TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

Response to Decision XXXVII/2: Emissions of HFC-23

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DECISION XXXVII/2: EMISSIONS OF HFC-23

1. To request the Technology and Economic Assessment Panel and the Scientific Assessment Panel to provide an update on emissions of HFC-23 to the Thirty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, taking into account the information submitted by parties in response to decision XXXVI/3 and pursuant to paragraph 2 below and including the following:
   a) Additional analysis of the discrepancy between reported emissions and those derived from atmospheric measurements, including the methodologies applied;
   b) A description of the information and data sources used, identifying any gaps or limitations;
   c) Additional information on methodologies adopted by parties for estimating and reporting HFC-23 emissions as well as best practices for improvements to minimize such emissions;

DECISION XXXVII/2: EMISSIONS OF HFC-23

2. To invite parties that have HCFC-22 production facilities and did not submit information pursuant to decision XXXVI/3 to submit to the Ozone Secretariat, by 28 February 2026, on a voluntary basis, their current methodologies for estimating and reporting HFC-23 emissions from HCFC-22 production;
3. To invite relevant parties:
   a) To report 2025 data, consistent with form 6 of the data reporting forms, on the amounts of HFC-23 generated, captured, destroyed and stored;
   b) To examine, as appropriate, their HFC-23 emissions and the sources of those emissions and encourage scientific research institutions in their countries to undertake or collaborate internationally on research on their HFC-23 emissions and the sources of those emissions, and to report to the Ozone Secretariat new relevant information, if any.

RELEVANT TEAP REPORTS ON HFC-23 EMISSIONS

- MCTOC Assessment Report 2022
- TEAP September 2023: Response to decision XXXIV/7: Strengthening institutional processes with respect to information on HFC-23 by-product emissions (volume 6)
- TEAP September 2024: Response to decision XXXV/7: Emissions of HFC-23 (volume 5)
- TEAP September 2025: Response to decision XXXVI/3: Emissions of HFC-23 (volume 2)
- *TEAP September 2026: Response to decision XXXVII/2: Emissions of HFC-23 (volume 3)*

TEAP'S RESPONSE TO DECISION XXXVII/2

- MCTOC led preparation of the report on behalf of TEAP.
- MCTOC and SAP collaborated closely in preparation of the report.
- TEAP included information provided by SAP from 2026 Assessment, including updated estimates of HFC-23 emissions derived from atmospheric measurements.
- TEAP has updated estimates of HFC-23 emissions as by-product from the production of HCFCs and HFCs based on A7 data, and from other chemical production pathways not reportable under the MP.
- For additional context, TEAP has included updated information on HFC-23 emissions from emissive uses and from feedstock uses of HFC-23.
- TEAP considered available information, including submissions from 4 parties*, as invited in decision XXXVII/2, HFC-23 generation (voluntary), consumption and emissions data (mandatory) reported by 14 parties.

**China, EU, Peru, and Russian Federation*

BACKGROUND (1)

- There are several chemical mechanisms that can generate HFC-23 as a by-product in chemical production processes, including:
  - ***Over- or under-reaction of chemicals*** present in the reaction vessel enroute to the intended product, e.g., HFC-23 is an over-fluorination of HCFC-22.
  - ***Presence of impurities in the feedstocks that are being reacted***, e.g., chloroform impurity in dichloromethane feedstock, used to produce HFC-32, is hydro-fluorinated to HFC-23.
  - ***Unintended side reactions***, where the feedstock follows a different reaction path than the one that is desired to make the product, e.g., cleavage of carbon–carbon bond in the production of HFC-125 from perchloroethylene, with subsequent hydro-fluorination of the resulting mono-carbon molecule to form HFC-23.

BACKGROUND (2)

- The generation of HFC-23 as a by-product during HCFC/HFC production is far greater than the amount of HFC-23 required for use as feedstock or for consumption in applications.
- Parties to the Kigali Amendment in which controlled HCFC/HFCs are produced are required to destroy HFC-23 using a destruction technology, e.g., incineration, approved by the Montreal Protocol.

SOURCES OF INFORMATION AND ESTIMATION METHODOLOGIES (1)

- SAP estimates of HFC-23 emissions are derived from atmospheric observations and analysis with an understanding of atmospheric processes.
- Article 7 data on quantities of controlled **HCFC/HFC production** and associated **HFC-23 emissions** are reported by parties under **mandatory** obligations.
  - Emissions are defined as the total HFC-23 emitted from a facility that generates HFC-23 as a by-product **after abatement**.
- Article 7 data on quantities of **HFC-23 generation** from controlled **HCFC/HFC production** are reported by parties on a **voluntary** basis and are not published in the report by party. HFC-23 generation data are not reported by all parties known to produce HCFC-22.
- Data on HFC-23 emissions reported to the UNFCCC, which can differ from A7 emissions data due to additional included processes and different methodologies. E.g., IPCC Tier 1 methodology assumes **no abatement** in its HFC-23 emission estimations.
- Data submitted to ExCom, as in May 2026 TEAP RTF Report.

SOURCES OF INFORMATION AND ESTIMATION METHODOLOGIES (2)

- If not reportable under Article 7, TEAP estimations of **other HFC-23 emissions** are based on available information and published literature, as documented in the September report and its annexes, and include HFC-23 emissions resulting from:
  - TFE/HFP production (using generation factor estimates before abatement)
  - Other fluorochemical manufacturing (using generation estimates before abatement)
  - Feedstock use (using MCTOC emission factor estimates that assume abatement)
  - HCFC-22 plant waste and product streams (using emission factor estimates)
  - Impurity in HCFC-22 bank emissions (using impurity % and bank emissions estimates)
  - Electrochemical fluorination (using UNFCCC estimates)
  - Emissive sectoral uses i.e., fire suppression, low temperature refrigeration, semiconductor/electronics manufacturing (using a combination of TEAP expertise, UNFCCC estimates, industry information, to inform an estimated range)
- Uncertainties elaborated in the report, where possible, but not always quantifiable.

HFC-23 CONSUMPTION AND EMISSIVE USES (1)

- Several parties that manufacture HCFCs/HFCs capture the HFC-23 generated as a by-product for feedstock and/or emissive uses or divert it for destruction.
- HFC-23 is consumed for:
  - Feedstock uses
  - In very small quantities, for uses:
    - Fire suppression
    - Very low temperature refrigeration
    - Semiconductor and electronics manufacturing.
- Consumption data is not always readily available by sector.
- Uses result in associated emissions, which are estimated.

HFC-23 CONSUMPTION AND EMISSIVE USES (2)

- A7 reported HFC-23 production for feedstock use was 710 tonnes in 2024 (associated estimated emissions presented later in summary slide).
- A7 reported total HFC-23 consumption was about 2,200 tonnes in 2024.
  - Excludes mandatory destruction of HFC-23 by-product emissions from controlled HCFC/HFC production as required by the Kigali Amendment.
  - Includes reported HFC-23 destroyed following use, e.g., as refrigerant.

UPDATED ESTIMATES OF HFC-23 GENERATED AT, AND EMISSIONS FROM, HCFC/HFC PRODUCTION FACILITIES

- The consolidated voluntary reported data for HFC-23 ***by-product generation*** (before abatement) from controlled HCFC/HFC production was **23,809 tonnes** in 2024.
- The consolidated mandatory reported data for HFC-23 ***emissions*** reported as by-product from controlled HCFC/HFC production was **1,003 tonnes** in 2024.
- HFC-23 emissions were reported from 45 facilities and by 10 parties (with 1 party not reporting its number of facilities).
- Methodologies used by different parties for estimating HFC-23 emissions for reporting under A7 are not provided in submissions in sufficient detail to know if parties use the same methodology and scope to estimate HFC-23 emissions.

UPDATED TEAP ESTIMATES OF HFC-23 EMISSIONS FROM KNOWN EMISSIONS SOURCES (1)

- Updated estimates of global HFC-23 emissions are provided, including from facilities that manufacture controlled HCFCs and HFCs, from other fluorocarbon manufacturing not reporting HFC-23 emissions under the MP, and emissive uses.
- Annual estimates of HFC-23 emissions are based on known sources and updated available information for the year of most recent data.
- Some of these are broad estimates where further information to improve their accuracy is currently not available.

COMPILATION OF REPORTED AND AVAILABLE RECENT ANNUAL ESTIMATES OF HFC-23 EMISSIONS FROM KNOWN SOURCES (TONNES)

Sources of HFC-23 (for the year with available data)	Estimated HFC-23 emissions
Reported HFC-23 emissions under Article 7	
HCFC-22, other Annex C Group 1, and Annex F production (2024)	~1,003
Estimated HFC-23 emissions	
TFE/HFP manufacture (estimated, 2023)	~100–1,000
Other fluorochemical manufacturing (estimate given for hexafluoroacetone)	~70
Feedstock use (estimated based on A7 reported consumption data, 2024)	~26
HCFC-22 plant waste and product streams (estimated, 2023)	~10–1,000
Impurity released from HCFC-22 bank (estimated, 2024)	~27
Electrochemical fluorination (estimated, 2020)	~10–100
Fire protection	~100
Low temperature refrigeration	~80–100
Semiconductor/electronics manufacturing	~100
Total reported and estimated HFC-23 emissions from known sources	~1,500–3,500

UPDATED TEAP ESTIMATES OF HFC-23 EMISSIONS FROM KNOWN EMISSIONS SOURCES (2)

- TEAP's "bottom-up" estimation of HFC-23 emissions from known sources of ~1,500–3,500 tonnes/year **excludes** the potential additional source of HFC-23 from atmospheric degradation of HFCs, HFOs, and HCFOs. An upper-limit of this source is assessed to be ~200 tonnes/year, as reported by SAP.
- Emissions derived from atmospheric observations peaked at 17,000 ± 1,000 tonnes/ year in 2018 and 2019 and have since decreased and been relatively constant at **14,000 ± 1,000 tonnes/year** in 2022, 2023, and 2024 (SAP 2026).
- The difference (gap) in top-down versus bottom-up estimates of the order of about 10,000 tonnes/year in 2024 and recent years cannot be explained by uncertainties in atmospheric-derived estimates or by using the data reported under A7 and other sources.

INFORMATION FROM PARTIES ON MEASUREMENT, ESTIMATION, REPORTING, VERIFICATION OF HFC-23 EMISSIONS

- Several parties provided information on best practices under decisions XXXVI/3 and XXXVII/2 for measuring, verifying, reporting of HFC-23 generation and emissions.
- Measures are designed to meet national and regional reporting requirements under national and regional regulatory regimes.
- Practices used to control emissions of HFC-23 are consistent with those used to control other emissions associated with chemical manufacturing.
- Measures have been presented in the report under the following headings:
  - Estimation/Calculation of HFC-23 Generation and/or Emissions
  - Annual Verification
  - Regulation/Enforcement
  - Reporting
  - Specific Best Practice indicated in submissions
  - Additional Learning

SUMMARY AND POSSIBLE INFERENCES FROM DIFFERENCE IN HFC-23 EMISSIONS ESTIMATIONS

- There is a large unexplained difference (gap) between SAP top-down and TEAP bottom-up estimates of global HFC-23 emissions (of the order of 10,000 tonnes/year).
- This difference cannot currently be explained by:
  - Uncertainties in atmospheric-derived estimates.
  - Data reported under A7 and from other sources.
  - Any of the additional known sources identified in this review.
- TEAP has identified the major known industrial and use-related sources.
- TEAP continues to conclude that inaccuracies in bottom-up estimations for known sources are unlikely to bridge the difference with atmospheric-derived emissions estimates.
- Given the large difference, a question arises about the completeness of the HFC-23 emissions data reported under Article 7.
- Further work may be required by parties to identify any other significant sources and to further characterise the accuracy of bottom-up estimates. This work could be included by TEAP in future annual Progress Report updates.

Thank you

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