EMISSIONS OF SUBSTITUTES FOR OZONE-DEPLETING SUBSTANCES

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ABSTRACT

Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6) are emitted from a number of end use sectors in which they substitute for ozone-depleting substances. These include refrigeration, air conditioning, aerosol applications, fire suppression, foam blowing, sterilants, and solvents. Emissions of these gases may occur within a year of sale or gradually over several years depending on the application. Aerosols, open-cell foam blowing, and solvents are typical sectors where the chemical is rapidly emitted, while these emissions may be delayed for decades in refrigeration, fire suppression and closed-cell foam blowing. Recovery, recycling and destruction can further delay or eliminate the release of these gases into the atmosphere.

The Revised 1996 *IPCC Guidelines* for *National Greenhouse Gas Inventories (IPCC Guidelines)* include two methods:

- The Tier 1 or "potential" method estimates emissions as being equal to current chemical consumption, where consumption is defined as chemical production plus imports minus exports and destruction. This method of calculating national emissions is simple to perform and recognises that all material consumed has the potential of being emitted eventually, but it seriously distorts the timing of emission by assuming that it occurs when the chemical is first consumed. However, it is generally easy to obtain an accurate value for the quantity consumed and so this method can be used to report an accurate total emission, and
- The Tier 2 or "actual" method uses much more data to estimate when the chemical will be released into the atmosphere by taking into consideration the equipment-dependent delay that occurs between the time a chemical is sold and the time it is emitted from its end use. Since approximately twenty different HFC and PFC chemicals could potentially be used as substitutes to ozone-depleting substances, with numerous and extremely diversified emissions sources, implementing the actual methods would involve dealing with high volumes of data and levels of complexity.

Since Tier 2 methods can represent annual emissions more accurately, the Parties have decided that **actual** emissions of HFCs, PFCs, and SF_6 should be estimated and reported, where data are available, and that Parties should make every effort to develop the necessary sources of data (Decision 2/CP.3).

There are multiple options for implementing both the Tier 1 and Tier 2 methods. For Tier 1 methods, estimates can be simply based on consumption data (Tier 1a) or they can be adjusted to account for chemicals contained in imported and exported equipment (Tier 1b). For the Tier 2 method, estimates can be developed using a top-down approach that disaggregates chemical consumption data into sectors and then applies time-dependent emission factors. This method requires chemical distribution data that may not exist for some sectors and therefore may need to be derived from information on chemical sales from producers and purchases from users. Alternatively, emissions can be estimated using a bottom-up approach based on an inventory of the number of products and uses where these substances are consumed and emitted. This method does not require consumption data, but it does require extensive data from producers and users of chemicals to facilitate the estimation of emissions from end uses and applications.

Reporting has been problematic for this source. Not only have several countries not reported emissions from these chemicals, but the submissions from the Parties that reported lacked transparency [UNFCCC/SBSTA/1998/7]. Currently, HFCs, PFCs and SF_6 emissions are reported under the IPCC category 2E (production of halocarbons and sulphur hexafluoride) and 2F (consumption of halocarbons and sulphur hexafluoride). The tables do not have specific entries for the individual species of HFC or PFC. Emissions of different species cannot be summed on a mass basis because there are many different HFCs and PFCs, with

different global warming potentials (GWPs) and also it is not clear whether individual country reports have been weighted by GWP.

Ensuring the quality of an inventory also requires that countries implement quality assurance and quality control programmes, which will need to occur at several steps in the process. At the plant or company level, key activities include quality control to ensure the accuracy of data (such as plant level measurements, calculations and data), as well as the provision of sufficient documentation. At the level of the inventory agency, the accuracy of plant or company submissions as well as the compiled inventory must be ensured together with the maintenance of appropriate documentation. One or more different types of external reviews and audits may also be appropriate for these sources. This is particularly important for Tier 2 methodology which relies on subjective data.

1 INTRODUCTION

1.1 Nature, magnitude, and distribution of source

HFCs, PFCs, and SF_6 are emitted from a number of sectors in which they substitute for ozone-depleting substances. These include refrigeration, air conditioning, aerosol applications, fire suppression, foam blowing, sterilants, and solvents. Only those portions of HFC-23 and PFC emissions that are used in fire suppression, low-temperature refrigeration, heat transfer fluid and solvents are included in this paper. Table 1 lists most of these chemicals, their atmospheric life-times, global warming potentials (GWP) relative to CO_2 at a 100-year integrated-time-horizon and typical sectors or uses.

TABLE 1

PROPERTIES AND USES OF HFCS, PFCS, AND SF_6

Chemical	Life-time (years)	GWP (100-yr)	Sector/Use
HFC-23	264	11,700	Byproduct of HCFC-22, used in very-low temperature refrigeration, blend component in fire suppression, and plasma etching and cleaning in semiconductor production.
HFC-32	5.6	650	Blend component of numerous refrigerants.
HFC-43-10mee	17.1	1,300	Cleaning solvent.
HFC-125	32.6	2,800	Blend component of numerous refrigerants and a fire suppressant.
HFC-134a	14.6	1,300	Most widely used refrigerant, blend component of other refrigerants, propellant in metered-dose inhalers and aerosols and foam blowing agent.
HFC-152a	1.5	140	Blend component of refrigerant blends and aerosol propellant.
HFC-143a	48.3	3,800	Blend component of refrigerant.
HFC-227ea	36.5	2,900	Fire suppressant and propellant for metered-dose inhalers.
HFC-236fa	209	6,300	Refrigerant and fire suppressant.
HFC-245fa	7.7[1,2]	816[1,2]	Foam blowing agent and refrigerant.
HFC-245ca	6.6	560	Not in commercial use today, possible refrigerant in the future.
CF_4	50,000	6,500	Byproduct of aluminium production. Plasma etching and cleaning in semiconductor production and low temperature refrigerant.
C_2F_6	10,000	9,200	Byproduct of aluminium production. Plasma etching and cleaning in semiconductor production
C_3F_8	2,600	7,000	Low-temperature refrigerant and fire suppressant.
C_4F_{10}	2,600	7,000	Fire suppressant
C_6F_{14}	3,200	7,400	Precision cleaning solvent
SF_6	3,200	23,900	Cover gas in magnesium production and casting, dielectric gas and insulator in electric power equipment, fire suppression discharge agent in military systems, atmospheric and subterranean tracer gas, sound insulation, process flow-rate measurement, medical applications and formerly an aerosol propellant.

GWPs and atmospheric lifetimes from IPCC [1995, 1996], except as noted below:

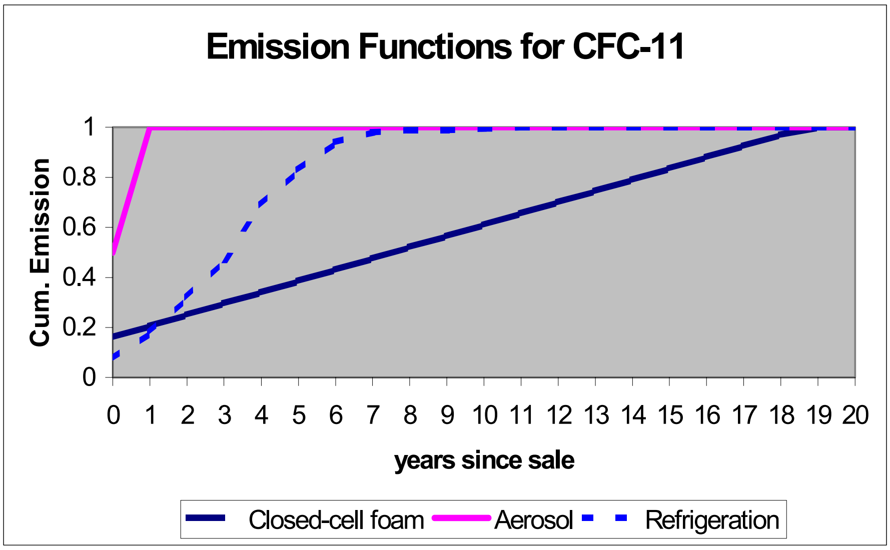
[1] Junyi Chen *et al.* [1997]

[2] Personal communication between Don Wuebbles, University of Illinois at Urbana-Campaign and Reynaldo Forte, U.S. Environmental Protection Agency, August 20, 1998

Emissions of these gases may occur within a year of sale or gradually over several years depending on the application. Aerosols, open-cell foam blowing and solvents are typical sectors where the chemical is rapidly emitted, while in refrigeration, fire suppression and closed-cell foam blowing these emissions may be delayed for decades. Recovery, recycling and destruction can further delay or eliminate the release of these gases into the atmosphere.

Figure 1 illustrates cumulative emissions for CFC-11 in three end-use sectors (Gamlen et al., 1986). CFC-11 is not a chemical under consideration in this paper and Figure 1 should not be taken to be definitive. However, the patterns illustrate how HFCs and PFCs may be emitted when used in similar applications. Emissions of substitutes in these sectors are likely to follow similar patterns. However, new refrigeration equipment, with better containment is likely to extend the time before full release.

Figure 1 Emission functions for CFC-11



Note: The emission function assumes full release with no destruction on disposal at end-of-life.

1.2 The current state of inventory methodologies

The *IPCC Guidelines* include two methods: potential (Tier 1) and actual (Tier 2) and variations within those methods:

- The potential method estimates emissions as being equal to current chemical consumption, where consumption is defined as chemical production plus imports minus exports and destruction. This method of calculating national emissions is simple to perform and recognises that all material consumed has the potential of being emitted eventually, but it seriously distorts the timing of emission by assuming that it occurs when the chemical is first consumed. However, it is generally easy to obtain an accurate value for the quantity consumed and so this method can be used to report an accurate total emission.
- The actual method uses much more data to estimate when the chemical will be released into the atmosphere by taking into consideration the equipment-dependent delay that occurs between the time a chemical is sold and the time it is emitted from its end use. Since approximately twenty different HFC and PFC chemicals could potentially be used as substitutes to ozone-depleting substances, with numerous and extremely diversified emissions sources, implementing the actual methods in the IPCC Guidelines would involve dealing with high volumes of data and levels of complexity.

The *IPCC Guidelines* acknowledge that the potential method does not take into account accumulation or possible release of chemicals in various products and equipment, which means that over the short term (e.g., 10-15 years) estimates will become very inaccurate. The *IPCC Guidelines* further indicate that since accumulation is thought to be the dominant process at the present time, potential emissions calculations will strongly overestimate current emissions. On this basis, the Parties decided, at the third Conference of Parties (in Kyoto), that the actual emissions of HFCs, PFCs, and SF_6 should be estimated, where data are available, and used for the reporting of emissions; and that Parties should make every effort to develop the necessary sources of data. (See Annex A: Decision 2/CP.3).

To date, estimation and reporting of emissions from this and other sources of industrial greenhouse gases has been incomplete and also lack in transparency. As summarised in a recent report of the United Nations

Framework Convention on Climate Change (UNFCCC) Secretariat, current reporting practices for these gases varies significantly among reporting Parties (FCCC/SBSTA/1998/7, para.77-81). In fact, several methodological issues associated with the reporting of the HFCs, PFCs and SF_6 have been identified by reviewing National Communications. A summary of those issues follows:

- Not all of the reporting Parties reported the three types of gases, and in general, data are incomplete. Only 21 of the 34 Parties which submitted the second National Communications included estimates for these gases;
- Five Parties only reported aggregated figures for HFCs and PFCs despite the differences between the GWP values for these gases;
- The methods used for estimating emissions varied significantly among reporting Parties. Seven out of 21 Parties used the actual approach, three included both approaches, eight Parties used the potential and it is not clear what the others used, and
- Estimates for actual and potential emissions can vary to a significant degree, depending on the mix of different types of HFCs and PFCs.

This assessment clearly highlights the importance of developing *good practices* for estimating and reporting emissions of these gases.

2 METHODOLOGICAL ISSUES

The IPCC has outlined two broad methods for estimating emissions of substitutes for ozone depleting substances. As discussed previously, the potential method (Tier 1) assumes that all emissions of these chemicals occur in the year of production/consumption. The advanced method (Tier 2), in contrast, takes into account the time delay in emissions from various sectors and end uses. Within each method at least two options can be used to estimate emissions. The following sections briefly describe each method and evaluate them in terms of several criteria, including resource requirements, the availability and quality of necessary data and accuracy. At the end of this section, some additional issues are presented which involve the choice and implementation of either of the methods.

2.1 Tier 1 - Potential method

Potential emissions are defined by the IPCC methodology as being equal to the amount of virgin chemical consumed in the country minus the amount of chemical recovered for destruction or export in the year of consideration. This is consistent with the method used under the Montreal Protocol to track and report consumption of CFCs and other ozone-depleting substances.

The potential method, when compared to the actual method, offers a simple approach to estimating total emissions of these gases. However, since it assumes that what is produced is emitted within the first year of consumption, it is not an accurate measure of actual annual emissions. In certain applications, such as aerosol products and open-cell foam blowing from which emissions are prompt, the potential method provides an adequate estimation of what is actually emitted in individual years. However, in other applications involving closed systems like refrigeration and fire suppression most of their chemical charges might not be released until many years or decades later.

2.1.1 Tier 1a - Basic potential method

Under the basic potential method, emissions equal current chemical consumption, where consumption is defined as chemical production plus imports minus exports and destruction. This is the simplest of all methods in terms of resource and data requirements. The Tier 1 method requires enough data to enable the estimation of total chemical consumption for each gas, which may be achieved by collecting chemical production, export, import, transformation and destruction data.

The precision of this type of estimate should be quite high, since it relies on data of commercial importance that is likely to be carefully tracked. The accuracy of this method as an estimate of actual emissions in a given year, however, is more problematic. As mentioned above, this method will overestimate emissions, possibly by large amounts. The review of submissions from countries that have estimated emissions using both actual and potential emission methods, for example, indicates that potential emission estimates can exceed actual emission estimates by a ratio of 16 to 1. On the other hand, the estimate of global emissions in AFEAS [2000], which is consistent with measured atmospheric concentrations, suggests that emissions are one third of production. This indicates that low national estimates of emissions are incorrect, probably due to flawed emission functions.

2.1.2 Tier 1b - Adjusted potential method

Tier 1b is similar to Tier 1a except that the estimates are adjusted to take into consideration the chemicals contained in imported/exported products. By making this adjustment, estimates reflect more accurately the national distribution of emissions from products, as opposed to assigning emissions to the country where equipment is manufactured.

Issues associated with Tier 1b are similar to those under Tier 1a in terms of the overestimation of actual emissions. In addition, resource and data requirements are higher, because Tier 1b requires the same data in Tier 1a plus data on imports and exports of chemicals contained in products. Determining the specific chemicals used in imported products, including their quantity, could be a difficult task, and access to such data may be limited. Custom agencies may be a key resource in facilitating the gathering of these data.

2.2 Tier 2 - Advanced method (actual)

The IPCC recommended method combines the use of chemical consumption and detailed emissions from areas of application to estimate what is actually emitted in a given year. It requires calculation or estimation of the consumption of each individual HFC and PFC chemical at its application level (i.e., refrigerators, foam blowing, fire suppression equipment) to establish the volume basis for emissions calculations. Estimates of emissions are then developed on the basis of the consumption distribution among the different sectors. In other words, under this method, emissions are estimated by combining data on sector consumption with emissions information from products and applications from within that sector.

The actual method explicitly accounts for the fact that chemicals are released in different forms and at different times, ranging from when they are manufactured and charged into equipment to the time of disposal of the equipment. Thus, this method can reflect the emissions that may occur as fugitive losses during chemical manufacturing, distribution, or product assembly, or be related to operation and maintenance or disposal of the equipment using the chemicals. The method can also allow for recovery of chemicals from equipment at disposal.

The actual method incorporates emissions functions designed to simulate these chemical releases on a sectoral or end-use basis. For example, the emissions from household refrigerators may be estimated by adding up emissions during chemical manufacturing, equipment assembly, operation, and disposal. This requires the calculation or estimation of average values for chemical charge, equipment lifetime, operation leak rates, percent of chemical in the system at disposal, percent of recovery, etc. The *IPCC Guidelines* currently include default values for various sectors and categories where the HFCs and PFCs are used, and suggest that these values may be adjusted based on country circumstances. A series of equations is also included in the *IPCC Guidelines* to facilitate emissions calculations.

The actual method may be implemented using two very distinctive approaches: the "top-down" (consumption derived) or a "bottom-up" (application based). Both approaches are described below.

2.2.1 Tier 2 Top - down method

The top-down approach relies on the establishment of a history of consumption of each chemical in each sector and estimation of emissions from those sectors based on emissions functions. As discussed above, the emissions functions take into consideration when and how these chemicals are emitted within each sector. For sectors or applications where the chemical is fully released during product manufacturing or use, such as open-cell foams and metered-dose inhalers, the emissions may be estimated as being equal to the consumption in that sector or application. However, emissions from other products may continue over several years, and so the functions are established as time series, which produce estimates of emissions over the service life of the product.

The top down approach requires the same data used in Tier 1b plus data on the sectoral distribution of chemicals. Countries that are Parties to the Montreal Protocol may already be familiar with determining and reporting annual consumption (based on similar reporting for CFCs). This approach goes beyond that required under the Montreal Protocol by requiring disaggregation of consumption data into the sectors where such consumption takes place. Chemical distribution data may not exist for some sectors and therefore may need to be derived from information on chemical sales from producers and purchases from users.

The top-down approach estimates emissions from equipment stocks (the "bank") by including the temporal distribution of emissions from equipment into the emissions functions i.e., the equations produce estimates for the year of chemical sale or product introduction up to the present and into the future, until equipment disposal.

Therefore, in a given year, the method will estimate emissions for equipment introduced in that same year as well as its future emissions through its estimated service life.

Starting in any particular year, these emissions functions can take into consideration emissions from equipment sold in prior years and still in service. However, the method requires an initial study to estimate the size of the existing bank and how it has accumulated so that emissions can be calculated for current and future inventories. Depending on its scope and depth, this study could also be used to adjust or validate default values for average charges, service life, leak rates, etc.

To develop a top-down actual emission estimate, countries should undertake the following steps:

- Estimate chemical consumption: firstly, countries must determine how much chemical is consumed. This can be achieved by using the data described in Tier 1b above;
- Allocate consumption data to sectors: the unique element of this method is the allocation of chemical consumption data to sectors. In some cases, these data may be readily available. Countries may have producers, importers, and exporters of HFCs and PFCs (and also the manufacturers of equipment) reporting confidentially to a government department, annual consumption by chemical and sector e.g., x metric tons of HFC-134a sold into (alternatively, purchased by) the mobile air-conditioning sector. For other sectors, however, it may be difficult to determine the exact amounts of a chemical going into a particular sector, especially when the chemical is sold through many distributors before reaching its application. A one-time study may assist in determining typical chemical distribution. Sector experts may want to discuss means to overcome this data limitation and defaults for the fractions so distributed may be required for particular geographical regions;
- Estimate Emissions from each Sector: the *IPCC Guidelines* include a series of emissions equations and default values to go with those equations for estimating the emissions profile of particular sectors. These equations may be expressed in a time series to estimate current and future year emissions for each selected sector. The validity of these factors should be considered, and for some sources, countries may want to develop customized factors or further disaggregate factors to account for national conditions;
- Estimate emissions from the existing bank: a one-time study may be necessary to estimate current and future emissions from HFC and PFC equipment units sold prior to the year of method implementation. This study should include an estimate of the inventory of units in use, their remaining service life, average charge, leak rates, disposal quantities, and recovery practices. Data on quantities of chemical sold for the servicing of these units could also help in estimating emission profiles;
- Estimate fugitive emissions: fugitive emissions may be estimated by using a production emissions factor as illustrated in the *IPCC Guidelines*. The one-time study in third bullet may also be used to assess fugitive emissions from equipment assembly and chemical distribution (from chemical manufacturers to suppliers and users), and
- Compile the estimate: a country's emissions then become the sum of the estimates developed under fourth, fifth and sixth bullets.

A useful, simple, variation of the top-down method employs the assumption that material sold into a particular sector is used in one of two ways: (a) In filling original equipment, in which case it becomes part of the bank and is not emitted promptly, and (b) In the servicing of existing systems, in which case it is actually being used to replace material that has been emitted. Thus, to a first approximation for each year, if the total sales and the quantity used in original equipment are known, then the emissions can be calculated simply and robustly.

Countries would need to gather the following data as part of implementing this method:

- Total annual sales of each chemical: annual sales should include manufacturer and importer sales of new chemical both in bulk and in equipment sold to equipment manufacturers;
- The portion of new chemical sales used to charge new equipment: for certain end uses, manufacturers and importers of chemicals are likely to track how much chemical is sold for use in new equipment versus servicing of existing units. However, this type of information may not be readily available for all end uses, in which case, industry statistics or trade information may be available to generate a reasonable estimate of the sales allocation;
- The amount of chemical originally used to charge equipment that is being phased out: a portion of the total new chemical sales is used to charge units that replace phased out equipment, and such equipment may have lost its charge by the time it is phased out. Had these units been charged, the amount would have been considered as part of the chemical used for servicing, and therefore added to the total emissions. These

amounts may be estimated based on current and historical data on production growth of the equipment under consideration or estimates of equipment in service;

- Destruction amounts: in the event that chemicals are used to replace material that has been destroyed, rather than emitted, the emissions estimates would need to be adjusted to account for the associated emissions reductions, and
- Emissions the resulting emissions can then be estimated by subtracting the amount of chemical used to charge phased out equipment and chemical destroyed to the total sales of chemical and adding the amount of chemical used to charge phased out equipment.

Note that above approach makes it unnecessary to separately calculate emissions from disposal, recycling, maintenance, or equipment assembly since such emissions are reflected on the total amount of chemical sales.

2.2.2 Tier 2 Bottom-up (application based) method

The "bottom-up" approach is based on an inventory of the number of products and uses where these substances are consumed and emitted. It estimates the number of equipment units that use these substances, average chemical charges, average service life, emissions rates, recycling, disposal and other pertinent parameters. Annual emissions are then estimated as a function of these parameters through the life of these units. Since equipment units vary significantly in the amount of chemical used, service life and emissions rates, characterisation of this equipment becomes a resource intensive task. The “bottom-up” approach can provide a good estimate of emissions if detailed equipment and end-use data are available but relies critically on accurate and realistic emissions functions for the whole range of equipment.

The “bottom-up” method does not require consumption data although, if available, it could be used as a quality assurance check. This method does require extensive data from producers and users of chemicals to facilitate the estimation of emissions from end uses and applications.

The method includes estimation of new units sold in a given year as well as those in the existing stock. Once the number of equipment units is estimated, and associated emissions characterised, an estimate of total emissions can be derived by simply summing up all the individual emissions. Since the number of units varies continually due to new additions every year and the phasing out of old or dysfunctional units from service, the equipment inventories will need annual updating.

The need to update equipment inventories on an annual basis can be a major implementation issue for countries with limited resources. One possible alternative may involve the inclusion of algorithms that account for equipment phased out and additions based on their estimated average lifetimes and production growth.

Another issue with this method is that because it takes a micro approach, the need for data and assumptions becomes greater. In contrast with the “top-down” approach, where the consumption may be estimated with high certainty, the bottom-up approach does not include an equivalent set of data to formally limit the magnitude of errors. This may create the need for extensive data gathering or more reliance on expert judgement.

The detailed steps for implementing the “bottom-up” approach include:

- Develop an inventory of existing HFC/PFC-containing units: some countries may have data published in trade magazines or technical reports. However, it is more likely that a study may be necessary to come up with good estimates of the inventory of existing units and/or chemical. Expert panels can also facilitate the generation of this information;
- Estimate annual inventories of new HFC/PFC-containing units: countries may decide to conduct annual studies to update their inventories of sector units. An alternative to this may be to calculate or estimate production growth for each one of the sectors under consideration. The method needs to reflect that new units are introduced every year while a number of old or dysfunctional ones are phased out. Phasing out of units should be calculated based on the average service lives of those units;
- Estimate emissions from each sector: similar to the third bullet under the top-down approach - countries implementing this approach should conduct a study to estimate remaining service lives of units in stock, average charges, leak rates, disposal quantities, and recovery practices. The *IPCC Guidelines* include default values for some of the parameters that are not necessarily country-specific. These values can be used to estimate the annual emissions from all of the equipment in service in each year in the country;
- Estimate fugitive emissions: the discussion for fugitive emissions under the top-down approach is also applicable to the bottom-up approach;

- Estimate emissions from applications where the HPF/PFC is released within a year of being manufactured: these emissions are easier to estimate on the basis of consumption i.e., by using the top-down approach, and
- Compile the estimate: country's emissions will be the sum of the estimates developed under fourth, fifth and sixth bullets.

2.3 Uncertainty assessment

Parallel to the IPCC sector-specific workshops on *good practice* guidance, the IPCC is completing a programme of work on emissions inventory uncertainty. This work will result in recommendations to the UNFCCC on approaches to assessing and managing uncertainty. During the IPCC Inventory Experts Group Meeting in Paris (October 1998), technical experts in the uncertainty subgroup developed a series of questions to be answered in the sector workshops. Specifically, the sector workshops should provide answers to these questions in the individual source context, to inform work of the uncertainty programme on establishing a general methodological approach.

2.4 Completeness

For this source, ensuring completeness requires that all uses of these chemicals as substitutes for ozone depleting substances are estimated and reported. Given the many chemicals and end uses, it may be difficult for countries to develop complete emission estimates for numerous end-uses and also difficult for those that review inventories to identify gaps or missing sources. To address these issues, *good practice* guidance should consider the following issues for this source:

- Clear definitions of what is included in a particular source category;
- Clear definitions of thresholds for reporting and the use of terms such as Not Applicable (NA) and Not Estimated (NE), and
- Identification of the documentation needed to demonstrate completeness, including confirmation of non-occurring sources.

2.4.1 Defining what is included

As mentioned above, completeness for this source requires that emissions of all chemicals used as substitutes for ozone depleting substances be estimated and reported. Depending on the method employed, meeting this requirement will be more or less difficult. For “top-down” methods, completeness will be a function of the availability of consumption data. Countries with access to annual chemical production, export, import, and destruction should be able to account for all emissions of these gases. “Bottom-up” methods, on the other hand, must ensure that all of the sectors or end uses taken into consideration account for all the HFCs, PFCs, and SF_6 that are consumed.

Potential method

Completeness may be readily attainable under a potential or Tier 1 method, since this method is based on the establishment of consumption. By estimating or calculating total consumption for these gases a country is considering all emissions.

Actual method

The Actual method can be implemented in two ways – “top down” or “bottom up” – which have different implications for completeness.

Option 1: “Top-down” Similar to the potential method, the “top-down” approach may be implemented in a comprehensive manner by establishing total HFC and PFC consumption and allocating such consumption to different sectors. Sectors or applications that are relatively small and difficult to track may be grouped as "other" and still be included in inventories (see Section 2.2).

Option 2: “Bottom-up” It becomes more difficult to account for all uses and products because this approach relies on inventories of HFC and PFC using-units. When this method is used, ensuring completeness will require a review of all end-uses and sectors where ODS have been used to determine which chemicals are being used as substitutes and estimation of emissions of each chemical for every sector. Given the pace of change in this area, it will also be necessary to review and revise the assessment of which chemicals are being used in various sectors and end-uses at yearly intervals. It is also necessary to cross-check the results against the potential emissions (which define the maximum).

2.4.2 Defining thresholds for reporting

Given the possible difficulties in ensuring complete coverage of all chemicals and/or sectors, it may be necessary to consider thresholds for reporting. The IPCC has developed guidelines for the use of various terms that could be applied to estimates of these gases (i.e., “0” when the source is estimated to be zero; “NE” when not estimated; “IE” for sources estimated but included elsewhere; and “NO” for not occurring.) If thresholds are to be used, they must be clearly defined as to their meaning and when they are to be used.

Reporting thresholds may or may not be necessarily based on which method is selected. For any of the methods that are consumption-based, completeness is likely to be less of a challenge. It may be discussed, however, whether countries should disregard small-volume chemicals with low GWPs in cases where the obtaining of the corresponding consumption data becomes too resource intensive. Another area where a compromise may be considered is in accounting for imported chemicals contained in products.

For methods based on application, such as “the bottom-up”, thresholds may be needed to avoid intensive data collection efforts associated with small and extraneous uses.

2.4.3 Meaning of “other” categories

Since the phasing-out of ozone-depleting substances is still in progress and expected to continue for the next 20 or 30 years, it is possible for new substitutes, which are greenhouse gases but not listed by the IPCC, to be introduced in different applications. Since the listing of the HFCs, PFCs, and SF_6 in the IPCC Second Assessment Report, a few new gases have already been identified as possible source of emissions e.g., HFC-245fa, HFC-365mfc, and a couple of hydrofluoroethers. Estimation and reporting of these new gases may be desirable in order to ensure complete coverage of chemicals used in this sector.

It is also likely that new sectors or uses not presently anticipated may be identified.

Emissions from these other sources may be estimated as part of the estimation methods that rely in consumption as the basis for estimating emissions. One option may be to group these uses as "other" categories, allocate gas consumption and establish corresponding emissions functions. If the “bottom-up” approach is implemented, however, it becomes more difficult to gather data on these uses or to process them as "other" categories.

2.5 Other important issues

2.5.1 Consistency among national methods

Experts may want to consider whether there are problems posed by the possibility that some countries will use actual methods and others will use potential methods in terms of developing an accurate accounting of emissions. This issue may be of particular concern if there is no agreement on how to treat imported/exported equipment (as discussed below). For example, a country that imports equipment but neither produces nor consumes the chemical directly, could estimate its emissions as “0” using the Tier 1a potential approach. At the same time, a country that exports equipment could use an actual approach that does not include emissions from chemicals used in equipment for export. Under this case, emissions from the chemical produced in the second country but contained in equipment sold to the first country would be unaccounted for.

2.5.2 Treatment of imported and exported equipment

The only method that explicitly accounts for chemicals contained in equipment that is imported or exported is Tier 1b. In other cases, not including these chemicals, results in inaccuracies. In considering how to treat chemicals contained in imported/exported equipment, experts should consider the following:

- Data requirements - data may be difficult obtain, although custom agencies may be a key resource in facilitating the gathering of these data;
- Significance - are the amounts significant enough to warrant their estimation, and

- Added complexity - a process for accounting for imports/exports of chemicals contained in products may also be difficult to implement. Accounting for emissions from import or export of chemicals contained in products may be complex.

2.5.3 Establishing baselines

Experts should consider whether it will be difficult to develop estimates that use consistent methods and data sets between the base year (either 1990 or 1995) and later years.

2.5.4 Accounting for fugitive emissions

In addition to emissions from equipment, some emissions will also occur during chemical manufacturing and product assembly. These fugitive emissions should be included in emission estimates. Experts should consider the extent to which various methodological approaches can address fugitive emissions.

3 REPORTING AND DOCUMENTATION

3.1 Reporting substitute HFC/PFC emissions to the UNFCCC

The UNFCCC Secretariat report mentioned in section 1.2 noted some reporting problems. Not only have several countries not reported emissions from this source, but reports from the countries that reported lacked transparency. This section provides information on the current *IPCC Guidelines* and outlines some options for improving reporting transparency.

3.2 Current IPCC reporting guidelines

The *IPCC Guidelines* are used to guide countries in the preparation and submissions of annual greenhouse gas emissions inventories to the UNFCCC Secretariat. The *IPCC Guidelines* establish:

- Standard tables, definitions, units, and time intervals for reporting all types of emissions;
- The necessary documentation to enable comparison of national inventories, including worksheets, major assumptions, methodological descriptions and enough data to allow a third party to reconstruct the inventory from national activity data and assumptions, and
- An uncertainty assessment.

HFC/PFC/SF_6 emissions are reported in Table 2: Sectoral Report for Industrial Processes, which calls for entries for each source of emissions totals of carbon dioxide, methane, nitrous oxide, precursor gases (NO_X, CO, NMVOCs, SO_2), HFCs, PFCs and SF_6. Table 2 further disaggregates the reporting of these gases into Production and Consumption of Halocarbons and Sulphur Hexafluoride and within Consumption, the following sectors are listed:

- Refrigeration and Air Conditioning Equipment;
- Foam Blowing;
- Fire Extinguishers;
- Aerosols;
- Solvents, and
- Other.

Currently, the table incorporates aggregated entries for the HFC, PFC, and SF_6 gases. The following are the several problems encountered when presenting the data in this aggregated format:

- Because there are many different HFCs and PFCs, with different global warming potentials (GWPs) and different masses, aggregating emissions within a class of gas (i.e., for all HFCs) on a mass of chemical basis does not enable derivation of the carbon equivalent emissions, and
- At the same time, providing emission estimates in terms of carbon equivalent emissions does not allow for reconstruction of the inventory since a third party will not know the relative share of each gas to the total sum.

In addition to the lack of transparency in the emissions estimates, there is also a lack of clear information on how the estimate was prepared. Among the issues to be considered are:

- Reporting on what method was used for estimation;
- Reporting on what chemicals, and if necessary sources/end-uses, are included in the estimate;
- Reporting on how data were obtained, and
- Reporting on how QA/QC was conducted.

3.3 Confidential business information

The issue of confidential business information may complicate the desire for clear and transparent reporting. Just as for production and consumption of ozone-depleting substances, the HFCs, PFCs, and SF_6 consumption data will require confidential handling. Countries may need to establish a confidential data tracking and reporting system similar to that used for the ozone-depleting substances to ensure the accuracy of consumption data. Emissions estimates that could be back-tracked into consumption amounts should not be released. To avoid this, emissions of certain gases may need to be reported in aggregated amounts. Nevertheless, the reporting country should be able to produce the data to substantiate their aggregated reports if requested by the UNFCCC Secretariat. These data **MUST** be held in commercial confidence. Countries may also want to explore additional sources of data to derive consumption estimates.

4 INVENTORY QUALITY

For this source, inventory QA/QC process will need to be applied at several points in the inventory process. Figure 2 outlines a possible model for the flow of information and the inventory quality process at each step.

As illustrated in Figure 2, internal audits on HFC and PFC consumption should be done at plant or company-level by plant/company personnel, and at the national aggregation level by government agencies. Independent objective review by a third party aimed at assessing the effectiveness of the internal QC programme and the quality of the inventory and reducing or eliminating any inherent bias in the inventory processes will also be necessary.

4.1 Internal inventory QA/QC process

4.1.1 Plant and company-level activities

Given that the number of plants producing substitute chemicals, the number of chemicals under consideration (i.e., over 20) and the complexity of the methods used, experts may want to consider the feasibility of establishing a rigorous QA/QC programme at plant level for each of these gases. On the other side, periodic internal audits of plant production, transformation and destruction data should be conducted. Similar audits may be required for company-level compilation of these data as well as records of chemical transactions (e.g., sales, imports, exports, and sector consumption allocation).

4.1.2 Inventory agency level activities

Inventory Agency Review (QA) of Plant or Company-Level Information: Before accepting consumption data, the inventory agency should carry out an assessment of data quality. This type of review requires close cooperation with company owners to obtain enough information to verify the reported consumption as discussed above. The assessment should include sample calculations, an examination of the representativeness of the data, an identification of potential bias in the methodology and recommendations for improvement.

Figure 2 Key steps in the inventory QA/QC process

Plant/Company

Internal QC: Plant-level measurement and calculations and/or company-level records of chemical production, destruction, sales, exports, imports, and related transactions (sufficient to establish consumption).

Documentation: Plant-level information provided to the government agency, or company-level information provided or made accessible to the government agency, and results of internal QC.

Note: Workshop experts may want to discuss what level of data and documentation would be adequate and practical given the number of chemicals and the amount of data required to support any of the methods.

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Government Agency

Review/QA: Plant or company-level inputs

Internal QC: Compilation of chemical consumption by sector from plant or company-level data and calculation of national inventory from chemical consumption.

Documentation: Results of compilation and calculations, and results of QA/QC.

Reporting: Official submission to UNFCCC

Note: This step assumes that the government agency, and not the reporting companies, will calculate emissions from reported consumption.

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External Review

External Review: External audit; stakeholders, peer & public review of inventory results; external verification against other data etc.

Documentation: Results of external review.

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UNFCCC Secretariat

External Review: Requires standard format and transparency - ensure consistency with other inventories and external data

Inventory Agency QC on Compiling National Emissions: In addition to a thorough quality assessment of company-level data discussed above, the inventory agency should ensure that the process of aggregating company data to develop the national inventory undergoes quality control. This should include, among other things:

- Ensuring all plants are included;
- Comparison with industry trends to identify anomalies and patterns, and
- Cross-referencing production data with sectoral consumption information from chemical users.

Inventory Agency Documentation on Compiling National Emissions: The agency's QA/QC management plan should address the specific items needed to perform audits and reviews. When the consumption estimates are provided by each company, the details should be documented at the company level to account for differences in the procedures among companies. Examples of the types of information needed for documentation and external audit include:

- Proof of sales exports, imports, and related transactions;
- A detailed description of the inventory methodology;
- Identification of the input parameters that are needed and how they are obtained (measured or estimated);
- Results of determinations of accuracy and precision for the measurements;
- An estimate or discussion of uncertainty and variability for input parameters that are estimated instead of measured, and
- Enough data for the input parameters to reproduce the calculations.

4.2 External inventory QA/QC systems

Several types of external reviews, or audits, may be appropriate for HFC/PFC inventories.

Third party audit by an accredited organisation, expert, independent third party: An audit of the documentation and calculations ensures that each number is traceable to its origin. Given that much of the information with consumption of these gases may be proprietary, a third party audit that protects confidentiality may be a necessary type of review.

Expert (peer) review: A detailed peer review would be appropriate when a new procedure for calculating emissions, such as the implementation of new emission functions, is first adopted.

Stakeholder review: Review by HFC/PFC producing companies, industrial organisations, and air pollution consultants can provide a forum for review of the methods used.

Public review: Some countries make their entire inventory available for public review and comment. This process may result in a range of comments and issues broader than those from other review processes.

4.3 Examples of QA/QC systems

The ozone depleting substances tracking system implemented by the US EPA includes the submission of purchase, sales, export and import records in addition to consumption data from chemical producers. These records provide US EPA with the ability to verify that the submitted consumption data is correct. An additional tool available to the US EPA is its ability to audit the submitter. This system would be suitable for the Potential Method and the submission of consumption data under the “top-down” approach.

5 CONCLUSIONS

The most important consideration in this sector is that, despite the high Global Warming Potentials of the gases concerned, their current absolute contribution to global greenhouse gas forcing is comparatively small. It is therefore worthwhile for each Party to the Convention and Protocol to perform a preliminary scoping study to ascertain the balance of efforts required to obtain the data (at the detail required) against the national contribution to the global source strength. The essential first step is therefore to establish whether or not there are emissions in this category. Hence, there are several options to estimate the importance of these emissions.

The Tier 1 methodologies to estimate potential emissions may be appropriate when the national contribution to these greenhouse gases is very small. However, for significant emissions from many of the developed countries, Tier 2 methodology should be used and actual emissions estimated.

Verification of these emissions is crucial, especially since many estimates will have been made from relatively subjective information. Alternative sources of data should be examined, wherever possible and it may also be appropriate to attempt to balance the calculated emissions with atmospheric measurements using suitable dispersion modelling.

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