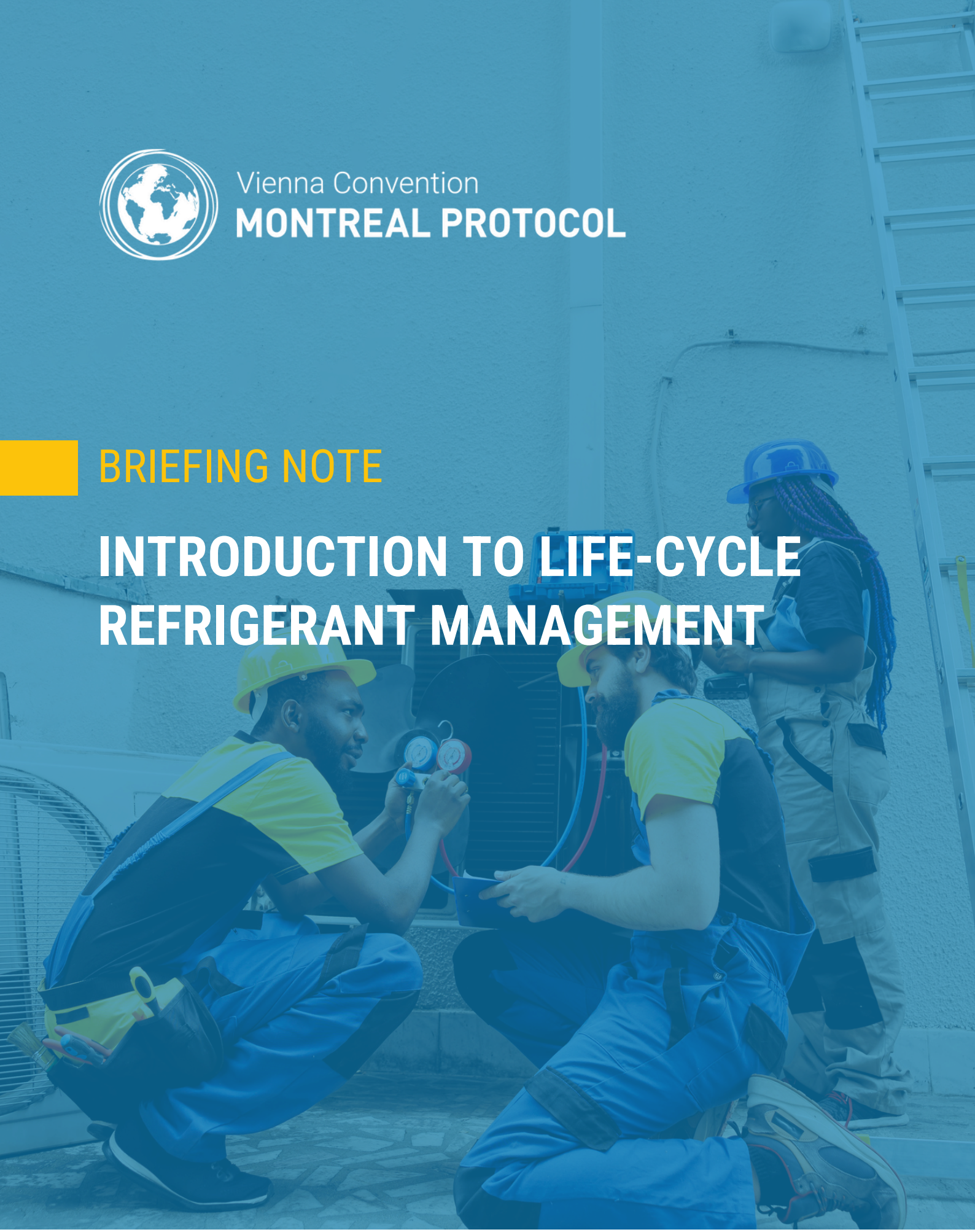
Vienna Convention
MONTREAL PROTOCOL

BRIEFING NOTE

INTRODUCTION TO LIFE-CYCLE REFRIGERANT MANAGEMENT



UN environment programme | ozone secretariat

2024 WORKSHOP
ON LIFE-CYCLE REFRIGERANT MANAGEMENT

I. Scope of the Briefing Note

1. The purpose of this briefing note is to introduce the life-cycle refrigerant management (LRM) approach in the context of the Montreal Protocol on Substances that Deplete the Ozone Layer. One of the main uses of ozone-depleting substances (ODS) and hydrofluorocarbons (HFCs), which are controlled under the Montreal Protocol (referred to as controlled substances) is as refrigerants.[1]

2. The note details various LRM components and describes its potential contributions to ozone layer protection, climate mitigation and the circular economy. The note also discusses some challenges to be overcome in its implementation. The note is a summary of relevant key points drawn from the Technology and Economic Assessment Panel (TEAP) Task Force report[2] on LRM, prepared pursuant to paragraph 1 of decision XXXV/11, and other sources of information.[3]

II. What is Life-cycle Refrigerant Management?

3. A critical challenge in managing refrigerants is addressing what are known as "banks". These are substances contained in existing equipment, chemical stockpiles, foams and other products that are not yet released into the atmosphere.[4] The total quantity of substances in the current banks is estimated to be substantial (see para 27 below). Given the ozone-depleting and high global-warming potential of many refrigerants in banks, failing to manage them effectively through containment, reuse, and destruction of refrigerants could result in significant emissions, undermining both efforts to protect the ozone layer and climate action goals.

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* The views expressed herein do not necessarily reflect the views of the parties to the Montreal Protocol, the Secretariat to the Protocol or the United Nations Secretariat.

[1] The controlled substances are also used as foam-blowing agents, aerosol propellants, solvents and fire suppressants

[2] In response to decision XXXV/12 of the parties to the Montreal Protocol, TEAP prepared a report on available technologies for managing refrigerants, including leakage prevention, recovery, recycling, reclamation and destruction, the obstacles and challenges associated with effective refrigerant management, the costs and climate and ozone benefits associated with such management, and policies and incentive schemes for ensuring effective management.

[3] Technology and Economic Assessment Panel (TEAP), "Decision XXXV/11 Task Force Report on Life-cycle Refrigerant Management". (United Nations Environment Programme, 2024); Aditya Garg and others, "Activating best practices on life-cycle refrigerant management: global best practices on life-cycle refrigerant management", (New Delhi, Council on Energy, Environment and Water, 2023); Sonal Kumar and others, "Activating circular economy for sustainable cooling: how can India manage the life cycle of refrigerants?, (New Delhi, Council on Energy, Environment and Water, 2023; Charlie Mayhew, Tilden Chao and Anastasia O'Rourke, "Background paper on life-cycle refrigerant management: maximizing the atmospheric and economic benefits of the Montreal Protocol, (Yale Carbon Containment Lab, 2023); American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), "Guidelines for Refrigerant Management", (2018).

[4] IPCC and TEAP, "Safeguarding the Ozone Layer and the Global Climate System: issues related to hydrofluorocarbons and perfluorocarbons", Joint IPCC/TEAP Special Report, (2005).

4. LRM offers a comprehensive structured strategy to mitigate these risks by managing refrigerants in an environmentally sound manner throughout their entire life cycle. It encompasses the production, storage, and transportation of refrigerants, the design, manufacturing and installation of refrigeration, air-conditioning and heat-pump equipment (RACHP), its operation and maintenance, as well as the recovery, reuse, and environmentally sound disposal of refrigerants.

5. In some jurisdictions, RACHP equipment at the end of its life is classified as electronic waste (e-waste) requiring environmentally sound management and disposal. This classification falls under the scope of LRM, which aims to manage refrigerants and their associated equipment in a sustainable way. Environmentally sound management of end-of-life RACHP equipment is therefore included in this note.

6. In business-as-usual refrigerant management, there are several deficiencies and gaps that lead to uncontrolled emissions. Refrigerants are charged into new equipment during manufacturing and installation process. Gases can leak from such equipment if not properly installed and maintained throughout the equipment's operational lifetime, typically ranging from 8 to 20 years or more. Such leaks can compromise the overall performance and energy efficiency of equipment. Servicing technicians may vent these gases and recharge leaky equipment with virgin substances. Although venting is illegal in many countries, compliance is difficult to monitor and enforce because of often informal nature of the refrigeration servicing sector and dispersed location of end-users. Recovering refrigerants creates a cost to technicians, and markets for recovered substances are still small and undeveloped in many places. When equipment reaches the end of its useful life, the remaining refrigerant is commonly released into the atmosphere.

7. Leakage prevention, reuse of substances, destruction, and environmentally sound management of products containing controlled substances have been widely promoted by the parties to the Montreal Protocol.[5] However, the Protocol does not regulate the end-of-life treatment of controlled substances, leaving this responsibility to individual countries at the national and sub-national level. As a result, effective containment, recovery, reuse, and destruction of refrigerants from banks is not systematically undertaken. To address this gap, scalable and replicable models for LRM must be developed and implemented. For more detailed information, refer to the briefing notes on policy options and financing for LRM.

8. To mitigate potential emissions, LRM promotes following management practices:

   - Maintaining accurate and comprehensive accounting of refrigerants, through inventories, to track their use and estimate emissions;

[5] Please see the information note by the Ozone Secretariat summarizing relevant provisions of the Montreal Protocol, decisions and discussions related to various aspects of LRM *(link to be posted soon)*.

8.
- Improving the design of new equipment to prevent leakage during operation, enable the switch to climate-friendly refrigerants, increase energy efficiency, and facilitate responsible decommissioning and recycling;
- Applying good and safe practices for installation, servicing, and monitoring to reduce leakage during operation of equipment;
- Recovering refrigerant at the point of equipment decommissioning, with recycling or reclaiming of used refrigerants as viable options to decrease demand for virgin refrigerant production;
- Destroying recovered refrigerant only for substances that are no longer viable and needed, using environmentally sound technology;
- Ensuring environmentally sound management of decommissioned refrigeration, air-conditioning and heat-pump equipment.

III. What are key components and management practices of LRM?

9. LRM practices can be broadly grouped into key management strategies as described below. For more information, please see the briefing note entitled “Deep dive into LRM”. For these strategies to be more effective in ensuring cumulative emissions reductions and avoiding the negative environmental impacts of the RACHP sector as a whole, they should be implemented ideally in an integrated and coordinated way.

A. Leakage Prevention:

10. Leakage prevention begins at the design stage, where selecting appropriate components and materials and applying the required design standards can prevent leaks during the equipment's operational life. Leakage can also happen during transportation and storage of refrigerants, including from the equipment itself. Refrigerant cylinders and equipment should be properly packed and designed to withstand transport conditions.

11. The role of trained and independently certified servicing sector technicians is critical to maintaining high standards of leakage prevention and energy efficiency levels. During the use phase, maintenance and tightness inspections by qualified personnel need to be performed regularly to reduce leaks.

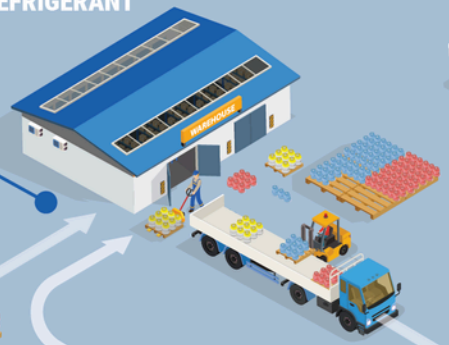
LIFE-CYCLE REFRIGERANT MANAGEMENT

L Leakage | 3R Recovery, Recycling and Reclamation | M Management Practices

PRODUCTION OF REFRIGERANT

STORAGE AND TRANPORTATION OF REFRIGERANT

M
Secure storage
Leak-proof containers
Proper handling



DESIGN OF EQUIPMENT

M
Equipment design
Components and material selection
Design standards

MANUFACTURING OF EQUIPMENT

L

Reverse supply chain
Use of refillable cylinders
M

Trained and certified technicians
Proper tools
Selection of location
M

INSTALLATION OF EQUIPMENT

L

Suitable packaging to withstand road conditions
M

Reverse supply chain
M

3R

RECYCLING

M
Testing and recycling equipment

RECLAMATION

M
Equipment for complex analysis and processes

RECOVERY
ON SITE OR AT A FACILITY

L

M
Trained and certified technicians
Using appropriate equipment

MANAGEMENT OF USED AND WASTE EQUIPMENT

M
Reuse, refurbishment, recycling
Envorimentally sound final disposal

DESTRUCTION OF REFRIGERANT

L

M
Approved technologies
Code of Good Housekeeping procedures

Transboundary movement
M

END-OF-LIFE OF EQUIPMENT

L

OPERATION & MAINTAINANCE OF EQUIPMENT

M
Trained and certified technicians for maintainance
Regular checks for tightness and leak detection

BENEFITS

1. Prevents emissions of harmful substances, protecting both the climate and the ozone layer. Estimated to mitigate up to 67 Gt CO_2e emissions by 2100.
2. Reduces refrigerant leaks, improving cooling efficiency, cutting operational costs, and minimizing indirect emissions from energy use.
3. Promotes resource efficiency and reduces carbon footprint through reuse of refrigerants and decreasing reliance on virgin substances.
4. Generates new employment opportunities, e.g. in system maintenance, recovery, recycling, and environmental auditing.

12. The parties to the Montreal Protocol have been implementing some of these practices. There remain operational challenges, however, to ensuring adherence to leakage prevention standards. While technological advancements have significantly improved leak detection, challenges persist in their accessibility, with some regions still relying on the traditional, less effective detection methods. Another challenge relates to the nature of the refrigeration servicing sector which, in many countries, tends to be seasonal and informal.

13. Regulatory measures mandating regular leak inspections, mandatory technician certification, and systematic enforcement of leakage prevention across the industry are some key options in the policy suite needed for LRM.

B. Recovery, Recycling and Reclamation:

14. The parties of the Montreal Protocol clarified the definitions of recovery, recycling and reclamation (or 3R) in the following way[6]:

- Recovery is the collection and storage of controlled substances from machinery, equipment, containment vessels, etc., during servicing or prior to disposal;
- Recycling is the re-use of a recovered controlled substance following a basic cleaning process such as filtering and drying. For refrigerants, recycling normally involves recharge back into equipment it often occurs "on-site;
- Reclamation is the re-processing and upgrading of a recovered controlled substance through such mechanisms as filtering, drying, distillation and chemical treatment in order to restore the substance to a specified standard of performance. It often involves processing "off-site" at a central facility.

15. For recovery, special recovery machines capable of handling a variety of substances need to be used to safely extract refrigerants from the systems. Once the refrigerant has been properly recovered, it can be recycled, reclaimed or destroyed. For reuse, recovered refrigerants need to be tested for purity and treated through recycling. Reclamation restores refrigerants to a specified standard of purity using advanced processes of distillation and chemical treatment. These processes require specialized equipment and logistics, which can make reclaimed refrigerant more expensive than virgin material.

16. Recovered refrigerants need to be stored in special cylinders or tanks, validated for integrity and safety, which are not always available in sufficient quantities. In the context of many developing countries in particular, adequate capacity of the servicing sector is crucial to successfully

[6] Decision IV/24 *"Recovery, reclamation and recycling of controlled substances"*

16. adhere to such best practices and perform recovery, recycling and reclamation properly. Attempts have been made to promote refrigerant recovery, recycling and reclamation, which Article 5 parties to the Montreal Protocol (that is, mainly developing countries) find challenging owing to a lack of capacity in the servicing sector, lack of finance and access to technology, and other difficulties that need to be overcome to sustain the process.

17. Regulations prohibiting venting and mandating the recovery of refrigerants play a vital role in enforcing 3R practices. These policies need to be coupled with financial incentives, capacity building, streamlined processes such as cylinder exchange programmes that can reduce logistical barriers and encourage compliance and participation. Regional cooperation and infrastructure for reclamation and destruction facilities in the context of low-volume consuming countries can help address some economic and logistical challenges in this respect.

C. Destruction and Environmentally Sound Disposal:

18. Refrigerants that cannot be reused need to be safely destroyed to ensure that they do not contribute to ozone depletion or global warming. Various technologies and approaches are used to achieve environmentally sound destruction of refrigerants at their end of life, each presenting different advantages, challenges and cost implications.

19. The Montreal Protocol Technology and Economic Assessment Panel periodically reviews existing and new technologies based on their efficiencies and accessibility to suggest to parties for safe and effective destruction of controlled substances. Technologies are broadly categorized into thermal oxidation commonly known as incineration, plasma technologies that have high destruction efficiency, and chemical transformation technologies.

20. Globally, refrigerant destruction facilities are unequally distributed, and for parties that do not have domestic destruction facilities the process can be expensive as it may involve transboundary movement of refrigerants that are classified as hazardous waste under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. Transportation of refrigerants to a location with available facilities across borders creates logistical and economic barriers.

21. Carbon credit markets can play an important role in supporting the recovery, recycling, reclamation and destruction of refrigerants. These markets provide financial incentives for reducing greenhouse gas emissions by allowing companies and projects that reduce emissions to sell carbon credits. These credits can then be purchased by entities looking to offset their emissions. For more information, please see the briefing note on “Potential financing mechanisms for life-cycle refrigerant management”, which presents an overview of funding options.

D. Environmentally sound management of used and waste equipment

22. The end-of-life disposal of equipment containing refrigerants needs to adhere to environmentally sound standards and practices. Owing to the presence of controlled substances classified as hazardous waste and other toxic substances as well as valuable materials (metals and plastics) that can be further processed for reuse, RACHP equipment is classified as electronic and electrical waste (e-waste) in many jurisdictions. Robust and solid e-waste management systems need to be in place to handle the disposal of appliances and vehicles with air-conditioning systems, integrating e-waste and scrappage policies.

23. The Basel Convention "Partnership for Action on Challenges relating to E-waste" (PACE II)[7] has been developing a technical guidance document for the environmentally sound management of used and waste RACHP equipment, and is promoting the development of relevant policies for the environmentally sound management of e-waste, such as extended producer responsibility policy[8] schemes. The technical guidance document[9] aims to provide a comprehensive, standardized approach to managing end-of-life RACHP equipment.

24. The draft document outlines protocols for the collection, separation, storage, handling, cleaning, refurbishment, repair, testing and labelling of refrigerants, including:

- Guidelines for setting up collection systems, ensuring careful handling to avoid damage and release of hazardous substances, with emphasis on the importance of proper storage and transportation to prevent leaks and contamination;
- Need for pre-sorting through initial visual inspection and sorting at collection points to determine suitability for reuse, refurbishment or disposal;
- Detailed steps for testing the functionality and safety of equipment, including electrical safety tests, functionality checks and cosmetic assessments;
- Repair protocols, including the controlled removal and replacement of refrigerants and the proper documentation of repairs;
- Cleaning and packaging: cleaning procedures to remove hazardous residues and ensure equipment is visually appealing for resale or donation. Packaging guidelines to protect refurbished equipment during transport;

[7] Partnership for Action on Challenges relating to E-waste (decision BC-15/22 Part I of the parties to the Basel Convention).

[8] Extended Producer Responsibility is a policy approach that makes producers responsible for their products along the entire life cycle, including at the post-consumer stage. (OECD, Extended Producer Responsibility: Basic facts and key principles, OECD Environment Policy Papers, No. 41, 2024).

[9] UNEP/CHW/OEWG.14/INF/32, Draft guidance document on the environmentally sound refurbishment and repair of used and waste equipment of refrigerators, cooling and heating equipment and on the environmentally sound management of waste equipment of refrigerators, cooling and heating equipment.

24.
- Dismantling and treatment of waste: procedures for the safe dismantling of equipment, removal of refrigerants, and segregation of recyclable materials. Guidelines for the manual and mechanical separation of components and the disposal of non-recyclable waste;
- Safe transport of waste equipment to treatment facilities and storage requirements for impermeable surfaces and weatherproof storage areas to prevent environmental contamination;
- Administrative measures such as record-keeping to ensure traceability and compliance with regulatory requirements, and implementation of certification schemes and regular inspections to ensure adherence to ESM practices;
- Mandatory training for personnel involved in refurbishment and repair activities, with a focus on handling hazardous substances and the provision of personal protective equipment to ensure worker safety;
- Strategies to manage hazard risks associated with refurbishment and repair, including the safe handling of refrigerants and other hazardous materials;
- Relevance to international agreements such as the Montreal Protocol and the Stockholm Convention on Persistent Organic Pollutants;
- Compliance ensuring that refurbished and repaired equipment meets applicable operational standards and import and export requirements, with clear labelling of refurbished equipment with information about the re-use operator, unique device identification, and year of re-market.

IV. Why is LRM needed?

25. ODS and HFCs are powerful greenhouse gases with short atmospheric lifetimes relative to carbon dioxide. The urgent need for immediate and deep cuts in greenhouse gas emissions across all sectors to continue protecting the ozone layer and mitigate climate change necessitates the effective management of controlled substances throughout all stages of their life cycle.

26. The reduction of emissions is not mandatory under the Montreal Protocol, which achieves its goals by reducing production and consumption of ODS and HFCs. Reductions in greenhouse gases through LRM are, however, a beneficial consequence of the work of the Montreal Protocol. Decreasing these emissions offers a relatively low-cost option to achieving short-term climate benefits while also supporting long-term mitigation efforts. LRM also facilitates the long-term recovery of the ozone layer, as it will prevent millions of tonnes of ODS from reaching the atmosphere.

27. The current banks of these substances represent massive potential emissions, with estimates suggesting that "ODS and HFC banks (inclusive of foams and other non-refrigerant uses) range from 16 gigatons CO2-eq to 24 gigatons CO2-eq. On top of today's installed banks, it is projected that approximately 67 gigatons CO2-eq in ODS and HFCs is expected to enter the global market by 2100, even with full compliance with the Montreal Protocol, across all applications".[10] The important climate and ozone protection benefits achieved by the parties to the Montreal Protocol could be severely undermined if LRM is not implemented at scale to prevent the release of controlled substances into the atmosphere.

28. LRM can also aid in maintaining energy efficiency of equipment. Leak reduction measures reduce emissions and conserve refrigerant while increasing equipment operating efficiency. A reduction by 10 per cent in refrigerant charge in a system can make the system work less efficiently – for example, the efficiency in a cooling system might drop by 15 per cent.[11] Maintaining energy efficiency not only reduces operational costs, but also decreases indirect greenhouse gas emissions associated with increasing energy consumption for cooling.

29. LRM can bolster the circular economy through recycling and reclamation by helping to conserve the amount of new refrigerant to be produced for use, including for servicing operating equipment. Life-cycle assessments indicate that recovery and reclamation processes have a significantly lower carbon footprint compared to the production of new refrigerants.[12]

30. Implementing LRM can create substantial employment opportunities, including for women, particularly in developing countries. The sector offers diverse jobs in different roles, including technicians for system maintenance, refrigeration recovery, recycling and reclamation specialists, and auditors optimizing management practices and new services in collection, transport and destruction. As LRM becomes more recognized and more widely implemented, the demand for skilled professionals is expected to grow.

[10] TEAP, "Decision XXXV/11 Task Force Report on Life-cycle Refrigerant Management", (May 2024), p.108

[11] Ibid. p.113

[12] Ibid, p.117.

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Montreal Protocol (Ozone) Secreteriat
United Nations Environment Programme
United Nations Avenue, Gigiri
P.O. Box 30552
Nairobi 00100 KENYA

mea-ozoneinfo@un.org