]

Figure 2-31 summarizes the relationships between parties responsible for refrigerant management in California.

[108] ICF International. "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.
[109] Southern California Edison (SCE) (Link) and Pacific Gas and Electric Company (PG&E) (Link) Refrigerator Recycling Programs. Accessed August 2015.
[110] CARB. "Refrigerant Management Program Question and Answer Guidance Document." November 2013. Accessed August 2015.
[111] CARB comments. Note that CARB uses GWP values defined by IPCC Fourth Assessment Report values.

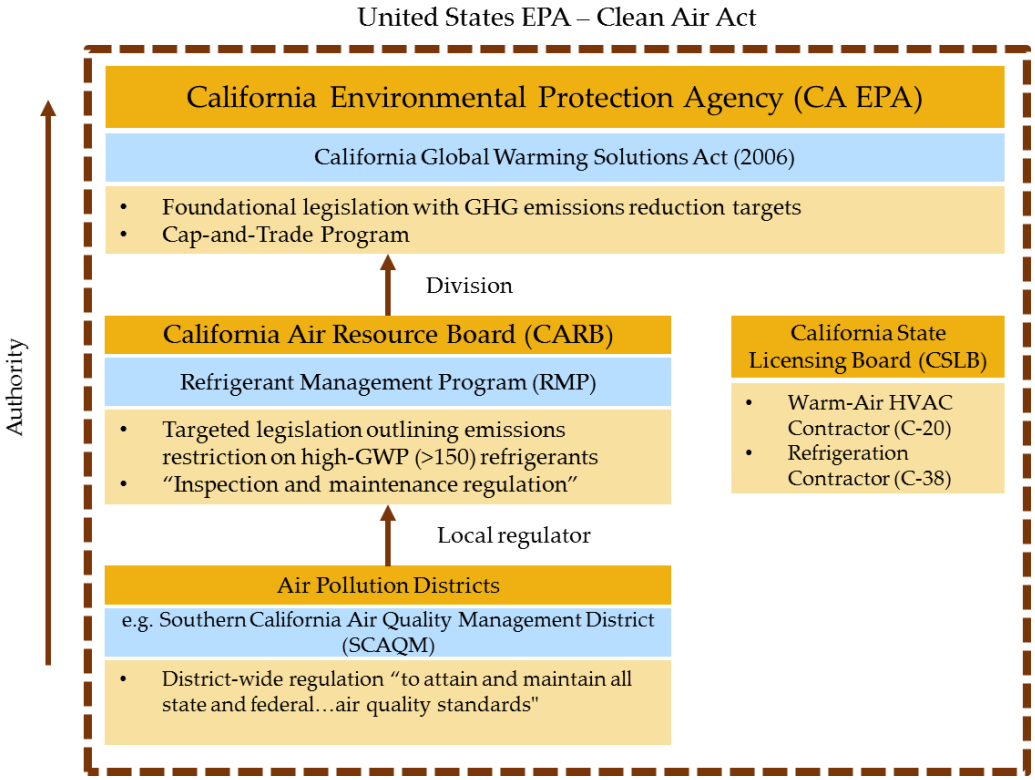



**Figure 2-31. California's Regulatory and Enforcement Landscape**

**Table 2-23. Summary of RMP Requirements for Businesses with High-GWP Refrigerants[112]**

| Requirements | Large Facilities (2,000+ lbs.) | Medium Facilities (200 – 2,000 lbs.) | Small Facilities (50 – 200 lbs.) |
|---|---|---|---|
| **Inspection Schedule** | - Every three months for non-enclosed systems or seasonally operated systems<br>- None for systems with automatic leak detection | - Every 3 months<br>- None for systems with automatic leak detection | Annual |
| **Monitoring** | Automatic leak detection system required by January 2012 for all fully enclosed components. | None | None |
| **Leak Repair** | Fix all leaks within 14 days of detection<br>EPA-certified technicians only | | |

[112] Adapted from CARB "Refrigerant Management Program Rules for Businesses with Refrigeration Systems." March 2011. Accessed August 2015. Link

| Requirements | Large Facilities (2,000+ lbs.) | Medium Facilities (200 – 2,000 lbs.) | Small Facilities (50 – 200 lbs.) |
|---|---|---|---|
| **Recordkeeping** | Keep all service records on site for at least 5 years for each refrigeration unit, including those concerning:<br>- Leak inspections and leak repairs<br>- Installation, calibration, and annual audits of leak detection systems<br>- Refrigerant purchases<br>- Refrigerant additions to the system<br>- Shipment of refrigerants for reclamation or destruction<br>- Calculations, data and assumptions used to determine the refrigerant capacity<br>- Retrofit or retirement plans | | |
| **Registration** | March 1, 2012 | March 1, 2014 | March 1, 2016 |
| **Annual Reporting** | Annual Reporting (March 1) | Annual Reporting (March 1) | None |
| **Fees** | $370 | $170 | n/a |

**Table 2-24. Summary of RMP Requirements for Wholesalers, Distributors, and Reclaimers[113]**

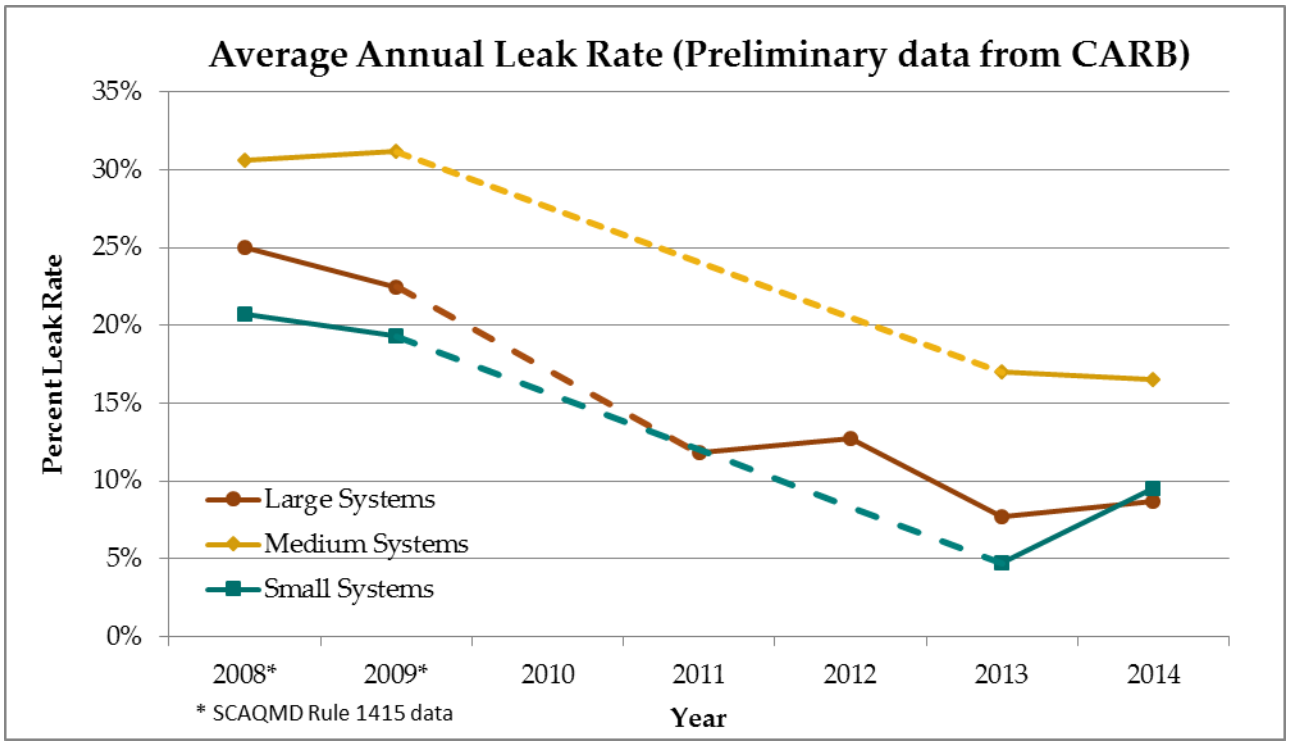
| Requirements | Wholesalers and Distributors | Reclaimers |
|---|---|---|
| **Recordkeeping** | - Retain on site for at least 5 years all invoices of refrigerant received or distributed | |
| **Recordkeeping** | - Invoices must include purchaser's name and contact information, sales date and the types and quantities of all high-GWP refrigerants purchased, sold, or transferred.<br>- Records of refrigerant sales or transfers to a company that services refrigeration systems must include documentation showing that the company currently employs at least one U.S. EPA-certified technician. | - Invoices must include purchaser's name, sale's date and the type and quantity of refrigerant.<br>- Records must be made available to the Executive Officer upon request. |

[113] Adapted from CARB "Refrigerant Management Program (RMP) Refrigerant Wholesalers and Distributors," Link and "Refrigerant Management Program (RMP) Refrigerant Reclaimers," Accessed August 2015. Link

| Requirements | Wholesalers and Distributors | Reclaimers |
|---|---|---|
| **Annual Reporting** | - Report prior year's refrigerant purchases, sales, and shipments to reclaimers by March 1<br>- Cover all CA facilities that bought or received refrigerant from wholesaler or distributor<br>- Includes total weight of each type of refrigerant purchased, received, sold or transferred in the previous year, including transactions for eventual resale or delivery and shipments to certified reclaimers | - Report previous year's sales or transfers by March 1<br>- Cover all CA facilities that delivered refrigerant to the reclaimer<br>- Include total weight of each type of refrigerant that was:<br>o Reclaimed/destroyed in CA<br>o Shipped out of state |

### 2.8.3 Effectiveness Data

RMP's robust reporting requirements enables CARB to estimate the annual leak rates of facilities covered by RMP. By pairing SCAQMD Rule 1415 leak data with recent RMP leak data, CARB developed the following historical leak rate plot (Figure 2-32), which shows a significant decrease in leak rate after the implementation of the RMP.




Note that dashed lines indicate estimated data.

**Figure 2-32. Preliminary California Average Annual Leak Rate by System Type, 2008-2014[114]**

[114] Aggregated RMP data provided by CARB.

ICF International estimates that California retires approximately one million domestic refrigerators and freezers annually. ICF estimated that in 2011 85% of these units were transported to Certified Appliance Recyclers (CAR), while 15% of these units were processed by dedicated appliance recyclers through utility programs.[115] While U.S. and California law prohibit refrigerant venting from all sources, the time, effort, and costs of domestic appliance refrigerant recovery may disincentivize compliance for domestic refrigerant recovery. Thus, the above estimates do not account for the small number of units that are abandoned or landfilled without proper handling.

ICF International estimated that more than one million pieces of commercial equipment reached end-of-life in 2010. If all these units contained full charges at end-of-life, this would amount to 10.8 million pounds of refrigerant.[116] Based on the more rigorous maintenance and training requirements for large commercial equipment, RMPs estimate that 70%-80% is recovered from large equipment, while less than 2% of refrigerant is recovered from small equipment (e.g. appliances).[117]

ICF International estimates that 732,350 disposable refrigerant cylinders are used for MVAC and stationary refrigeration/AC service and repair in CA annually. While venting is illegal and the "Small Cans" regulations have increased the technical requirements of and incentives for properly handling small disposable cylinders, anecdotal information suggests that compliance is still low. Assuming an average "heel" of 1.85%, emissions from disposable small cans is estimated as 0.25-0.31 Million Metric Tons of $CO_2$ equivalent (MMT $CO_2e$).[118] Table 2-25 summarizes CARB estimated recovery rates.

**Table 2-25. CARB Estimates of EOL Loss and Recovery Rates by Equipment Type[119]**

| Equipment Type or Emissions sub-sector | Avg. EOL Loss Rate | EOL Recovery Rate |
|---|---|---|
| Refrigeration Large Centralized System ≥ 907.2 kg (2,000 lbs.) | 20% | 80% |
| Refrigeration Med. Centralized System 90.7-< 907.2 kg (200-< 2,000 lbs.) | 20% | 80% |
| AC Large Centrifugal Chiller ≥ 907.2 kg (2,000 lbs.) | 20% | 80% |
| AC Medium Centrifugal Chiller 90.7-< 907.2 kg (200-< 2,000 lbs.) | 20% | 80% |
| AC Chiller - Packaged 90.7-< 907.2 kg (200-< 2,000 lbs.) | 20% | 80% |

[115] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015 and CARB September 2015 communication with CARs.
[116] Even with best practices, most large commercial equipment experiences some leakage over the course of its life. Thus, assuming full refrigerant charge at the time of disposal likely overstates refrigerant stock. See Section 2.4.3 for estimated refrigerant recovery potential.
[117] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.
[118] Ibid.
[119] CARB estimates based on ICF International, "Development of the GHG Refrigeration and Air Conditioning Model." December 2011. Because collecting data on emissions (inadvertent or intentional) is so difficult, these values should be considered as anecdotal.

| Equipment Type or Emissions sub-sector | Avg. EOL Loss Rate | EOL Recovery Rate |
|---|---|---|
| Refrigeration Large Cold Storage ≥ 907.2 kg (2,000 lbs.) | 16% | 84% |
| Refrigeration Medium Cold Storage 90.7-< 907.2 kg (200-< 2,000 lbs.) | 16% | 84% |
| Refrigeration Process Cooling ≥ 907.2 kg (2,000 lbs.) | 20% | 80% |
| Refrigerated Condensing units 22.7-≤ 90.7 kg (50-≤ 200 lbs.) | 20% | 80% |
| Unitary AC 22.7-≤ 90.7 kg (50-≤ 200 lbs.) | 20% | 80% |
| Refrigerated Condensing Units ≤ 22.7 kg (50-lbs. or less) | 34% | 66% |
| Refrigerated stand-alone display cases | 100% | 0% |
| Refrigerated vending machines | 100% | 0% |
| Unitary A/C ≤ 22.7 kg (50-lbs. or less) (central) | 56% | 44% |
| Unitary A/C ≤ 22.7 kg (50-lbs. or less) (window unit) | 100% | 0% |
| Residential Appliance (refrigerator-freezer) | 77% | 23% |
| Residential A/C (central) | 56% | 44% |
| Residential A/C (window unit) | 100% | 0% |
| Transport Refrigerated Units (TRUs) | 15% | 85% |
| Refrigerated Shipping Containers | 19% | 81% |

Recent enforcement actions reinforce California ARB's commitment to enforcing the RMP. In January 2015, CARB announced $160,000 fines to two different organizations for late submission of their mandatory 2012 annual reports.[120]

### 2.8.4 Key Findings

Table 2-18 summarizes the successes and challenges of California's refrigerant management program.

**Table 2-26. Successes & Challenges of California's Refrigerant Management Program**

| Key Successes | Key Challenges |
|---|---|
| CARB reporting mechanism has functioned as an education tool | Current programs target stationary refrigeration equipment only, excluding other major sources |
| Regulations create a level playing field amongst industry member | High volume (thousands) of covered facilities creates burden on CA ARB |

[120] CARB Press Release "Air Resources Board fines pair of food suppliers $160,000 for violating refrigerant management rule." January 2015. Accessed September 2015. Link

| Key Successes |
| --- |
| Reporting requirements & economics of ODS phase out make venting uncommon for large stationary equipment |
| Reporting requirements engage non-technical "higher ups"[121] |
| Domestic appliance refrigerants often handled by utilities through energy efficiency programs |

| Key Challenges |
| --- |
| Designs of covered refrigeration equipment are innately leaky—regulations do not address "chronic leakers" by mandating improved technology or system design |
| RMP "does not directly address emissions that may occur at equipment disposal or end-of-life"[122] |

[121] Interview Notes

[122] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.

# 3. Findings for Secondary Target Jurisdictions

Navigant conducted limited desk research on Brazil and China's refrigerant management programs. Sections 3.1 and 3.2 present the readily available information on the regulations, and relevant parties responsible for refrigerant management.

## *3.1 Brazil*

### 3.1.1 Summary

Table 3-1 summarizes the key characteristics of Brazil's programs.

**Table 3-1: Summary of Brazil Programs**

| |
|---|
| **Program Type/Characterization** |
| Federal regulations mandating recordkeeping, responsible refrigerant management for CFCs |
| **Funding Source** |
| United Nations Development Programme and Deustche GIZ GmbH funding Programa Brasileiro de Eliminação de HCFCs (PBH) to develop and train industry on best practices and phase out HCFC-22 |
| **Incentives & Enforcement Mechanisms** |
| No information at this time |
| **Outreach/Involvement** |
| No information at this time |
| **Tracking/Reporting Mechanisms** |
| September 14, 2000 Regulations mandate "substance usage reports" for companies that use, and handle CFCs |
| **Training** |
| Receita Federal and IBAMA technicians were trained to verify imported refrigerants and products containing refrigerants |
| **Reusable Canisters** |
| Required in some applications (CFC-11, CFC-12) |

### 3.1.2 Regulations & Programs

Refrigerant management in Brazil is driven by import controls (all refrigerants are imported) and focuses on ozone protection, including the following regulations:

**Resolution 267 (September 2000)**[123]

- Issued by Conselho Nacional do Meio Ambiente (CONAMA)
- Montreal Protocol Annex A & B substances phased out of many appliances by 2001
- Phased out CFC-12 imports by 2007
- Mandates adequate recovery, storage, incineration, or recycling of refrigerants
- Sets licensing requirements for destruction and recycling facilities
- Sets storage requirements, which include reusable canisters for CFC-11 and CFC-12
- Mandated that all companies that benefited from "Multilateral Fund for the Implementation of the Montreal Protocol" stop using CFCs as soon as they finish replacing refrigerants
- Requires companies that use CFCs to register with IBAMA
    - Excludes low volumes
    - Excludes companies that resell products that contain refrigerants (e.g. big box stores)
- Requires companies to provide IBAMA with substance usage reports
- Mandates that equipment owners with CFCs create plans to recover, recycle, or reclaim refrigerants

**Programa Brasileiro de Eliminação de HCFCs (PBH):**[124]

- Funded by United Nations Development Programme and Deustche GIZ GmbH
- Phase I (2013-2015):
    - Development and training on repair, maintenance, installation, and operation best practices
        - Includes:
            - Training technicians
            - Developing and publishing case studies on how to reduce leaks
            - Online database
    - Froze use of HCFC-22 in 2013, currently phasing down
    - Phase out of 16.6% of HCFC22 and HCFC-141b
- Phase II (2015-2020):
    - Phase out of 28.41% HCFC-22 and HCFC-141b in new equipment
- Phase III (2020-2030):
    - Phase out of 52.49% of HCFC22 and HCFC-141b until 2030 (97.5% in new equipment)
    - Phase out of 2.50% of HCFC22 until 2040 (100% in new equipment)

**Other Notable Facts**[125]

- **Resolution 340 (September 2003)**
    - Issued by CONAMA
    - Prohibits the use of disposable cylinders for CFCs
- **Resolution 207 (November 2008)**
    - Issued by IBAMA
    - Outlines import controls of Annex C Group 1 HCFCs and mixtures containing HCFCs
- Brazilian government is helping private sector draft standard and regulations to:
    - ARI 700-93: pertaining to the purity of the refrigerants
    - ARI 740-93: pertaining to the final disposal of CFC equipment
    - Also helping with HC and ammonia applications

[123] Conselho Nacional do Meio Ambiente (Brazil). "Resolution 267." September 2000. Accessed September 2015. Link
[124] Ministerio do Meio Ambiente (Brazil). "Brazilian HCFC Elimination Program." February 2012. Accessed September 2015. Link and Input from AHRI contacts.
[125] Input from AHRI PMS contacts.

Figure 3-1 summarizes the roles and responsibilities of relevant Brazilian organizations.

**Ministério do Meio Ambiente (MMA)**

- Brazilian Ministry for the Environment
- Governing body that drafts regulations and verifies compliance

**Conselho Nacional do Meio Ambiente (CONAMA)**

- Part of MMA
- Draft and issue regulations pertaining to refrigerant management

**Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA)**

- Part of MMA
- Responsible for compliance/verification
- Responsible to keep track and verify use of controlled refrigerants

**Comitê Interministerial para a Proteção da Camada de Ozônio (PROZON)**

- Committee created by MMA to enable dialogue about ozone protection with other ministries

**Organizações Estaduais e Municipais de Meio Ambiente (OEMA)**

- Several state and municipal agencies/organizations that aid IBAMA in keeping track of refrigerant use and verifying and enforcing regulations
- For example, OEMA compiles refrigerant usage data from their jurisdictions and send it to IBAMA for control at federal level
- Also aid IBAMA in providing training on these subjects

**Receita Federal**

- Brazilian equivalent of the IRS
- Responsible for all import taxation and recordkeeping at customs

**Private Industry Groups:**

- Associação Brasileira de Normas Técnicas (ABNT): Standards organizations
- Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento (ABRAVA): Industry group

**Figure 3-1: Brazil's Roles and Responsibilities**

## *3.2 China*

### 3.2.1 Summary

**Table 3-2: Summary of China's Programs[126]**

| |
|---|
| **Program Type/Characterization** |
| Federal regulations phasing down use of CFCs and banning CFC-containing products. Sector plan for HCFC phase-out, as outlined by Montreal Protocol. |
| **Funding Source** |
| Montreal Protocol Multilateral Fund and "self-raised funds by Chinese enterprises"[127] |
| **Incentives & Enforcement Mechanisms** |
| Different mechanisms based on refrigerant type (CFC vs HCFC)<br>– CFC: Mandatory reporting on manufacturing, sales, recovery, import and export of CFCs from industry<br>– HCFC: Production control of HCFC, consumption quotas for enterprises that consume over 100t of HCFC, initiative to encourage enterprises to apply for conversion projects of production lines |
| **Outreach/Involvement** |
| Different mechanisms based on refrigerant type (CFC vs HCFC)<br>CFC: Two parties responsible for industry outreach:<br>– Bureau of Machinery Industry (Now China Machinery Industry Federation)<br>– Bureau of Light Industry (Now China National Light Industry Council)<br>HCFC: Three parties responsible for industry outreach:<br>– China Refrigeration and Air-Conditioning Industry Association<br>– China Household Electrical Appliances Association<br>– China Association of Fluorine and Silicone Industry |
| **Tracking/Reporting Mechanisms** |
| Ministry of Environmental Protection manage a database where industry must report the use and consumption of ODS |
| **Training** |
| No information at this time |
| **Reusable Canisters** |
| No information at this time |

[126] AHRI PMS Contact feedback.
[127] Ibid.

### 3.2.2 Regulations & Programs

Refrigerant management in China focuses on the phase out of CFCs, including the following regulations:

**National Program to Phase Out Ozone-Depleting Substances (1st version approved 1993, Revised 1999)**[128]

- Focused on phase out of CFC
- Explicit plan to phase out CFC by January 1, 2010 in affected industries
- Specified responsibilities of related government agencies that oversee manufacturing, sales, recovery, import and export
- Bans manufacture, sale, and use of CFCs by 2010

**China's Atmospheric Pollution Prevention Act, 1998 (Revised in 1995, 2000, 2016)**[129]

- Enabling legislation enacted by National People's Congress of the People's Republic of China

**Regulation on the Administration of Ozone Depleting Substances, 2010**[130]

- Enables Ministry of Environmental Protection to draft and publish checklist of ODS
- Specify Ministry of Environmental Protection in charge of supervision and administration of ODS
- Enables Ministry of Environmental Protection to draft and catalogue recommended ODS substitutes

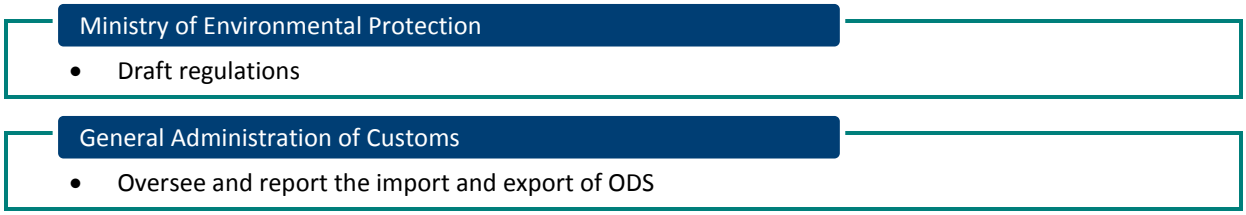
**HCFC Phase-Out Management Plan (HPMP), 2011**

- Passed at the meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol
- Focused on phase-out of HCFCs in industrial and commercial refrigeration and air conditioning (ICR) and residential air conditioning (RAC) sectors
- Explicit plan to freeze HCFC consumption at a 2013 baseline, target 10% reduction by 2015, 35% reduction by 2020, and cap consumption at 2.5% of baseline during 2030-2040 for maintenance

**China's Atmospheric Pollution Prevention Act, 1998 (Revised in 1995, 2000, 2016)**[131]

- Enabling legislation enacted by National People's Congress of the People's Republic of China focused on both CFCs and HCFCs

Figure 3-2 summarizes the roles and responsibilities of relevant Chinese organizations.




[128] Ministry of Environmental Protection. "Domestic Policies." September 2004. Accessed September 2015. Link
[129] National People's Congress of the People's Republic of China. "Revision of China's Atmospheric Pollution Prevention Act." December 2014. Accessed September 2015. Link
[130] The State Council of the People's Republic of China. "Decree of the State Council, No. 573" April 2010. Accessed September 2015. Link
[131] National People's Congress of the People's Republic of China. "Revision of China's Atmospheric Pollution Prevention Act." December 2014. Accessed September 2015. Link


**Figure 3-2: China's Roles and Responsibilities**

# 4. Recommendations and Conclusions

## *4.1 Comparison of Programs*

Table 4-1 summarizes Navigant's evaluation of each jurisdiction. Note that these comparisons are relative. In some instances, best practices or high levels of success do not indicate absolute success. Highly successful jurisdictions can still improve their refrigerant management programs. Likewise, low levels of success does not denote failure, but rather lower success and/or effectiveness relative to other jurisdictions' programs.

**Table 4-1. Comparison and Ranking of Programs**

| Programs | Enforcement Rigor | Effectiveness | Cost/Burden | Stakeholder Engagement | Training/ Support | Relative Level of Success |
|---|---|---|---|---|---|---|
| Japan | High | High | High | High | Info. Unavailable | High |
| Australia | High | High | Low | High | Medium/High | High |
| UK | Medium | Medium | High | Info. Unavailable | High | Medium |
| EU | Medium/Low | Medium | High | Low | High | Medium |
| Canada | Low | Low | Low | High | High | Low/Medium |
| California | Medium/High | Medium | Medium | Medium | High | Medium |
| U.S. | Low | Low | Low | Medium | Low | Low/Medium |

Table 4-2 describes the approach for developing each of the rankings in Table 4-1.

**Table 4-2: Ranking-Metric Definitions**

| Metric | Definition |
|---|---|
| Enforcement Rigor | Metric is evaluated based on breadth and depth of regulations. Japan is considered "high" because regulations extend to all major sectors (e.g. Stationary equipment, domestic appliances, MVAC) and all high-GWP refrigerants (ODS and HFCs). California ranks "medium/high" here because major refrigerant management regulation-RMP-does not target all major sectors. |
| Effectiveness | Metric is evaluated based on available data and anecdotal evidence. U.S. is considered "low" because relatively small percentages of total available refrigerant (e.g. HFCs) is properly recovered and destroyed. |
| Cost/Burden | Metric is evaluated based on direct costs to industries. Japan is considered "high" because of the large capital costs manufactures shouldered to implement compliant EOL management. Canada is considered low because levies are a small percentage of total purchase price and recordkeeping requirements are minimal. |

| Metric | Definition |
|---|---|
| Stakeholder Engagement | Metric is evaluated based on government-industry collaboration during regulation/program development. |
| Training/ Support | Metric is evaluated based on jurisdictions' efforts (public or private) to educate, promote best practices, and provide high quality training to industry participants |
| Relative Level of Success | Metric is evaluated based on jurisdictions' ability to minimize refrigerant emissions. Note that this is rating does not measure the jurisdictions against their own goals, but rather holistic emissions abatement from responsible refrigerant management. |

Japan is consistently viewed as a leader because of a number of unique characteristics: cultural sensitivity to minimizing waste and to environmental stewardship, robust product EOL supply chains, and integrated relationship between industry and government. Japan's major challenges center on the high burden on industry. ICF International estimates that the motor vehicle industry spent +130M[132] to develop a comprehensive vehicle EOL supply chain.

Australia exhibited a high level of success because of the impact of robust national regulations. By combining ODS and SGG phase downs with detailed reporting and licensing requirements, Australia is able to closely track refrigerant throughout its lifecycle. Note that these licensing and reporting requirements are in part supported by mandatory reusable cylinder regulations. Australian refrigerant management leadership indicated that without such regulations, Australia's program would not have achieved the same level of success. A deficiency in Australia's refrigerant management is the lack of reporting and recordkeeping required upon installation and recovery from end use. By not mandating the same level of reporting at this stage of the products' lifecycle, Australia is unable to proactively identify and enforce regulations on many noncompliant equipment owners. Australia is working to rectify this gap.[133]

As a member of the EU, the U.K. must fulfill very rigorous regulatory requirements. Compliance in the U.K. is likely above the average of the EU. The UK's major successes center on the implementation of the EU's strict regulations. For example, the multiple appliance compliance schemes enable competition and choice amongst manufacturers. Additionally, the robust network of designated collection facilities makes responsible appliance recycling almost frictionless for consumers. Conversely, stakeholders express concern that the haste of some U.K. regulations likely resulted in major disruption to appliance recycling.

Compliance varies across the EU. As noted above, the EU has very aggressive phase down, product and service ban, and licensing regulations. If met, these regulations will likely result in robust emissions abatement. Unfortunately, anecdotal evidence suggests these regulations may overburden refrigerant management union-wide, ultimately reducing compliance in some areas. One of the prominent

[132] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[133] Interview with representative of AEHA.

characteristics of refrigerant management in the EU is the presence of research institutions and industry's commitment to developing and researching best practices. The REAL programs have demonstrated measureable improvements to leak prevention with equipment owner, technician, and other educational programs.

Similar to the U.S., Canada is considered to be behind relative to the top jurisdictions in refrigerant management because of limited regulatory coverage of HFCs. While well subscribed, the RMC program is still voluntary, does not cover HFCs, and is limited to stationary HVAC/R equipment. Indeed, the costs and burden on industry are very low; however, Canada pays for this low burden with relatively low performance. With stronger regulations and enforcement, RMC's "frictionless" destruction program would serve as a good model for the U.S.

California's RMP includes many industry best practices for maintenance and service. This includes robust reporting, leak detection scheduling, and proper licensing. By heavily focusing on demand side energy efficiency, California utilities have become the default collection vector for many refrigerant-containing appliances. "Small Can" recycling (i.e. do-it-yourselfer motor vehicle refrigerant management) is estimated at 70-80%, which is substantially above the U.S. Many aspects of California's program are scalable to the U.S., particularly on a voluntary basis. The major challenges of California's refrigerant management programs is RMP's limitation to larger stationary equipment and lack of detailed visibility into effectiveness.

The U.S. lacks a number of the characteristics of the most successful refrigerant management programs. Current regulations enable limited-to-no national refrigerant tracking. Additionally, beyond venting prohibitions, current regulations for licensing do not extend to HFCs. Perhaps the most encouraging success of the U.S.'s refrigerant management program is the success of RAD and GreenChill. Both voluntary programs enjoy emissions reductions well-above industry averages.

By combining some of the above best practices, the U.S. can greatly improve refrigerant management while still minimizing the burden on industry. Table 4-3 highlights key advantages and best practices of the programs in the jurisdictions studied for this report that the U.S. could consider in developing more robust programs. We denote many as best practices for consideration in the U.S., recognizing that not every features will, or should, map directly to a U.S. based program. Additionally, we believe that the others program characteristics are also relevant and may ultimately contributor to a comprehensive, nationwide program.

**Table 4-3. Notable Advantages of Researched Refrigerant Management Programs**

| Program | Best Practice Advantages | Consideration for U.S. |
|---|---|---|
| Australia | **Comprehensive product stewardship scheme that is built upon existing distribution channels minimizes cost burden** on industry; friction for contractors, who are "perhaps the most important stakeholder"[134] | U.S. program will minimize cost burden on industry. |
| Australia | Inclusion of **all synthetic refrigerants** (CFCs, HCFCs, HFCs) in phase down & regulatory requirements has created consistent market incentives for better refrigerant management | Meaningful GHG emissions abatement should target both ODS and high-GWP HFCs. |
| Australia | **Robust recordkeeping from point of entry to destruction** (despite one major exception) makes accurate emissions tracking very achievable | Robust recordkeeping drives industry-wide accountability. |
| California | **Robust maintenance and servicing requirements** for major refrigerant charges has served as **educational tool to industry and promoted best practices** | Strong maintenance and service requirements save end users money. Building requirements around this benefit will increase compliance. |
| California | Utility energy efficiency programs successfully capture large volumes of appliances. This enables easy refrigerant/resource management. | Non-traditional vectors, such as utility programs, can serve as consumer-facing entry points for domestic appliance refrigerant management. |
| California/ Australia | *California:* Moving away from disposable small refrigerant cans sets **reusable canister precedent (**despite limited volumes of recoverable refrigerant from small cans). | Mandatory small can deposits greatly increases recycling rate. |
| | *Australia:* **Banning disposable cylinders** was pivotal in improving refrigerant management. Returning cylinders for refills supports the ethos that refrigerants are not a commodity but a specialized good and encourages refrigerant return for destruction.[135] | Programs and policies should shift perception of refrigerants from a commodity to a specialized and environmentally damaging good. |
| European Union | Robust reporting requirements **respect industry confidentiality** concerns but enable EU to publish detailed refrigerant flow data | Ensuring industry-appropriate confidentiality will reduce barriers to industry participation. |

[134] Interview with Greg Picker.
[135] Interview with Greg Picker.

| Program | Best Practice Advantages | Consideration for U.S. |
|---|---|---|
| European Union | **Collaborative training and best practice development proven to reduce leak rates** (REAL Skills, Zero, etc.). EC committed to developing easy-to-use, robust, and thorough documentation for industry | Leverage existing international research, training material to improve industry best practices. |
| Japan | **Industry-specific** refrigerant management **programs built upon current product EOL infrastructure** with opportunities for innovation, **competition between product stewardship schemes** | Nationwide program should respect differences between refrigerant-using industries. |
| Japan/ United Kingdom | *Japan*: Fees for motor vehicle EOL management (including refrigerants) charged **at time of purchase**. This greatly encourages compliance. *United Kingdom*: No explicit cost to consumers for appliance disposal— instead manufacturers incur cost as part of operations and **build costs into retail prices** | Capturing funding for refrigerant management up front (through explicit fees or increased retail price) incentives consumers to handle products responsibly at end of life. Any program that funds operation by collecting fees at end of life may disincentivize full compliance. |
| United Kingdom | **Multiple product stewardship schemes** encourages competition, low cost EOL management | Nationwide program with competing implementations can foster innovation, low cost best practices. |
| United Kingdom | Societal norms that value environmental stewardship have made REALSkills certifications popular | As environmental stewardship grows more important to consumers and governments, members of transparent and well-publicized refrigerant management program will continue to gain popularity. |
| United States | **Voluntary programs (e.g. GreenChill, RAD) exhibit above-industry-average performance** and marketing benefits to partners | Cite marketing benefits, cost savings to encourage industry to support voluntary programs or mandatory regulations. If well designed, either can abate emissions and benefit end-users. |

| Program | Other Notable Advantages | Consideration in the U.S. |
|---|---|---|
| Canada | **Voluntary** ODS program, which was built upon existing infrastructure, minimizes burden on industry. | Voluntary programs minimize cost, but lack weight to ensure level playing field. |
| Japan | Comprehensive product, raw material, and refrigerant management programs encourage very responsible refrigerant management | While similarly comprehensive end-of-life management is unlikely in the U.S. due to cultural differences, efforts to boost cultural awareness may enable elements of this hugely successful recycling program. |

Table 4-4 summarizes a selection of the key challenges encountered by the jurisdictions studied in this report.

**Table 4-4. Select Challenges of Researched Refrigerant Management Programs**

| Program | Challenges |
|---|---|
| Australia | Carbon tax engendered perverse refrigerant management practices. Compliance and responsible management likely dropped during carbon tax era. |
| Australia | Lack of blanket recordkeeping, reporting requirements from install to recovery creates gap in an otherwise robustly tracked lifecycle |
| Australia | Lack of mandatory leak testing undermines robust management practices throughout supply chain |
| Canada | Regulations prevent HFC emissions but do not provide additional requirements for management (e.g. membership in PSS or mandatory leak checks). This creates unleveled playing field. |
| Canada | RMC focuses exclusively on stationary HVAC/R industry. This discourages best practices amongst other industries. RMC focuses on destruction; does not promote reclamation. |
| Canada | Limited to no tracking of total stock of refrigerant, including no tracking for refrigerants in pre-charged equipment |
| Canada | Voluntary nature of RMC enables some limited free ridership. |
| California | RMP targets stationary equipment only, but large number of covered facilities creates burden on California ARB |
| European Union | Variability of member state implementations results in variable compliance levels |
| European Union | Reporting requirements do not extend to all relevant parties (e.g. domestic reclaimers, destroyers), making complete tracking very difficult |
| Japan | Comprehensive product, raw material, and refrigerant management programs not easily transferable to the U.S. or other western countries |
| Japan | Proper compliance with regulations creates heavy cost burden on industry |
| United Kingdom | Aggressive regulations resulted in temporary collapse of appliance recycling industry |

| Program | Challenges |
|---|---|
| United States | Inconsistent regulations governing HFCs vs. HCFCs and CFCs creates confusion, noncompliance in the marketplace |
| *General* | Nature of violations makes enforcement very difficult. Few jurisdictions frequently identify and prosecute bad actors |

## *4.2 Recommendations*

As public opinion and regulatory bodies increase their focus on, and prioritization of, environmental stewardship, U.S. refrigerant management practices will need to improve. Through our research, Navigant has identified the eight best practices from other jurisdictions that can be adopted in the U.S. Based on these attributes, AHRI can develop a construct for improved refrigerant management that helps achieve global climate goals while maintaining key characteristics that are important to AHRI member organizations. Navigant did not quantitatively analyze the cost impacts of these programs, so further study would be required to identify the costs and benefits associated with individual program features. The recommendations in Table 4-5 (numbered for identification only, not to indicate priority) represent valuable components to a broader program that will require involvement across industry and government to execute successfully:

**Table 4-5: Recommendations**

| | |
|---|---|
| **1** | Strengthen national regulations to include HFCs.<br>– **Example:** Australia, Japan, and the EU all explicitly extend refrigerant management regulations to HFCs. These regulations extend beyond "not venting" and include similar (if not identical) licensing, maintenance, and reporting requirements for ODS and HFC refrigerants.<br>– **Outcome:** Levels the playing field for industry with less confusion in the marketplace. Reduced environmental impact by targeting all major high GWP refrigerants instead of high ODS refrigerants only. |
| **2** | Charge end users of refrigerant-containing equipment for any necessary costs associated with refrigerant management **up front** (as opposed to at end-of-refrigerant or -equipment life). Standardize costs across sectors so that individual manufacturers do not gain an unfair advantage.<br>– **Example:** Relative to all other refrigerant management regulations, Japan's End-of-Life Vehicle Recycling Law has enjoyed extensive compliance (order of magnitude drop in illegally dumped vehicles).<br>– **Outcome:** Up-front fees minimize EOL product management friction and noncompliance. End users enjoy no benefit by ignoring regulations—they have "pre-paid" the costs associated with responsible product management. |

| | |
|---|---|
| **3** | Ensure tracking and reporting requirements are balanced against the additional costs and benefits of tracking and reporting, while still maintaining confidentiality where needed (i.e., in cases where manufacturers consider the data to be valuable intellectual property).<br>– **Example:** EU F gas and ODS regulations mandate robust reporting to EEA, while still compelling EEA to protect confidentiality. Annual report contains detailed data by sector but prioritizes confidentiality over transparency.<br>– **Outcome:** Tracking reinforces industry and regulatory accountability. |
| **4** | Model maintenance regulations after voluntary partnerships (e.g. GreenChill, RAD).<br>– **Example:** GreenChill partner leak rates are half of overall food-sales industry average.<br>– **Outcome:** Portraying refrigerant management as a cost saver to equipment owners greatly improves participation and performance. Our interviews suggest that involvement with environmental stewardship programs can improve brand perception. |
| **5** | Develop and implement regulations at appropriate speed for industry.<br>– **Example:** U.K.'s aggressive implementation of foam recovery laws for appliances negatively impacted appliance recycling industry. Australia's carbon tax increased the value of ODS refrigerants, which incentivized unlicensed operators to recover EOL refrigerants from vehicles and resell refrigerant through illicit channels.<br>– **Outcome:** Overambitious phase outs, recycling requirements, or service bans can drive undesirable behavior (e.g. venting, unlicensed operator recovery). |
| **6** | Leverage a broad range of sources (e.g. other governments, industry groups, research, training programs, etc.) that have more experience with comprehensive refrigerant management.<br>– **Example:** AHRI-commissioning Navigant report surfaces key characteristics of international programs.<br>– **Outcome**: Tapping robust international subject matter expertise will minimize duplicating effort and expedite the development of a U.S.-specific program. |
| **7** | Promote unified, actionable, and application-specific education and training programs.<br>– **Example:** REAL skills research suggests substantive (+25%) reduction in leakage rates with more effective refrigerant management training. REAL Zero research demonstrated an average 44% reduction in leakage rates for trained equipment owners.<br>– **Outcome:** Robust education and training programs unlock meaningful savings by boosting compliance and efficacy within the context of current regulations. |
| **8** | Work proactively with responsible regulators (e.g. EPA, state agencies) to ensure all parties are fully enforcing existing regulations.<br>– **Example:** Our interviews suggest that full enforcement lags across all researched jurisdictions.<br>– **Outcome:** Industry supported regulations and enforcement levels the playing field, improves national environmental stewardship, and improves compliance and efficacy of current regulations. |

While comprehensive refrigerant management will require a thorough development process to outline the most appropriate policies for the U.S., We can learn valuable lessons from the successes and failures in other jurisdictions. The key advantages and recommendations reviewed here represent a starting point for development of a comprehensive approach.

# Appendix A. Regulations for Primary Target Jurisdictions

The following subsections summarize the relevant overarching legislation and regulations that drive the programs described in the body of this report.

## *A.1 Australia Regulations*

Australia manages refrigerant with an enabling legislative act and accompanying regulation:

**Ozone Protection and Synthetic Greenhouse Gas Management Act (1989, amended 1995, collectively "the Ozone Acts")**[136]

- Includes import and manufacture levy acts
- Mandates phase-out for ODS
- Controls manufacture, import and export of ODS and SGG
- Provides authority to regulate the sale, purchase, use, storage, and disposal of ODS and SGG
- Requires and establishes standards for recovery
- Controls imports of pre-charged refrigeration and AC equipment

**Ozone Protection and Synthetic Greenhouse Gas Management Regulations (1995, amended 2004, 2014)**[137]

- Supports Ozone Acts
- Covers ODS and SGG (CFCs, HCFCs, and HFCs)
- Requires licensing fees for import, export, and manufacture of ODS and SGG
- Requires refrigerant importers to participate in a product stewardship scheme (PSS), which extends the producers' responsibility (both physical and financial) to the "post-consumer stage of a product's life cycle"[138]
- Imposes import levies on ODS and SGG and sets reporting requirements for importers
- Mandates licensing for and reporting by individuals and corporations using ODS and SGG
- Requires trading authorizations to purchase ODS and SGG

## *A.2 Canada Regulations*[139]

**Canadian Environmental Protection Act (1999)**

- Enables Ozone-depleting Substance and Federal Halocarbon Regulations

**Ozone-depleting Substances Regulations (1998)**

- Implemented by Environment Canada on behalf of federal government
- Controls the export, import, manufacture, sale, offer for sale, and certain uses of ozone-depleting substances (meets requirements of Montreal Protocol); prohibits venting of controlled substances

**Federal Halocarbon Regulations (2003, amended 2009)**

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[136] Australian Government Department of the Environment. "Commonwealth legislation." Accessed August 2015. Link

[137] Ibid.

[138] Environment Canada. "FAQ about Extended Producer Responsibility." Accessed August 2015. Link

[139] Environment Canada. "Regulatory Information." Updated 05/25/2010. Accessed August 2015. Link, and ICF International.

- Implemented by Environment Canada on behalf of federal government
- Controls use and handling of halocarbons in equipment on federal land

**Provincial Regulations**

- Vary by province
- Some have instituted seller take back provisions for refrigerants and equipment
- Include provisions that promote the proper handling of refrigerants

*Non-Regulatory Policies*[140]

- Initiatives by federal government to protect environment
- Used by federal government to precipitate voluntary industry-driven solutions

**National Action Plan (NAP) for the Environmental Control of Ozone-Depleting Substances and their Halocarbon Alternatives (1992)**

**Strategy to Accelerate the Phase-Out of CFC and Halon uses and to Dispose of the Surplus Stocks (Phase-Out Strategy) (2001)**

## *A.3 European Union Regulations*

*Ozone Depletion Regulations:*[141]

**Regulation (EC) 1005/2009 on substances that deplete the ozone layer**

- Controls the use and trade of controlled substances. Stipulates that producers, importers, exporters, feedstock users, process agent users, and destruction facilities must report activities (related to controlled substances) annually (March 31)
- Controlled substances are the 200+ covered by the Montreal Protocol + five additional substances

*High GWP Regulations: i.e., "F gas Regulations"* [142]

**Regulation (EC) No 845/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases**

- Original regulation to control the import, use, and emission of HFCs

**Regulation (EC) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 845/2006**[143]

- Replaces 2006 regulation with stronger framework to:
  - Limit and phase down total amount of HFCs that can be sold in EU (two-thirds reduction of 2014 levels by 2030)

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[140] Environment Canada. "Other National Initiatives." Updated November 2013. Accessed September 2015. Link

[141] European Commission (EC) Climate Action. "Protection of the ozone layer." Accessed August 2015. Link
Secondary regulations focused on exceptions include:
*Commission Regulation (EU) 537/2011 on mechanism for the allocation of quantities of controlled substances allowed for laboratory and analytical uses*
*Commission Regulation (EU) 291/2011 on essential uses of controlled substances other than hydrochlorofluorocarbons for laboratory and analytical purposes*
*Commission Decision 2011/372/EU on the use of controlled substances as process agents*

[142] EC Climate Action. "Fluorinated greenhouse gases." Accessed August 2015. Link

[143] EC. "Company Reporting for Regulation (EIU) No 517/2014 on fluorinated greenhouse gases. Frequently Asked Questions." February 2015. Accessed August 2015.

    - Ban use of HFCs in many new types of equipment (e.g. residential, commercial refrigerators, air conditioners, foams, and aerosols) where less harmful alternatives are widely available
    - Prevent emissions of HFCs from existing equipment by "requiring checks, proper servicing and recovery of the gases at the end of the equipment's life"[144]
- Requires companies to report on production, import, export, feedstock use, and destruction of covered refrigerants (fluorinated GHGs) through F-gas portal
- Reporting threshold for producers, importers, exporters, destroyers, and users of high-GWP feedstock vary from 100 to 1,000 metric tons of $CO_2$ equivalent ($CO_2e$)
- Reporting threshold for companies that place products or equipment that contain $CO_2e$ begins at 500 metric tons of $CO_2e$
- All reporting done in metric tons of $CO_2e$ (See Appendix A for conversions)
- Requirements for service technicians and operators include[145]:
    - Proper technician certification and training (Operators must confirm personnel are qualified/certified)
    - Proper recovery and destruction of F-gas refrigerants
    - Scheduled leakage checks or installation of automatic leakage detection system (varies by equipment type and charge $CO_2e$)
    - Robust recordkeeping (varies by equipment type and charge $CO_2e$)
    - Proper labeling

**Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air conditioning systems in motor vehicles and amending Council Directive 70/156/EEC[146]**

- Covers mobile air conditioners (MACs) in passenger and light commercial vehicles
- Bans the registration, sale, or use of vehicles with refrigerants above 150 GWP
- Phased-in enforcement with final compliance date of January 2017

## *A.4 Japan Regulations*

**Home Appliance Recycling Law (Enacted 2001):**

- Defines procedures for recycling domestic appliances, including refrigerators, air conditioners, televisions, and washing machines
- Mandates recovery of fluorocarbon refrigerants and foams
- Requires retailers to collect appliances
- Requires manufacturers/importers to recycle appliances
- Consumer pays fees associated with collection, transport, and recycling at time of disposal

**Fluorocarbons Recovery and Destruction Law (Enacted 2002):**

[144] EC Climate Action. "EU legislation to control F-gases." Accessed August 2015. Link

[145] EC. "Information for technicians and users of refrigeration, air conditioning and heat pump equipment containing fluorinated greenhouse gases." January 2015. Accessed August 2015.

[146] EC. "The mobile air-conditioning systems MACS." Accessed August 2015. Link

- "Requires the recovery of fluorocarbon refrigerants (i.e., CFCs, HCFCs, HFCs) from commercial equipment during service and disposal"[147]
- Requires recovery by operators registered with prefecture government
- Requires operators to report on amount of refrigerant recovered annually
- Requires destruction to occur at permitted facilities (granted by national government: Ministry of the Environment (MOE) and the Ministry of Economy, Trade and Industry (METI))
- Mandates end-users to pay fees associated with recovery and destruction
- 2006 amendment increased reporting requirements for commercial equipment owners and strengthened local governments' authority to improve refrigerant recovery
- Does not appear to allow import of ODS waste for destruction

**Fluorocarbons Emission Control Law (Enacted April 2015)**

- Strengthens previous Fluorocarbons Recovery and Destruction Law by adding new requirements for HFCs
- "Marks the beginning of comprehensive regulations covering the entire lifecycle from the manufacture of fluorocarbons to their disposal"[148]
- Includes:
    - Restriction on FC manufactures
    - Directives for appliance manufacturers to convert to low-GWP refrigerants
    - Requirements for appliance owners to maintain appliances properly
- Enables regulators to develop incentives for low GWP refrigerants
- Starts process of leveling playing field between HFCs, CFCs, and HCFCs

**End-of-Life Vehicle Recycling Law (enacted 2005)**

- Mandates that vehicles are disposed with collection operators (i.e. registered car dealers and auto repair shops)
- Mandates that registered recovery operators remove refrigerant prior to permitted dismantling and shredding operators
- Mandates that recovery operators submit annual reports to the (JARC)
- Recovery operators receive rebates if they recover more than 270 g of refrigerant per MAC[149]
- Consumers pay fees related to recovery, transport and destruction

**Waste Management & Public Cleansing Law**

- Bans dumping of domestic appliances, punishable by fine and imprisonment

[147] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[148] Tsukada, Toshihiko. "Overview of the Fluorocarbons Emission Control Law." July 2015. Accessed September 2015.
[149] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.

## *A.5 United Kingdom Regulations*

*Ozone Depletion Regulations:*[150]

**Regulation EC 1005/2009 on substances that deplete the ozone layer**

- See Section 2.4 for more details on EU regulations
- Once recovered, CFCs, HFCS must be destroyed (reuse not allowed)
- Use of recycled or reclaimed HCFCs to "top up or service existing equipment" is banned[151]
- Technicians must hold qualifying certification from City and Guilds or Construction Industry Training Board[152]
- Leak checks are required every: [153]
    - Three months for +300kg of HCFCs
    - Six months for +30kg of HCFCs
    - Twelve months for +6 kg of HCFCs in hermetically sealed system
    - Twelve months for +3kg of HCFCs not in a hermetically sealed system

*High GWP Regulations:* [154]

**Regulation (EC) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 845/2006**[155]

- See Section A.3 for more details on EU regulations
    - Mandates recovery of F gas from:
        - Commercial, industrial refrigeration systems
        - Refrigeration systems used in trucks, trailers, ships, and other vehicles
        - Stationary air conditioning and heat pump systems
        - Portable or mobile air conditioning systems
        - Other non-refrigerant applications
    - Mandates recovery of F gas "when technically feasible (and) doesn't involve disproportionate cost" in all other equipment
    - See section A.3 for information on phase down. U.K. Department for Environment directs all relevant parties to European Commission reporting and quota application websites.[156]

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[150] European Commission (EC) Climate Action. "Protection of the ozone layer." Accessed August 2015. Link
Secondary regulations focused on exceptions include:
*Commission Regulation (EU) 537/2011 on mechanism for the allocation of quantities of controlled substances allowed for laboratory and analytical uses*
*Commission Regulation (EU) 291/2011 on essential uses of controlled substances other than hydrochlorofluorocarbons for laboratory and analytical purposes*
*Commission Decision 2011/372/EU on the use of controlled substances as process agents*

[151] U.K. Department for Environment. "HCFCs in refrigeration and air conditioning equipment." December 2014. Accessed September 2014. Link

[152] Ibid.

[153] Ibid.

[154] EC Climate Action. "Fluorinated greenhouse gases." Accessed August 2015. Link

[155] EC. "Company Reporting for Regulation (EIU) No 517/2014 on fluorinated greenhouse gases. Frequently Asked Questions." February 2015. Accessed August 2015.

[156] U.K. Department for Environment. "Guidance – HFC phase down in the EU: how it works and exemptions." December 2014. Accessed September 2015. Link

  - Equipment bans exclude buying and selling of second-hand equipment.
  - See Appendix G for details of new equipment ban.
  - Quotas allocated to "incumbent" and "new entrants"[157]
  - Starting in 2017, equipment manufacturers must use HFCs quotas for any equipment that is pre-charged and sold in the EU.[158]
  - In 2020, equipment owners will not be allowed to use some virgin F gases to refill existing equipment.[159]
- Company certifications required for installing, repairing, maintaining, and decommissioning equipment[160]
  - Certifications offered by Burea Veritas, Quidos, Refcom
    - Renewed every 3 years
    - Company must demonstrate that they "employ sufficient trained staff to carry out…work" and "have procedures in place for the safe handling of F gases to minimise emissions" [161]
  - Excepts companies that service their own equipment (note that technician must be certified)
- Individual qualifications required to install, maintain, leak check, recover, decommission, and dispose of refrigeration or stationary air conditioning equipment[162]
- Labeling requirements extend to manufacturers and importers of equipment[163]
  - Currently, manufacturers must label equipment with name of F-gas.
  - In 2017, manufacturers must include mass of F gas, $CO_2e$ of F gas, GWP of F gas

**Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air conditioning systems in motor vehicles and amending Council Directive 70/156/EEC**[164]

- Bans include:
  - HFCs with GWPs above 150 in new cars (2013)
- Requires use of qualified technicians. Qualifying certification include:[165]

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[157] U.K. Department for Environment. "Guidance – HFC producers and importers: get and transfer EU quotas." December 2014. Accessed September 2015. Link
[158] Ibid.
[159] U.K. Department for Environment. "Guidance - F gas in refrigeration, air conditioning and fire protection systems." December 2014. Accessed September 2015. Link
[160] U.K. Department for Environment. "Guidance – Certification for companies working on equipment containing F gas." December 2014. Accessed September 2015. Link
[161] Ibid.
[162] U.K. Department for Environment. "Guidance - Qualifications required to work on equipment containing F gas." December 2014. Accessed September 2015. Link
[163] U.K. Department for Environment. Guidance – Manufacturers of products with F gas: labels and record keeping." December 2014. Accessed September 2015. Link
[164] U.K. Department for Environment. "Guidance – F gas requirements for air conditioners in cars and other vehicles." December 2014. Accessed September 2014. Link
[165] U.K. Department for Environment. "Guidance - Qualifications required to work on equipment containing F gas." December 2014. Accessed September 2015. Link

    - City & Guilds certificate
    - Institute of the Motor Industry (IMI) certificates
    - Other MVAC certificate that is recognized by other EU member states
- Requires vehicle owner "to prevent leaks" by getting a technician "to regularly service…and check (your MAC) for leaks."[166]
- Requires technicians to recover F gas prior to vehicle disposal

## *A.6 United States Regulations*

Refrigerant management in the U.S. is driven by five different pieces of federal regulation, primarily authorized by the Clean Air Act of 1970:

**Clean Air Act (CAA) (1963 with major amendments in 1970, 1977, 1990)**

- Enabling legislation enacted by Congress
- Title VI gives EPA responsibility for program "that protect the stratospheric ozone layer"[167]
- Sections 601-607: Phase Out
    - Regulations issued by EPA under CAA
    - "Phase out the production and import of ODS, consistent with the scheduled developed under the Montreal Protocol"
- Section 608[168]: ODS-focused
    - Regulations issued by EPA under CAA
    - Prohibits intentional venting of refrigerants
    - "(Requires) service practices that maximize recovery and recycling of ODS…during service and disposal of air conditioning and refrigeration equipment"
    - "(Sets) certification requirements for refrigerant recycling and recovery equipment, technicians, and refrigerant reclaimer"
    - "(Restricts) the sale of refrigerant to certified technicians"
    - "(Requires) persons servicing or disposing of air-conditioning and refrigeration equipment to certify to EPA that they have acquired refrigerant recovery and/or recycling equipment and are complying with the requirements of the rule"
    - "(Requires) the repair of substantial leaks in air-conditioning and refrigeration equipment with a refrigerant charge greater than 50 pounds"
    - "(Establishes) safe disposal requirements to ensure removal of refrigerants from goods that enter the waste stream with the charge intact (e.g., motor vehicle air conditioners, home refrigerators, and room air conditioners)"
- Section 609: Motor Vehicle Air Conditioning (MVAC)[169]
    - Regulations issued by EPA under CAA
    - Requires certification for repair or service technicians
    - Requires final party in disposal chain to verify that refrigerants were properly removed

[166] Ibid.
[167] EPA. "Ozone Layer Protection – Regulatory Programs." Accessed August 2015. Link
[168] EPA. "Complying With The Section 608 Refrigerant Recycling Rule." Accessed August 2015. Link
[169] EPA. "Just the Facts for MVACs." Accessed August 2015. Link

- Requires that technicians use approved recovery equipment
- Requires MVAC service shops to certify equipment and technician
- Requires MVAC service shops to maintain records
- Prohibits sale of "small cans" (less than 20 lbs.) of CFC-12 to anyone other than EPA-certified technician
- Regulates ODS as controlled substances[170]
  - Class 1 (ODP > 0.2) final phase out in 2005[171]
  - Class 2 (ODP < 0.2, e.g. HCFCs) Phase down: 90% in 2015, 99.5% in 2020, 100% in 2030

**Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling HCFC Production, Import and Export (2015-2019)**

– Most recent phasedown rule for ODS issued by EPA under CAA

**Pre-Charged Appliances Rule (2010)**

– Regulations issued by EPA under CAA
– "Bans the sale or distribution of pre-charged air-conditioning and refrigeration products and components containing HCFC-22, HCFC-142b, or blends"[172]

**Significant New Alternatives Program (SNAP) (1994)**

– Regulations issued by EPA under CAA
– Updated through EPA rulemaking process
– EPA examines new substances for "ozone-depleting, global warming, flammability, and toxicity characteristics"[173]
– Requires manufacturers to submit new substitutes to EPA for review/approval
– Program is designed to:
  - "Identify and evaluate substitute (refrigerants) in end-uses that have historically used ODS"
  - "Look at overall human health and the environment of both existing and new substitutes"
  - "Promote use of acceptable substitutes"
  - "Provide the public with information about the potential environmental and human health impacts of substitutes"

**Resource Conservation and Recovery Act (RCRA) (1976)[174]**

– Enabling legislation enacted by Congress
– Defines hazardous wastes
– If ODS is considered hazardous, must be destroyed at RCRA-approved facilities with destruction efficiency (DRE) of 99.99% (while most ODS are not classified as hazardous waste, most are destroyed at RCRA facilities)
– ODS destruction (non-hazardous) stipulated at 98% DRE

[170] EPA. "The Phaseout of Ozone-Depleting Substances." Accessed August 2015. Link
[171] EPA. "Phaseout of Class I Ozone-Depleting Substances." Accessed August 2015. Link
[172] EPA. "Phaseout of HCFCs (Class II Ozone-Depleting Substances)." Accessed. August 2015. Link
[173] EPA. "Choosing and Using Alternative Refrigerants for Motor Vehicle Air Conditioning." Accessed August 2015. Link
[174] EPA. "Destruction of Ozone Depleting Substances." Accessed August 2015. Link

## *A.7 California Regulations*

**All Federal Regulations**

- See Section 2.7 for details.

**California Global Warming Solutions Act (2006) (AB 32)[175]**

- Underlying law that requires the state to reduce its GHG emissions to 1990 levels by 2020
- Mandates Air Resource Board to "to achieve the maximum technologically feasible and cost-effective GHG emission reductions"[176]
- Sets framework for ozone depleting and high-GWP substances, and thus refrigerant regulation
- Allows refrigerant destruction to count toward cap and trade offset credits

**Regulations for the Management of High Global Warming Potential Refrigerants for Stationary Sources (commonly referred to as Refrigerant Management Program (RMP)) (Adopted 2006, Amended 2010)[177]**

- Commercial air-conditioning used for comfort cooling (with more than 50 pounds of high GWP refrigerant) is covered by required service practices, but are exempt from registration and reporting requirements.[178]
- Also contains provisions pertaining to companies and facilities that distribute and reclaim refrigerants and technicians that service refrigerant contain appliances
- Generally considered an "inspection and maintenance regulation"[179]
    - Requires leak inspection, prompt leak repair, and registration
    - Also requires recordkeeping and reporting of leak inspections and of high GWP refrigerant purchases
- Extension of U.S. EPA rule (Section 608)
    - Applies to any refrigeration system with more than 50 lbs. of a high-GWP HFC or any ODS.
    - Addresses all high-GWP refrigerants, including non-ODS (HFCs)
    - "Most prevision apply to refrigeration systems only, limited to service practice requirements for air-conditioning"[180]

**Rule 1415 Reduction of Refrigerant Emissions from Stationary Air Conditioning Systems (Adopted 1991, Amended and split in 2010-see Rule 1415.1 below)[181]**

- Regulation specific to South Coast
- Adopted "to reduce ozone-depleting refrigerant emissions from stationary, non-residential air conditioning…and refrigeration systems with full charge capacity…greater than 50 pounds"[182]
- Amended to include high-GWP refrigerants

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[175] California EPA Air Resource Board. "Assembly Bill 32 Overview." Accessed August 2015. Link

[176] Ibid.

[177] CARB. "Refrigerant Management Program Question and Answer Guidance Document." November 2013. Accessed August 2015.

[178] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed September 2015.

[179] Ibid.

[180] Ibid.

[181] South Coast Air Quality Management. "Rule 1415 – Reduction of Refrigerant Emissions from Stationary Air Conditioning Systems." Accessed August 2015. Link

[182] Ibid.

- Regulations require:
  - Owners/operators of applicable air conditioning systems to submit facility registration form every two years
  - Conduct annual leak inspection
  - Repair any refrigerant leak within 14 days of initial leak detection
  - Maintain records of leak inspection, repair, and amount of refrigerant added to system on site[183]

**Rule 1415.1 Reduction of Refrigerant Emissions from Stationary Refrigeration Systems**

- Result of 2010 amendment that split 1415 into two regulations (1415 – air conditioning, 1415.1 – refrigeration)
- Local implementation of RMP – "virtually the same as RMP"[184]

**HFC Emission Reduction Measures for Mobile Air Conditioning - Regulation for Small Containers of Automotive Refrigerant, 2009[185]**

- "Applies to the sale, use, and disposal of small containers of automotive refrigerant with a GWP greater than 150"
- Targets containers holding between 2 ounces and 2 pounds of refrigerant
- Focuses on do-it-yourselfer motor vehicle refrigerant service
- Regulation requires
  - Use of self-sealing valve
  - Improved labeling instructions
  - Deposit and recycling program
  - Education program
- Mandates cylinder evacuation prior to recycling or disposal
- Target recycling rate for containers was initially set at 90% within two years; CARB calculates return rate of 70-80% over last four years

**Cap-and-Trade Program[186]**

- Destruction of ODS count toward GHG credits, which can be auctioned to other entities
- CARB provides rigorous methodology to calculate GHG credits from ODS destruction

[183] Ibid.

[184] CARB comments.

[185] CA ARB. "HFC Emission Reduction Measures for Mobile Air Conditioning - Regulation for Small Containers of Automotive Refrigerant." Updated June 2015. Accessed September 2015. Link

[186] CARB. "Overview of ARB Emissions Trading Program." February 2015. Accessed September 2015.

## Appendix B. Further Reading

Table 4-6 lists key secondary sources that provide additional detail on international refrigerant management programs.

**Table 4-6. Valuable Secondary Sources with Details on International Refrigerant Management**

| Source | Comments |
|---|---|
| Cemafroid and IRSTEA, "Refrigerant Containment Study." September 2015 | Field and research study requested by Alliance Froid Climatisation Environnement (AFCE) to understand containment of refrigerant at refrigerating plants. Provides very technical detail on refrigerant containment methods. |
| Department for Environment, Food & Rural Affairs and Environment Agency "Environmental Management Collection" website | Detailed website with information on EU F gas regulations and impact on U.K. |
| EEA. "Fluorinated greenhouse gases 2013." September 2014 | Annual reports which aggregates "data reported by companies on the production, import, and export of fluorinated greenhouse gases in the European Union." |
| EEA. "Ozone-depleting substances 2013." September 2014 | Annual report which aggregates "data reported by companies on the import, export, production, destruction and feedstock and process agent use of ozone-depleting substances in the European Union<br>Note: New version published late September 2015 |
| ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. | Comprehensive but outdated overview of ODS management. |
| ICF International, "Development of the GHG Refrigeration and Air Conditioning Model." December 2011. | Technical report outline the GHG emissions of the U.K.'s refrigeration and air conditioning sector. Provides assumptions on leak rates by sector, end-use. |
| ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. | Study which "assesses various end-of-life management options for reducing GHG emissions at time of disposal."[187] Focuses on domestic appliances, other stationary refrigeration/AC equipment, 30 lbs. refrigerant cylinders used in service sector, and non-refrigerant applications |

[187] ICF International, "Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction." October 2011. Accessed October 2015.

## Appendix C. ODP Metric Tons and $CO_2e$ Conversion

Some jurisdictions regulate refrigerants in ODP metric tons, which is defined as the metric tons of ODS weighted by their ozone depletion potential (e.g. 1 ton of CFC-11 x 1.0 (ODP of CFC-11) = 1 ODP metric ton).[188]

***Table 2: Converting charge limits in CO2 equivalent in in kilograms for most common refrigerants and blends***

| | Charge limits in t $CO_2$-equiv. | | | | |
|---|---|---|---|---|---|
| | 5 | 40 | 50 | 500 | 1,000 |

| Refrigerant | GWP | Conversion of charge limits in kg | | | | |
|---|---|---|---|---|---|---|
| R134a | 1,430 | 3.50 | 27.97 | 34.97 | 349.65 | 699.30 |
| R32 | 675 | 7.41 | 59.26 | 74.07 | 740.74 | 1,481.48 |
| R404A | 3,922 | 1.27 | 10.20 | 12.75 | 127.49 | 254.97 |
| R407C | 1,774 | 2.82 | 22.55 | 28.18 | 281.85 | 563.70 |
| R410A | 2,088 | 2.39 | 19.16 | 23.95 | 239.46 | 478.93 |
| R422D | 2,729 | 1.83 | 14.66 | 18.32 | 183.22 | 366.43 |
| R507A | 3,985 | 1.25 | 10.04 | 12.55 | 125.47 | 250.94 |

**Figure 4-1. Conversion between EU Charge Limits in $CO_2e$ to Common Refrigerants in kg[189]**

Similar to ODP metric tons, $CO_2e$ metric tons are calculated by multiplying the mass (in metric tons) of the refrigerant by its GWP.

[188] United Nations Statistics Division. "Goal 7. Ensure environmental sustainability." Accessed September 2015.
[189] European Commission. "Information for technicians and users of refrigeration, air conditioning and heat pump equipment containing fluorinated greenhouse gases." January 2015. Accessed September 2015.

## Appendix D. Supplementary Australia Information

Figure 4-1 lists additional performance data provided by RRA.

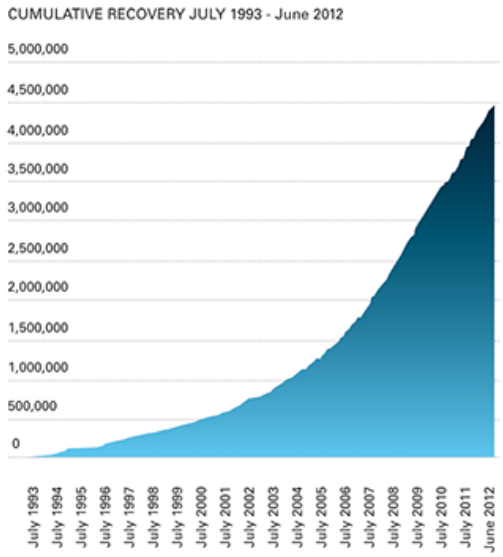



**Figure 4-2. RRA Cumulative Recovery of Refrigerant (July 1993 – June 2012)[190]**

Note that Australia's Department of the Environment recently undertook a review of the Ozone Protection and Synthetic Greenhouse Gas Management (OPSGGM) Programme. The options paper and accompanying attachments provide deep insight into Australia's refrigerant management program, the costs, benefits advantages, and challenges associated with implementing new or different refrigerant management regulations, and the environmental impact of the proposed options. See http://www.environment.gov.au/protection/ozone/legislation#review for additional detail.

[190] Refrigerant Reclaim Australia. "program performance." Accessed August 2015. Link

## Appendix E. Supplementary Canada Information

Figure 4-3 lists an ICF International developed summary of RMC stakeholder responsibilities.

**Exhibit II-3: RMC Stakeholder Responsibility Chart**

| Stakeholder | Responsibility | Role |
|---|---|---|
| Manufacturers & Importers | Economic | Refrigerant manufacturers, importers and reclaimers remit a voluntary levy on the sales of virgin and reclaimed HCFC refrigerants. |
| Wholesalers | Physical, Economic | Wholesalers collect refrigerants from equipment service contractors or qualified refrigeration and air conditioning service contractors. Wholesalers record information on the RMC tag and store the refrigerant until a sufficient quantity is collected for shipment to an RMC CSP. The wholesaler also provides contractors with information on the program. |
| Collection Services Providers (CSP) | Physical | CSPs accept the refrigerant from the wholesaler. The CSP performs a variety of services for RMC, such as: perform purity and contaminate tests; bulk and store refrigerant; and prepare the refrigerant for shipment to an RMC approved disposal facility. In tracking all program refrigerants, CSPs are required to provide monthly activity reports to RMC. CSPs are subject to annual quality audits to ensure that their operations meet RMC's environmental standards. |
| Administrative Oversight Body | Physical, Economic, Informative | RMC, a non profit industry group, collects an environmental levy from the sales of virgin and reclaimed HCFCs and informs industry, the government and the public of the implementation and progress of the program. |
| Consumers | Physical | Consumers, in this case, are building owners and homeowners. When they hire qualified equipment service contractors or refrigeration and air conditioning service contractors to service their refrigeration equipment, the used ODS are managed for proper disposal through the program. |
| Federal Government | N/A | Canada's Federal Government has no direct responsibility for the operation of this program. Environment Canada has assisted industry by establishing a baseline of stockpiled CFCs. Environment Canada also participates in the board meetings. |
| Provincial and Territorial Governments | N/A | Provincial and Territorial Governments do not have any roles or responsibilities for this program. |
| Local Government | N/A | Local Governments do not have any roles or responsibilities for this program. |

Source: Environment Canada 2007.

**Figure 4-3. RMC Stakeholder Responsibility Chart[191]**

Table 4-7 lists Canada's fine schedule based on the Environmental Enforcement Act.

[191] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.

**Table 4-7. Canada's Fine Scheme under the Environmental Enforcement Act[192]**

| New Fine Scheme under the *Environmental Enforcement Act* | | | | | |
|---|---|---|---|---|---|
| Offender | Type of Offence | Summary | | Indictment | |
| | | Minimum | Maximum | Minimum | Maximum |
| **Individuals** | Most serious offences | $5 000 | $300 000 | $15 000 | $1 M |
| | Other offences | N/A | $25 000 | N/A | $100 000 |
| **Small Corporations & Ships under 7500 metric tons** | Most serious offences | $25 000 | $2 M | $75 000 | $4 M |
| | Other offences | N/A | $50 000 | N/A | $250 000 |
| **Corporations & Ships over 7500 metric tons** | Most serious offences | $100 000 | $4 M | $500 000 | $6 M |
| | Other offences | N/A | $250 000 | N/A | $500 000 |

Note: All fines doubled for second and subsequent offenses.

[192] Environment Canada. "Environmental Enforcement Act." Accessed October 2015. Link

## Appendix F. Supplementary California Information

Figure 4-4 summarizes CARB data on total refrigerant added to covered facilities.

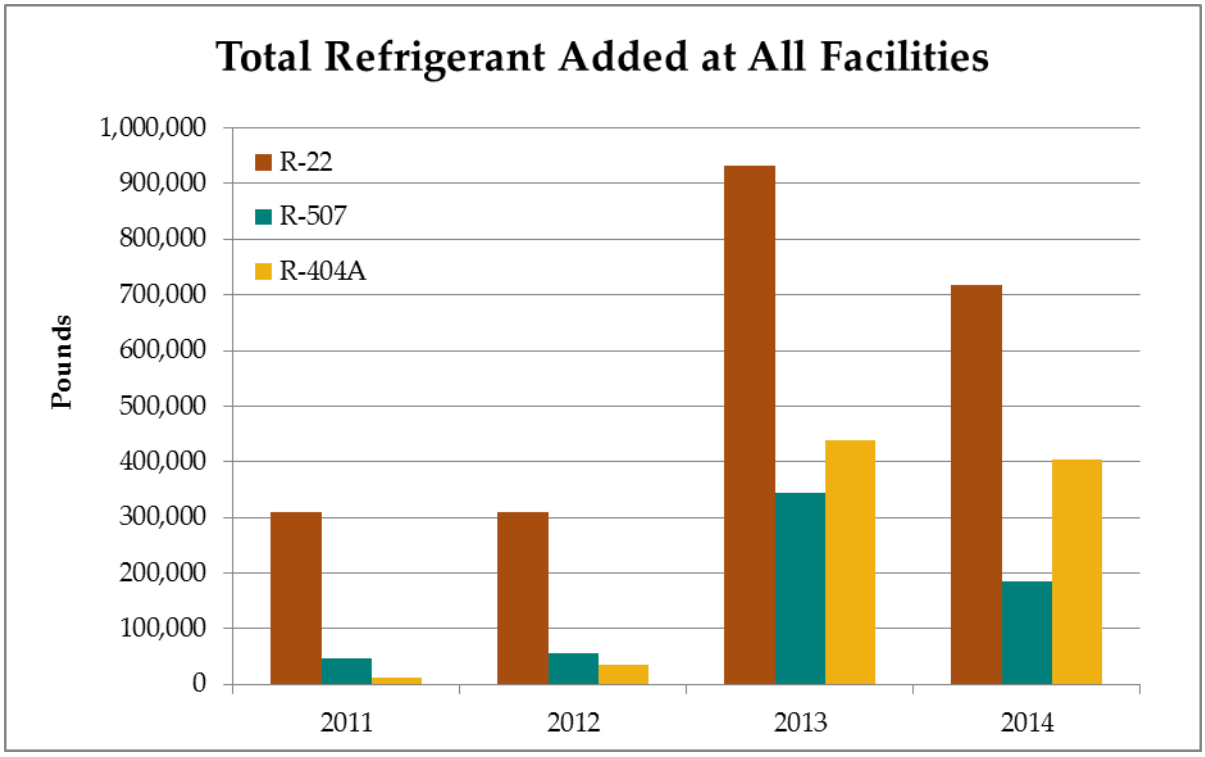



**Figure 4-4. Total Refrigerant Added at All RMP-Covered Facilities, 2011-2014**[193]

Figure 4-5 summarizes CARB data on total refrigerant purchased by and added to covered facilities.

[193] Aggregated RMP data provided by CARB.

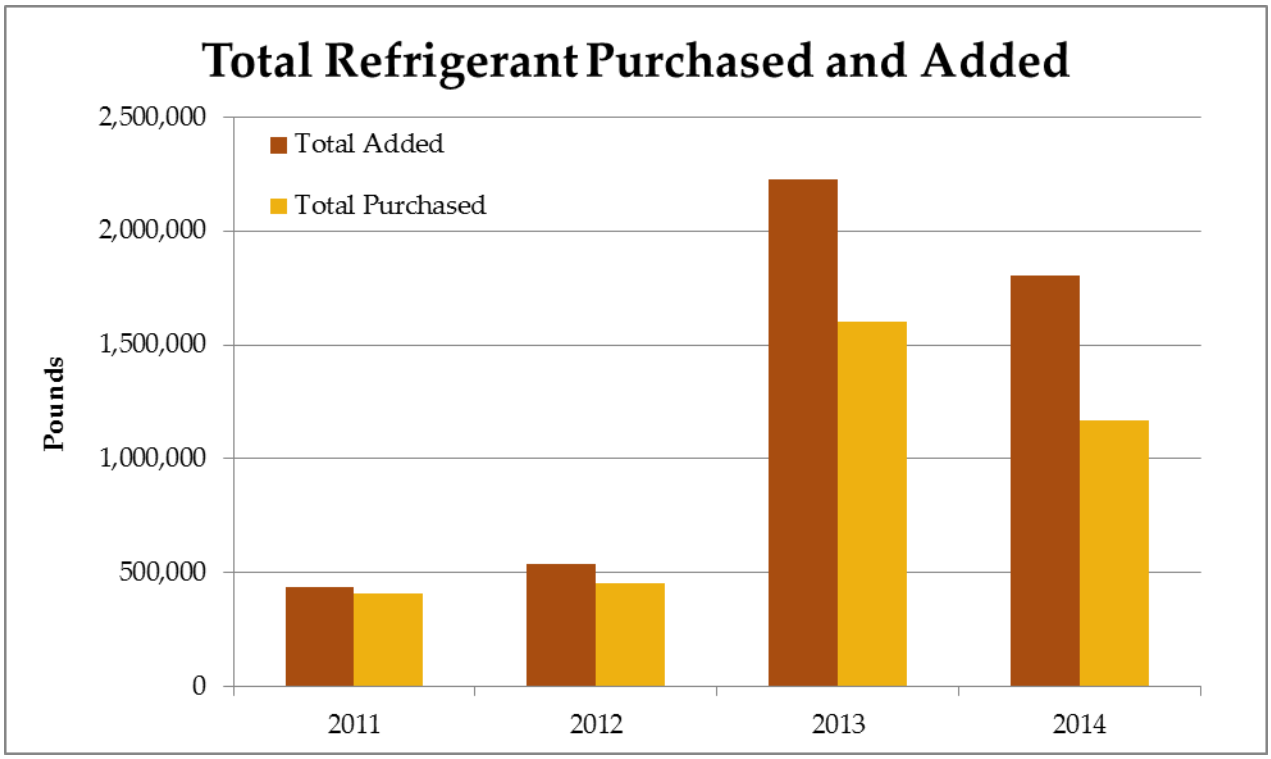



**Figure 4-5. Total Refrigerant Purchased and Added by RMP-Covered Facilities, 2011-2014[194]**

Figure 4-6 summarizes CARB data on total volume of refrigerant in covered facilities.

[194] Ibid.

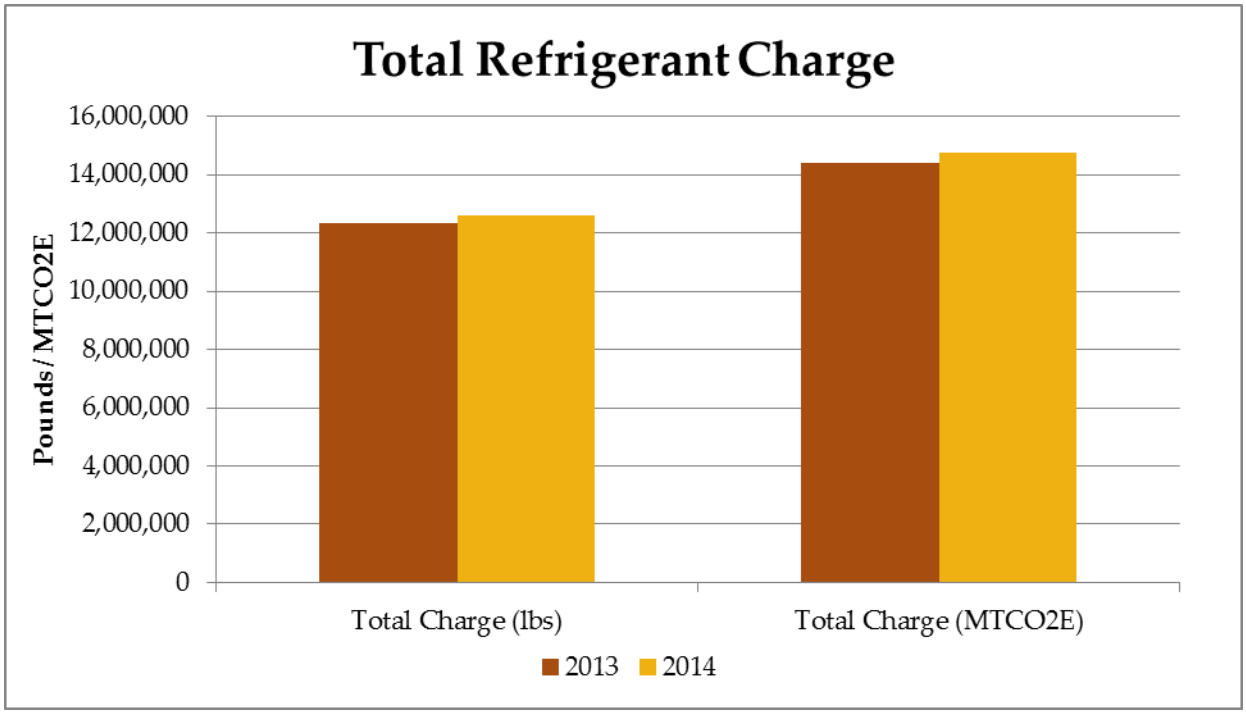



**Figure 4-6. Total Refrigerant Charge in lbs. and $MTCO_2e$ at RMP-Covered Facilities[195]**

Figure 4-7 and Figure 4-8 present CARB data on number of service records. Note that Figure 4-8 focuses on three key metrics: leak inspection, leak repair, and routine service. Also note that RMP received 44,849 and 57,212 service records in 2013 and 2014 respectively.

[195] Ibid.

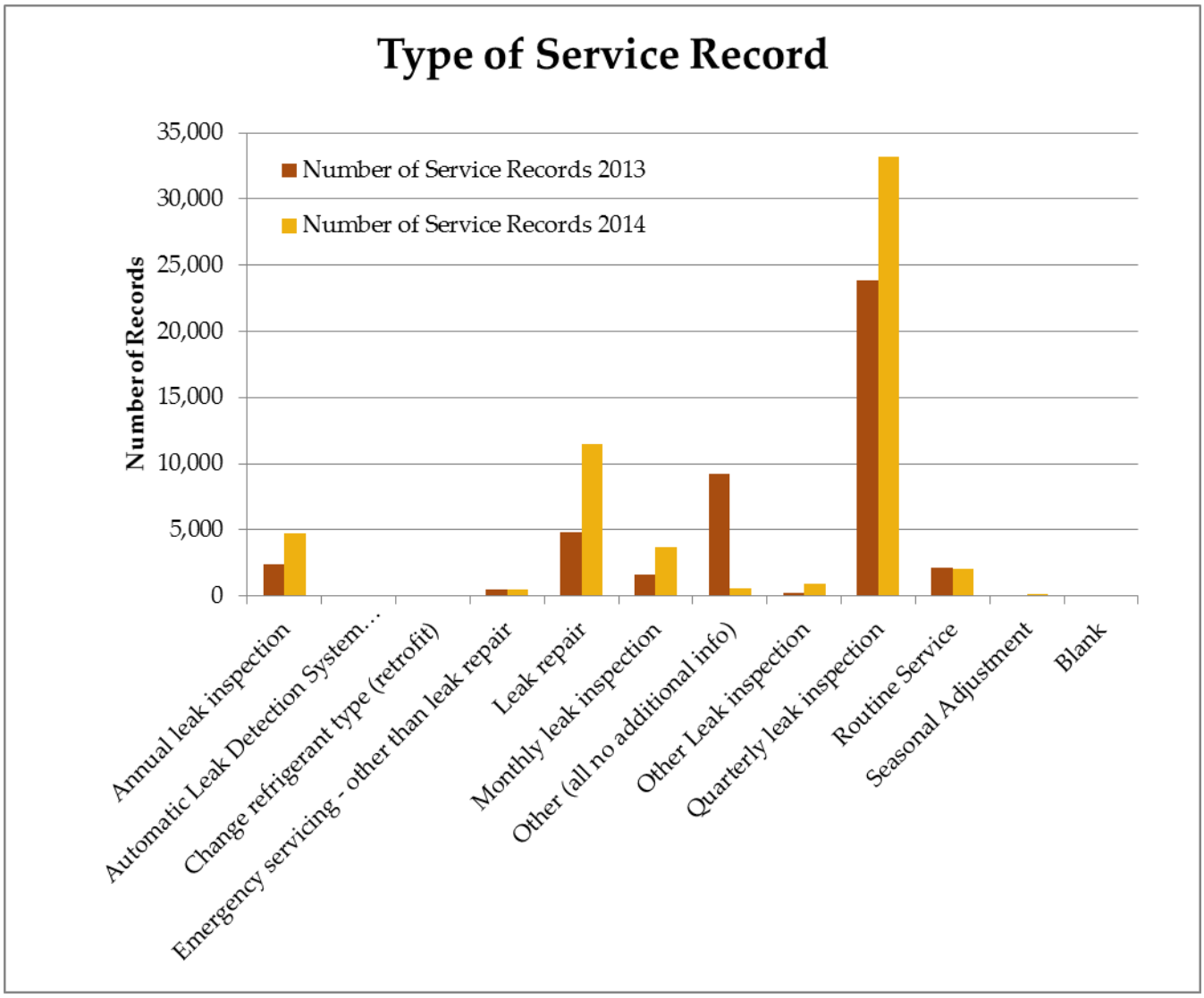



**Figure 4-7. CARB RMP Service Records, 2013-2014[196]**

[196] Ibid.

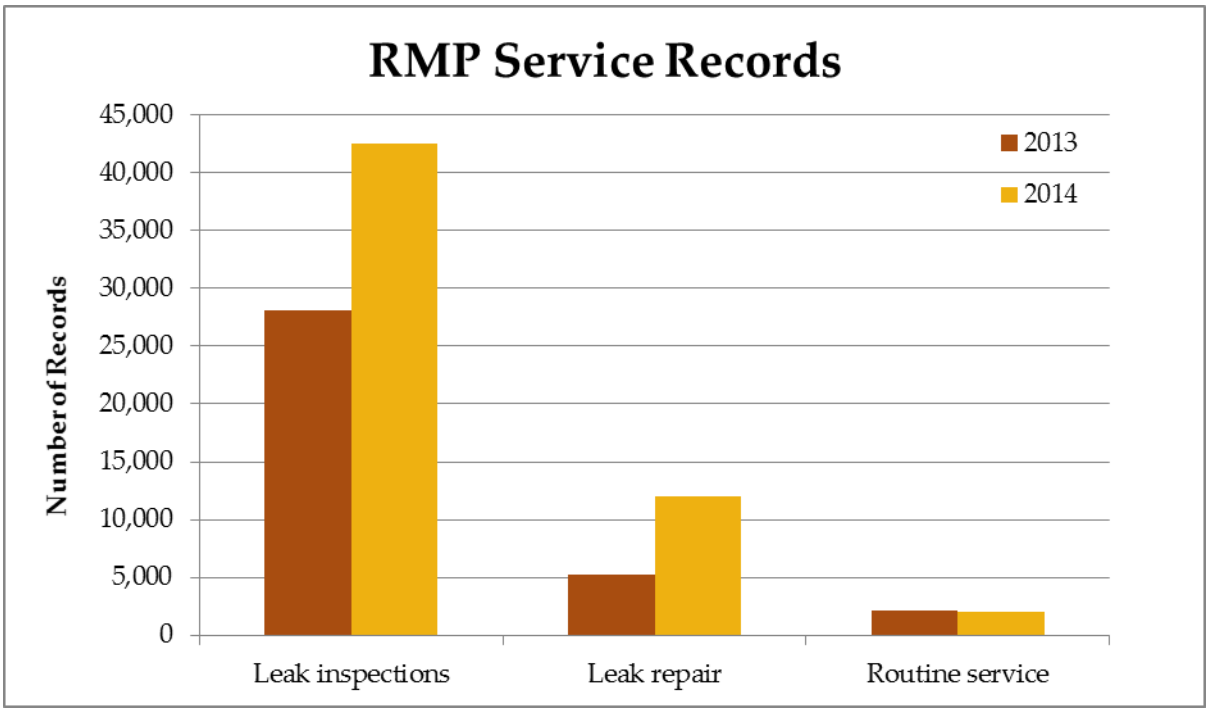



**Figure 4-8. Select CARB RMP Service Records, 2013-2014[197]**

[197] Ibid.

## Appendix G. Supplementary European Union Information

Summary of EU Equipment Bans:[198]

- From 2015
  - "HFCs with GWPs above 150 are banned in domestic fridges and freezers."
- From 2020
  - "HFCs with global warming potentials of more than 2,500 will be banned in all refrigeration systems."
  - "HFCs with GWP of more than 150 will be banned in movable air-conditioning (e.g. PAC)"
- From 2022
  - "All F gases with GWPs of more than 150 will be banned as the refrigerant…in any hermetically sealed system."
  - "F gases with GWPs of more than 150 will also be banned in central pack systems with a rated cooling capacity of 40 kW or more."
  - "Central pack systems involve several refrigerated display cases connected to a central refrigeration system located in a plant room, or outdoors."
  - Note: ban does not apply to "refrigeration systems used in industry, e.g. in chemical processes."
- From 2025
  - "From 2025 F gases with a global warming potential above 750 will be banned in 'single split' systems that contain less than 3 kg of refrigerant."
  - Note: "no bans for larger air-conditioning or heat pump systems, e.g. chillers or larger split systems."

[198] U.K. Department for Environment. "Guidance – Bans on F gas in new equipment." December 2015. Accessed September 2015. Link

Guidance for equipment operators

***Table 3: Overview of requirements in stationary equipment categories***

| Measure | Stationary refrigeration and AC | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Leakage prevention and repair as soon as possible (Art. 3) | ✓ | ✓ | ✓ | ✓ |
| Installation[13], maintenance or servicing of the equipment by certified personnel and companies (Art. 3) | ✓ | ✓ | ✓ | ✓ |
| Minimum frequency of leak checks by certified personnel (Art. 4) | | **12 mo.** (*) | **6 mo.** (*) | **3 mo.** (*) |
| Installation of leakage detection system which must be checked at least every 12 mo. (Art. 3) | | | | ✓ |
| Record keeping (Art. 6) | | ✓ | ✓ | ✓ |
| Recovery of F-gases before final disposal of the equipment, and when appropriate during maintenance or servicing, by certified personnel (Art. 8 and Art. 10) | ✓ | ✓ | ✓ | ✓ |
| Labelling of equipment (Art. 12) | ✓ | ✓ | ✓ | ✓ |

(*) If the stationary refrigeration or air conditioning equipment is equipped with a leakage detection system the frequency of leak checks doubles to 24 months, 12 months and 6 months for classes B, C and D, respectively.

***Table 4: Overview of requirements in mobile equipment categories***

| Measure | | Mobile refrigeration | | | Mobile AC | |
|---|---|---|---|---|---|---|
| | | MRX | MRA | MRB | MAX | MAC |
| Leakage prevention and repair as soon as possible (Art. 3) | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Installation, maintenance or servicing of the equipment by certified personnel and companies (Art. 3) | | | ✓ (*) | ✓ (*) | | |
| Minimum frequency of leak checks by certified personnel (Art. 4) | | | | **12 mo.** | | |
| Installation of leakage detection system which must be checked at least every 12 mo. (Art. 3) | | | | | | |
| Record keeping (Art. 6) | | | | ✓ | | |
| Recovery of F-gases before final disposal of the equipment, and when appropriate during maintenance or servicing (Art. 8 and Art. 10) | ...by certified personnel | | ✓ | ✓ | | |
| | ...by personnel with training attestation | | | | | ✓ |
| | ...by appropriately qualified personnel(**) | ✓ | | | ✓ | |
| Labelling of equipment (Art. 12) | | ✓ | ✓ | ✓ | ✓ | ✓ |

(*) Only servicing personnel must be certified, not servicing companies.
(**) Only necessary if technically feasible and no disproportionate costs are incurred (Article 8 (3) Regulation (EU) No 517/2014).

**Figure 4-9. EU Guidance for Equipment Owners of Stationary or Motor Vehicle Refrigerant Equipment[199]**

[199] European Commission. "Information for technicians and users of refrigeration, air conditioning and heat pump equipment containing fluorinated greenhouse gases." January 2015. Accessed September 2015.

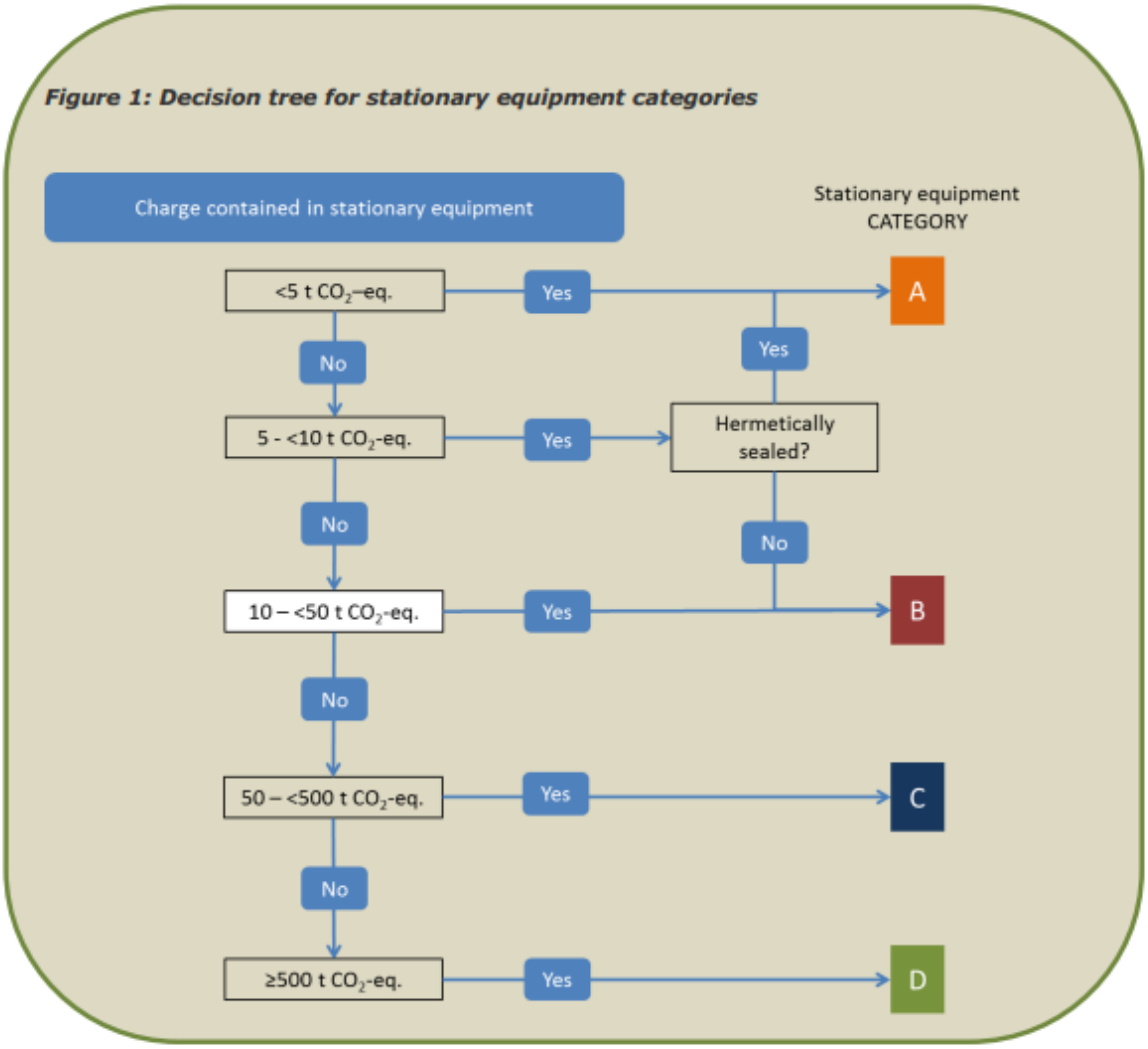
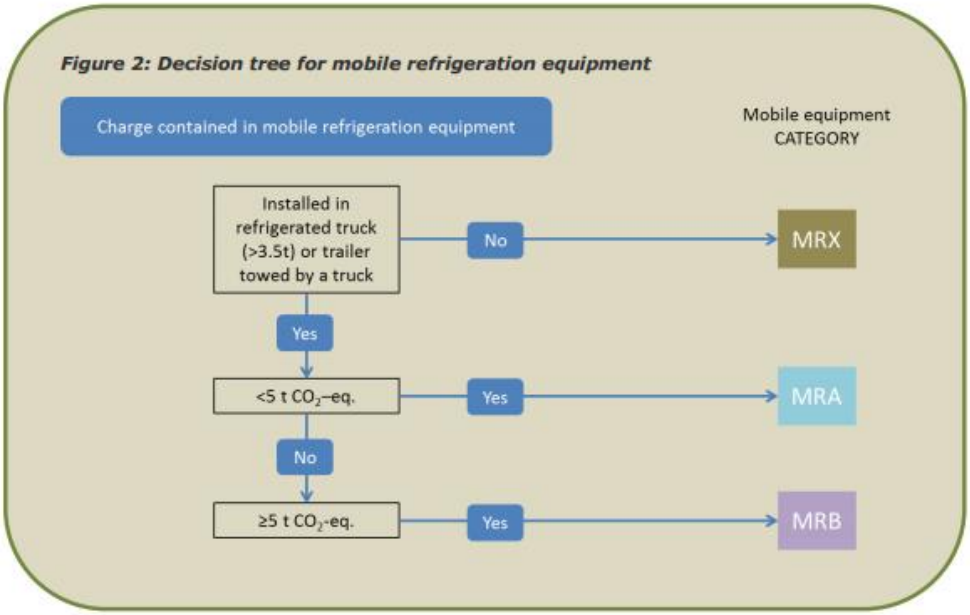



**Figure 4-10. EU Decision Tree to Classify Stationary Equipment Requirements[200]**

[200] Ibid.

Guidance for equipment operators



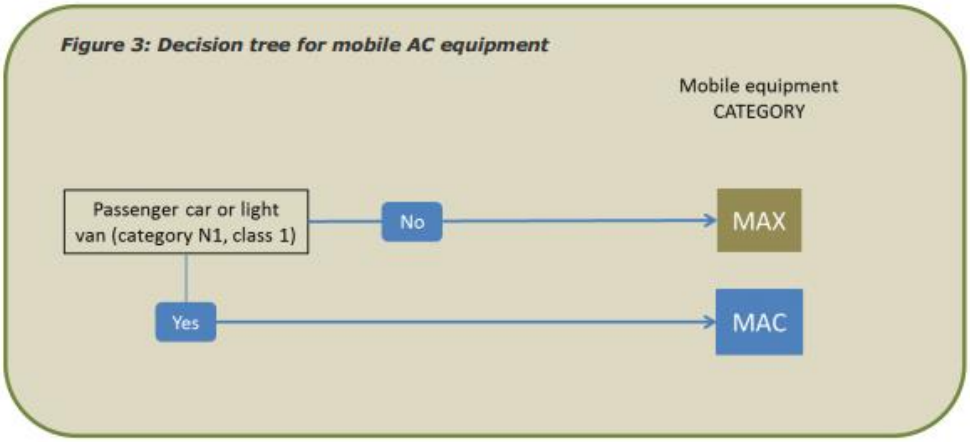




**Figure 4-11. EU Decision Tree to Classify Mobile AC Equipment Requirements[201]**

[201] Ibid.

***Table 5: Overview of minimum frequency of leakage checking***

| Equipment category | Stationary refrigeration and AC | | | Mobile refrigeration |
|---|---|---|---|---|
| | B | C | D | MRB |
| **Without** a properly functioning, appropriate leakage detection system in place | 12 months | 6 months | 3 months* | 12 months |
| **With** a properly functioning, appropriate leakage detection system in place | 24 months | 12 months | 6 months | 24 months |

(*) A leakage detection system which on detection alerts the operator is mandatory for applications containing a charge of 500 t $CO_2$-equiv. or more

**Figure 4-12. Overview of Minimum Leak Check Frequency in the EU[202]**

***Table 6: Activities on stationary RAC and mobile refrigeration equipment in refrigerated trucks and trailers that need to be carried out by certified servicing personnel and companies***

| Activity | Certified personnel (*) | Certified company |
|---|---|---|
| Installation | ✓ | ✓ |
| Maintenance or servicing | ✓ | ✓ |
| Leak checks of charge categories B, C, D and MRB | ✓ | |
| Recovery of F-gases | ✓ | |

(*) Certain exemptions are listed in Article 4 (3) of Commission Regulation (EC) No 303/2008.

**Figure 4-13. Summary of Motor Vehicle Service Activities that Require a Certified Technician in the EU[203]**

[202] Ibid.

[203] Ibid.

***Table 7: Personnel certification categories for all equipment categories***

| | Equipment categories A and MRA | | | Equipment categories B, C, D and MRB | | | | |
|---|---|---|---|---|---|---|---|---|
| | R | I | M | L1 | L2 | R | I | M |
| Category I | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Category II | ✓ | ✓ | ✓ | | ✓ | | | |
| Category III | ✓ | | | | | | | |
| Category IV | | | | | ✓ | | | |

**Note:** L1=Leak check including breaking into refrigeration circuit; L2=leak check without breaking into refrigeration circuit; R=Recovery; I=Installation; M=Maintenance or servicing

**Figure 4-14. Summary of Certification Categories and Permitted Activities in the EU[204]**

***Figure 4: F-gas phase down under the new Regulation***

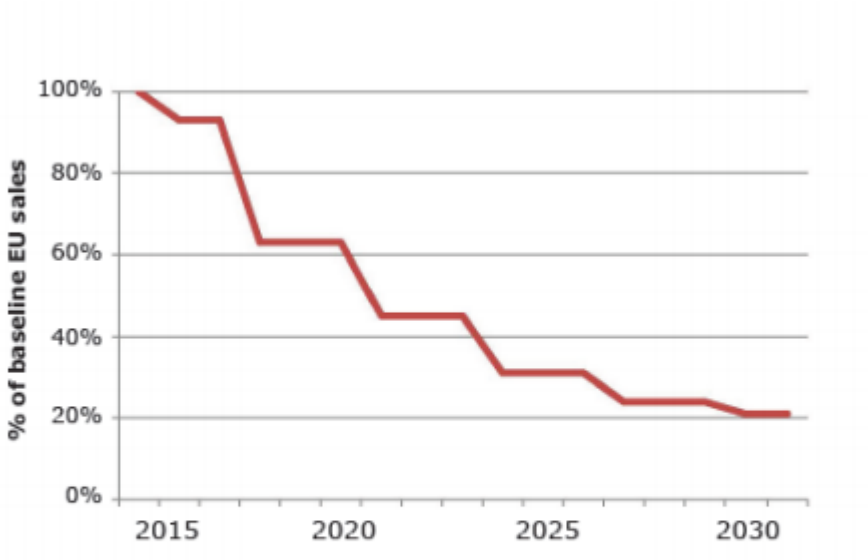



***Table 8: Phase down steps until 2030***

| 2009-12 | 2015 | 2016-17 | 2018-20 | 2021-23 | 2024-26 | 2027-29 | 2030 |
|---|---|---|---|---|---|---|---|
| Baseline (100 %) | 100 % | 93 % | 63 % | 45 % | 31 % | 24 % | 21 % |

**Figure 4-15 Summary of EU F Gas Phase Down[205]**

[204] Ibid.
[205] Ibid.

***Table 9: New equipment bans introduced in addition to those contained in Regulation 842/2006***

| Ban description | | Date of prohibition |
|---|---|---|
| Domestic refrigerators and freezers that contain HFCs with GWP of 150 or more | | 1 January 2015 |
| Refrigerators and freezers [...] for commercial use (hermetically sealed systems) | That contain HFCs with GWP of 2,500 or more | 1 January 2020 |
| | That contain HFCs with GWP of 150 or more | 1 January 2022 |
| Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2 500 or more except equipment intended for application designed to cool products to temperatures below – 50 °C | | 1 January 2020 |
| Multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1 500 may be used | | 1 January 2022 |
| Movable room air-conditioning equipment (hermetically sealed equipment which is movable between rooms by the end user) that contain HFCs with GWP of 150 or more | | 1 January 2020 |
| Single split air-conditioning systems containing less than 3 kg of fluorinated greenhouse gases, that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 750 or more | | 1 January 2025 |

**Figure 4-16 Summary of EU New Equipment Bans[206]**

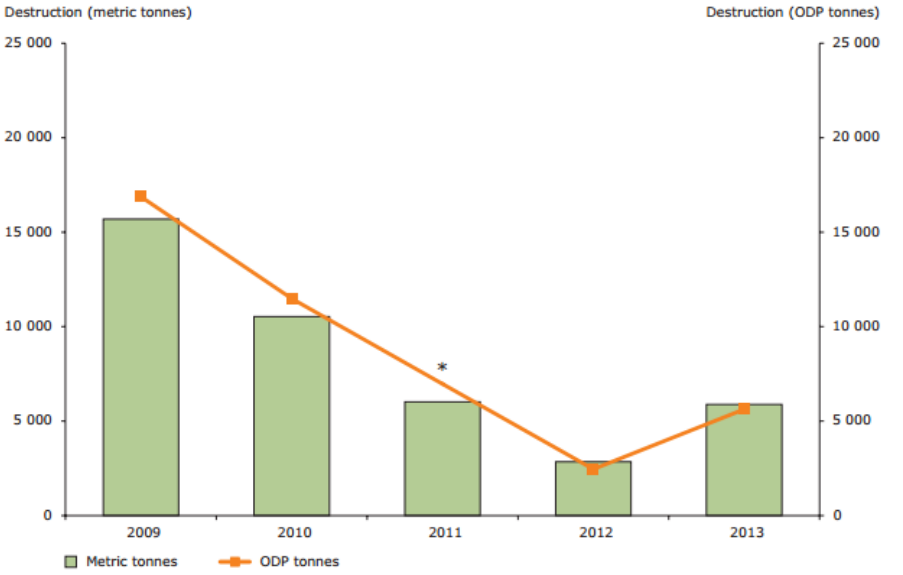
***Table 10: Charge size limits above which service and maintenance bans will apply with regard to the 40 t $CO_2$ equivalent threshold***

| Refrigerant | Charge size threshold (40 t $CO_2$-equiv.) |
|---|---|
| R23 | 2.72 kg |
| R404A | 10.20 kg |
| R507 | 10.04 kg |
| R422D | 14.66 kg |

**Figure 4-17. EU Charge Size Limits that will Trigger Service and Maintenance Bans[207]**

[206] Ibid.
[207] Ibid.

**Figure 2.6 Trend in the destruction of controlled substances within the EU**




**Note:** Destructed mixtures of ODS are excluded. Amount for 2011 (marked with *) in ODP tonnes is excluded for confidentiality reasons.

**Sources:** European Commission (DG CLIMA), 2006-2010; and EEA, 2011-2013.

**Figure 4-18. Summary of ODS Destruction in the EU[208]**

[208] EEA. "Ozone-depleting substances 2013" September 2014. Accessed August 2015.

**Table A.1.1 Production, import, export and destruction of controlled and new substances, EU, 2013 (metric tonnes)**

| | Production | Import | Export | Destruction * |
|---|---|---|---|---|
| CFCs | C | C | C | 1 059.688 |
| Halons | C | 100.293 | 36.703 | 14.243 |
| Other CFCs | C | - | - | C |
| CTC | 30 864.753 | C | C | 4 035.835 |
| TCA | C | C | C | C |
| HCFCs | 114 907.366 | 3 475.734 | 8 608.541 | 737.916 |
| HBFCs | C | C | C | - |
| BCM | - | C | - | - |
| MB | - | C | C | C |
| Total controlled substances | 163 664.494 | 8 501.483 | 11 622.477 | 5 883.409 |
| Halon-1202 | - | C | 0.003 | - |
| MC | C | 10 121.971 | C | - |
| EB | C | C | C | - |
| TFIM | - | C | C | - |
| n-PB | C | 1 014.324 | C | - |
| Total new substances | 1 122 116.609 | 11 187.680 | 5 898.488 | - |

**Note:** Additionally, mixtures of CFC, HCFC and HFC were destroyed in 2013, but are not included in the data.

* Destruction of new substances is not subject to reporting obligations under ODS Regulation (Regulation (EC) No 1005/2009)

C: For confidentiality reasons, data are not included.

**Figure 4-19. Summary of Controlled Substance Use in the EU[209]**

[209] Ibid.

# Appendix H. Supplementary Japan Information

## Table 4-8: Historical Recycling Fees Charged to Consumers in Japan[210]

**Exhibit V-4: Approximate Recycling Fees Charged to Consumers***

| Appliance | Fee (Yen) | Fee (Approximate US Dollars) |
|---|---|---|
| Air-conditioner | ¥3,000 | $26.50 |
| TV (CRT Types) | ¥2,700 | $24.30 |
| Refrigerator/Freezer | ¥4,600 | $41.40 |
| Washing Machine | ¥2,400 | $21.60 |

* Actual recycling fees may vary by manufacturer. Additional fees are charged by retailers for collection and transport.

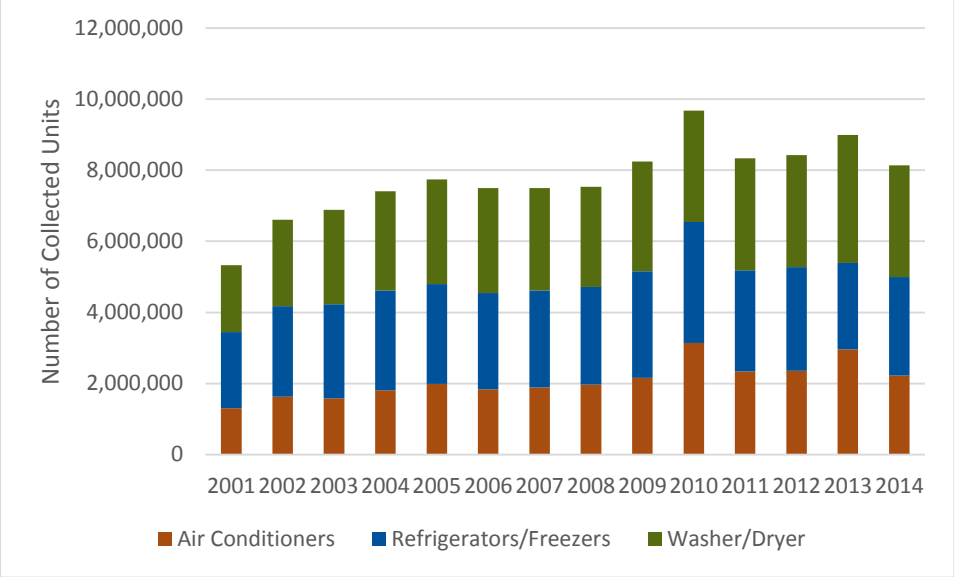



**Figure 4-20. Number of Household Appliances Collected for Recycling in Japan, 2001-2014[211]**

[210] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.
[211] Interview with representative of AEHA.

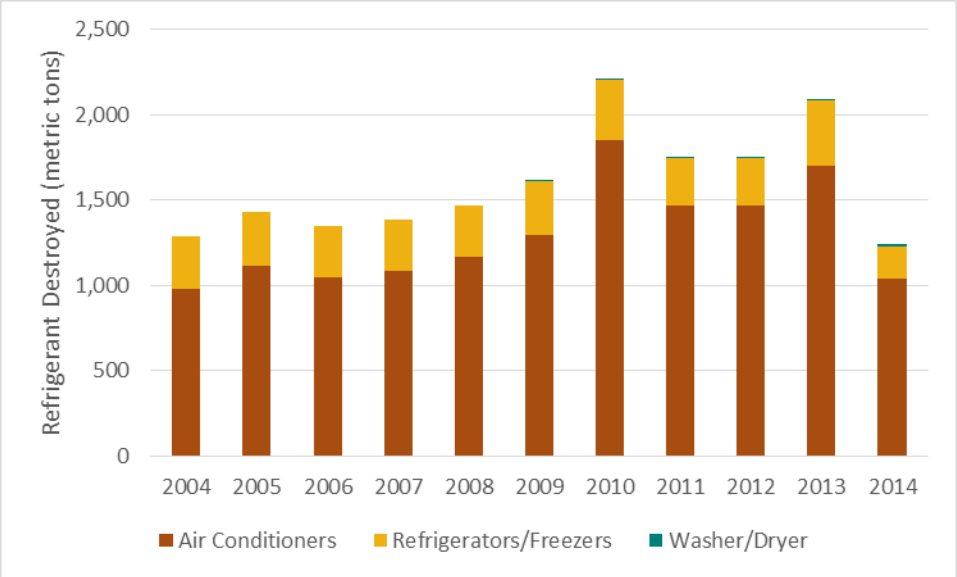



**Figure 4-21. Amount of Refrigerant Destroyed from Home Appliances in Japan, 2004-2014[212]**

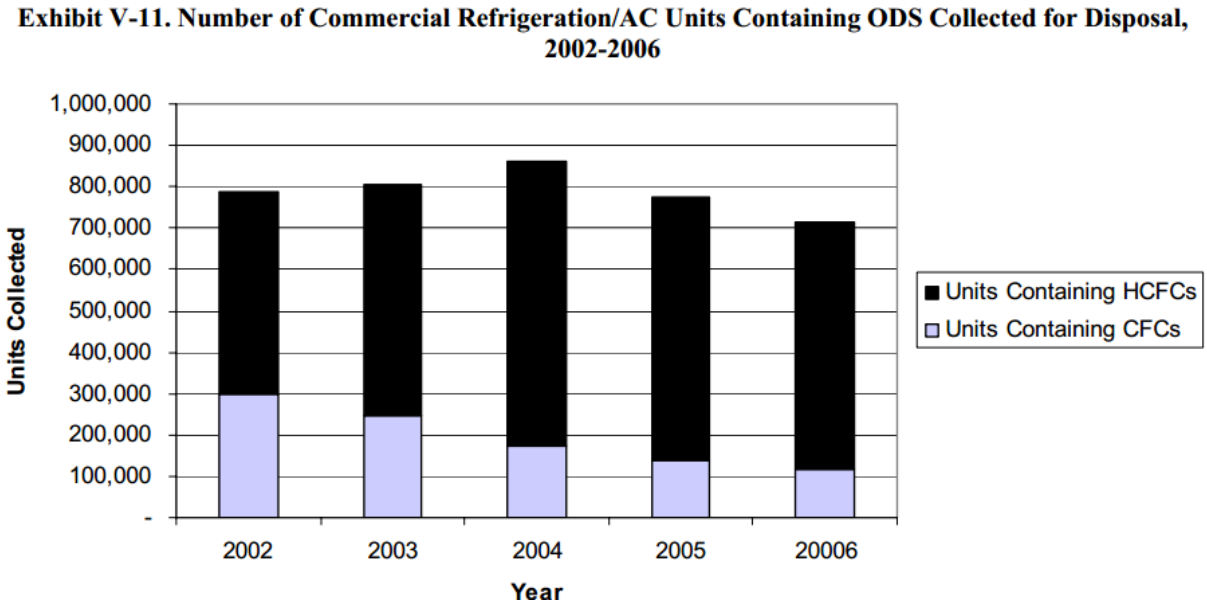



**Figure 4-22. Number of Commercial Refrigeration/AC Units Containing ODS Collected for Disposal in Japan, 2002-2006[213]**

[212] Interview with representative of AEHA.

[213] ICF International, "Study on the Collection and Treatment of Unwanted Ozone-Depleting Substances in Article 5 and Non-Article 5 Countries." May 2008. Accessed August 2015.

# Appendix I. Supplementary U.K. Information

**Table 4-9. U.K. Leak Check Requirements[214]**

| Maximum interval between leak checks | $CO_2e$ (metric tons) |
|---|---|
| 3 months | 500 |
| 6 months | 50 |
| 1 year | 5 |

[214] U.K. Department for Environment. "Guidance – F gas in refrigeration, air conditioning and fire protection systems." December 2015. Accessed September 2015. Link

## Appendix J. Supplementary U.S. Information

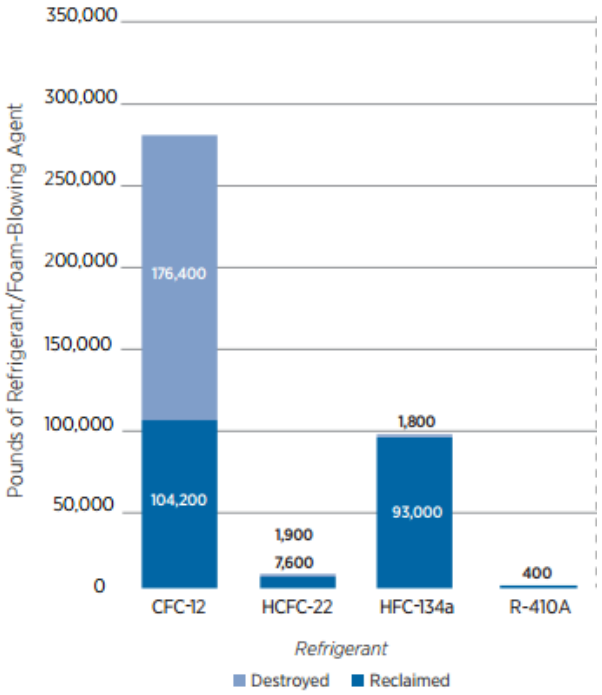



**Figure 4-23. Refrigerants Reclaimed and Destroyed by EPA RAD Partners in 2013**[215]

[215] EPA. "RAD 2013 Annual Report." Accessed August 2015.

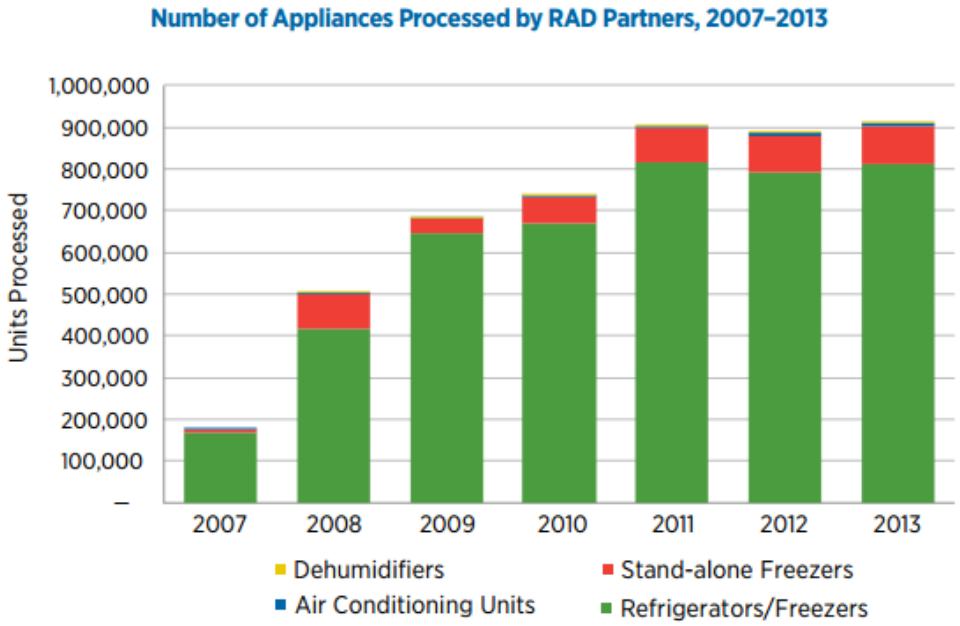



**Figure 4-24. Number of Appliances Processed by EPA RAD Partners, 2007-2013** [216]

Note: numbers based on a total estimate of 11.1M Refrigerators, 5.8M window air conditioners, and 800,000 dehumidifiers.

[216] Ibid.