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Enhancing regional atmospheric monitoring of substances controlled by the Montreal Protocol (decision XXXVI/1)

Updates to the cost estimates associated with enhancing regional atmospheric monitoring of substances controlled by the Montreal Protocol

Note by the Secretariat

I. Introduction

1. The present note provides supplementary information related to updates to the Ozone Secretariat's cost estimates associated with enhancing the atmospheric monitoring of substances controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer, as provided for under decision XXXV/14, set out in the addendum to the note by the Secretariat (UNEP/OzL.Pro.37/2/Add.1, paras. 20–51). The updates were requested by the Thirty-Sixth Meeting of the Parties in paragraph 5 of decision XXXVI/1, on enhancing regional atmospheric monitoring of substances controlled by the Montreal Protocol, for consideration by the Thirty-Seventh Meeting of the Parties.

2. The Secretariat's response to sub-paragraph (a) of decision XXXV/14 on cost estimates associated with enhancing atmospheric monitoring of controlled substances was presented to the Open-ended Working Group of the Parties to the Montreal Protocol at its forty-sixth meeting in document UNEP/OzL.Pro.WG.1/46/2/Add.1 (paras. 41–63). Those cost estimates referred to the establishment and operation of a station monitoring controlled substances using a step-by-step (establishment of a single site and its operation for five years) and a programmatic (establishment and operation of a station with a mix of high-frequency in situ and low-frequency flask sampling) approach for a period of five years. Those estimates were based on a costing model that had been developed by a financial expert in consultation with experts in monitoring of controlled substances and taking into consideration the outcomes of a 2024 online workshop on costs of atmospheric monitoring of gases controlled under the Montreal Protocol, organized by the Ozone Secretariat and the steering committee of the European Union-funded pilot project on regional quantification of emissions of substances controlled under the Montreal Protocol (hereafter referred to as the 2024 model).

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3. Building on the 2024 model, the updated costing model (hereafter referred to as the 2025 model) was developed further by a financial expert, based on all previously available information; extensive consultations with additional experts in atmospheric monitoring of controlled substances, including members of the Advisory Committee of the General Trust Fund for Financing Activities on Research and Systematic Observations Relevant to the Vienna Convention; and the outcomes of the European Union-funded pilot project.

4. The key differences between the two models relate to the implementation approach to measuring controlled substances and in estimating associated costs for the establishment and operation of one station, refinements in capital and operational cost categories and incorporation of previously missing cost items such as those related to personnel, knowledge transfer and site identification.

5. Section II of this note outlines the process followed in the development of the 2025 model and describes the revisions made to the 2024 model both in terms of the approach adopted for the setup of a station, as recommended by the experts on the Advisory Committee, and refinements in the associated cost categories.

II. Development of 2025 costing model and planned improvements

A. Process followed in the development of the 2025 costing model

6. In developing the 2025 model, targeted consultations with selected Advisory Committee members have been pivotal, enabling a redesign of the approach to the measurement programme and a synthesis of available resources to clarify the scope and definitions of cost items. Based on these considerations, survey materials were developed to solicit broader expert input on monitoring and data analysis of controlled substances. Experts were then asked to review cost items, definitions, assumptions for different phases of the monitoring programme, and cost ranges for establishing and maintaining flask sampling and high-frequency in situ monitoring stations worldwide.

7. This process provided valuable insights into real-world operational challenges, allowing for further refinement of both cost items and estimates. For example, additional expert recommendations were taken into account, such as costs related to carrying out automated flask sampling as an alternative option to manual flask sampling not included in previous cost estimates; and potential alternatives to a permanent tower, such as collecting samples using a telescopic mast or a drone.

8. Overall, this process resulted in significant revisions to cost categories, items and definitions, and refinements to the overall structure and framework of the cost model. The details of these revisions and refinements are presented in the following sections.

B. Revised implementation approach to measuring controlled substances

9. In the 2024 model, atmospheric monitoring was assumed to follow one of two specific approaches: low-frequency flask sampling or high-frequency in situ sampling. Cost estimates were based on maintaining a single approach throughout the entire lifespan of the measurement programme. Furthermore, the costs incurred during the site selection process were bundled in the lumpsum amount assumed under a category indicated as "preparatory and capacity building costs." By contrast, the 2025 model estimates costs for the implementation of a *phased monitoring approach,* recommended by the Advisory Committee, drawing also on the lessons learned from the European-Union-funded pilot project. This phased approach is outlined in the addendum to the note by the Secretariat (UNEP/OzL.Pro.37/2/Add.1, paras. 33–41) and is reproduced below for ease of reference:

(a) **Step 1**: Observing System Simulation Experiments analysis to assess site suitability on the basis of atmospheric transport patterns;

(b) **Step 2**: after the selection of a site based on the Observing System Simulation Experiments analysis, start of the measurement programme with a survey period for the collection of six months' worth of data through flask sampling at a frequency of two samples per week (approximately 60 samples, including some duplicate samples to check reproducibility) to verify operability, site representativeness and basic logistics;

(c) **Step 3**: subject to satisfactory performance after the survey period, continue the measurement programme with flask sampling for two years at a frequency of every two days (approximately 200 samples per year), regarded by Advisory Committee experts as the default operational setting in view of the need for balance between data value and cost/logistics;

(d) **Step 4**: transition to high-frequency in situ measurements (approximately 4,400 samples per year) or daily flask sampling (approximately 440 samples per year), provided that the programme objectives have been justified during the survey and the two-year flask sampling period (steps 2 and 3).

C. Key refinements to cost estimates

10. Based on the new phased approach described in the previous paragraph, the 2025 model includes explicit costs associated with site selection through OSSEs and estimated costs for a phased establishment and operation of atmospheric monitoring sites. Other key revisions relate to:

(a) **Disaggregation of capital and operational costs at item level:** In the 2024 model, a costing item was either classified as a capital or an operational cost. For example, the cost for a tower was only classified as a capital cost. The 2025 model now includes capital and operational costs for each item, making the cost model more realistic. In the example of a tower, capital costs now include a full set of ancillary work such as fencing, fall-arrest system, while the operational costs include recurring inspection, tensioning and painting.

(b) **Changes to the definition of low and high-cost estimates:** In the 2024 model, the total low and high-cost values represented the costs of establishing and operating a monitoring programme at a site with pre-existing infrastructure versus a site with no infrastructure. In the 2025 model, low and high-cost estimates are provided for each cost item for both capital and operational costs. Total low and high-cost values in this model now reflect primarily variations in costs of establishing and operating all the required elements depending on site location and available infrastructure.

D. Revised cost categories

11. The original six cost categories considered for the establishment and operation of a measurement programme at a site in the 2024 model were revised to nine in the 2025 model to reflect further input from experts. A short description of all nine cost categories along with key revisions made per category are provided in the table below. These are further disaggregated to a total of 36 cost items, the complete list of which is set out in the annex to this note along with the corresponding low and high-cost ranges of capital and operational costs, as appropriate.

No.	Cost category	Short description	Key revisions
1	Access and utility infrastructure	Includes costs for construction, upgrade and/or operation of roads, paths, and electricity supply	In the 2024 model, road access to a site and a reliable power supply were treated as scenario specific. In the 2025 model, these are treated as an integral part of the site attributes.
2	Sampling tower	Includes costs for constructing and maintaining sampling towers	In the 2024 model, a tower height of 20–30 metres was assumed. The 2025 model provides cost estimates for either a 30 or 100 metre tower, depending on local site conditions.
3	Site building and personnel facilities	Includes costs for construction and maintenance of buildings or shelter needed to house instruments and equipment	Compared with the 2024 model, the 2025 model refines building requirements by including more realistic construction and operational costs and differentiating them by station type (flask or high-frequency in situ).
4	Analytical instrumentation and laboratory equipment	Includes costs for purchase and deployment of equipment such as gas chromatograph/mass spectrometer (GC/MS) systems for a high-frequency in situ station, along with calibration cylinders, pumps, fittings, and the software required for GC/MS operation	In the 2024 model, only the cost of purchasing the GC/MS was included. The 2025 model refines this by also accounting for the required auxiliary equipment and control software needed for its smooth operation. It also incorporates operational costs for consumables, such as liquid nitrogen and helium carrier gas, and for GC/MS spare parts.

No.	Cost category	Short description	Key revisions
5	Hardware, sampling equipment and laboratory consumables	Includes costs for flasks and pumps (manual or automated) used for flask sampling, as well as the laboratory costs for their analysis	In the 2024 model, costs for different flask-sampling frequencies and methods were presented as a single range, and laboratory analysis costs were not included. In the 2025 model, these costs are disaggregated, with separate estimates for each sampling frequency and for both manual and automated methods, along with the associated laboratory analysis costs.
6	Shipping and sample transport	Includes costs for transporting flask samples and calibration materials to and from sampling site	In the 2024 model, costs for shipping were not differentiated for the diverse sampling frequencies. In the 2025 model, cost estimates are provided for each of the sampling frequencies considered for the phased monitoring programme.
7	Calibration and standardization	Includes costs for purchase and maintenance of calibration standards	No key revision made.
8	Staffing, operations and analytical capacity	Includes personnel costs for technical staff responsible for site operation, sample collection, logistics and data oversight, and personnel training	In the 2024 model, personnel costs were not included. The 2025 model incorporates these costs, covering one scientific lead, one technical assistant, sample collectors for each sampling frequency, and training of these personnel.
9	Miscellaneous, data processing and reporting systems	Includes costs for miscellaneous items such as information technology (IT) equipment, internet connectivity and for atmospheric numerical modelling	In the 2024 model, there was no equivalent cost category.

E. Costing model status and planned improvements

12. The current version of the 2025 costing model is in the form of a spreadsheet. Costs can be estimated with user-defined inputs for one or more of the following variables:

- Height of required tower (with a choice of either 30 m or 100 m)
- Method of flask sampling during survey period (either automated or manual)
- Number of years for flask sampling at a frequency of every two days after the survey period
- Choice of daily flask sampling or high-frequency in situ measurements for long-term monitoring.

13. Based on these inputs, the model calculates the annual breakdown of estimated capital and operational costs with their low and high range of values reflecting costs of establishing and operating one monitoring site across different regions in the world.

14. In its current form, the 2025 model is not sufficiently flexible in calculating site-dependent estimates. For example, it cannot account for existing infrastructure and generates estimates for all required elements. Funds permitting, the Secretariat plans to develop a user-friendly web-based tool based on the spreadsheet model. This upgraded tool would allow users to select individual cost items and adjust their values based on the local circumstances and specified assumptions about available infrastructure and regional costs. Where users do not provide inputs, the tool would apply as default the cost estimates indicated in the annex to the present note as advised by experts. Such a tool is expected to enable estimation of costs for establishing and operating a monitoring programme at a particular location, reflecting more accurately the resources needed and their costs in that location including accounting for existing infrastructure.

Annex

Complete list of cost items included in the 2025 costing model

(in United States dollars)

Notes:

HF refers to a high-frequency in situ monitoring station.
FS refers to a flask-sampling monitoring station.
FS-Daily refers to the daily flask sampling phase, as described in step 4 of paragraph 9 of the note.
FS-DD refers to the every-two-day sampling phase, as described in step 3 of paragraph 9 of the note.
FS-WW refers to the twice a week survey sampling phase, as described in step 2 of paragraph 9 of the note.

Item reference number	Item name	Capital costs		Operational costs		Remarks
		Low estimate	High estimate	Low estimate	High estimate	
Category 1: Access and utility infrastructure						
1	Access road/path	5,000	170,000	500	2,000	High-frequency sites typically require vehicle access to the site, whereas for flask-sampling sites, access on foot may be sufficient. Estimates include costs for constructing or upgrading access path to the monitoring site. Variations in cost depend on local terrain, land ownership/permits, drainage, distance from public road, environmental constraints, etc.
2	Electrical power connection – high-frequency station (HF)	10,000	30,000	1,000	5,000	High-frequency sites require grid-connected electricity supply. Estimates include costs for reliable and continuous electricity supply with a back-up system such as a generator.
3	Electrical power connection – flask-sampling station (FS). *Automated* and *manual*	5,000	10,000	200	1,000	Manual flask sampling requires minimal power. Automated sampling needs a small power source, such as a battery or solar, but a grid connection is preferable when available. Estimates include costs for these items along with a back-up system such as a generator or uninterruptible power supply.
Category 2: Sampling tower						
4	Sampling tower (30 m)	50,000	370,000	5,000	15,000	Capital costs include a tower or pole, foundations, installation, lightning protection and safety systems, which can be substantially higher where terrain requires earthworks. Operating costs include annual safety inspections, painting, replacement of guy wires, and lightning protection maintenance.
5	Sampling tower (100 m)	150,000	1,000,000	25,000	75,000	A 100-metre tower is required primarily for HF monitoring stations and generally not necessary for FS. Other details are the same as above.
6	Alternatives to tower: drone, telescopic mast, other	0	0	0	0	Because of the experimental nature of these alternative platforms, cost estimates are not available (not included in the cost model calculations).

Item reference number	Item name	Capital costs		Operational costs		Remarks
		Low estimate	High estimate	Low estimate	High estimate	
Category 3: Site building and personnel facilities						
7	Building (HF)	30,000	100,000	10,000	15,000	Estimates include costs for construction or upgrades and maintenance of a building housing HF monitoring systems. Container-based solutions provide most cost-effective option, while costs rise for fully constructed buildings.
8	Building (FS)	7,000	10,000	200	300	Estimates include costs for construction or upgrades and maintenance of a building used for FS operations, providing shelter for sampling equipment and secure flask storage.
9	Personnel facilities	0.00	0.00	0.00	0.00	Cost estimates are not included in the model calculations. Such estimates may include construction or upgrade and maintenance of a building for staff at monitoring sites, such as offices, rest areas, or accommodation. These facilities are considered optional and may only be required in remote locations.
Category 4: Analytical instrumentation and laboratory equipment (HF)						
10	GC/MS instrument and ancillary equipment (HF)	400,000	500,000	6,000	30,000	Estimates include costs for the purchase, deployment, and maintenance of the gas chromatograph-mass spectrometer (GC/MS) system.
11	Helium carrier gas for analytical instruments (HF)	0	0	5,000	5,000	Estimates include the recurring cost of helium carrier gas needed for GC/MS operation.
Category 5: Hardware, sampling equipment and laboratory consumables (FS)						
12.1	Flasks for sampling, stock of 48 to 72 flasks (FS-Daily). *Automated*	120,000	180,000	0	0	Estimated cost of a stock of 48 to 72 automated flasks for the FS-Daily phase. Automated flasks are supplied in programmable flask packages, each containing 12 flasks. Operating costs are assumed to be zero as flasks are durable with long reuse potential.
12.2	Flasks for sampling, stock of 48 to 72 flasks (FS-Daily). *Manual*	31,200	86,400	900	2,300	Estimated cost of a stock of 48 to 72 manual flasks for the FS-Daily phase. Costs vary by flask type (glass or stainless steel). Operating costs include replacements based on an annual breakage rate of 3–5%. For stainless steel flasks, breakage is rare, so replacements are minimal.
13.1	Flasks for sampling, stock of 36 to 48 flasks (FS-DD). *Automated*	90,000	120,000	0	0	Estimated cost of a stock of 36 to 48 automated flasks for the FS-DD phase. Automated flasks are supplied in programmable flask packages, each containing 12 flasks. Operating costs are assumed to be zero as flasks are durable with long reuse potential.
13.2	Flasks for sampling, stock of 36 to 48 flasks (FS-DD). *Manual*	23,400	57,600	700	1,600	Estimated cost of a stock of 36 to 48 manual flasks for the FS-DD phase. Costs vary by flask type (glass or stainless steel). Operating costs include replacements based on an annual breakage rate of 3–5%. For stainless steel flasks, breakage is rare, so replacements are minimal.

Item reference number	Item name	Capital costs		Operational costs		Remarks
		Low estimate	High estimate	Low estimate	High estimate	
14.1	Flasks for sampling, stock of 30 to 48 flasks (FS-WW). *Automated*	90,000	120,000	0	0	Estimated cost of a stock of 30 to 48 automated flasks for FS-WW phase. Automated flasks are supplied in programmable flask packages, each containing 12 flasks. Operating costs are assumed to be zero as flasks are durable with long re-use potential.
14.2	Flasks for sampling, stock of 30 to 48 flasks (FS-WW). *Manual*	19,500	57,600	600	1,600	Estimated cost of a stock of 30 to 48 manual flasks for FS-WW phase. Costs vary by flask type (glass or stainless steel). Operating costs include replacements based on an annual breakage rate of 3-5%. For stainless steel flasks, breakage is rare, so replacements are minimal.
15	Manual pump (FS)	5,000	15,000	0	0	Estimated cost of a manual pump used in the case of manual flask sampling.
16	Automated pump (FS)	15,000	20,000	0	0	Estimated cost of an automated pump used in the case of automated flask sampling.
17.1	Laboratory per-sample charge (FS-Daily = 440/year). *Automated*	0	0	23,000	110,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-Daily phase (440 samples per year), where samples are collected with automated flasks.
17.2	Laboratory per-sample charge (FS-Daily = 440/year). *Manual*	0	0	70,400	110,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-Daily phase (440 samples per year), where samples are collected with manual flasks.
18.1	Laboratory per-sample charge (FS-DD = 200/year). *Automated*	0	0	10,400	50,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-DD phase (200 samples per year), where samples are collected with automated flasks.
18.2	Laboratory per-sample charge (FS-DD = 200/year). *Manual*	0	0	32,000	50,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-DD phase (200 samples per year), where samples are collected with manual flasks.
19.1	Laboratory per-sample charge for FS-WW scenario (twice a week = 60 total samples for six months limited survey phase to test instruments). *Automated*	0	0	3,120	15,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-WW phase (60 samples for 6 months’ worth of data), where samples are collected with automated flasks.
19.2	Laboratory per-sample charge for FS-WW scenario (twice a week = 60 total samples for six months limited survey phase to test instruments). *Manual*	0	0	9,600	15,000	Estimated costs covering per-sample charge at analytical laboratory under the FS-WW phase (60 samples for 6 months’ worth of data), where samples are collected with manual flasks.

Item reference number	Item name	Capital costs		Operational costs		Remarks
		Low estimate	High estimate	Low estimate	High estimate	
20	Cryogens and software licences (HF)	0	0	2,000	5,000	Estimated recurring costs for liquid nitrogen and annual software licences to operate GC/MS instruments.
21	General consumables (HF)	0	0	2,000	4,000	Estimated costs include general consumables required to maintain the GC/MS instruments, such as analytical traps, tubing, filters, plumbing parts, fittings and replacement of hardware components subject to wear and tear.
Category 6: Shipping and sample transport						
22	Shipments of helium in canisters, per year (HF)	0	0	20,000	20,000	Estimated logistics and transport costs for helium canisters required at HF stations.
23	Shipments (FS Daily = 440/year)	00	0	2,800	33,000	Estimated shipping costs, based on expert input, for transporting 440 flask samples per year in the FS-Daily phase.
24	Shipments (FS-DD = 200/year)	0	0	1,300	15,000	Estimated shipping costs, based on expert input, for transporting 200 flask samples per year in the FS-DD phase.
25	Shipments (FS-WW = 60)	2,500	10,500	400	4,500	Estimated shipping costs, based on expert input, for transporting 60 flasks in the FS-WW scenario.
Category 7: Calibration and standardization						
26	Propagation scales and calibration standards for measurements (HF)	30,000	30,000	3,000	3,000	Estimated procurement and maintenance costs for propagation scale calibration standard gases for GC/MS instruments at HF station.
Category 8: Staffing, operations and analytical capacity						
27.1	Scientific personnel (HF)	0	0	50,000	140,000	Estimated cost of renumeration for one scientist (an analytical chemist) responsible for the oversight, quality assurance, and analysis of data generated at an HF station.
27.2	Technical assistant (HF)	0	0	15,000	60,000	Estimated cost of renumeration for one technical assistant responsible for routine operation and maintenance of an HF station.
28.1	Personnel (Daily = 440 samples over 365 days). *Automated*	4,000	4,000	650	1,550	Estimates cost of renumeration for personnel operating an FS station during the FS-Daily phase, using an automated flask sampling system.
28.2	Personnel (Daily = 440 samples over 365 days). *Manual*	4,000	4,000	18,000	22,000	Estimates cost of renumeration for personnel operating an FS station during the FS-Daily phase, using a manual flask sampling system.
29.1	Personnel (FS-DD = 200/year). *Automated*	4,000	4,000	400	800	Estimates cost of renumeration for personnel operating am FS station during the FS-DD phase, using an automated flask sampling system.
29.2	Personnel (FS-DD = 200). *Manual*	4,000	4,000	10,000	15,000	Estimates cost of renumeration for personnel operating an FS station during the FS-DD phase, using a manual flask sampling system.
30.1	Personnel (FS-WW), 6 months. *Automated*	4,000	4,000	100	300	Estimated cost of renumeration for personnel operating an FS station during the FS-WW phase, using an automated flask sampling system.

Item reference number	Item name	Capital costs		Operational costs		Remarks
		Low estimate	High estimate	Low estimate	High estimate	
30.2	Personnel (FS-WW), 6 months. *Manual*	4,000	4,000	1,300	1,300	Estimated cost of renumeration for personnel operating an FS station during the FS-WW phase, using manual flask sampling system.
31.1	Knowledge transfer - sample collectors	3,000	5,000	0	0	Estimated cost of one-time knowledge transfer (capacity-building) activities per site, focused on training flask sampling personnel in sample collection.
31.2	Knowledge transfer: Observation system simulation experiments (OSSEs)	10,000	20,000	0	0	Estimated cost of one-time knowledge transfer (capacity-building) activities, focused on carrying out OSSEs.
31.3	Knowledge transfer of modelling capability (see conflict with 31.2) FS-WW	40,000	120,000	0	0	Estimated cost of training host-country staff in carrying out inverse atmospheric modelling to estimate emissions from concentration data generated during FS-WW phase. Training would be provided by an established atmospheric inverse modelling group to two host-country staff members.
Category 9: Miscellaneous, data processing and reporting systems						
32	IT equipment and computers (HF and FS - *Automated*)	1,000	2,000	0	0	Estimated costs to purchase a computer to support data handling, analysis and communication at the monitoring site.
33	Internet (HF and FS - *Automated* when necessary, not applied here)	10,000	20,000	0	0	(Not included in the cost estimate calculations) Represents optional cost of establishing internet connectivity at monitoring site.
34	Storage space equipment	0	0	0	0	Assumed to be part of service provided by host institute, and therefore assumed to be zero.
35	Data analysis, 6-months period, FS-WW	50,000	150,000	0	0	Estimated cost of analysing data generated during the FS-WW phase, along with the cost of inverse modelling for emission estimation performed by an established atmospheric modelling group.
36	OSSE	3,000	6,000	0	0	Estimated cost of conducting an OSSE by an established atmospheric modelling group to assess the suitability of one proposed monitoring site.