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° Report

Cool Humans, Hot Earth? HFCs:

The Paradox of Artificial Refrigerants Fueling the Climate Crisis

SFOC
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Solutions for Our Climate(SFOC) is an independent policy research and advocacy group that aims to make emissions trajectories across Asia compatible with the Paris Agreement 1.5°C warming target.

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Abbreviations and acronyms

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BTR	Biennial Transparency Report
CFCs	Chlorofluorocarbons
COP	Conference of the Parties
EPR	Extended Producer Responsibility
F-gases	Fluorinated gases
GHG	Greenhouse gas
GWP	Global warming potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefins
HVACR	Heating, ventilation, air-conditioning and refrigeration
IPCC	Intergovernmental Panel on Climate Change
LRM	Lifecycle Refrigerant Management
MOE	Ministry of Environment of the Republic of Korea
MOTIE	Ministry of Trade, Industry and Energy of the Republic of Korea
NDC	Nationally Determined Contribution
NFA	National Fire Agency of the Republic of Korea
NIR	National Inventory Report
ODP	Ozone depletion potential
ODS	Ozone-depleting substance
OECD	Organisation for Economic Co-operation and Development
PFAS	Per- and polyfluoroalkyl substances
PFCs	Perfluorocarbons
RT	Refrigeration ton
TEAP	Technology and Economic Assessment Panel of the Montreal Protocol
TFA	Trifluoroacetic acid

Executive Summary

- Hydrofluorocarbons (HFCs) have been added to the list of controlled substances with the coming into force of the Kigali Amendment to the Montreal Protocol in 2016. The Republic of Korea ratified the Kigali Amendment in 2023, and bears the obligation of phasing down HFCs, similar to how CFCs and HCFCs—the successor to CFCs—were gradually phased out from 1987 onwards.

- HFCs, first introduced to replace ozone depleting substances commonly used in refrigerants, are among the fastest-growing of the seven greenhouse gases, due to rising global demand for cooling systems. Besides this, refrigerants are also used to cool data centers, which are one of the fastest-growing industries owing to the exponential growth in demand for products and services related to artificial intelligence (AI).

- The Republic of Korea is the world's fifth-largest producer of refrigeration and air conditioning equipment. However, over 95% of refrigerants used in the South Korean market either contain HFCs, or HCFCs. Under the Kigali Amendment, South Korea must reduce its production and consumption of HFCs by 80% in comparison with the baseline by 2045. However, our analysis shows that the share of national greenhouse gas (GHG) emissions from HFCs have increased dramatically over the past decade, and that HFCs were the main reason why South Korea's GHG emissions increased for the year 2021.

- To phase down and to replace HFCs with low-GWP alternatives, it is necessary to establish an effective system to manage refrigerants across its entire lifecycle, as well as an improved statistical framework to gauge progress. While the South Korean government should incentivize industry's transition to natural refrigerants on the one hand, it should not neglect to put in place policies to fill the current gaping loopholes in the lifecycle management of refrigerants.

- The current legal framework for HFCs management is far from comprehensive, as it applies across varying legislation that each deal only with specific product groups and only certain stages of the product's lifecycle. The government should consider enacting a comprehensive law to manage all F-gases, while at the same time supporting comprehensive data collection across all product groups that contain HFCs.

Introduction:
HFCs, an underestimated problem fueling the climate crisis

Non-CO_2 greenhouse gases with high global warming potentials[1] (GWP) are attracting growing attention from policymakers to prevent global temperatures from rising 1.5 degrees Celsius above pre-industrial levels. Among these, hydrofluorocarbons (HFCs)—one of the fluorinated greenhouse gases (F-gases)—have GWPs of up to 12,400 times that of carbon dioxide and are used principally as refrigerants for air conditioning, and more recently, in the cooling of data centers that sustain artificial intelligence (AI) systems.

However, HFCs suffer from poor public awareness in South Korea and their management has so far been overlooked by government policymakers. Although South Korea is required to reduce HFCs emissions by 80% by 2045 under the Kigali Amendment, HFCs emissions have been increasing year on year. In addition, South Korea's HFCs-related laws and regulations only address certain product groups and only apply to certain stages of the products' lifecycle, hence making it difficult to manage their emissions in an integrated manner. This may result in slower domestic reductions compared to other East Asian countries, such as Japan and China.

This report analyzes the current state of policies related to HFCs in the Republic of Korea and at the same time seeks to enhance the overall understanding of HFCs to the public. It examines international agreements vis-à-vis HFCs, the current status of emissions and management systems in South Korea, and analyzes the South Korean government's recently announced "Roadmap For Improved Management of HFCs with the Goal of Greenhouse Gas Reductions" in order to propose concrete policy recommendations to reduce domestic HFCs emissions, and to improve their management.

1 GWP (Global Warming Potential): A number that shows the degree of impact on planetary warming for each greenhouse gas, i.e., how much a specific gas affects global warming as compared to a unit of carbon dioxide. The GWP is 1 for carbon dioxide, 28 for methane, 310 for nitrous oxide, and between 116~12,400 for hydrofluorocarbons (Dictionary of Information and Communication Terms, 2025).

I. Hydrofluorocarbons (HFCs): A super-polluting greenhouse gas used in refrigeration, air conditioning, and AI

Hydrofluorocarbons (HFCs)—among the fastest-growing of the seven greenhouse gases

Hydrofluorocarbons (HFCs) are one of six[2] greenhouse gases specified in the Kyoto Protocol, and—along with the other fluorinated gases (F-gases)—do not occur naturally but are 100% artificially produced. Hydrofluorocarbons, though less well-known than some of the other GHGs, possess global warming potentials (GWP) of up to 12,400 times greater than CO_2 (Annex). Currently, 4% of global greenhouse gas emissions can be attributed to the use of air conditioning equipment that contain HFCs as refrigerants—an amount that is double the emissions of the global aviation industry (Woods et al., 2022). In addition, the use of HFCs is increasing by an average of 10-15% per year due to the rising demand for cooling in developing regions of the world, making it among the fastest-growing of the seven major greenhouse gases (Shah, N., Wei, M., Letschert, V., & Phadke, A., 2019).

Refrigerants used in the HVACR (heating, ventilation, air conditioning and refrigeration) industry account for the largest proportion of HFCs emissions. Main emission pathways include refrigerant leakage due to long-term use of equipment without proper management, and intentional or unintentional leakage into the atmosphere at the end of the product lifecycle. In South Korea, HFCs are mainly used as refrigerants (71.3%), as foam agents for building insulation (18.4%), as fire extinguishants (7.4%), and as various solvents (2.5%) (Box 1).

Refrigerants containing HFCs are used in nearly all sectors of the economy, and in emerging industries such as AI

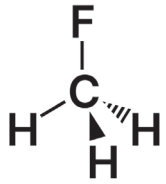
Refrigerants, which contain HFCs, are essential products integral to the 21st century economy. Refrigeration is an indispensable element in agriculture, being responsible for food preservation and distribution. Refrigerants are also key factors in manufacturing, including in the chemical industry, food processing, and the automotive and electronics industries, where air conditioning and refrigeration are essential to production and distribution. Refrigerants are also omnipresent in the tertiary sector—composed of countless service companies—and notably in cooling systems that cool the heat produced by data centers, which is currently fueling the growth of the artificial intelligence (AI) industry (HVACR Journal, 2024).

For data centers in particular, it is worth noting that cooling accounts for about 30-50% of their energy use (CCAC, 2025). Data centers have seen a rapid increase in demand since the beginning of cryptocurrency mining for Bitcoin, throughout the 5G era, and the mainstreaming of artificial intelligence (AI) technology. The sustained growth of the AI industry depends on data centers that serve as its physical infrastructure. Global demand for data centers is expected to increase by 16% annually from 2022 to 2026, while the capacity of domestic data centers is expected to increase to 1,850MW in 2027, more than three times that for 2023 (CBRE, 2024).

2 The seventh greenhouse gas, nitrogen trifluoride (NF_3), was added in 2012 as part of the Doha Amendment to the Kyoto Protocol.

South Korea is the world's fifth-largest producer of refrigeration and air conditioning equipment. Despite this, more than 95% of all refrigerant products used in the industry are HFCs or HCFCs, all subject to international phasedown regulations (KTC, 2024). Of the 200 companies that make up the HVACR (heating, ventilation, air conditioning and refrigeration) manufacturing and equipment industry in South Korea, 186 (93%) are small and medium-sized enterprises (based on sales in 2023).

[Box 1] HFCs: definition and main uses

Chemical formula and structure	HFCs, Hydrofluorocarbons 
Consumption by product (average share of domestic consumption, %, 2020-2022) (MOE, MOTIE, NEFA, 2024)	Refrigerants(71.3%), Foam agents(18.4%), Fire extinguishants(7.4%), Solvents(2.5%), Others(0.4%)
One of the seven greenhouses gases under the Kyoto Protocol	Seven GHGs: Carbon dioxide(CO_2), Methane(CH_4), Nitrous oxide(N_2O), Hydrofluorocarbons(HFCs) Perfluorocarbons(PFCs), Sulfur hexafluoride(SF_6), Nitrogen trifluoride(NF_3)
Global Warming Potential (GWP)	CO_2: HFCs (varies by substance) 1: 116~12,400
Commonly used HFCs by substance and GWP	HFC-134a (1,430); HFC-143a (4,470); HFC-32 (675); HFC-125 (3,500); HFC-227ea (3,220)
R-number used for classifying refrigerants (ASHRAE Standard 34)	An R-number is used to streamline classification for blends of HFCs. Ex: R-404A = blend of HFCs 125, 134a, 143a; R-407A = blend of HFCs 32, 125, 134a

From the Montreal Protocol to the Kigali Amendment: the international framework for reducing HFCs

The origin of the agreement to phase down HFCs dates back 28 years before the Paris Agreement was signed. The Montreal Protocol, signed in 1987, was the first multilateral environmental agreement to achieve universal ratification by all countries on Earth to phase out ozone-depleting substances (ODS). HFCs were produced as a substance to replace hydrochlorofluorocarbons (HCFCs) which were themselves developed to replace chlorofluorocarbons (CFCs), the main cause of the destruction of the ozone layer in the atmosphere.

With an ozone depletion potential (ODP) of zero, HFCs were initially developed to minimize damage to the ozone layer. However, as it became known that HFCs have global warming potentials (GWP) up to 12,400 times greater than that of carbon dioxide, the international community came together to ratify the Kigali Amendment in 2016, agreeing to comprehensively regulate the production and consumption of HFCs (Box 2). The Kigali Amendment, which has been ratified by 163 countries to date, aims to reduce global HFCs production and consumption by more than 80% over the next 30 years (2020-2050), which is equivalent to avoided greenhouse gas emissions of approximately 70 billion tons of CO_2eq internationally by 2050. Reducing HFCs may prove to be key in preventing the crossing of major climate tipping points—the threshold of catastrophic climate change—that would be caused by a global temperature rise of more than 1.5°C, as it can prevent up to 0.4°C of additional warming by the end of the century (Ozone Secretariat, 2016) (CCAC, 2025).

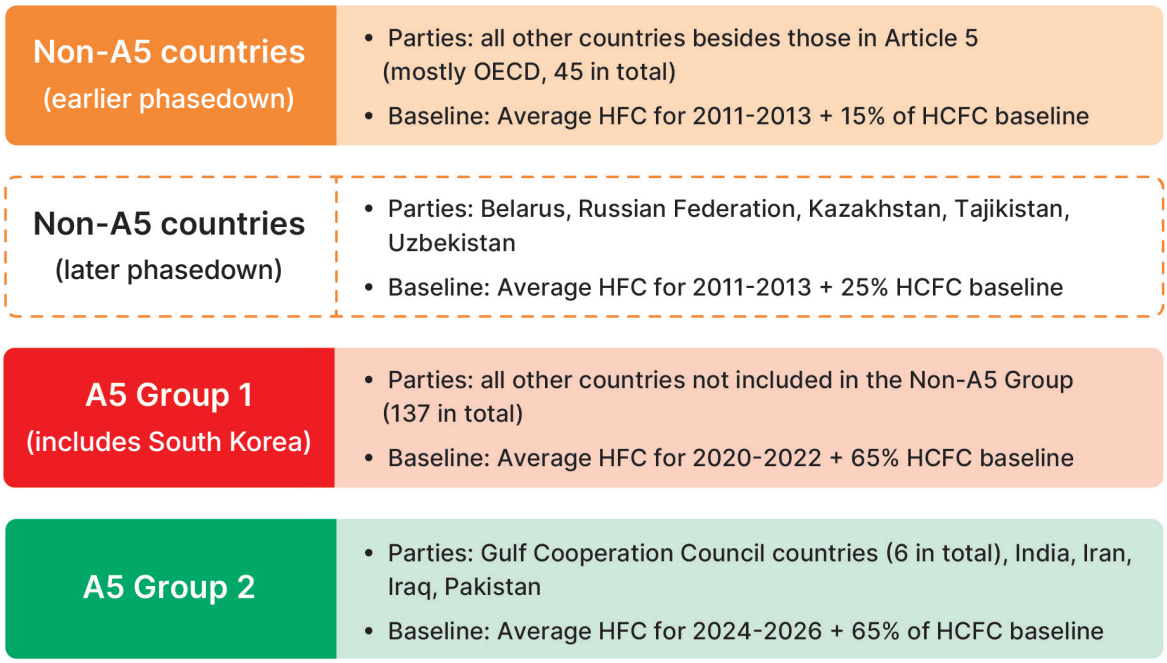
[Box 2] Timeline of international agreements related to HFCs

II. Where was South Korea when major countries rushed to establish policies to reduce HFCs?

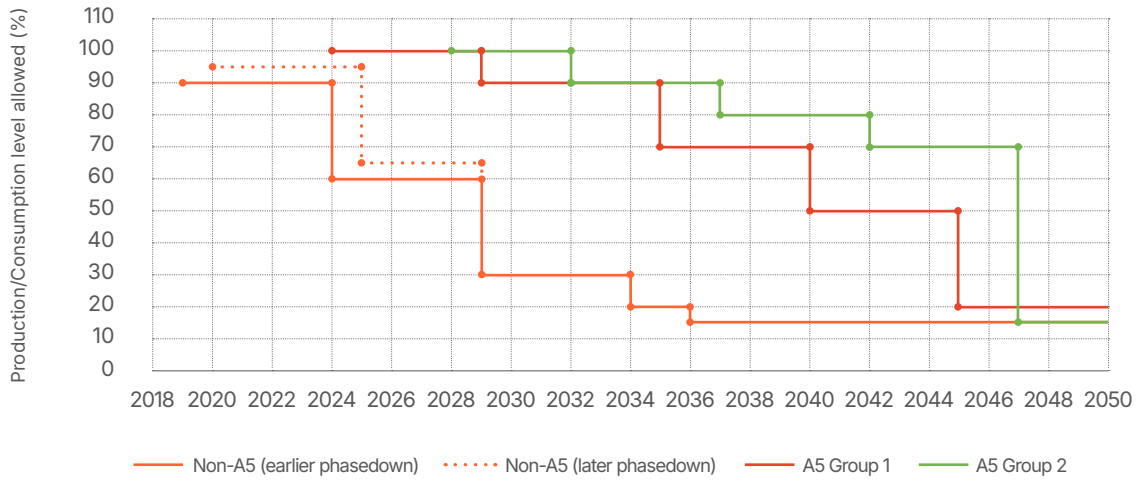
South Korea's slow ratification of the Kigali Amendment may have stalled progress

South Korea, as an Article 5 country of the Montreal Protocol, is subject to a more "generous" HFCs reduction schedule than non-Article 5 (i.e. developed) countries. Despite this generous reduction schedule, South Korea ratified the Kigali Amendment in 2023, only one year before the start of its obligations under Article 5 Group 1. In contrast, Japan, belonging to the non-Article 5 group of countries, ratified the Kigali Amendment in 2018, while China—which is in the same Article 5 category as South Korea—ratified the Kigali Amendment in 2021. Compared to other OECD countries, South Korea ranked near the bottom at 36th out of 38, suggesting a belated response in ratification not befitting its economic level and status. In line with the Kigali phasedown schedule, the South Korean government is obligated to set a baseline HFCs production/consumption level in the form of a freeze in 2024, with the baseline quantity derived from the average domestic production and consumption of HFCs over the years 2020-2022 plus 65% of the baseline quantity of HCFCs. In relation to that baseline quantity, South Korea is is obligated to reduce HFCs production and consumption by 10% in 2029, 30% by 2035, 50% by 2040, and 80% by 2045. (Figure 1-2). The reported production/consumption baseline for South Korea is currently about 82.2 million tons CO_2eq (MOTIE, 2024).

[Figure 1] Country groupings under the Kigali Amendment



[Figure 2] HFCs production/consumption reduction schedule under the Kigali Amendment



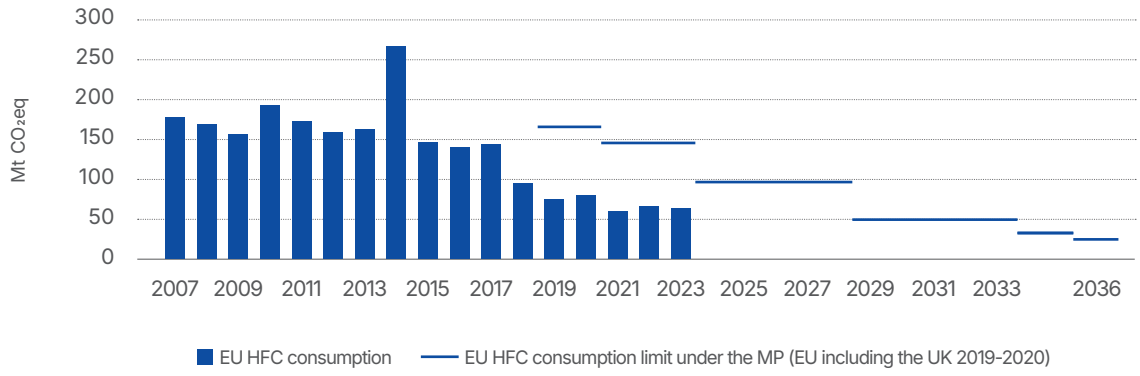
*Republic of Korea is included under A5 Group 1 (red line)

Source: (Ozone Secretariat, 2016)

South Korea's HFCs consumption steadily increased, even as major countries implemented policies early on to reduce HFCs

A number of OECD countries enacted and implemented regulations on F-gases (fluorinated gases) and developed policies to encourage substitution away from HFCs well before 2019, and some even before the signing of the Kigali Amendment. Notably, the European Union enacted the F-gas Regulation (EC) No. 842/2006 and established an F-gas leak prevention training and certification system ten years before the Kigali Amendment was ratified. Thanks to these early measures, the annual consumption of HFCs in Europe declined more or less continuously since 2009 (Figure 3).

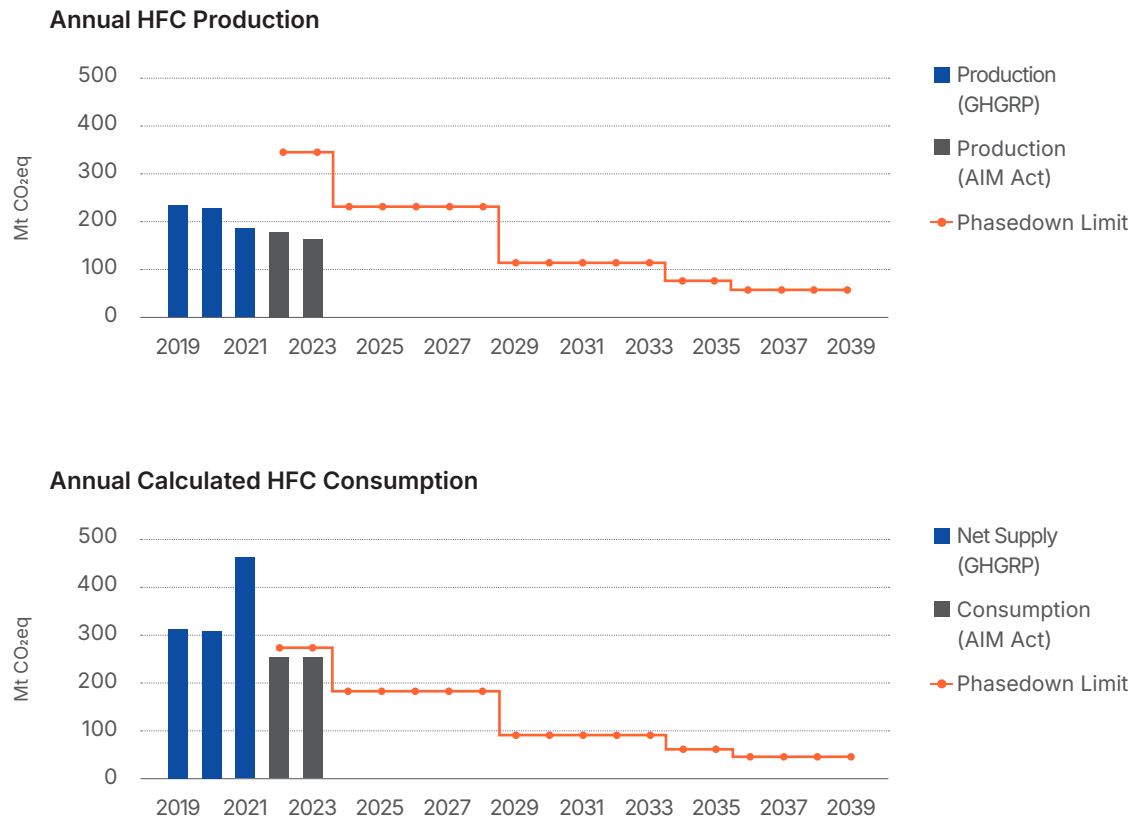
[Figure 3] Annual HFCs consumption in the European Union (2007-2023)



Source: (European Environment Agency, 2024)

The United States ratified the Kigali Amendment in 2022, but already in 2020, the American Innovation and Manufacturing (AIM) Act enabled the United States to apply a regulatory and management system to HFCs similar in kind to that mandated under the Montreal Protocol (US EPA, 2025). This allowed the United States to make the necessary reductions in line with the Kigali Amendment to reduce HFCs production and consumption (Figure 4).

[Figure 4] Annual HFCs production & consumption in the United States (2019-2023)

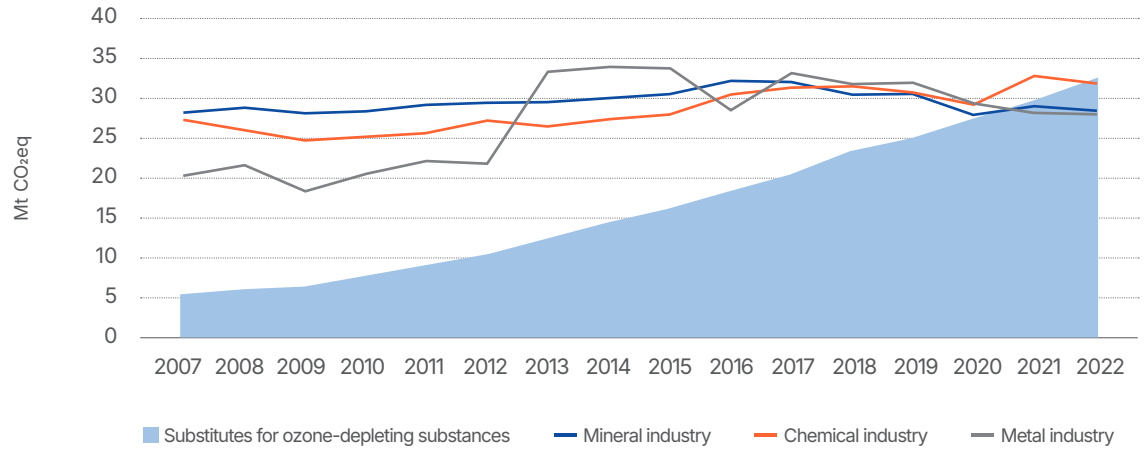


Source: (US EPA, 2024)

On the other hand, South Korea's HFCs emissions increased continuously up to 2022—the last reporting year and two years prior to the production/consumption freeze for Article 5 Group 1 countries. According to the national greenhouse gas inventory statistics, HFCs accounted for the largest increase among all GHGs for 2021-2022 (Greenhouse Gas Inventory and Research Center, 2025). During 2007-2022, HFCs emissions increased much more rapidly compared to other greenhouse gases, with an average annual growth rate of 13%, to reach 32.94 million tons of CO_2eq in 2022, or 4.4% of total national greenhouse gas emissions (Greenhouse Gas Inventory and Research Center, 2025). It is worth noting that even as total national greenhouse gas emissions decreased by 7.6% compared with 2018 levels (i.e. the NDC baseline), HFCs emissions *increased* by 39.3% (Greenhouse Gas Inventory and Research Center, 2025) (Figure 5).

It is likely that HFCs would play an influential role in whether South Korea achieves its NDC target. Recent changes to the accounting framework for national greenhouse gas inventories (i.e. from the 1996 IPCC Guidelines to the 2006 IPCC Guidelines) increased overall national emissions by a total of 44.7 million tons of CO_2eq in 2021, of which half (about 22.3 million tons of CO_2eq) was attributed to HFCs (MOE, MOTIE, NFA, 2024). With the inclusion of "substitutes for ozone-depleting substances" as a new category, the number of HFCs included in the accounting framework expanded from two (i.e. production and consumption of halocarbons and sulfur hexafluoride) to cover 29 refrigerant products (i.e. to include those used in refrigeration and air conditioning, blowing agents, fire extinguishers, aerosols, solvents, etc.), which together accounted for a majority of emission increases (Greenhouse Gas Inventory and Research Center, 2025).

[Figure 5] Comparison of greenhouse gas emissions by sub-category for the industry sector in South Korea (2007-2022)



Source: (Greenhouse Gas Inventory and Research Center, 2025)

An incomplete statistical framework contributed to a lack of meaningful progress in HFCs reduction for the past decade

South Korea has been calculating HFCs emissions based on import and export trade statistics using the 1996 IPCC Guidelines Tier 1 methodology until 2023. Of the 29 types of HFCs-based products imported and used throughout South Korea, only two types, HFC-152a and HFC-134a—each with designated HS codes—were able to be included in the emissions calculation. Twenty-seven others, including those that contain R-410A, which is the most commonly-used refrigerant in South Korea, and HFC-23, which has a global warming potential 12,400 times that of carbon dioxide, were excluded from the emissions calculation until 2024 (ColdChain News, 2023), as they were all previously grouped under a single HS code. As the import and export volumes could not be confirmed, it was not possible to calculate emissions by applying different global warming potentials to each substance.

One explanation for the lack of an HFCs reduction policy and management system in South Korea thus far may have been because the steep growth trend of HFCs emissions could not be properly identified due

to hitherto incomplete statistics. Had South Korea continued to use the calculation methodology used for the 1996 IPCC Guidelines, HFCs emissions in 2022 would have been considerably lower—7.54 million tons of CO_2eq, or a 19% reduction from 2018 levels—and any government-wide reduction measures for HFCs would not have been forthcoming.

Current regulations to manage HFCs in South Korea concern only 'refrigerants', and apply only to certain product groups

After the ratification of the Kigali Amendment in 2023, the South Korean government defined HFCs as a 'Type 2 Specific Substance' under the **"Act on the Management of Specific Substances for the Protection of the Ozone Layer"** that regulates second-generation (CFC and HCFC) refrigerants and established legal grounds for a phasedown of HFCs in alignment with the Kigali phasedown schedule. However, the law does not include provisions that regulate the end-of-life stage of products that contain HFCs. While there do exist recovery, treatment, and reporting obligations for some products, these pertain not to "HFCs", but to products under the "refrigerant" category—and only for those products that meet the "RT"[3] criteria set forth under the **"Clean Air Conservation Act"** and the **"Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles"** (i.e. cars and certain electronic equipment) (Table 1).

[Table 1] Current legal framework for HFCs management in South Korea

Regulated Substance	Law currently in force		
	Production/Export/Import/ Sale	Use/Re-use	Recovery/Disposal
Hydrofluorocarbons (HFCs)	Act on the Management of Specific Substances for the Protection of the Ozone Layer	-	Act on the Management of Specific Substances for the Protection of the Ozone Layer (verification of HFCs destruction)

Regulated Product	Law currently in force		
	Production/Export/Import/ Sale	Use/Re-use	Recovery/Disposal
Products containing refrigerants >20RT (Used for buildings, food preservation, other industrial uses)	Clean Air Conservation Act	Clean Air Conservation Act, High-pressure Gas Safety Control Act (only applies to certain refrigerants)	Clean Air Conservation Act, Wastes Control Act
Electronic equipment and vehicles containing refrigerants	-	-	Act on Resource Circulation of Electrical and Electronic Equipment and Vehicles, Wastes Control Act
Products other than refrigerants that contain HFCs (e.g. aerosols, solvents, fire extinguishants)	Act on Registration and Evaluation of Chemical Substances	-	-

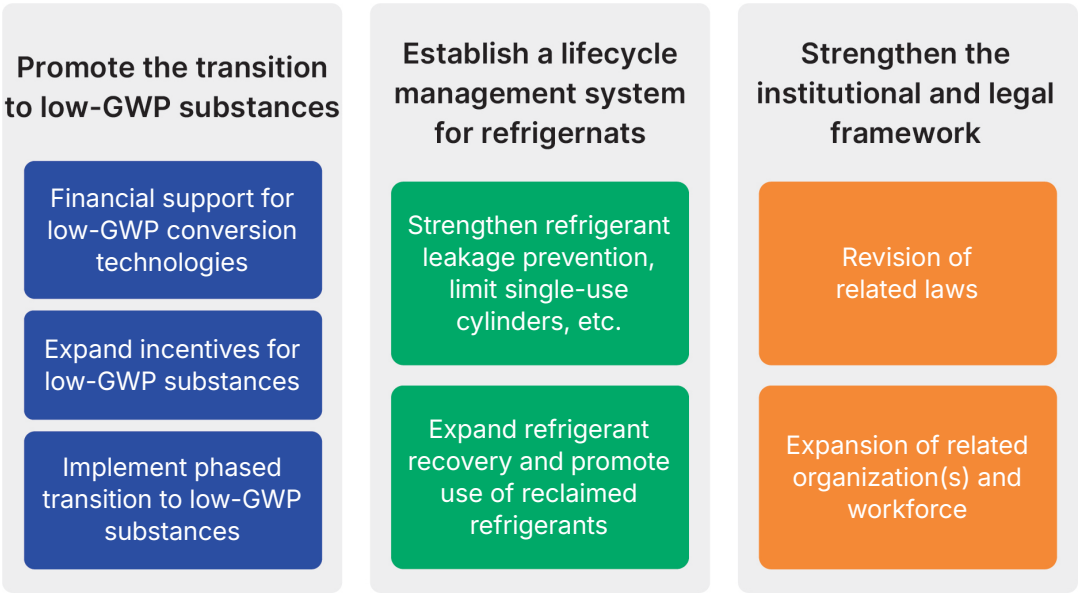
Source: Adapted from information received from the office of Hakyoung Lee (National Assembly Member)

3 RT (Refrigeration Ton): A unit of measure that quantifies the freezing capacity of turning 1 ton of water at 0°C into 1 ton of ice at 0°C for 24 hours. The higher the RT, the higher the freezing capacity.

What is included in the "Roadmap for Improved Management of HFCs" released at the end of 2024?

The relevant Ministries of the South Korean government (Ministry of Environment, Ministry of Trade, Industry and Energy, and the National Fire Agency) released the "Roadmap for Improved Management of HFCs with the Goal of Greenhouse Gas Reductions" in December 2024. This plan, which aims to reduce HFCs emissions by about 20 million tons of CO_2eq by 2035 through gradual reduction of HFCs consumption in line with the Kigali Amendment's phasedown schedule, has three Focus Areas: 1) promoting the transition to low-GWP substances; 2) establishing a lifecycle management system for refrigerants; and 3) strengthening the institutional and legal framework. The number of projects included were three for Focus Area 1, and two each for Focus Areas 2) and 3) (Figure 6).

[Figure 6] Focus Areas and projects specified under the "Roadmap for Improved Management of HFCs with the Goal of Greenhouse Gas Reductions"



Source: (MOE, MOTIE, NFA, 2024)

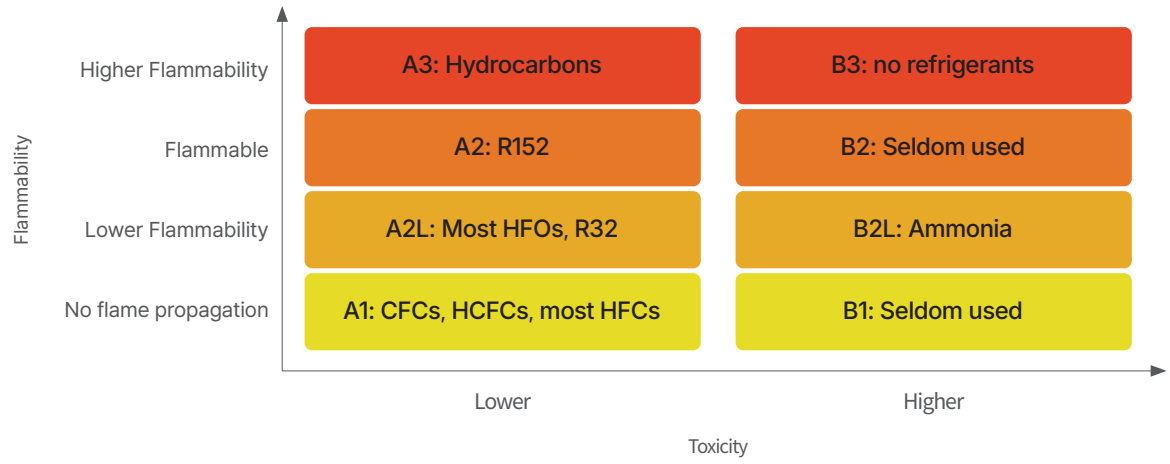
The relevant ministries and agencies stated that a consultative body was formed to prepare a low-GWP transition schedule categorized by product group, and that around thirty consultative discussions were held with stakeholders of the HVACR industry in 2024 (MOE, MOTIE, NFA, 2024). Despite this, the Roadmap was met with opposition by the consultative body for suppliers of specific substances shortly after its release, with their main contention being that the use of patented substances as low-GWP substitutes would lead to increased production costs for these new refrigerants (ColdChain News, 2025). In addition to this, the Roadmap does not state whether discussions were held on the challenges of establishing a lifecycle management system for refrigerants with relevant stakeholders from that sector, such as with refrigerant recovery, recycling and waste management companies (MOE, MOTIE, NFA, 2024).

III. Additional considerations for policymakers in the "Roadmap for Improved Management of HFCs"

HFOs, despite their low GWP, are not without flammability risk, alongside a definite risk of PFAS emissions

Domestic industry is likely to use products in the Hydrofluoroolefin (HFO) category of substances to replace HFCs once the "Roadmap for Improved Management of HFCs" is implemented. Even though HFOs have on average only a fraction (1/100th) of the global warming potentials compared to HFCs, they can be flammable and can turn toxic when emitted into the atmosphere (Figure 7) (ColdChain News, 2025). There have been reports that HFOs decompose in the atmosphere to form trifluoroacetic acid (TFA), which can fall to the ground with rain and contaminate drinking water (HVACR Journal, 2020). In Europe, where HFOs were introduced earlier than in Korea, the number of HFO-related substances detected in the atmosphere increased since 2015, suggesting the need for a more thorough management system (Vollmer MK, Reimann S, Hill M, Brunner D, 2015).

[Figure 7] Refrigerant classification based on flammability and toxicity



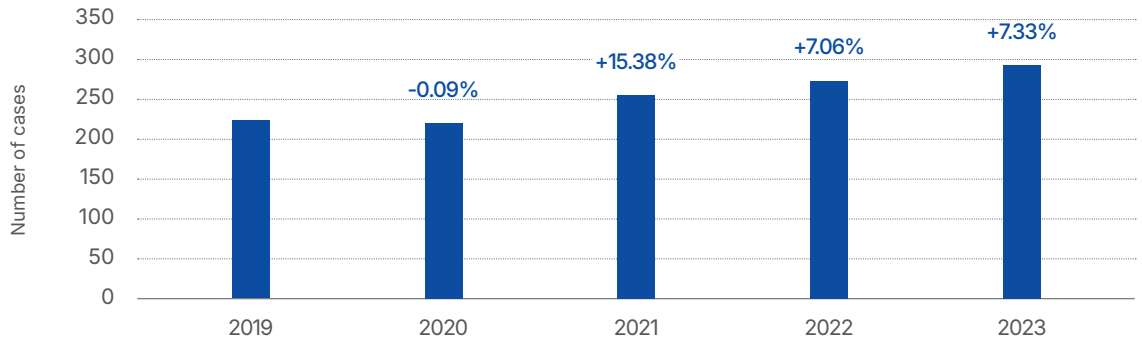
Source: (Danfoss, 2025)

The aforementioned TFA is a type of PFAS (per- and polyfluoroalkyl substance), or "forever chemical" that is part of a class of substances subject to stringent regulations in developed countries. Notably, major European countries have been discussing the inclusion of HFOs along with HFCs in the EU REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) regulations since 2023 to collectively restrict a total of over 10,000 PFAS-containing substances (European Chemicals Agency, 2023). The future of the HFO category of substances is becoming increasingly uncertain also in the US, where regulations related to PFAS are also being actively pursued (US EPA, 2025).

Lifecycle Refrigerant Management (LRM) can also aid in disaster prevention and safety assurance

Refrigerants can be flammable products that can cause a large fire if not managed properly. Fires can start through sparks in the insulation of the wire or surrounding combustible materials. There have been reports that an increase in air conditioner fires in past years may be related to the introduction of next-generation flammable refrigerants (MBC News, 2024), and if gaps persist in the management system of refrigerants—a management system that should include leak prevention, recovery, and safe disposal—there is a possibility that the number of fires caused by air conditioners and other HVACR equipment will increase in the future (Figure 8). In the absence of long-term, low-GWP alternatives in South Korea to certain refrigerants currently in use, focus should be put on establishing a comprehensive Lifecycle Refrigerant Management (LRM) system to prevent leakage of refrigerants during use, and to minimize leakage to the atmospheric during product disposal.

[Figure 8] Frequency of fires caused by air conditioners in South Korea (% on top of bar: rate of increase compared to previous year)



Source: (National Fire Data System, 2025)

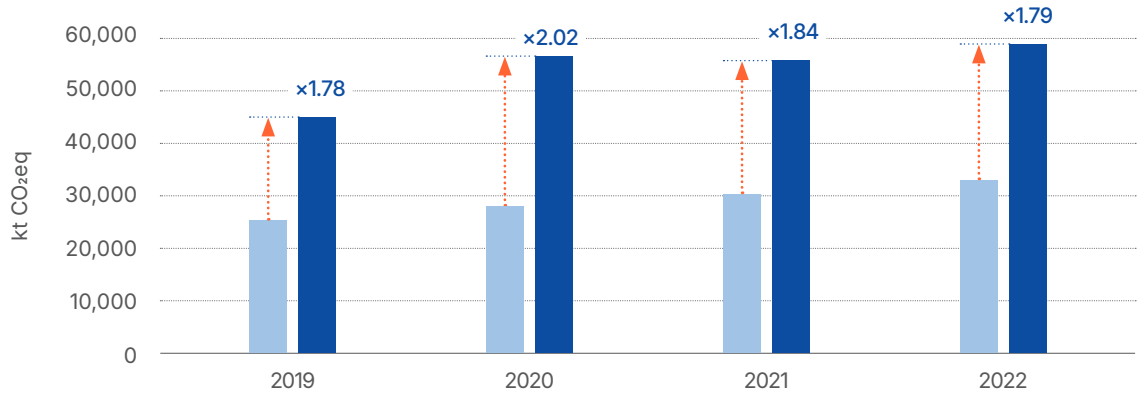
Looking at "potential emissions" data can be a helpful indicator in gauging HFCs emissions already present in considerable amounts in HVACR equipment

Currently, 95% of the refrigerants used in HVACR equipment manufactured and sold in Korea are HFC- or HCFC-based refrigerants, except for those exported to the US and Europe, which are mainly produced by large conglomerates (HVACR Industry Seminar, 2025). In the future, HFCs consumption is expected to increase due to the growing demand for refrigerants in heat pumps and domestic data centers (HVACR Industry Seminar, 2025).

Refrigerant leakage tends to occur as refrigeration and air conditioning equipment are used over extended periods of time. Though actual leakage may not occur until a later time in the future, it is necessary to consider the "potential emissions" of the refrigerants existing inside the system. Domestic greenhouse gas statistics show the difference between 'potential' and 'actual' HFCs emissions—and that "potential emissions" of HFCs is around twice as much as the "actual emissions" calculated by applying a certain emission factor over time (Figure 9). Given the risk of release of these 'potential' emissions, should

thorough refrigerant leakage management be neglected, the proportion of HFCs in national greenhouse gas emissions would likely continue to increase in the future.

[Figure 9] Comparison of 'actual[4]' with 'potential[5]' HFCs emissions in South Korea (2019-2022)



Source: (Office of Hakyoung Lee, Member of National Assembly, 2025)

Another reason why annual emissions of HFCs continue to increase is the need for continuous charging of refrigerants to ensure the normal operation of refrigeration and air conditioning equipment. According to a field survey conducted in 2014, which focused on commercial refrigeration equipment in the fisheries sector, it was discovered that about 20%-40% of total refrigerant charge is released annually (Park, 2014). The main causes of leakage according to the survey were 1) equipment not being installed properly; 2) emissions due to temperature changes, pressure changes, and vibration; 3) faulty equipment parts and insufficient sealing of products; 4) fugitive emissions during the maintenance (refrigerant charging) and repair stage (opening the system without recovering the refrigerant); 5) losses due to accidents (natural disasters, fires, explosions, etc.); and 6) release into the atmosphere before refrigerant recovery at the product disposal stage. All of these causes can engender the actual release of a large amount of "potential emissions" if management is neglected during the refrigerant use and after-use phase.

Low domestic refrigerant recovery rates and the absence of refrigerant lifecycle statistics can pose major obstacles to South Korea's achievement of its NDC

In South Korea, refrigerants used for charging are mainly injected into single-use cylinders. It has been reported that the residual gas remaining in these single-use cylinders after charge is close to 2-10% (Gas News, 2024). It can thus be assumed that the totality of the residual gas in the single-use cylinders get released into the atmosphere, and the amount of HFCs emitted from these alone is said to be as high as 1 million tons CO_2eq per year (National Assembly Seminar, 2025). It can also be inferred that HVACR equipment that have reached their end-of-life and left unattended in waste piles account for a significant portion of the current HFCs emissions in South Korea. Currently, the percentage of refrigerants that are

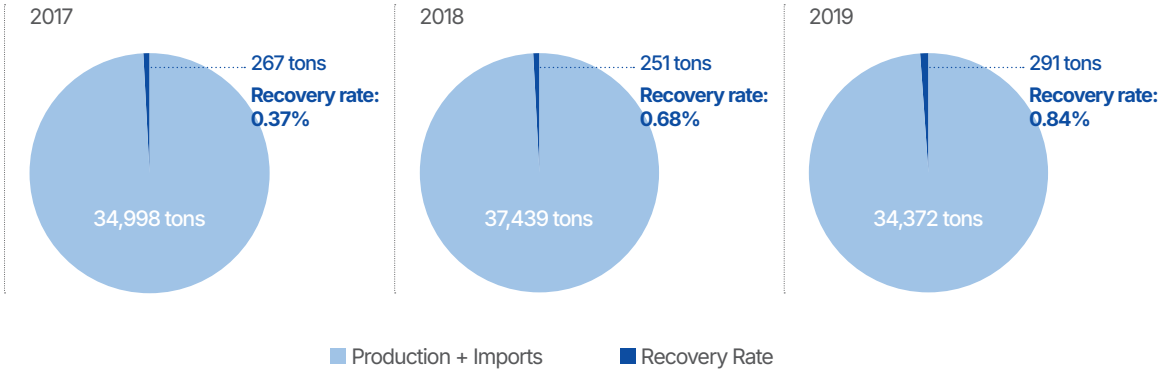
4 Method for calculating actual emissions: The refrigerant (HFCs) injected into the product is emitted at a certain rate during the product life cycle (= [(net HFCs consumption in year n + HFCs bank in year n-1] x emission factor x GWP)

5 Method for calculating potential emissions: 100% of HFCs consumed in the year are emitted (= net HFC consumption x GWP)

successfully recovered in South Korea is only a miniscule fraction of the total distribution volume (Figure 10). Moreover, only products classified as “appliances using refrigerants of 20 RT or more” and “electronics and automobiles” are included in the statistics, leaving all products that fall outside these two categories unaccounted for.

Fluorinated greenhouse gases have shown the fastest growth rate among domestic greenhouse gas emissions between 2007 and 2022—calculated according to the 2006 IPCC guidelines—and HFCs account for a significant portion of this increase (Government of the Republic of Korea, 2025). In the future, the influence of these "hidden emissions" of HFCs could hinder the achievement of South Korea’s NDCs and put a brake on achieving carbon neutrality.

[Figure 10] Comparison of refrigerant production and import by volume and refrigerant recovery rates in South Korea (2017-2019)



Source: (Gas News, 2022)

IV. Policy Recommendations for a successful HFCs phasedown in South Korea

Focus Area 1: Promote the transition to low-GWP substances

Policy Recommendation 1: Promote a direct transition from HFCs to natural refrigerants, leapfrogging over HFOs

While the "Roadmap for Improved Management of HFCs" jointly announced by the relevant ministries does mention "a gradual transition to low-GWP substances," it stops short of specifying what kind of low-GWP substances should be used (MOE, MOTIE, NFA, 2024). HFOs, as mentioned earlier, cannot be a sustainable solution for the future, considering the environmental impact of PFAS. In contrast, not only do natural refrigerants have no adverse effects on the environment, but they also have lower production costs and higher energy efficiency than HFCs. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) defines natural refrigerants as "substances that occur in nature's biological and chemical cycles without human intervention" (ASHRAE, 2011).

Currently, various natural refrigerants are being introduced in all areas, including refrigeration, air conditioning, heat pumps, and data centers (Figure 11). According to an industry report published in 2023, the natural refrigerant market is expected to grow to $2.7 billion by 2032 (HVACR Journal, 2023). The government needs to induce a switch from HFCs to natural refrigerants to ensure that the Kigali Amendment's reduction schedule is not disrupted, while at the same time exploring support measures to help the domestic HVACR (heating, ventilation, air conditioning and refrigeration) industry—which is mostly made up of small and medium-sized enterprises—to achieve a soft landing in its transition away from HFCs to natural refrigerants.

[Table 2] Natural refrigerants currently in use and major sectors of application

✓ = Domestic/international case of application exists

Natural refrigerants (nonexhaustive)	Sectors of application								
	Refrigeration			Air conditioning			Heat pumps		Data centers
	Commercial	Household	Transport	Commercial	Household	Transport	Commercial	Household	
Ammonia(R717)	✓		✓	✓	✓		✓	✓	✓
Water(R718)	✓			✓	✓		✓		✓
Propane(R290)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Isobutane(R600a)	✓	✓		✓				✓	
Carbon dioxide (R744)	✓	✓	✓	✓		✓	✓	✓	✓

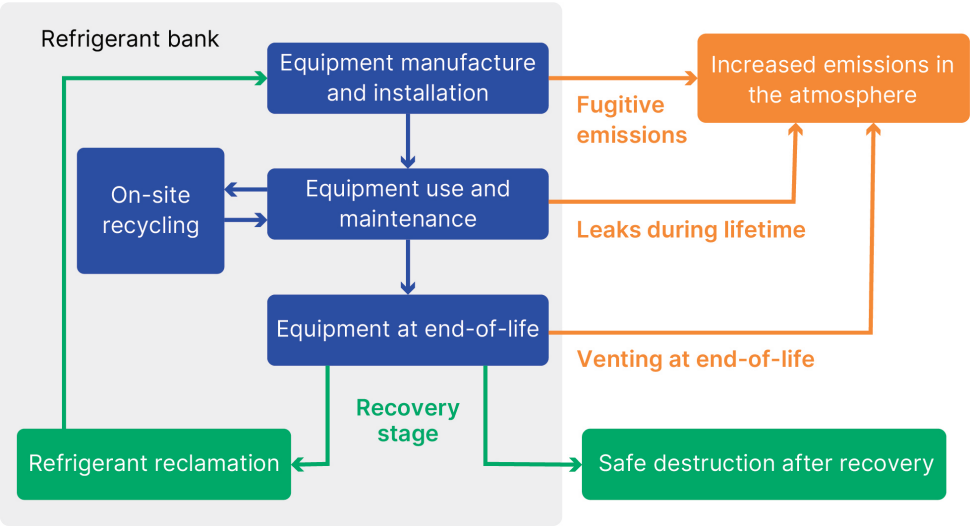
Source: (Cool Technologies, 2025)

Focus Area 2: Establish a lifecycle management system for refrigerants

Policy Recommendation 2: Implement a comprehensive Lifecycle Refrigerant Management (LRM) system that does not contain gaps in the responsibility of producers, users, recyclers, and waste managers

Introducing a Lifecycle Refrigerant Management (LRM) system can effectively reduce greenhouse gases emitted from refrigerants. According to the Technology and Economic Assessment Panel (TEAP) report, which provides the latest technical and economic information to the parties to the Montreal Protocol, the introduction of LRM could achieve a reduction of approximately 39 billion tons CO_2eq worldwide by 2050 (TEAP, 2024). This is an additional reduction that can be achieved separately from the 70 billion tons of CO_2eq emissions reductions that a successful implementation of the Kigali Amendment will bring—and hence an opportunity that must not be missed in preventing global temperature rise of more than 1.5°C. Robust refrigerant management is required at all stages to prevent 1) fugitive emissions during the production process; 2) leakage during use; and 3) unintentional/intentional emissions during the end-of-life stage. Stringent and coherent policies should be introduced in advance to ensure that producers, users, recyclers, and processors cooperate in a virtuous cycle to prevent the occurrence of blind spots and the transfer/shirking of responsibility (Figure 12).

[Figure 11] Lifecycle Refrigerant Management schematic with points of GHG emissions



Source: Adapted from (Yale Carbon Containment Lab, 2023)

Policymakers could consider including refrigerants in the product groups subject to the existing Extended Producer Responsibility (EPR) system in South Korea, in such a way that the producer would bear the responsibility and the costs of recycling that have so far been borne by companies specializing in refrigerant recovery.

Focus Area 3: Strengthen the institutional and legal framework

Policy Recommendation 3: Consider enacting new legislation to regulate all F-gases and to fill legal gaps in HFCs management

Although the legal management of refrigerant-containing equipment is being expanded from at least 20 RT (refrigeration ton) to at least 10 RT under the existing legal system, this still only covers about 34% of commercial and industrial equipment, which is an obstacle to establishing a comprehensive Lifecycle Refrigerant Management (LRM) system. There is currently an urgent need to establish a legal basis that can be used to manage all refrigerant-filled equipment and products—without exception—by reforming the current legal framework to be founded upon a wider-reaching standard than the present standard based on "RT". Furthermore, fluorinated greenhouse gases (F-gases) to which HFCs belong are used in a wide range of fields, including chemistry, electricity, and semiconductor manufacturing. By enacting a comprehensive new law (tentative name: "Act on the Management of Fluorinated Greenhouse Gases") that will form the legal foundation for management of these substances—whose demand is expected to increase into the future—agencies could be given the mandate, by virtue of the law, to establish a system in advance that can account for the emissions of these substances, and act quickly to manage said emissions if and when these substances become subject to gradual phasedown, much like HFCs in the present.

Additional Focus Area: Expand and enhance the current national greenhouse gas statistics framework

Policy Recommendation: Add granularity to HFCs accounting by including sub-categories differentiated by lifecycle emissions of each product

In September 2024, the government revised the national greenhouse gas statistics by applying the 2006 IPCC guidelines in accordance with the Paris Agreement (Ministry of Environment, 2024). Due to this change in the accounting framework, the number of products included under the "HFCs" category has increased from 2 to 29, with their "actual emissions" being calculated instead of "potential emissions". However, the Tier 1 calculation method currently in use applies only a basic, default emission factor that does not reflect the characteristics of domestic refrigerant emissions, nor does it allow the verification of emissions by use, such as industrial, household, commercial, and transportation. This contrasts with the way developed countries are calculating emissions statistics both by product group, and by lifecycle stage of the refrigerant—including manufacturing, use, and disposal—using the IPCC Tier 2 methodology.

HFCs are a major source of emissions accounting for 4.4% of national GHG emissions as of 2022, and emissions are expected to increase until 2034 (Ministry of Environment, 2024). More detailed statistics are required to develop appropriate reduction policies and to evaluate the results of implementation of various reduction measures. To serve as a compass for more ambitious HFCs reduction policies, increased granularity should be applied to the current statistical framework by transitioning to the Tier 2 methodology of the 2006 IPCC Guidelines to calculate emissions by detailed application of refrigerant-using equipment and by manufacturing, installation, use, and disposal stages.

Conclusion: The need to shift from the 'ozone-depleting substances' regime to the 'greenhouse gases' regime, and to expand 'ozone layer protection' to include 'climate crisis response'

The **Act on the Management of Specific Substances for the Protection of the Ozone Layer** was enacted in the Republic of Korea to implement the Montreal Protocol, and to establish a legal framework for managing and phasing out CFCs and HCFCs, the second generation of refrigerants. However, with the passing of the Kigali Amendment and the addition of HFCs to the list of controlled substances, the focus has expanded to cover not only 'ozone-depleting substances,' but also 'greenhouse gases.' By virtue of this fact, the HFCs phasedown has become intimately tied, if not on paper, then at least in spirit and substance, to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. One difference between the 'ozone-depleting substances' and 'greenhouse gases' is that whereas 'ozone-depleting substances' are artificially synthesized and produced, this is not the case for 'greenhouse gases,' which have the character of being environmental 'externalities' of human activity, rather than as the direct output of production, as CFCs and the "Freon" gases were throughout the 20th century. Seen from the point of view of public policy, this means that policies designed to mitigate ozone-depleting substances may not achieve the same effectiveness when applied, without change, to greenhouse gases, and vice versa.

Therefore, in the context of South Korea, the author argues that a new framework for a management system that focuses on reduction of "emissions" is needed, rather than continuing to rely on a framework geared towards simply replacing one "substance" with another, as was the case when CFCs were replaced with HCFCs, and HCFCs with HFCs. Though HFCs themselves are artificial substances, the greenhouse gases to which HFCs belong require emissions-focused reductions—and hence the establishment of Lifecycle Refrigerant Management (LRM) and an emissions-accounting system for HFCs are both indispensable elements to achieve this end. Poor management across parts of the lifecycle and the absence of a statistical framework across the entire lifecycle could have negative consequences not just for HFCs emissions, but on the achievement of broader national targets such as the NDC and carbon neutrality. Furthermore, unlike the "ozone-depleting substances" regime under the Montreal Protocol, the "greenhouse gases" regime under the Paris Agreement requires the reporting of *emissions*, and the *sources* for those emissions, on a regular basis (e.g. Biennial Transparency Reports (BTR), National Inventory Reports (NIR)). In addition, there is a process of establishing revised emissions targets based on the results of the inventories conducted under the leadership of the Conference of the Parties (COP) (i.e. Global Stocktake and Nationally Determined Contribution, or NDC). All of the above provide sufficient grounds, in the author's view, for establishing a comprehensive Lifecycle Refrigerant Management (LRM) and a detailed emissions-accounting system that can more precisely measure emissions with increased levels of granularity.

The **Act on the Management of Specific Substances for the Protection of the Ozone Layer**, the core domestic law for implementing the Montreal Protocol, sets out a regime for gradually inducing the transition to alternative substances by limiting the production and consumption of specific substances. However, the Montreal Protocol Secretariat makes clear that the issue is not only to replace specific substances worldwide, but also to comprehensively manage the upstream (import, manufacturing) and downstream (use, recovery, recycling, and disposal) stages of HFC-containing products that constitute the majority of HFCs emissions. Lifecycle Refrigerant Management (LRM) is thus a long-term, reliable means of reducing

greenhouse gases more rapidly and effectively. The establishment of LRM for comprehensive emissions management requires both efficient and steady collaboration between the private sector, government, and civil society actors.

This report makes clear that HFCs emissions have been steadily increasing throughout the past decade in South Korea without the government's notice. Due to differences in statistical calculation methods (mentioned in the previous section), about 20 million tons of extra CO_2eq emissions have been discovered that have previously been overlooked (Greenhouse Gas Inventory and Research Center, 2025). This is a stark reminder of the importance of accurate and reliable national greenhouse gas statistics. The government, in preparing an industry transition roadmap and supporting policies to gradually replace HFCs with natural refrigerants, should at the same time prioritize refrigerant recovery, recycling, and safe disposal in order to prevent the situation wherein the accumulated 'potential' emissions become actualized. In sum, South Korea, in addition to establishing a comprehensive legal framework focused on greenhouse gas mitigation, should work towards establishing a complete "climate crisis response" system, which would include a comprehensive statistical system to manage "emissions" from each stage of a product's lifecycle—and thereby doing its part as a responsible member of the international community.

Annex: Classification of HFCs by Group, Substance and Global Warming Potential

Group	Substance	100-Year Global Warming Potential (GWP)	
		GWPs according to Annex F of the Kigali Amendment (e.g. used to calculate the production/consumption of HFCs using the 1996 IPCC Guidelines prior to 2024)	GWPs used for GHG accounting under the Paris Agreement (e.g. used for the 1st Biennial Transparency Report and the subsequent National Inventory Report)
Group 1			
CHF_2CHF_2	HFC-134	1,100	1,120
CH_2FCF_3	HFC-134a	1,430	1,300
CH_2FCHF_2	HFC-143	353	328
$CHF_2CH_2CF_3$	HFC-245fa	1,030	858
$CF_3CH_2CF_2CH_3$	HFC-365mfc	794	804
CF_3CHFCF_3	HFC-227ea	3,220	3,350
$CH_2FCF_2CF_3$	HFC-236cb	1,340	1,210
CHF_2CHFCF_3	HFC-236ea	1,370	1,330
$CF_3CH_2CF_3$	HFC-236fa	9,810	8,060
$CH_2FCF_2CHF_2$	HFC-245ca	693	716
$CF_3CHFCHFCF_2CF_3$	HFC-43-10mee	1,640	1,650
CH_2F_2	HFC-32	675	677
CHF_2CF_3	HFC-125	3,500	3,170
CH_3CF_3	HFC-143a	4,470	4,800
CH_3F	HFC-41	92	116
CH_2FCH_2F	HFC-152	53	16
CH_3CHF_2	HFC-152a	124	138
Group 2			
CHF_3	HFC-23	14,800	12,400

Source: (Ozone Secretariat, 2016), (Government of the Republic of Korea, 2025)

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Solutions for Our Climate

Cool Humans, Hot Earth? HFCs:

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Solutions for Our Climate(SFOC) is an independent policy research and advocacy group that aims to make emissions trajectories across Asia compatible with the Paris Agreement 1.5°C warming target.