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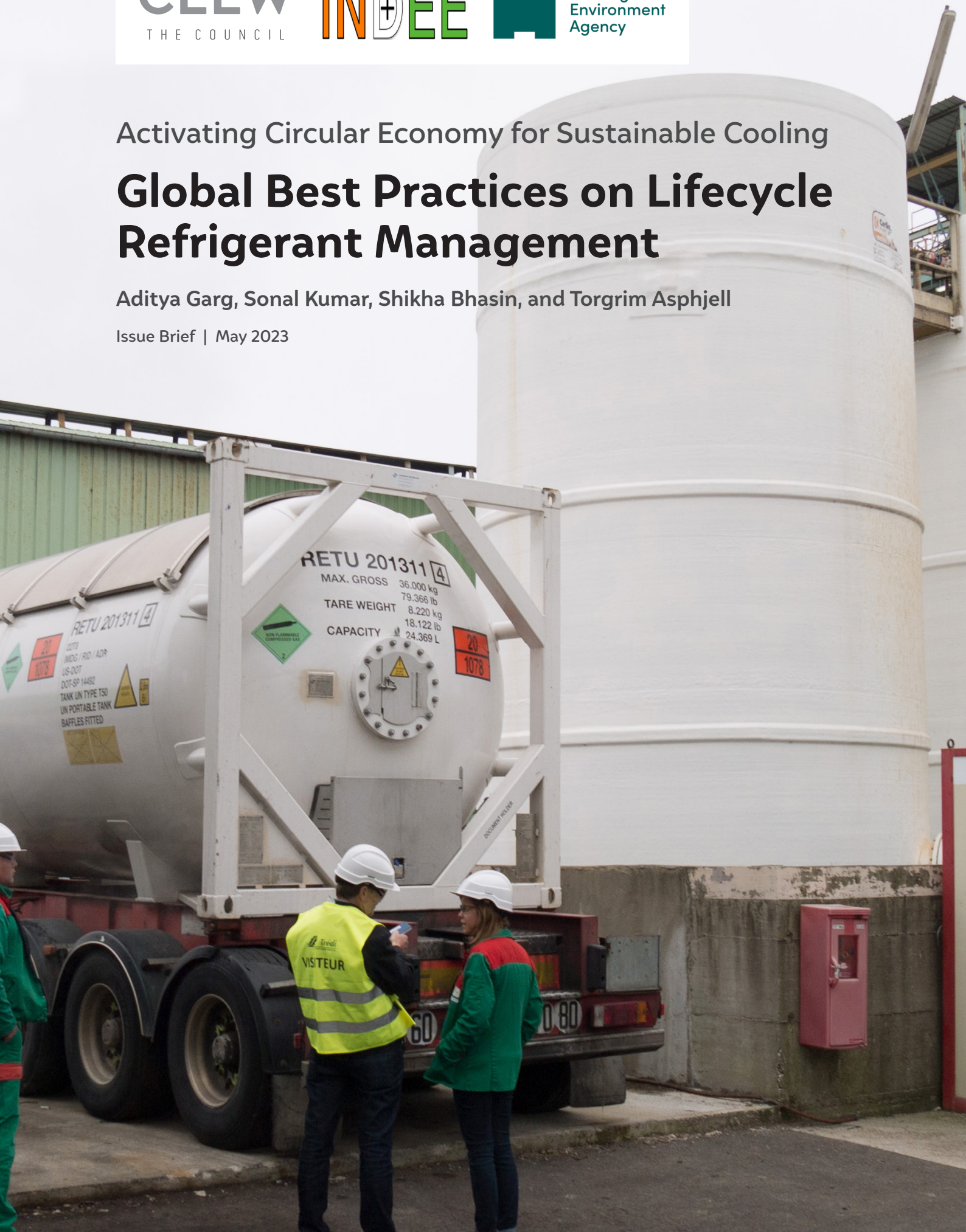
Norwegian Environment Agency

Activating Circular Economy for Sustainable Cooling

Global Best Practices on Lifecycle Refrigerant Management

Aditya Garg, Sonal Kumar, Shikha Bhasin, and Torgrim Asphjell

Issue Brief | May 2023



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About the report: This issue brief on *Global Best Practices on Lifecycle Refrigerant Management* is part of a series of publications on on "Activating Circular Economy for Sustainable Cooling" through lifecycle refrigerant management under the INDEE+ project. The publication series offers a comprehensive analysis of refrigerant management practices in India and globally, including a case study of Norway's legislation, proposals for effective implementation in India, and innovative business models.

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Organisations: The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*, including being ranked as South Asia's top think tank (15th globally) in our category for the eighth year in a row. The Council has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

Future Refrigeration India (INDEE+) is an umbrella project, focused at enhancing the use of natural refrigerants, and lifecycle management of refrigerant gases having ozone depletion and high global warming potential. Overall, this project aims to achieve the goals of the ratified Kigali Amendment of the Montreal Protocol. Under this project, CEEW and NEA have collaborated to support the lifecycle management of highly potent refrigerants in an environmentally sound manner in India. This project will focus on the lifecycle management of the refrigerants used in the various cooling systems.

The **Norwegian Environment Agency (NEA)** is a government agency under the Ministry of Climate and Environment, Government of Norway. The NEA employs over 700 personnel across two offices stationed in Trondheim and Oslo and at the Norwegian Nature Inspectorate's (SNO) sixty local offices. NEA's primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

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About CEEW

The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions and one of the world's leading climate think tanks. **The Council uses data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources.** The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public.

The Council's illustrious Board comprises Mr Jamshyd Godrej (Chairperson), Mr Tarun Das, Dr Anil Kakodkar, Mr S. Ramadorai, Mr Montek Singh Ahluwalia, Dr Naushad Forbes, Ambassador Nengcha Lhouvum Mukhopadhaya, and Dr Janmejaya Sinha. The 140-plus executive team is led by Dr Arunabha Ghosh. CEEW was certified a **Great Place To Work® in 2020 and 2021**.

In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report*, including being ranked as **South Asia's top think tank (15th globally) in our category for the eighth year in a row**. CEEW has also been ranked as South Asia's top energy and resource policy think tank for the third year running. It has consistently featured among the world's best managed and independent think tanks, and twice among the world's 20 best climate think tanks.

In twelve years of operations, The Council has engaged in nearly 400 research projects, published 320+ peer-reviewed books, policy reports and papers, created 160+ databases or improved access to data, advised governments around the world 1100+ times, promoted bilateral and multilateral initiatives on 110+ occasions, and organised 460+ seminars and conferences. In July 2019, Minister Dharmendra Pradhan and Dr Fatih Birol (IEA) launched the CEEW Centre for Energy Finance. In August 2020, Powering Livelihoods — a CEEW and Villgro initiative for rural start-ups — was launched by Minister Mr Piyush Goyal, Dr Rajiv Kumar (NITI Aayog), and H.E. Ms Damilola Ogunbiyi (SEforAll).

The Council's major contributions include: The 584-page *National Water Resources Framework Study* for India's 12th Five Year Plan; *the first independent evaluation of the National Solar Mission*; India's first report on global governance, submitted to the National Security Adviser; irrigation reform for Bihar; the birth of the Clean Energy Access Network; work for the PMO on accelerated targets for renewables, power sector reforms, environmental clearances, *Swachh Bharat*; pathbreaking work for the Paris Agreement, the HFC deal, the aviation emissions agreement, and international climate technology cooperation; the concept and strategy for the International Solar Alliance (ISA); the Common Risk Mitigation Mechanism (CRMM); critical minerals for *Make in India*; modelling uncertainties across 200+ scenarios for India's low-carbon pathways; India's largest multidimensional energy access survey (ACCESS); climate geoengineering governance; circular economy of water and waste; and the flagship event, Energy Horizons. It recently published *Jobs, Growth and Sustainability: A New Social Contract for India's Recovery*.

The Council's current initiatives include: A go-to-market programme for decentralised renewable energy-powered livelihood appliances; examining country-wide residential energy consumption patterns; raising consumer engagement on power issues; piloting business models for solar rooftop adoption; developing a renewable energy project performance dashboard; green hydrogen for industry decarbonisation; state-level modelling for energy and climate policy; reallocating water for faster economic growth; creating a democratic demand for clean air; raising consumer awareness on sustainable cooling; and supporting India's electric vehicle and battery ambitions. It also analyses the energy transition in emerging economies, including Indonesia, South Africa, Sri Lanka and Vietnam.

The Council has a footprint in 22 Indian states, working extensively with state governments and grassroots NGOs. It is supporting power sector reforms in Uttar Pradesh and Rajasthan, scaling up solar-powered irrigation in Chhattisgarh, supporting climate action plans in Gujarat and Madhya Pradesh, evaluating community-based natural farming in Andhra Pradesh, examining crop residue burning in Punjab, promoting and deploying solar rooftops in Delhi, Bihar and Jharkhand.

Contents

Refrigerant recovery, reclamation, and reuse are essential to reduce demand of virgin potent refrigerants, promote circular economy, and combat climate change.

Image: Stena Recycling

Summary

Reducing refrigerant emissions helps safeguard the environment and the stratospheric ozone layer. Refrigerants are often colourless and odourless, unlike other environmentally harmful waste or emissions, making violations (such as discharging them into the air) simple to cover up and challenging to trace. Several laws and initiatives are in place worldwide in numerous nations to reduce refrigerant emissions and encourage refrigerant management.

Around the world, there are several refrigerant management programmes and strategies. Some nations, including Australia, Japan, and Norway, rely on solid regulatory regimes that regulate refrigerants from upstream to downstream. Others, including New Zealand, Denmark, and the US, combine voluntary initiatives with less stringent requirements. Variables, such as cultural, climatic and market variations, influence these strategies. Unfortunately, evaluating the strictness and efficiency of these programmes is exceedingly challenging.

This issue brief identifies and makes sense of the international laws, policies, mechanisms, and infrastructure that govern refrigerant lifecycle management. A study trip to Norway was included to better understand the infrastructure and overall regulatory system that facilitates refrigerants recovery, collection, and destruction there. The issues covered in this review include business models, regulations, policies governing the operational equipment management and the end-of-life (EOL) disposal of refrigerants and appliances, and the lessons India may use to manage refrigerants over their lifetimes.

The conclusion of this issue brief is that sector-specific stringent regulations accompanied by a robust monitoring and reporting mechanism plays a critical role in limiting refrigerant lifecycle emissions. Additionally, voluntary actions by the industry, incentives to waste handlers to recover the refrigerant, licensing of refrigerant handlers, and the infrastructure act as supportive measures. Limiting refrigerant emissions is a challenging task to achieve and will require a mix of the above-mentioned measures used globally.

> **The Montreal Protocol does not regulate emissions from banks, which might be due to practical and techno-economic challenges.**

1. Introduction

Ozone-depleting substances (ODS), such as chlorofluorocarbons (CFCs), are being phased out of production and consumption worldwide as part of the Montreal Protocol on Substances that Deplete the Ozone Layer, which was finalised in 1987. Due to the phase-out of ODS, substitute substances, including hydrochlorofluorocarbons (HCFCs) and later hydrofluorocarbons (HFCs), were introduced. Although HFCs do not deplete stratospheric ozone, many are potent greenhouse gases with a high global warming potential (GWP). Because of this, even modest atmospheric quantities of these gases can significantly impact the Earth's temperature. The Kigali Amendment to the Montreal Protocol, which aims to phase down the HFCs with the highest GWP in the following decades, was eventually adopted as a result. Without the Kigali Amendment, HFC emissions will lead to a 0.5°C increase in global temperatures by 2100, whereas its effective implementation could limit this increase to 0.06°C (UNEP IEA 2020). In light of the Paris Agreement's mandate to keep warming to well below 2°C and strive for no more than 1.5°C, this differential of up to 0.44°C is significant.

A significant quantity of these refrigerants is present in equipment and systems, including domestic refrigerators and air conditioners, stockpiles stored by countries, and industrial and commercial applications, while global phase-out of production and new use of potent refrigerants is in progress. These quantities are referred to collectively as 'banks'. If the refrigerants from these banks are not recovered and appropriately treated, they could be leaked or vented, over time, into the atmosphere. The Montreal Protocol does not regulate emissions from banks, which might be due to practical and techno-economic challenges. However, many nations have voluntary or regulatory measures to decrease refrigerant emissions both during operation and at the EOL of these goods and equipment. The fluorocarbon emissions are projected to account for 72 billion t-CO_2 eq in the next 40 years if concrete steps on refrigerant emissions are not taken in the particular middle (operational life) to downstream (EOL) of the lifecycle of refrigerants (CCAC UNEP 2020). Thus, it becomes essential to control and treat refrigerant banks through refrigerant management practices.

2. Norway: Tax and refund scheme

Financial inducements are thought to boost the returns of refrigerants for destruction in Norway. Norway has implemented a method for tax refunds if the refrigerants are delivered for destruction due to high import duties. The gas is analysed before being destroyed to guarantee proper refund and paperwork because the tax rate relies on the GWP of the gas. These sums serve as the foundation for calculating Norway's recovery.

2.1 Policy initiative

Norway is phasing out CFCs, the transitional substances in the HCFC group and other relatively low ODS as per the reduction targets for non-Article 5 countries under the ambit of the Montreal Protocol. The situation now is that natural or synthetic refrigerants with low GWP are gradually replacing HFCs with a lower contribution to global warming.

Norway is not a member of the European Union but is connected to the union by the European Economic Area (EEA) Agreement. This facilitates the implementation of EU regulations in Norway. The EU regulations and directives on ODS, fluorinated gases (F-gases), waste and industrial pollution are incorporated into Norwegian national regulation. In addition, Norway has implemented some domestic-only regulations and measures.

Norway introduced the first regulations to limit the import and use of CFCs in 1979. Subsequent legislation was adopted to include the other ODS. These had requirements that the used ODS could be handed in for safe destruction free of charge. This resulted in the establishment of the Norwegian Foundation for Refrigerant Recovery (SRG). Norway implemented the EU regulations on ODS, including Regulation No. 2037/2000 in 2002 and the revised Regulation No. 1005/2009 in 2013 (EU 2000). This latter regulation introduced further restrictions on using all ODS controlled under the Montreal Protocol to ensure a complete phase-out of the substances according to the obligations under the Protocol.

The EU F-gas regulation was adopted by the EU in 2006 and implemented in Norwegian national legislation in 2010 (EU 2006). The intention behind the regulation is to limit the emissions of HFCs, PFCs and SF_6 through containment, recovery, and restrictions of use in products, equipment, and applications. The regulation is supplemented by implementing regulations on topics such as leakage checking, labelling, reporting and certification.

According to the F-gas regulation, HFC refrigerants shall be adequately recovered by certified personnel from all stationary refrigeration and air-conditioning equipment, and SF_6 shall be recovered from gas-insulated switchgear (GIS). Recovery is mandatory for most other gases and uses, with foam-blowing agents being the most notable exception.

A revised EU F-gas regulation entered into force in the EU in 2015. This regulation introduced further measures to reduce emissions, including a phase-down scheme for HFCs. Norway implemented this regulation in 2018, as well as its own phase-down scheme in accordance with its compliance obligations with the Montreal Protocol. While the F-gas regulation constitutes a solid legal basis for the recovery of gas, Norway has also established a domestic incentive through a tax and refund scheme for HFCs and PFCs. All imports of HFCs and PFCs in bulk and in products are taxed.

The tax also applies to production, but since Norway has no domestic production of HFCs and PFCs (or any other F-gas), it is, in practice, to tax imports. The level of the tax is according to the GWP of the gas and is tied to the CO_2 tax for mineral oils. It was NOK 766 (INR 6,311) per GWP-weighted tonnes in 2022. The tax is refunded to those who deliver HFCs or PFCs for destruction. There is no documentation requirement that the tax was paid. But there are detailed requirements regarding documentation of the amount and composition of the gas destructed.

The requirements as regards the treatment of the waste gases after recovery from products and equipment is found in the national waste regulation directive, which covers the collection, recycling, destruction, export and other aspects as regards all types of waste. This is primarily based on the EU Waste Framework Directive and implementing acts (EU Directive 2008).

Waste CFCs, HCFCs and HFCs in bulk or in waste electric or electronic products (WEEE) are classified as hazardous waste and have specific requirements for storage, transport, and treatment applications. Personnel handling the waste shall have documentable adequate skills, and undertakings shall have a permit to handle hazardous waste and deliver the waste to an approved undertaking at least once a year.

> **Financial inducements are thought to boost the returns of refrigerants for destruction in Norway.**

2.2 Implementation mechanism and reverse logistics

A system for collection, recycling and other treatment of WEEE was established in Norway in 1999. This system is based on the Extended Producer Responsibility (EPR), which requires that all importers and producers of relevant products must be a member of a producer responsibility organisation, which is responsible for establishing and operating a system for the collection and treatment of WEEE. Household appliances such as fridges, freezers and domestic air conditioners or heat pumps (domestic AC/HP), as well as smaller gas-insulated switchgear (GIS) containing SF_6, can be handed in free of charge at collection facilities for subsequent environmentally sound treatment. The regulation specifies that CFCs, HCFCs, HFCs, and other gases that are ozone-depleting or have a GWP of more than 15 shall be recovered at an early stage in the treatment process.

For the collection of the EOL vehicles, a similar producer responsibility scheme has been established. The regulation requires that vehicles shall be delivered free of charge. As an extra incentive, compensation is being paid to those delivering the car, financed by governmental subsidies. In 2022 this amounted to NOK 3000 (INR 24,000) for a passenger car.

Enterprises that collect, treat, or destroy waste gases or other waste need an emission permit to operate. These permits, which come in addition to the specific legislation on F-gases and ODS and the general regulations on waste, set specific requirements for the operation and management of the plant. All undertakings with emission permits are audited regularly, evaluating all aspects of the permits as well as compliance to relevant regulations.

In addition to the environmental regulation, other legislation and policy, on safety and working environment in particular, is also essential and will indirectly affect environmental performance as well.

In Norway, there are primarily three companies involved in the recovery and collection of gas on a large scale, commercial basis, and each of them has a somewhat different approach:

- Norwegian Foundation for Refrigerant Recovery (SRG) is the sole commercial provider of refund for HFCs in bulk, and its operations are, to a large degree, financed by the governmental refund scheme. SRG has a subsidiary, Isovator, that analyses the gas eligible for refunds or for other purposes. Isovator also issues mandatory F-gas certificates for personnel and companies and training attestations on behalf of the government.
- Stena Recycling is a company that treats all kinds of WEEE. It serves as a collection point for WEEE and surplus SF_6 in cylinders. Home appliances and small commercial appliances, such as refrigerators, freezers and domestic AC/HP, are sent to their facility in Sweden, where refrigerants and foam-blowing agents are recovered and destroyed on-site. At the facility in Norway, they also have a vacuum chamber for the complete recovery of SF_6 from medium-voltage GIS.
- Revac is another company specialising in the treatment of WEEE. In addition to recycling other WEEE, they have a separate line for refrigeration devices containing refrigerants. This fridge line at REVAC is responsible for the collection of refrigerants from freezers and fridges, and foam-blowing agents from insulation used in some of these appliances.

Most of the first-line collection of products containing ODS and F-gases is done by municipal waste companies, local retailers in the case of WEEE, car collection sites or businesses in the refrigeration and air conditioning (RAC) sector. Businesses in the RAC sector also collect gas recovered on-site in cylinders for delivery into the SRG system.

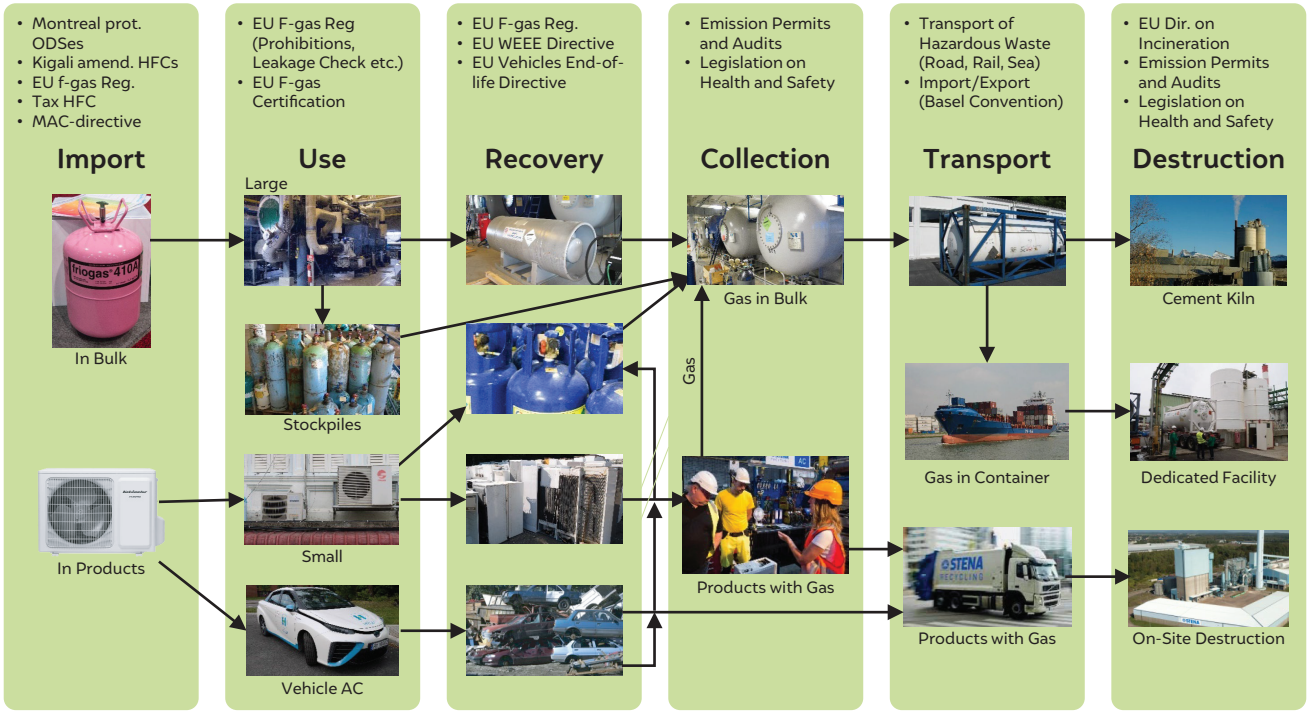
Norway has the technical capacity to destroy refrigerants by co-processing in cement kilns. However, for logistical reasons, today, all ODS and F-gases collected in Norway are sent to other European countries for destruction or, possibly, reclamation, as is the case for halons.

Destruction is done thermally by incineration or by high-temperature plasma arc technology. Only ODS and HFC destruction technologies approved by the Montreal Protocol are used and the facilities are covered by the EU directive on the incineration of waste.

Norway through its tax and refund scheme has been successful in destroying up to 1200 MT of used refrigerants in the period of 2009-21 (CCAC 2021).

> **Norway has implemented a method for tax refunds if the refrigerants are delivered for destruction.**

Figure 1 Refrigerant lifecycle management mechanism in Norway from a cradle-to-grave perspective



Source: Authors' analysis

3. New Zealand: Recovery – A product stewardship scheme

The product stewardship scheme, Recovery, supplemented by advanced destruction fees and strict regulations, has been instrumental in managing refrigerant emissions in New Zealand. The recovery centres across the country have expanded the reach of technicians, servicing agencies and the EOL handlers to deposit the recovered refrigerant, thereby increasing refrigerant collection and destruction.

3.1 Policy initiatives

The Ozone Layer Protection Regulations 1996 governs the production, consumption, and import of fluorocarbons in New Zealand (New Zealand Legislation 2018). To lessen the emissions of fluorocarbons to the atmosphere, it also promotes their responsible management and handling. Additionally, it has implemented the permit system for exporting virgin HFCs and importing recycled HFCs. According to New Zealand's plan, consumption of HFC is to be reduced by more than 80 per cent by 2037, and imports are to be significantly reduced (New Zealand Legislation 2018). There is a cap on the amount of new bulk HFCs that can be imported for a given calendar year, determined by the number of permits issued. The majority of the refrigerants are imported into New Zealand because there is currently no refrigerant production there. This import streams primarily in bulk or in different pre-charged cooling devices (Synthetic Refrigerant Stewardship 2019).

The management of used fluorocarbons coming from the EOL of the devices is controlled by the Waste Minimisation Act of 2008 (Ministry for the Environment 2008). Refrigerants must be recovered from decommissioned cooling appliances because not doing so is prohibited (by the Ozone Layer Protection Act 1996) and has consequences. Since 1993, a product stewardship programme called Recovery—The Trust for the Destruction of Synthetic Refrigerants has been in place in New Zealand to ensure the safe disposal of refrigerants (Recovery 2020).

3.2 Implementation mechanism and reverse logistics

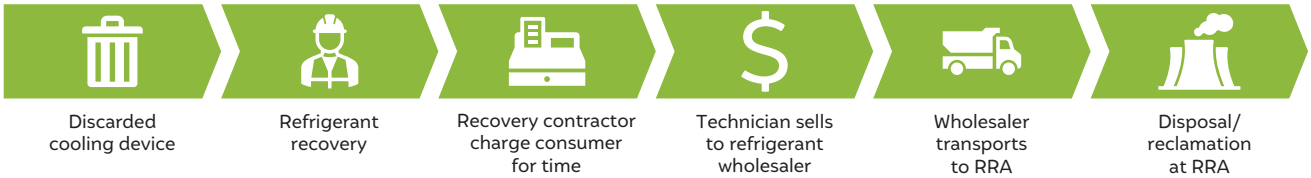
Participants in the product stewardship programme Recovery are accountable for the environmental effects of their products and factor these costs into their production, purchase, and disposal decisions. The majority of large-scale refrigerant importers pay advanced destruction fees (ADFs), which are used to support recycling and destruction. This ultimately shifts the expense to the consumer, who benefits from the refrigerant gas (Recovery 2020). This fee pays for the collection, transportation, and disposal of refrigerant left behind at particular locations, such as service enterprises and e-waste businesses across the nation. Regardless of whether the producer or the holder has paid the advanced disposal fee for recycling, the service is free for all refrigerant holders.

Cooling units must be de-gassed prior to dismantling, and the gas must be stored when the cooling device is decommissioned. Recovery during maintenance and the EOL of commercial cooling devices, such as chillers, is a prevalent practice and is mandatory. The Health and Safety at Work (Hazardous Substances) Regulations 2017 state that anyone handling or recovering compressed gases must possess the necessary training and a valid approved filler license (AFL) (Synthetic Refrigerant Stewardship 2019). On the collection of refrigerants in a cylinder, the cylinder needs to be handed in at the nearest recovery centre. The recovery centre generates a receipt on the collection of unwanted refrigerants. The recovery centre team records the details of the recovered cylinder, such as the type of refrigerant and its weight. Further, these cylinders are decanted into 20 large containers as per the protocol for the accumulation of bulk-used refrigerant, then transported to Australia for destruction through the plasma arc technique (Recovery 2020).

All large and small vehicles that contain refrigerants and are imported into New Zealand must pass a vehicle pre-import inspection (to check compliance with New Zealand standards for a vehicle), and during this process, the ADF for the refrigerant is charged to the manufacturer or importer (Synthetic Refrigerant Stewardship 2019). The Ministry for the Environment updates the ADF annually to reflect current emission trading scheme (ETS) costs and is tied to the price of carbon. Levy rates vary depending on the item and are affected by the type, quantity, and GWP of the gas in question. The refrigerants, during the servicing and prior to dismantling at the recycling facility, are recovered and stored and subsequently transferred to the recovery centres for collection and storage (Synthetic Refrigerant Stewardship 2019).

Since Recovery's founding, it has collaborated closely with the New Zealand government, providing information on its operations and serving as a representative for the refrigeration and air-conditioning sector. Recovery collaborates with a variety of stakeholders, including the motor trade, the automotive air-conditioning industry, chemical companies, retail grocers' associations, the refrigeration and air-conditioning industry, etc. (Recovery 2020). This enables them to represent the entire supply chain, from the importation and supply of refrigerants to their application and use for end users, in a fair and impartial manner. Although the recovery rate was relatively low (merely 5 per cent) in the initial years of the implementation of the product stewardship programme, in the last few years, New Zealand has been destroying 30 MT annually (Cooling Post 2014). From 1993–2020, 390 MT was collected and destroyed in New Zealand (Recovery 2020).

Figure 2 Mechanism followed in Australia for collecting refrigerants at the EOL of a cooling appliance



Source: Authors' analysis from RRA 1993 and Department of Environment 2014

4. Australia: Refrigerant Reclaim Australia

The federal government of Australia supports the industry-led Refrigerant Reclaim Australia (RRA) programme, which collects import levies based on semi-annual (self) reporting. The effectiveness of RRA depends on rewarding contractors and wholesalers with rebates on a recovered refrigerant that is returned. This rebate covers the expense of handling the take-back of refrigerants and storing them.

4.1 Policy initiatives

The *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* in Australia regulates the production, import, export, use, and disposal of ODS, synthetic greenhouse gases, and the products that contain these gases (DCCEEW 1989). It also encourages responsible management and handling of ODS and HFCs to lessen their emissions and impact on the atmosphere (DCCEEW 1989). One of the industry's fundamental obligations under this law is the compulsory recovery of refrigerants from the cooling devices and their subsequent return and safe disposal. This legislation applies to all refrigerants, such as CFCs, HCFCs and HFCs.

Anyone working on refrigeration and air-conditioning equipment is required by law to have a refrigerant handling licence (RHL), which is given by the Australian Refrigeration Council (ARC) (DCCEEW 1989). The Industry Board has appointed the ARC to administer the regulations. According to the law, anyone handling fluorocarbons, such as purchasing, storing, or disposing of them, must have a Refrigerant Trading Authorisation (RTA) (ARC 1989). Waste handling organisations and individuals dealing with products containing refrigerants are by law required to have a Restricted Refrigerant Trading Authorisation (RRTA) to recover and store refrigerants from the EOL cooling devices (ARC 1989).

4.2 Implementation mechanism and reverse logistics

RRA is the product stewardship body, funded by a levy on the import and sale of new refrigerants and approved by the Australian federal government for the Australian refrigerants industry (RRA 1993). RRA has been working since 1993 to recover, reclaim, and destroy surplus and undesired refrigerants on a nationwide scale (RRA 1993). It runs the refrigerant take-back programme. The programme is built on an existing distribution channel, which makes it very convenient and cost effective for recovery operators to purchase and return the recovered gas (Bhasin et al. 2019). There are representatives from bulk refrigerant importers, cooling devices importers, distributors and wholesalers of refrigerant, as well as contractors from the commercial and automotive sectors.

Once the user discards the cooling appliance, such as ACs/domestic heat pumps and fridges, the recovery of refrigerant is made by the refrigerant recovery contractor or the waste management businesses at the consumer's premises or e-waste collection centre, respectively (RRA 1993). The cost of recovery of refrigerant and recycling of e-waste is borne by the user, who discards their appliances with the help of a service technician and who installs a new cooling device in place of the discarded one. A licensed service technician is required to remove gas from the cooling appliance (RRA 1993). They perform the degassing service as an 'add-on' to the air conditioner uninstalling service and charge the same to the customer. Once the bulk amount is collected, the recovery contractor or a servicing technician further sells the recovered refrigerant to the refrigerant wholesaler (Department of Environment 2014). Contractors, waste management businesses and servicing technicians are encouraged by the rebate to recover and return used refrigerants that they purchase from refrigerant wholesalers or recover from the decommissioned air conditioner and refrigerator (Department of Environment 2014). Contractors can rent, purchase, or take on-deposit cylinders from wholesalers to return refrigerants, and can then return the full cylinders to the same wholesaler (Department of Environment 2014).

In Australia, 90 per cent of the remaining refrigerants from the EOL vehicles are released into the atmosphere when the vehicles are being dismantled to recover valuable scrap (DoE 2015). Due to the low value of recovered refrigerant gas compared to the value of the other materials in an EOL vehicle, the refrigerants are generally vented. Properly recovering the gas, reusing it, or sending it back for destruction is an expensive process and acts as a disincentive to the majority of industry participants in the automobile sector (DoE 2015). Most of the gas that is recovered (which is done by a few EOL vehicle handlers) from the EOL vehicles is destroyed, with only a small percentage being resold or reused (DoE 2015).

Further, the collected refrigerant from wholesalers of refrigerants is sent to RRA, where it is destroyed or reclaimed for reuse. RRA gives the wholesalers a rebate for handling the refrigerant take-back programme (RRA 1993). The 500-branch network of wholesalers across Australia serves as collection points for refrigerants and offers administration, cylinders, and decanting services. The rebate paid to the wholesalers and contractors (servicing agencies) is channelised through RRA (DCCEEW 1989).

RRA manages the waste refrigerants that have been recovered and collected for reclamation or destruction (RRA 1993). It destroys refrigerants using plasma arc technology. With an efficiency of 99.99 per cent, the plant converts harmful fluorocarbon refrigerants into salty water that is even safe to consume (RRA 1993).

RRA has been destroying 92 per cent of the refrigerants recovered by the programme. Over the years, RRA has achieved an up to 70 per cent recovery rate and has recovered 6,000 tonnes of refrigerant (US EIA 2019). Since 2014, RRA has destroyed between 0.6–1.1 million MT of refrigerants (RRA 1993).

> **Due to the low value of recovered refrigerant gas compared to the value of the other materials in an EOL vehicle, the refrigerants are generally vented.**

5. Japan: Robust regulatory framework

Japan has comprehensive legislation on refrigerant management for all sectors—ranging from residential, commercial, and industrial cooling and refrigeration to mobile air conditioning—involved with cooling and refrigerant requirements. The laws target the different lifecycle stages of refrigerant management across the sectors, from the production of refrigerant, manufacturing or import of appliances containing refrigerants, and maintenance to the EOL collection, recycling or destruction of the controlled substances under the Montreal Protocol.

5.1 Policy initiatives

The management of refrigerants during the EOL of the cooling appliances in Japan is governed under these four laws:

- **The Law Concerning the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures** (Ministry of Economy, Trade and Industry of Japan 2000): This law seeks to regulate the production and import of controlled substances under the Montreal Protocol and imposes limits through the permit system on their production and consumption. Under this law, refrigerant manufacturers must obtain licences from the Ministry of International Trade and Industry. Further, refrigerant producers and importers are required to promote and produce low-GWP refrigerants and subsequently attempt refrigerant recovery, reclamation and destruction. Along with getting the permission required for the production of refrigerants, the refrigerant producer must commit that the specified substance will indeed be destroyed within the control year in accordance with the standards specified and provide details on the destruction quantity, destruction operators and destruction facility. In addition, the law states that the product-manufacturing companies using these substances are required to cooperate in the rationalisation of their use and restriction of their release.

- **Act on Rational Use and Proper Management of Fluorocarbons** (MoE Japan 2015): This law implements comprehensive measures throughout the lifecycle of fluorocarbons in commercial systems. This law specifies specific rules for reporting requirements and breaks down the necessary reporting system in relation to refrigerant treatment. Additionally, it covers the entire fluorocarbon lifecycle, from reducing production and imports to encouraging the use of low-GWP refrigerants. This law puts significant responsibilities on multiple stakeholders throughout the lifecycle of refrigerants, such as fluorocarbon producers, designated product manufacturers, users, maintenance operators, recovery operators and destruction operators for implementing this law. Under this law, retailers and manufacturers are mandated to take back used products and are responsible for safely managing the waste along with recovered refrigerants.
- **Law on Recycling of Specified Kinds of Home Appliances** (MoE Japan 2011): Through waste reduction and full utilisation of recyclable resources, this law seeks to achieve proper waste treatment and efficient resource use to establish a sound circular economy. This law places air conditioners and refrigerators as two of four specified post-consumer appliances. It outlines the responsibilities of each participant, including collection from end users by retailers, recycling by producers or importers, and payment for transportation and recycling by consumers when they dispose of such equipment. The act also specifies how fluorocarbons in cooling equipment are to be recovered and processed. It requires record keeping regarding the weight of recovered fluorocarbons and shipped and destroyed fluorocarbons. As per this law, the refrigerant must be recovered and collected by the e-waste handlers while disposing of decommissioned home appliances in the recycling centre. Further, refrigerants should be transferred either for reuse or destruction to the destruction operator. The law states that failing to properly dispose of waste equipment can result in up to five years in jail and/or a fine of up to 10,000,000 yen (INR 62 Lakhs) to producers or importers (ICF 2008).
- **Law on Recycling End-of-Life Vehicles** (MoE 2010): Automobile manufacturers and importers are required to collect and dispose of fluorocarbons recovered during the treatment of the EOL vehicles under the extended producer responsibility principle, which is included in this statute. The fact that the recycling fees for motor vehicle EOL treatment (including refrigerants) are charged to the car owner at the time of the purchase of a new vehicle has significantly increased compliance. The fees for recycling are generally set by automobile manufacturers and are recommended/corrected by the national government.

5.2 Implementation mechanism and reverse logistics

The WEEE-containing refrigerants in Japan are governed under the *Home Appliance Recycling Law*, which specifies the responsibilities of all the stakeholders involved in the whole lifecycle of the cooling appliance and the cost-bearing mechanism, which are as follows:

- **Consumers and waste producers:** The consumer or business that wishes to dispose of its cooling appliances is responsible for covering the costs of collection, transportation, recycling, and proper return of the appliances to the store from which they were purchased (OECD 2014).
- **Retailers:** The retailers are responsible for handing the EOL devices to the responsible manufacturer. In addition, retailers are responsible for collecting the home appliances they sell or collect at the request of customers who purchase a replacement appliance from them (MoE Japan 2011).
- **Municipalities:** Municipalities are in charge of collecting municipal waste, and this legislation mandates that they send the specified household appliance waste they have accumulated to manufacturers so that they can further process it (MoE Japan 2011).
- **Manufacturers and importers of home appliances:** For further recycling, the responsibility falls on the manufacturers to collect and recycle the household appliances they produce or import (MoE Japan 2011).
- **E-waste recycler:** Once the equipment reaches the manufacturer's designated recycling site, the responsibility lies on the e-waste handler to recover and collect the refrigerant beforehand. They are further responsible for record keeping of the refrigerant recovered, shipped for reuse, or destruction and the amount of fluorocarbons destroyed (OECD 2014).

> Refrigerants must be recovered and collected by the e-waste handlers while disposing of decommissioned home appliances in the recycling centre.

- **Refrigerant recycling/destruction operators:** It is further the responsibility of the government-authorised fluorocarbon recycler or destructor to recycle or destroy the delivered fluorocarbons in accordance with the fluorocarbon recycling/destruction standards using the standardised equipment (OECD 2014).

Consumers are responsible for collection and transportation charges as well as the recycling fee when disposing of their e-waste (MoE Japan 2011). Retailers determine the collection and transportation fee, and manufacturers determine the recycling fee. According to the law, the recycling fee cannot be higher than the cost of recycling. The main logistics costs are represented by the collection and transportation fees (OECD 2014). If a retailer is collecting the waste appliances, this will cover the costs of transporting the appliances from the consumer's home to the retailer's shop and back again to a designated waste collection centre (CCAC 2021). The consumers are provided with the home appliance recycling ticket, as shown in the figure below.

The collection and transportation fee, in the case of collection by a municipality, denotes the cost of collecting waste home appliances from the consumer and transporting them to a designated collection site (OECD 2014). The fees for the transportation of waste from the collection sites to the manufacturer's recycling plant are not borne by the end consumer and are covered under the recycling fee (OECD 2014). Furthermore, different manufacturers charge different amounts for the recycling of different wastes.

In the MAC sector, when disposing of a car, the pick-up company picks it up from the last owner and delivers it to a business that dismantles cars (CCAC 2021). Refrigerants are properly collected by refrigerant recovery operators in accordance with regulations, and they are then delivered to importers and car manufacturers. The automobiles generally include all cars (light/compact/standard-sized and special cars), buses, and trucks (MoE 2010).

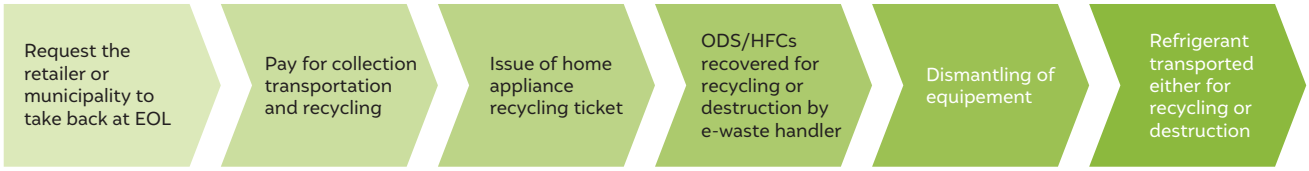
> **The legislation in Japan mandates all the refrigerant handlers involved in the different lifecycle stages of refrigerant to be licensed.**

Those who wish to discard commercial cooling appliances have to request the certified refrigerant recovery operator to recover the refrigerant prior to discarding the appliance (MoE Japan 2015). Once the refrigerant is recovered, the appliance owners are provided with the recovery receipt. The waste producer then has to pay for the refrigerant recovery, recycling, or disposal (MoE Japan 2015).

More than 60 facilities for the destruction of refrigerants were present in Japan as of 2014 (MoE Japan 2014). These facilities mostly use adaptable technologies such as rotary kiln incinerators or municipal waste incinerators, where fluorocarbons are burned alongside garbage from the municipal sector (Ohm and Myung 2015). The legislation in Japan mandates all the refrigerant handlers involved in the different lifecycle stages of refrigerant to be licensed (Ohm and Myung 2015). It is mandatory that refrigerant charging or recovery be done by a certified operator, recycling undertaken by a licenced recycling operator, and the destruction facility be authorised by the Japanese government. Throughout the entire process, from refrigerant manufacturing to usage and recovery, and then to its final recovery, recycling, or destruction, a reporting system is in place (Ohm and Myung 2015). To ensure that the refrigerant handlers are properly trained, the Japan Refrigerants and Environment Conservation Organisation (JRECO) certifies them after a training session and test. A fine of not more than 500,000 JPY (INR 2.5 Lakh) or imprisonment up to one year is imposed to the person or organisation if they are found not in compliance with permission standards regarding trading or handling of refrigerants at any stage of the lifecycle of refrigerants (MoE Japan 2015).

Japan's strong regulatory framework has been successful in achieving a recovery rate of 41 per cent. For the financial year 2013-14, the recovered refrigerant amount was 6528 MT from all the sectors combined (AHRI 2018).

Figure 3 Mechanism followed in Japan for collecting refrigerants at the EOL of a cooling appliance



Source: Authors' analysis from OECD 2014 and MoE Japan 2011

Figure 4 Refrigerant recovery, reclamation and destruction certificate flow in Japan

Source: Authors' analysis from CCAC 2021 and MoE Japan 2015

6. South Korea: Refrigerant information management system

The Korean law applies to the equipment that uses refrigerants for the cooling and heating of buildings, for freezing and refrigeration of foods, commercial and industrial cooling, and mobile air conditioning. The law prohibits the unauthorised discharge of refrigerants into the atmosphere and mandates the annual check of refrigerant leakage. The companies are regulated through an annual quota system for the production and import of refrigerants.

6.1 Policy initiatives

South Korea has four different pieces of legislation which directly and indirectly govern refrigerant management. These are as follows:

- **Act on Control of Manufacture of Specific Substances for the Protection of the Ozone Layer** (Ministry of Trade, Industry and Energy of Korea 2014): Phased annual reduction plan of ODS and high-GWP refrigerants, which includes their production and prohibition to use (Ohm and Myung 2015). A production and consumption reduction schedule is now followed by an annual quota system for businesses that are authorised to produce and import ODS.
- **Clean Air Conservation Act** (Republic of Korea 2017): Its Articles 9 & 14 talk about developing a management plan for the safe disposal of substances that affect global warming (Republic of Korea 2017). The owner or management of a cooling unit is also required by law to recover the refrigerant or commission its recovery and disposal.
- **Act on Resource Recycling of Electrical and Electronic Equipment and Vehicles** (Republic of Korea 2008): This act doesn't directly talk about refrigerant-related substances, but Article 27 of this law states that the waste-handling organisations have to separate and store substances coming from discarded equipment and automobiles that leads to climate and ecosystem change.
- **Waste Control Act** (Republic of Korea 2015): Although this South Korean regulatory framework requires the proper handling, recovery, or destruction of equipment containing refrigerants, it does not specifically or directly control ODS or HFCs. The rules for disposing of refrigerants are also laid out in this statute.

Figure 5 Mechanism followed in South Korea for collecting refrigerants at the EOL of a cooling appliance

Source: Authors' analysis from UNCRD 2012 and Ohm and Myung 2015

6.2 Implementation mechanism and reverse logistics

E-waste management of WEEE in South Korea is basically implemented through the EPR scheme, where the responsibility for the safe and efficient disposal of their EOL products lies on the manufacturer (Ohm and Myung 2015). Manufacturers are obligated under this system to meet recycling rates for specific materials, but refrigerants are not yet included. The cost of recycling is borne by the manufacturer and channelled to the recycling centres, which are the producer responsibility organisations. The cost is distributed for collection, transportation, recycling and other purposes (Republic of Korea 2008). If the manufacturer fails to recycle the targets, they have to pay for the recycling as well as a penalty amount which exceeds the recycling fee. At the time the cooling appliance is decommissioned, on request, it is collected by the e-waste collection agency and is further transported to the metropolitan electronic recycling centre (MERC) (Ohm and Myung 2015). The discarded appliances go through pre-treatment at the recycling centres, where the refrigerants are recovered prior to any dismantling of the components within the appliance (UNCRD 2012). The recovered refrigerants are segregated and stored in the larger tanks separately. The recovered refrigerant, once collected in bulk, is then transported to the waste refrigerant recycling and destruction facility. The destruction is done at a thermal treatment plant which is a commercially operated facility (Sunjin Environment n.d.).

Similarly, in the MAC sector, at the request of the automobile owner, the EOL vehicles are collected and taken to the automobile dismantling centre, where prior to the dismantling, the refrigerants are recovered and stored (Ohm and Myung 2015). Since they are acknowledged to have some residual value and can generate some profits during the dismantling process, the EOL vehicles are collected with an average amount paid to the car owner (Joung et al. 2007). Further, the refrigerants are transported to the refrigerant management facility for recycling or destruction. It is the automobile manufacturer or importer's responsibility to establish an EOL vehicle collection system and recycling centres (Republic of Korea 2008).

According to the standards for refrigerant management, commercial cooling appliance owners must handle refrigerants responsibly and in accordance with the *Clean Air Conservation Act*. The owner of the cooling appliances is required to commission the recovery and disposal of the waste refrigerants to the refrigerant recovery and disposal companies (MoE Korea 2018). Additionally, they must also keep track of their progress in refrigerant management files and submit copies of the files and supporting documentation to the refrigerant information management system (RIMS), which is managed by the Korea Environment Corporation (K-eco) (MoE Korea 2018). The recovery and handling of refrigerants need to be done by the refrigerant recovery companies authorised by K-eco (MoE Korea 2018). The company that made the service request must receive a refrigerant recovery declaration form from the recovery company after recovery, and it must be written by a registered technology staff member. The recovered, collected refrigerants are then either sent for purification for reuse or to destruction facilities (MoE Korea 2018).

7. USA: Strong legislations supported by voluntary programmes

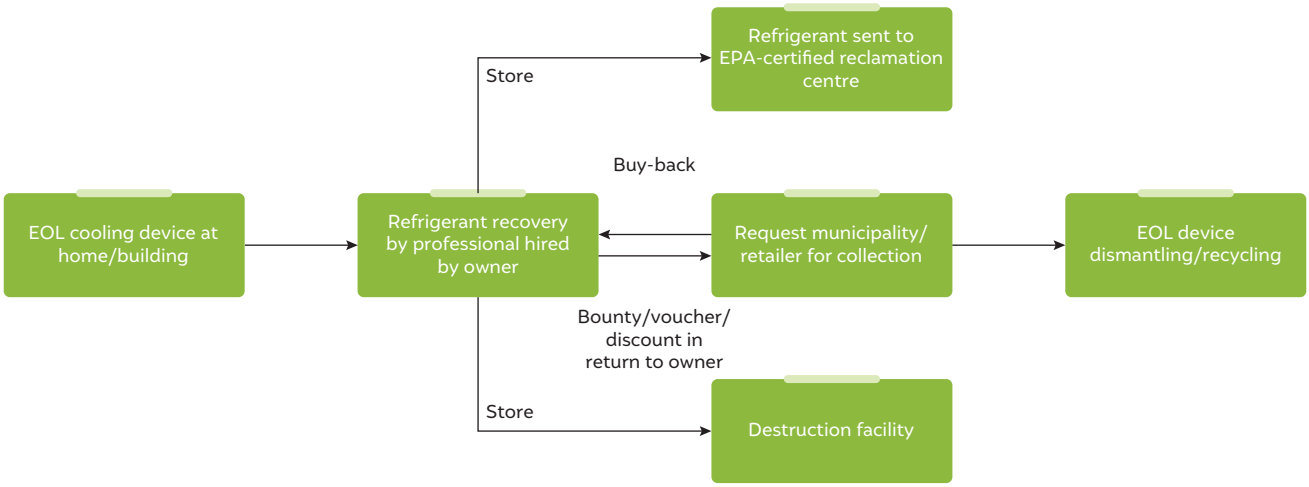
To manage refrigerants, the USA depends on the market's adherence to a broad and comprehensive regulatory structure. The USA Framework addresses venting, technician certification, certification of recovery equipment, repair of leaking systems, disposal requirements, and recordkeeping. It also addresses the phase-down of ODS. There are also voluntary initiatives for refrigerant management, such as responsible appliance disposal (RAD), which is in charge of reporting and marketing for utility, manufacturer, retail, and state partners that accept used home devices.

7.1 Policy initiatives

The Clean Air Act of the United States requires the Environmental Protection Agency (EPA) to protect and improve air quality and the stratospheric ozone layer (EPA 1990). Stationary refrigeration and air conditioning (Section 608) and motor vehicle air conditioning (Section 609) regulations were added to the federal Clean Air Act (EPA 1990). These sections primarily prohibit the intentional release of refrigerants. The section also proposes rules for the mandatory certification of technicians and the required refrigerant treatment infrastructure. When opening refrigeration/AC equipment for maintenance or disposal, technicians are required to evacuate the equipment to a specific vacuum level in order to minimise the emissions and maximise recovery of ODS and their substitutes for reuse or further treatment (ICF 2008).

The recovered refrigerant, once collected in bulk, is then transported to the waste refrigerant recycling and destruction facility.

Figure 6 Mechanism followed in the USA for collecting refrigerants at the EOL of a cooling appliance



Source: Authors' analysis from US EPA n.d. and ICF 2008

Section 608 only regulates ODS, such as CFCs and HCFCs, which HFCs being currently excluded (EPA 1990). Additionally, there is a legal restriction on the sale of bulk ODS refrigerants to only certified technicians, and there are limits on the amount of ODS that can leak from cooling devices with a charge greater than 50 pounds (22.7 kg) (ICF 2008). Depending on the type of equipment, maximum allowable leak rates currently range from 15–35 per cent over the equipment's lifetime. Leaks must be fixed by equipment owners if exceeding the maximum allowable leakage rates (ICF 2008). There are also certain taxes manufacturers or importers have to pay based on the ODP of the gas that is collected by the internal revenue service, which changes according to the class type of the gas (ICF 2008).

CFCs, HCFCs, and HFCs, on the other hand, are all listed as target substances in Section 609 for automobiles (EPA 1990). According to the law, the US EPA must create federal standards for the use, recycling, and disposal of CFC, HCFC, and substitute refrigerants. This legislation is detailed in the National Recycling and Emissions Reduction Program in Section 608 (Section 608 CAA n.d.). The law prohibits the intentional venting of the refrigerant, and if the data on reporting system doesn't match with the used and recovered refrigerant, the servicing agency is penalised for the same (Section 608 CAA n.d.).

7.2 Implementation mechanism and reverse logistics

Section 608 of the Clean Air Act bans the intentional venting of refrigerant into the air from the cooling devices from RAC, CAC, RR and CR sectors during maintenance, servicing, repair, or at the EOL (Section 608 CAA n.d.). CAC and CR devices which are generally dismantled on-site before disposal, should have their refrigerant recovered as per the EPA guidelines for the servicing prior to dismantling. When RAC, RR, CAC and CR appliances reach their EOL, the accepting entity is in charge of keeping a signed statement identifying the source of the appliance or appliances (ICF 2008). The signed statement must include the date that the refrigerant was recovered, the name and address of the person who recovered it, and a copy of a contract attesting that the refrigerant was removed before delivery (ICF 2008).

The EPA's responsible appliance disposal (RAD) program requires the safe disposal of decommissioned refrigeration and air-conditioning appliances (US EPA n.d.). When the cooling device is discarded by the owner/ commercial enterprise, the municipalities and retailers are required to collect them. With the purchase and delivery of a new model, some stores provide appliance pick-up and disposal services, while others allow the collection of old equipment (US EPA n.d.).

A fee of up to USD 50 (INR 4000) is charged for this service depending on the retailer, but some retailers offer incentives in the form of a voucher or a discount coupon for purchasing a new appliance (US EPA n.d.). Municipalities may or may not charge for collection, but appointments for large appliance pickup must be made. A bounty programme, which is an appliance turn-in programme, is also run by some of the local electric utilities (Bhasin et al. 2019). Under the programme, an appliance owner is compensated with a 'bounty' to allow the recycler to pick up and recycle their obsolete, inefficient appliance (US EPA n.d.). The municipalities sometimes require the refrigerant to be recovered prior to the collection of the cooling appliance by a professional using EPA-certified recovery equipment. The recovery professional thereafter stores the refrigerant and transfers it to the EPA-certified reclamation centre or destruction facility. The servicing professional, reclamation centre, destruction facility, and the operator of large appliances are mandated to maintain the records of the refrigerant they have handled (US EPA n.d.).

Similar to Section 608, once an automobile reaches its EOL, the refrigerants must be recovered before it is dismantled. When maintaining, servicing, fixing, or disposing of automobiles and similar vehicles, Section 609 forbids the deliberate release of refrigerants and the majority of substitutes (Section 609 CAA n.d.). The collected refrigerant at the automobile dismantling facility needs to be then transported to the EPA-certified reclamation centre or destruction facility. Refrigerants that are removed from a MAC and reused in another vehicle must be either reclaimed by a certified reclaimer or recycled by a certified technician using certified recovery equipment.

USA's combination of voluntary refrigerant management programmes and strong regulatory framework has significantly increased the refrigerant recovery rate from the commercial systems, but still lacks to address the recovery from EOL small cooling systems. Furthermore, this led to destruction of 800 MT of HCFC alone in 2016 (AHRI 2018).

> **The Danish Refrigerant Industry Environmental Scheme, established by the country's authorised refrigeration companies and refrigerant importers, is a voluntary deposit refund programme.**

8. Best practices in some other countries

This section highlights some of the other countries which have adopted refrigerant management practices either through robust regulations or voluntary programmes and are successful in limiting refrigerant emissions.

8.1 Denmark

The Danish Refrigerant Industry Environmental Scheme (KMO), established by the country's authorised refrigeration companies and refrigerant importers, is a voluntary deposit refund programme (MoE Denmark n.d.). It encourages the disposal, recycling, and collection of the Montreal Protocol's restricted substances. Equipment users must pay a deposit of DKK 27 per kg (INR 320 per kg) of refrigerant, regardless of the refrigerant's GWP value, and after the refrigerant is recycled or destroyed at its EOL, the equipment owner receives a refund of DKK 10 (INR 118) for recycling and DKK 5 (INR 59) for disposal (CCAC 2021). Of the DKK 27 (INR 320) collected from end users, the KMO receives DKK 22 (INR 260), while servicing businesses or the cooling appliances dismantlers keep the remaining DKK 5 (INR 59) to cover KMO reporting costs (MoE Denmark n.d.). The KMO secretariat is maintained with DKK 7 (INR 83), and the remaining DKK 15 (INR 178) is used to cover the cost of recycling or destroying refrigerants (CCAC 2021). Servicing businesses collect the refrigerant from the equipment, and then send the used refrigerant to KMO. At KMO, the refrigerant is recycled and destroyed, and the equipment users are reimbursed.

8.2 Sweden

Sweden's refrigerant management is governed by the European Union F-gas regulations. Refrigerants are covered in the national legislation on refrigerants, The Swedish Environmental Protection Agency's administrative provisions on refrigeration, air conditioning and heat pump equipment containing fluorinated greenhouse gases, CFCs, other CFCs and HCFCs. The F-gas Regulation and the national legislation regulates emissions of refrigerants by requiring leak checking, proper servicing and maintenance of refrigerant-containing equipment, and

recovery of refrigerants at the EOL (European Commission 2014). Where safer alternatives are available, it places restrictions on GWPs, restricts the use of F-gases, and gradually reduces the amount of F-gases that can be sold in the EU (European Commission 2014). Implementing WEEE directives in Sweden is the producer's obligation for the collection and recycling of decommissioned electronic waste (Swedish EPA 2007). The household collection is organised through individual municipalities. Collection and delivery of decommissioned refrigerators and air conditioners to certified recovery facilities allows for the recovery of ODS and HFCs from the insulation foam and refrigeration circuits (Swedish EPA 2007). It is the responsibility of appliance manufacturers and importers to set up the collection methods, which is accomplished mostly through a collective arrangement (ICF 2010). The regional environmental authority issues operational permits to appliance recycling facilities, and to ensure compliance, the facilities have to maintain the records of the refrigerant recovered from the cooling devices (ICF 2010).

8.3 Singapore

The Environmental Protection and Management (EPM) Bill, which specifies steps to limit the greenhouse gas impact of HFCs used in refrigeration and air-conditioning applications, has been amended by the Singapore National Environmental Agency (NEA, Singapore 2021). The EPM Bill gives the NEA the regulatory precedent it needs to put measures like limiting the provision of RAC equipment that uses high-GWP refrigerants, requiring technician training and certification, and requiring the collection and proper disposal of used refrigerants into effect. NEA has ambitious plans to ban the supply of products in 2022 using refrigerants having GWP from 15 to 750 for different refrigeration and air-conditioning equipment (NEA, Singapore 2021). The bill mandates compulsory training and certification of technicians handling decommissioned equipment. Once the decommissioned cooling devices reach the e-waste recycling facility, the Resource Sustainability Act forbids e-waste recyclers from releasing contained waste refrigerants into the atmosphere (NEA, Singapore 2021). Certified technicians and e-waste recyclers are mandated to recover refrigerants from the discarded cooling devices and send them for reclamation or destruction in the premises registered under toxic industrial waste collector (TIWC) by NEA (NEA, Singapore 2021).

8.4 Malaysia

The production, consumption, import, export, sale, and disposal of cooling devices containing Montreal Protocol-restricted substances are all governed by Malaysia's Environmental Quality (Refrigerant Management) Regulations 2020 (Ministry of Environment And Water, Malaysia 2020). The supporting tools to control the EOL management of refrigerants include penalties, reporting mechanisms, and manufacturers responsible for providing the technicians with the necessary training (Ministry of Environment And Water, Malaysia 2020). The law does not yet regulate HFCs; it only applies to HCFCs and CFCs. This law forbids the production and assembling of air conditioners or refrigeration devices using particular refrigerants and encourages the disposal of specified refrigerants (Ministry of Environment And Water, Malaysia 2020).

The law emphasises that it is the manufacturer's duty to guarantee that individuals performing the retrofitting by removing the refrigerant from the concerned manufacturer's equipment receive adequate training and that failure to comply with the law will result in a fine of 100,000 Ringgit (INR 19 lakh) or a two-year prison sentence, or both (Ministry of Environment And Water, Malaysia 2020). Any person or service technician caught releasing refrigerant into the environment will face the same punishment. The individual or organisation engaged in the trade, reclamation, recycling, or disposal of refrigerant on the property is required to keep records and submit an annual report to the Director General, with failure to do so resulting in fines or imprisonment (Ministry of Environment And Water, Malaysia 2020).

> **Collection and delivery of decommissioned refrigerators and air conditioners to certified recovery facilities allows for the recovery of ODS and HFC.**

9. Summary of best practices

Table 1 summarises the measures the above discussed countries have taken to tackle the refrigerant emissions and the impact of those initiatives.

Table 1 Summary of target countries on refrigerant management practices

Country	Sectors covered	Refrigerant covered	Policy measures	Rate of recovery (%)	EOL treatment (Reclamation/ destruction)	Impact	Challenges
Norway	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Tax and refund scheme	NA	Destruction	Destroyed refrigerant in FY 2009-21: 1200 MT In general, most gases that can realistically be recovered, are recovered	Uncertainty related to extent of recovery from EOL vehicles and foams
New Zealand	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Voluntary industry arrangement (Regulatory Product Stewardship Scheme) - RECOVERY	5% till 2013	Destruction	Collected and destroyed 430 tons of refrigerant from FY1993-2020 Impact of saving up to 423,655 MT of ozone and reducing the build-up of GHGs by up to 938,030 MT of CO_2 eq Destroys around 30 MT per year.	Transportation of refrigerants to the recovery centre acts as a disincentive Recovery from domestic equipment and vehicles low
Australia	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Industry-supported refrigerant take-back programme - Refrigerant Reclaim Australia Extended producer responsibility	50–70%	Reclamation & destruction	92% of recovered refrigerant destroyed by RRA Total refrigerant recovered since 2013: 4,600 MT Reduction of more than 10 million tons of CO_2 eq emissions	Leveraging a single organisation/system invites suspicion and anti-competitiveness charges Recovery from domestic equipment and vehicles is very low
Japan	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Strong regulatory framework Extended producer responsibility Industry-specific refrigerant management programmes	41%	Reclamation & destruction	In FY2020 - Refrigerant recovered- 8500 MT Refrigerant recycled- 1300 MT Refrigerant destroyed- 4100 MT	Some non-compliance is caused by fees for properly disposing of commercial and household appliances at the EOL Despite being a leader in appliance recycling, home appliances only recover 30% of the available refrigerant
South Korea	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Regulations on phase-down Regulatory framework regulations require record keeping Extended producer responsibility	NA	Destruction	NA	Absence of comprehensive regulation on refrigerant management
USA	RAC, RR, CAC, CR, MAC	CFC, HCFC, HFC	Robust regulatory framework focused on venting prohibitions Voluntary refrigerant management programmes	Not tracked	Reclamation & destruction	Rate of recovery in commercial systems: up to 80% RAD recovered refrigerant in 2013: 170 MT HCFC destroyed in 2016: 800 MT	Inconsistent framework (ODS vs HFCs) creates confusion and non-compliance Low recovery from domestic cooling appliances and vehicles

Source: Authors' compilation based on various studies, primarily AHRI 2018, ICF 2008, US EIA 2019 and CCAC 2021

10. Learnings for India

Clear requirements for the recovery and subsequent recycling, reclamation, or destruction of the various forms of refrigerants should be outlined in the legislation. Below are the key highlights of the policies which are operational in different nations for the refrigerant management, which can be examined in depth to assess their applicability and viability in the Indian context:

10.1 Regulatory measures

E-waste management and vehicle scrappage directives to regulate the EOL management of the refrigerants contained in the cooling devices and the vehicles. The e-waste management rules and vehicle scrappage rules must focus on the importance of recovering refrigerants from decommissioned refrigerators, air conditioners and vehicles. The rules should mandate the proper handling of discarded cooling devices containing high-GWP and flammable refrigerants. Further, the directives must outline at which stage of the reverse supply chain of the EOL cooling devices and vehicles the refrigerant must be recovered prior to its dismantling. The organisation involved in handling the e-waste and the EOL vehicles must be responsible for the recovery and storage of the refrigerant. The organisation must maintain records on the source, quantity and type of refrigerant which was recovered and should further report to the concerned agency or department on a periodic basis. In commercial applications, at the EOL of the cooling appliances, the on-site recovery, storage and subsequent destruction from the certified recovery operator and the record keeping is an instrumental measure to handle the refrigerants at their EOL.

A robust reporting mechanism needs to be in place. The producer, importer, manufacturer of cooling devices, servicing technicians, servicing agencies, large equipment contractors, the EOL cooling device and the EOL vehicle handlers should report on the amount of refrigerant they either have produced, used in servicing or recovered during the EOL processing, etc. It will play a huge role in managing the refrigerants during maintenance or at the EOL of the cooling device and will keep track of which sector and how much quantity of different refrigerants are being used across the country.

> The organisation involved in handling the e-waste and the EOL vehicles must be responsible for the recovery and storage of the refrigerant.

10.2 Fiscal measures

Rewards to the units or the servicing technicians for recovering, storing, recycling, reusing and destructing the refrigerants in an environmentally and socially sound manner.

Fees at the time of purchase, which is an amount to be charged to the end consumers, as an environmental tax, at the time of the purchase of a new cooling device/vehicle. This amount shall be used for the EOL management, be it for the refrigerant recovery, recycling or disposal; or the recycling and dismantling of the other parts.

10.3 Infrastructure and capacity building

Mandatory licencing of servicing technicians and reclamation/destruction facilities involved at different stages of the lifecycle of the refrigerant for proper handling while charging during manufacturing, safe recovery of refrigerants during servicing, transportation of the refrigerant, recycling or reclamation, or at the EOL of the discarded equipment.

Refrigerant collection infrastructure at the municipality level for effective refrigerant collection from the refrigerant recovery contractor. It increases the amount of refrigerant collected and makes economic sense for the recovery operator and collector to store the gas. Further, the bulk quantity of recovered refrigerant, when collected, could then be transferred for reclamation or destruction.

Refrigerant consumption is growing rapidly because of the unprecedented growth in the cooling demand. Adapting lifecycle refrigerant management practices will significantly avoid the harmful emissions and benefit climate and ozone layer protection. It will require various policy measures in general to establish a lifecycle refrigerant management ecosystem. It needs precise regulation and robust enforcement mechanisms supported by standards, capacity building, a supportive ecosystem and finance that may enable India's sustainable lifecycle refrigerant management ecosystem. Lifecycle refrigerant management will significantly limit emissions, help accelerate refrigerant recovery, recycling, reclamation and environmentally sound destruction, and further contribute to achieving India's net zero targets and remain on a pathway to limit global warming below 1.5 °C.

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Acronyms

AC	air conditioning
ADF	advance destruction fees
AFL	approved filler license
AHRI	Air Conditioning, Heating, and Refrigeration Institute
ARC	Australian Refrigeration Council
CAC	commercial air conditioning
CFC	chlorofluorocarbons
CO2	carbon dioxide
CO2eq	carbon dioxide equivalent
CR	commercial refrigeration
DCCEEW	Department of Climate Change, Energy, the Environment and water
DKK	Danish Krone
EEA	European Economic Area
EOL	end-of-life
EPA	Environment Protection Agency
EPR	extended producer responsibility
ETS	emissions trading scheme
EU	European Union
F-gas	fluorinated gas
GHG	greenhouse gases
GIS	gas insulated switchgear
GWP	global warming potential
HCFC	hydrochlorofluorocarbons
HFC	hydrofluorocarbon
HP	heat pump
IEA	International Energy Agency
K-eco	Korea Environment Corporation
MAC	mobile air conditioning
MERC	metropolitan electronic recycling centre
MT	metric tonnes
NOK	Norwegian Krone
ODP	ozone-depletion potential
ODS	ozone-depleting substances
OEM	original equipment manufacturer
PFC	perfluorocarbon
RAC	residential air conditioning
RAD	responsible appliance disposal
RHL	refrigerant handling licence
RIMS	refrigerant information management system
RR	residential refrigeration
RRA	Refrigerant Reclaim Australia
RRTA	restricted refrigerant trading authorisation
RTA	refrigerant trading authorisation
TIWC	toxic industrial waste collector
UNEP	United Nations Environment Programme
WEEE	waste from electrical or electronic equipment

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"Thermal comfort is a basic need, but refrigerant use has environmental consequences. India must adopt sustainable refrigerant management practices, learn from global best practices, and ensure access to thermal comfort while safeguarding the environment."

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Sonal is a Programme Lead in the Sustainable Cooling team at the Council. His work is focused around sustainable cooling wherein he supports implementation of the Kigali Amendment to the Montreal Protocol and ICAP.

"Given the expected high growth in the cooling demand and refrigerant use, it is imperative for India to develop strategies for refrigerant management. The learnings from the global experiences will be useful in developing an India-specific initiative for effective refrigerant management during its lifecycle."

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Shikha is a Researcher on climate change mitigation policies with a keen interest in innovation systems of low-carbon technologies. She is currently Adviser to the Sustainable Cooling team at The Council. She has previously worked on regulatory frameworks required to meet India's Kigali Amendment commitments, and the institutionalisation of an R&D platform for supporting the phase-out of HFCs in India. A co-author of ICAP, she continues to represent CEEW as a member of ICAP working groups to implement its R&D and servicing sector goals.

"Cognizant of the potential environmental and economic benefits of lifecycle refrigerant management, our study urges India to take a proactive approach to this critical issue. Drawing on global best practices and tailoring solutions to local conditions, India can promote sustainable development and safeguard the environment."

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Torgrim is a Senior Adviser at the Department of Climate in the Norwegian Environment Agency. His key fields of work include fluorinated greenhouse gases, climate gas inventories, and development assistance. With over 10 years of work experience on fluorinated greenhouse gases, Torgrim has been instrumental in the implementation of the regulations for these gases in Norway.

"As India's demand for cooling continues to surge, it is critical to ensure that this growth is sustainable. With Norway's expertise in sustainable refrigerant management, we believe that the experiences and practices from our country can play a significant role in guiding India's path towards HFC phase-down. By working together and sharing knowledge, we can create a more sustainable future for all."

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