

Calculating HFC and PFC Emissions from the Manufacturing, Installation, Operation and Disposal of Refrigeration & Air- conditioning Equipment (Version 1.0)

Guide to calculation worksheets (January 2005)

Table of Contents

- I. Overview**
 - I.A. Purpose and Domain of this Tool
 - I.B. Process Description and Assumptions
- II. Choice of Activity Data and Emission Factors**
- III. HFC Emissions from Refrigeration and Air-Conditioning**
 - III.A. Approach Description
 - III.B. Using the Worksheets
- IV. Ensuring Inventory Quality**
- V. Acknowledgements**
- VI. References**

I. Overview

I.A. Purpose and Domain of this Section

This guideline is written for plant managers and site personnel to facilitate the calculation and reporting of direct hydrofluorocarbon (HFC) emissions resulting from manufacturing, servicing, and disposal of refrigeration and air-conditioning equipment. Direct HFC emissions occur from sources that are owned or controlled by the company. A step-by-step approach is presented to cover every phase of the calculation process from data gathering to reporting.

This sector guideline should be applied to projects whose operations involve the manufacture, use, and disposal of refrigeration and air-conditioning equipment.

I.B. Process Description and Assumptions

Refrigeration and air-conditioning is composed of many end-uses, including household refrigeration, domestic air conditioning and heat pumps, mobile air conditioning, chillers, retail food refrigeration, cold storage warehouses, refrigerated transport, industrial process refrigeration, and commercial unitary air conditioning systems. Historically, this sector has used various ozone-depleting substances (ODS) such as CFCs and HCFCs as refrigerants. These ODS are being phased out under the Montreal Protocol and are being replaced with HFCs.

HFC emissions from the refrigeration and air conditioning sector result from the manufacturing process, from leakage over the operational life of the equipment, and from disposal at the end of the useful life of the equipment. These gases have 100-year global warming potentials (GWP), which are 140 to 11,700 times that of carbon dioxide, so their potential impact on climate change can be significant (Table 1). By the same token, any reductions of these gases can have a large potential benefit.

This protocol addresses emissions from manufacturing, operation, and disposal phases.

II. Choice of Activity Data and Emission Factors

HFC emissions can be estimated based on data readily available to manufacturers and users of refrigeration and air-conditioning equipment. This guideline contains a screening method to establish significance of HFC emissions and two quantification approaches to quantify HFC emissions. Reporters can choose a quantification approach based on data availability, purpose of quantification, and the level of accuracy required.

The recommended approach for equipment manufacturers and for equipment users who maintain their own equipment is to estimate HFC emissions based on the amount of refrigerant purchased and used. This “Sales-Based Approach” requires data that should be available from entity purchase and service records, and tracks emissions from equipment manufacturing (producers) or installation (users), operation, servicing, and disposal.

The recommended approach for equipment users who have contractors service their equipment is to track emissions at each stage of the lifecycle of the equipment. The “Lifecycle Stage Approach” requires information on the quantity of refrigerant used to fill new equipment during installation, the quantity of refrigerant used to service equipment, the quantity of refrigerant recovered from retiring equipment, and the full and proper charges of new and retiring equipment. If notified in advance of the need for this information, the contractor should be able to provide it. The approach tracks emissions from equipment manufacturing, operation, servicing, and disposal.

A screening approach is also provided if a company needs to establish whether its emissions from RAC equipment are significant or not compared to its other emission sources. The screening approach can be applied using default equipment emission factors or leak rates. This approach should not be used as a substitute of the two quantification methods provided in this tool as it is not as accurate as the other approaches. The leak rates can be highly uncertain. Using the screening approach, if a company determines that its emissions from RAC equipment are significant, it should use one of the two quantification methods to estimate HFC emissions.

Table 1. GWPs of Common Greenhouse Gases and Refrigerants

Gas or Blend	GWP	Source
CO ₂ *	1	IPCC Second Assessment Report (1995)
CH ₄ *	21	IPCC Second Assessment Report (1995)
N ₂ O*	310	IPCC Second Assessment Report (1995)
HFC-23	11,700	IPCC Second Assessment Report (1995)
HFC-32	650	IPCC Second Assessment Report (1995)
HFC-125	2,800	IPCC Second Assessment Report (1995)
HFC-134a	1,300	IPCC Second Assessment Report (1995)
HFC-143a	3,800	IPCC Second Assessment Report (1995)
HFC-152a	140	IPCC Second Assessment Report (1995)
HFC-236fa	6,300	IPCC Second Assessment Report (1995)
R-401A	18	ASHRAE Standard 34
R-401B	15	ASHRAE Standard 34
R-401C	21	ASHRAE Standard 34
R-402A	1,680	ASHRAE Standard 34
R-402B	1,064	ASHRAE Standard 34
R-403A	1,400	ASHRAE Standard 34
R-403B	2,730	ASHRAE Standard 34
R-404A	3,260	ASHRAE Standard 34
R-406A	0	ASHRAE Standard 34
R-407A	1,770	ASHRAE Standard 34
R-407B	2,285	ASHRAE Standard 34
R-407C	1,526	ASHRAE Standard 34
R-407D	1,428	ASHRAE Standard 34
R-407E	1,363	ASHRAE Standard 34
R-408A	1,944	ASHRAE Standard 34
R-409A	0	ASHRAE Standard 34
R-409B	0	ASHRAE Standard 34
R-410A	1,725	ASHRAE Standard 34
R-410B	1,833	ASHRAE Standard 34
R-411A	15	ASHRAE Standard 34
R-411B	4	ASHRAE Standard 34
R-412A	350	ASHRAE Standard 34
R-413A	1,774	ASHRAE Standard 34
R-414A	0	ASHRAE Standard 34
R-414B	0	ASHRAE Standard 34
R-415A	25	ASHRAE Standard 34
R-415B	105	ASHRAE Standard 34

R-416A	767	ASHRAE Standard 34
R-417A	1,955	ASHRAE Standard 34
R-418A	4	ASHRAE Standard 34
R-419A	2,403	ASHRAE Standard 34
R-420A	1,144	ASHRAE Standard 34
R-500	37	ASHRAE Standard 34
R-501	0	ASHRAE Standard 34
R-502	0	ASHRAE Standard 34
R-503	4,692	ASHRAE Standard 34
R-504	313	ASHRAE Standard 34
R-505	0	ASHRAE Standard 34
R-506	0	ASHRAE Standard 34
R-507 or R-507A	3,300	ASHRAE Standard 34
R-508A	10,175	ASHRAE Standard 34
R-508B	10,350	ASHRAE Standard 34
R-509 or R-509A	3,920	ASHRAE Standard 34
PFC-218 (C_3F_8)	7,000	UNEP OzonAction Programme Chemical Database (Online)
PFC-116 (C_2F_6)	9,200	IPCC Second Assessment Report (1995)
PFC-14 (CF_4)	6,500	IPCC Second Assessment Report (1995)

* Included for reference purposes only.

Note: GWPs of blends are based only on the GWPs of their HFC and PFC components as listed in ASHRAE Standard 34. For the purposes of this table and the Protocol, the GWP of all components other than HFCs and PFCs are considered to be zero. It is recognized that emissions of these components may have significant effects on climate change and other environmental consequences; however, such emissions are not included in greenhouse gas inventories because these gases are not part of the group of Kyoto protocol recognized gases (CO_2 , CH_4 , HFC, PFC, SF_6 , N_2O).

III. HFC Emissions from Refrigeration and Air-Conditioning

III.A. Approach Description

Direct emissions are emissions that are produced from controlled or owned sources. In this case, direct HFC emissions are emissions that result from the manufacturing, servicing, or disposal operation of any controlled or owned refrigeration and air-conditioning equipment. A screening method is provided to determine if emissions from RAC equipment may be significant. Two quantification approaches are presented to calculate these emissions, in decreasing order of certainty. Equipment manufacturers and equipment users who maintain their own equipment are likely to find Approach 1, the Sales-Based Approach, the easiest to use. Equipment users who have contractors maintain their equipment may find Approach 2, the Life-Cycle Stage Approach, the easiest to use.

Screening Method: Emission Factor Based Approach

This methodology is based on IPCC Good Practice Tier 2 Bottom-Up approach and requires data including the number of units, the type of refrigerant used, the total refrigerant charge for each type of equipment, and the annual leakage rate. This information should be available from the facility. Table 2 provides default values for equipment charge, equipment lifetime, assembly/installation emission factors, annual leakage rate, and recycling efficiency. This

approach is used only as a screening method since default emission factors can be highly uncertain.

The screening methodology can be summarized as follows:

$$E = AE + OE + DE$$

Where:

E – emissions from refrigeration/AC in carbon dioxide equivalents (tonnes)

AE – assembly emissions

OE – operating emissions

DE – disposal emissions

Assembly or installation emissions for a given time period of interest can be estimated using the following equation:

$$AE = \sum_{i=1}^m (N_i \times C_i \times AEF_i \times GWP \times CF)$$

Where:

AE – emissions from assembly of refrigeration/AC equipment in carbon dioxide equivalents

i – refrigeration/AC equipment type in the facility¹

N_i – the number of equipment of type i in the facility assembled

C_i – original refrigerant charge in each equipment of type i (kg)

AEF_i – the assembly leakage factor for manufacturing equipment of type i (%)

GWP – the 100-year global warming potential of the refrigerant used in equipment of type i

CF – the tonnes from kilograms conversion factor = 1 tonne/1000 kg

m – number of different types of equipment produced

Operation emissions for a given time period of interest can be estimated using the following equation:

$$OE = \sum_{i=1}^m (N_i \times C_i \times ALR_i \times GWP \times CF)$$

Where:

OE – emissions from operation of refrigeration/AC equipment in carbon dioxide equivalents

i – refrigeration/AC equipment type in the facility

N_i – the number of equipment of type i in the facility

C_i – original refrigerant charge in each equipment of type i (kg)

ALR_i – the annual leakage from equipment of type i (%). If the reporting period is more than or less than a year, a correction will be necessary to adjust for this; for example, if the reporting period is two years, the equation would be multiplied by 2.

GWP – the 100-year global warming potential of the refrigerant used in equipment of type i

Conversion Factor – the tonnes from kilograms conversion factor = 1 tonne/1000 kg

m – number of different types of equipment produced

Disposal emissions for a given time period of interest can be estimated using the following equation:

$$DE = \sum_{i=1}^m ((N_i \times C_i) \times ((1 - (ALR_i \times S_i)) \times (1 - R) \times D_i) \times GWP \times CF)$$

Where:

DE – emissions from disposal of refrigeration/AC equipment in carbon dioxide equivalents

i – refrigeration/AC equipment type in the facility

N_i – the number of equipment of type i in the facility disposed of

¹ "Equipment type" is defined as the individual models. If data is not available by model, data on all models using the same refrigerant should be used.

C_i – original refrigerant charge in each equipment of type i (kg)
 S_i – time since last recharge of equipment of type i (years)
 ALR_i – the annual leakage rate from equipment of type i
 R_i – amount of charge recycled (%)
 D_i – amount of refrigerant destroyed
 GWP – the 100-year global warming potential of the refrigerant used in equipment of type i
 CF – the tonnes from kilograms conversion factor = 1 tonne/1000 kg
 m – number of different types of equipment produced

Approach 1: Sales-Based Approach (Recommended for equipment manufacturers and for equipment users who service their own equipment)

The sales-based or mass-balance method works by tracking the quantity of each refrigerant used and systematically accounting for uses of this refrigerant that are not related to emissions. The used refrigerant that cannot be accounted for is then assumed to have been emitted to the atmosphere. The approach can be summarized as follows:

$$E = (D + P - S - C) * GWP * CF$$

Where:

E = emissions from refrigeration/AC in carbon dioxide equivalents (tonnes) for a given year

D = Decrease in Inventory. This is the difference between the quantity of the refrigerant in storage at the beginning of the year and the quantity in storage at the end of the year. This quantity will be negative if the inventory increases over the course of the year.

P = Purchases/Acquisitions of Refrigerant. This is the sum of all the refrigerant acquired from other entities during the year. This includes refrigerant acquired in either storage containers or equipment. This would also include refrigerant returned after off-site reclamation or recycling.

S = Sales/Disbursements of Refrigerant. This is the sum of all the refrigerant sold or otherwise disbursed to other entities during the year. This includes refrigerant sold or disbursed in either storage containers or equipment. This would also include refrigerant recovered and sent off-site for recycling, reclamation, or destruction.

C = Increase in Total Full Charge of Equipment (used for calculating emissions from equipment use but not from equipment manufacturing). This is the net change to the total equipment volume for a given refrigerant during the year. Note that "total full charge" refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage. This term accounts for the fact that if new equipment is purchased, the refrigerant that is used to charge that new equipment should not be counted as an emission. On the other hand, it also accounts for the fact that if the amount of refrigerant recovered from retiring equipment is less than the full charge, then the difference between the full charge and the recovered amount has been emitted. This quantity will be negative if the retiring equipment has a total full charge larger than the total full charge of the new equipment.

GWP = 100-year global warming potential of the refrigerant

CF = conversion factor to tonnes of carbon dioxide equivalents

Two spreadsheets using the sales-based method are provided: one for equipment manufacturing and one for equipment use. Equipment users who service and maintain their own equipment

should find it straightforward to provide the data required for this approach. This approach accounts for emissions from equipment manufacturing, operation (leaks), servicing, and disposal. One limitation of using this approach occurs with recently installed equipment. Equipment can leak for two or more years before needing a recharge, so emissions over this period are not detected until after they occur. Despite this minor drawback, the Sales-Based Approach provides a highly accurate estimate of emissions from this sector.

Approach 2: Lifecycle Stage Approach (Recommended for equipment users who have contractors service their equipment)

This method requires information on the quantity of refrigerant used to fill new equipment during installation, the quantity of refrigerant used to service equipment, the quantity of refrigerant recovered from retiring equipment, and the total full charges* of new and retiring equipment. It can be summarized as follows:

$$E = (IE + S + DE) \times GWP \times CF$$

Where:

E = emissions from refrigeration/AC in carbon dioxide equivalents (tonnes)

IE = installation emissions (refrigerant used to charge new equipment – total full charge* of new equipment.

This is omitted if the equipment is has been precharged by the manufacturer)

S = quantity of refrigerant used to service equipment

DE = disposal emissions (total full charge* of retiring equipment - refrigerant recovered from retiring equipment)

GWP = the 100-year global warming potential of the refrigerant

CF = the tonnes from kilograms conversion factor = 1 tonne/1000 kg

***Note:** “Total full charge” refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage. Please see Section III.A., Approach 1, for a discussion of this quantity and its importance.

This method may be used either by entities that service their own equipment or by entities that have contractors service their equipment. Those who have contractors service their equipment must obtain the required information from the contractor. If notified in advance of the need for this information, the service contractor should be able to provide it. If the service contractor and the user of the equipment track and maintain the required information carefully, the Lifecycle Stage Approach can provide a highly accurate estimate of emissions from equipment.

III.B. Using the Worksheets

An MS-Excel based workbook has been provided to assist with the calculations described in Section IIIA. The workbook contains:

- a copy of the introduction,
- a spreadsheet to apply the screening test using the Emission Factor-Based Approach and instructions,
- a spreadsheet to estimate emissions using the Sales-Based Approach and instructions,
- a spreadsheet to estimate emissions using the Life Cycle Stage Approach and instructions,
- a table of GWPs of greenhouse gases and refrigerants, and
- a table of default IPCC assumptions for equipment lifetime, equipment charge, assembly release, annual leakage, and refrigerant recovery at disposal for various applications.

The follow section contains step-by-step instructions on how to use the worksheets.

Worksheet 1a: HFC and PFC Emissions from Manufacturing of Refrigeration/AC Equipment: Sales Based Approach

1. Identify all air conditioning and refrigeration equipment and which refrigerants they use. Those using purely CFCs or HCFCs may be omitted. For your own reference, you may type in a description of the equipment in Column A.
2. If other refrigerants are used, use the additional rows at the bottom of the table or insert additional rows and enter the refrigerant in Column B. You may also use these lines or insert new rows if more than one type of equipment uses the same refrigerant and you wish to segregate them.
3. Enter into Column C the refrigerant inventory (in storage, not equipment) at the beginning of the year in kilograms. If one or more additional lines of the same refrigerant were added, be sure the total inventory of that refrigerant is either allocated between the additional rows or included in just one, not all, rows.
4. Enter into Column D the refrigerant inventory (in storage, not equipment) at the end of the year in kilograms.
5. The Decrease in Refrigerant Inventory (Beginning - End) should be automatically calculated in Column E.
6. Enter into Column F the amount of refrigerant (in kilograms) purchased from producers/distributors.
7. Enter into Column G the amount of refrigerant (in kilograms) returned by equipment users.
8. Enter into Column H the amount of refrigerant (in kilograms) returned after off-site recycling or reclamation.
9. The Total Refrigerant Purchases/Acquisitions should be automatically calculated in Column I.
10. Enter into Column J the amount of refrigerant (in kilograms) charged into equipment. If this is not known, please see Steps A1 to A4 (Columns W, X, Y and Z) for a default approach to estimating this value.
11. Enter into Column K the amount of refrigerant (in kilograms) delivered to equipment users in containers.
12. Enter into Column L the amount of refrigerant (in kilograms) returned to refrigerant producers.
13. Enter into Column M the amount of refrigerant (in kilograms) sent off-site for recycling or reclamation.
14. Enter into Column N the amount of refrigerant (in kilograms) sent off-site for destruction.
15. The Total Refrigerant Sales/Disbursements should be automatically calculated in Column O.
16. Emissions (Decrease in Inventory + Total Purchases/Acquisitions - Total Sales/Distributions) should be automatically calculated in Column P.
17. A Conversion Factor (tonnes/kilogram) has been entered in Column Q. You may adjust this conversion factor if you would prefer to enter all values in pounds or some other unit rather than kilograms.

18. The GWP of the refrigerant is automatically extracted from Table 1 and entered into Column R. If "#N/A" appears, check to make sure the refrigerant as typed in Column B appears in Table 1, or simply delete the lookup function and type in the GWP.
19. The CO2-Equivalent Emissions in tonnes (Emissions x Conversion Factor x GWP) should be automatically calculated in Column S.
20. Repeat Steps 1 to 19 for each type of equipment and refrigerant and delete unused rows.
21. Total CO2-Equivalent Emissions in tonnes should be automatically calculated in the last row of Column S.

Step A: Determine the amount of refrigerant charged into equipment (kg) in Column J

- A1. Enter into Column W the total full charge Nameplate Capacity of Partially Charged Equipment (in kilograms).
- A2. Enter into Column X the Density or Pressure of the partial refrigerant charge. If using pressure, use absolute units (e.g., Pa or psia).
- A3. Enter into Column Y the Density or Pressure of the full refrigerant charge. If using pressure, please use absolute units (e.g., Pa or psia).
- A4. The Refrigerant charged into equipment (Capacity x [Density Partial / Density Full] or Capacity x [Pressure Partial / Pressure Full]) should be automatically calculated in Column Z and automatically entered in Column J.

Worksheet 1b: HFC and PFC Emissions from Users of Refrigeration/AC Equipment: Sales-Based Approach

1. Identify all pieces of air conditioning and refrigeration equipment and group them according to which refrigerant they use. Those using purely CFCs or HCFCs may be omitted. Each refrigerant, and the equipment associated with it, should be tracked in a single row. For your own reference, you may type in a description of the equipment in Column A.
2. If refrigerants other than those listed are used, use the additional rows at the bottom of the table or insert additional rows and enter the refrigerant in Column B.
3. Enter into Column C the refrigerant inventory (in storage, not equipment) for that refrigerant at the beginning of the year in kilograms.
4. Enter into Column D the refrigerant inventory (in storage, not equipment) at the end of the year in kilograms.
5. The Decrease in Refrigerant Inventory (Beginning - End) should be automatically calculated in Column E.
6. Enter into Column F the amount of refrigerant (in kilograms) purchased from producers/distributors in bulk (e.g., in cylinders).
7. Enter into Column G the amount of refrigerant (in kilograms) provide by manufacturers with or inside equipment.

8. Enter into Column H the amount of refrigerant (in kilograms) added to equipment by contractors (e.g., when starting up, servicing or topping-off equipment).
9. Enter into Column I the amount of refrigerant (in kilograms) returned after off-site recycling or reclamation.
10. The Total Refrigerant Purchases/Acquisitions should be automatically calculated in Column J.
11. Enter into Column K the amount of refrigerant (in kilograms) you sold in bulk (e.g., in cylinders) to other entities.
12. Enter into Column L the amount of refrigerant (in kilograms) left in equipment you sold to other entities. If this is not known, you may assume it is equal to the full and proper charge, but that should be verified or altered based on the last service you performed on the equipment or the first service the buying entity performed.
13. Enter into Column M the amount of refrigerant (in kilograms) returned to suppliers.
14. Enter into Column N the amount of refrigerant (in kilograms) sent off-site for recycling or reclamation.
15. Enter into Column O the amount of refrigerant (in kilograms) sent off-site for destruction.
16. The Total Refrigerant Sales/Disbursements should be automatically calculated in Column P.
17. Enter into Column Q the total full charge* (in kilograms) of all new equipment purchased this year.
18. Enter into Column R the total full charge* (in kilograms) of all equipment retrofitted to use this refrigerant.
19. Enter into Column S the total full charge* (in kilograms) of all equipment retired or sold this year.
20. Enter into Column T the total full charge* (in kilograms) of all equipment that previously used this refrigerant but was retrofitted this year to use a different refrigerant.
21. The Increase in Total Full Charge of Equipment should be automatically calculated in Column U.
22. Emissions (Decrease in Inventory + Total Purchases/Acquisitions - Total Sales/Distributions - Increase in Total Full Charge of Equipment) should be automatically calculated in Column V.
23. A Conversion Factor (tonnes/kilogram) has been entered in Column W. You may adjust this conversion factor if you would prefer to enter all values in pounds or some other unit rather than in kilograms.
24. The GWP of the refrigerant is automatically extracted from Table 1 and entered into Column X. If "#N/A" appears, check to make sure the refrigerant as typed in Column B appears in Table 1, or simply delete the lookup function and type in the GWP.
25. The CO₂-Equivalent Emissions in tonnes (Emissions x Conversion Factor x GWP) should be automatically calculated in Column Y.

26. Repeat Steps 1 to 25 for each type of refrigerant and delete unused rows.
27. Total CO₂-Equivalent Emissions in tonnes should be automatically calculated in the last row of Column Y.

***Note:** "Total full charge" refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage. Please see Section III.A., Approach 1, for a discussion of this quantity and its importance.

**Worksheet 2: HFC and PFC Emissions from Users of Refrigeration/AC Equipment:
Lifecycle Stage Approach**

1. Identify all pieces of air conditioning and refrigeration equipment and group them according to which refrigerant they use. Those using purely CFCs or HCFCs may be omitted. Each refrigerant, and the equipment associated with it, should be tracked in a single row. For your own reference, you may type in a description of the equipment in Column A.
2. If refrigerants other than those listed are used, use the additional rows at the bottom of the table or insert additional rows and enter the refrigerant in Column B.
3. Enter into Column C the amount of refrigerant (in kilograms) used to fill new equipment. Note this applies only to equipment that is charged on-site, not pre-charged equipment. (Emissions from charging pre-charged equipment are counted as the manufacturer's emissions, not the user's emissions).
4. Enter into Column D the amount of refrigerant (in kilograms) used to fill equipment retrofitted to use this refrigerant.
5. Enter into Column E the total full charge* (in kilograms) of all new equipment using this refrigerant.
6. Enter into Column F the total full charge* (in kilograms) of all equipment retrofitted to use this refrigerant.
7. The Total Installation Emissions should be automatically calculated in Column G.
8. Enter into Column H the amount of this refrigerant (in kilograms) used to service equipment. If the old refrigerant remains in the equipment, or is recycled on site and returned to the equipment, this is the amount of new refrigerant required to restore the equipment to its full and proper charge (i.e., to "top off" the equipment). If the old refrigerant is recovered from the equipment and shipped off site for reclamation, this is the difference between the amount of old refrigerant recovered and sent off site and the full charge of the equipment. This equals the Use Emissions.
9. Enter into Column I the total full charge* (in kilograms) of equipment retired or sold this year.
10. Enter into Column J the total full charge* (in kilograms) of all equipment that previously used this refrigerant but was retrofitted this year to use a different refrigerant.
11. Enter into Column K the amount of refrigerant (in kilograms) recovered from equipment retired or sold to other entities.
12. Enter into Column L the amount of refrigerant (in kilograms) recovered from equipment retrofitted this year to use a different refrigerant.

13. The Total Final Use and Disposal Emissions should be automatically calculated in Column M.
14. Emissions (Installation Emissions + Use Emissions + Disposal Emissions) should be automatically calculated in Column N.
15. A Conversion Factor (tonnes/kilogram) has been entered in Column O. You may adjust this conversion factor if you would prefer to enter all values in pounds or some other unit rather than in kilograms.
16. The GWP of the refrigerant is automatically extracted from Table 1 and entered into Column P. If "#N/A" appears, check to make sure the refrigerant as typed in Column B appears in Table 1, or simply delete the lookup function and type in the GWP.
17. The CO2-Equivalent Emissions in tonnes (Emissions x Conversion Factor x GWP) should be automatically calculated in Column Q.
18. Repeat Steps 1 to 17 for each type of refrigerant and delete unused rows.
19. Total CO2-Equivalent Emissions in tonnes should be automatically calculated in the last row of Column Q.

***Note:** "Total full charge" refers to the full and proper charge of the equipment rather than to the actual charge, which may reflect leakage. Please see Section III.A., Approach 1, for a discussion of this quantity and its importance.

Worksheet 3: HFC and PFC Emissions from Refrigeration/AC Equipment: Screening Method Based on Emission Factor Based Approach

Step 1. Assembly Emissions

- 1.1 Enter the type of Refrigeration/AC equipment in Column A (Optional).
- 1.2 Enter the number of units produced during the current reporting period in Column B.
- 1.3 Enter the refrigerant in Column C (Optional).
- 1.4 Enter the GWP of refrigerant in Column D. Table 1 has been provided as a reference.
- 1.5 Enter the refrigerant charge (kg) for this type of equipment in Column E. Default values for various applications have been provided in Table 2.
- 1.6 Enter the assembly emission factor (%) in Column F. See default values for various applications that have been provided in Table 2.
- 1.7 Assembly Emissions (tonnes of CO2 equivalent/yr) should be automatically calculated in Column H.
- 1.8 Repeat Steps 1.1 to 1.7 for each type of equipment and each refrigerant.

Step 2. Operation Emissions

- 2.1 Enter the type of Refrigeration/AC equipment in Column A (Optional).
- 2.2 Enter the number of units in operation during the year of interest in Column B.

- 2.3 Enter the refrigerant in Column C (Optional).
- 2.4 Enter the GWP of refrigerant in Column D. Table 1 has been provided as a reference.
- 2.5 Enter the refrigerant charge (kg) for this type of equipment in Column E. Default values for various applications have been provided in Table 2.
- 2.6 Enter the annual leakage rate (%) in Column F. Default values for various applications have been provided in Table 2. If the reporting period is less than or more than a year, an adjustment will be necessary to account for this; for example, if the reporting period is two years, you would need to multiply by 2.
- 2.7 Operation Emissions (tonnes of CO₂ equivalent/yr) should be automatically calculated in Column H.
- 2.8 Repeat Steps 2.1 to 2.7 for each type of equipment and each refrigerant.

Step 3. Disposal Emissions

- 3.1 Enter the type of Refrigeration/AC equipment in Column A (Optional).
- 3.2 Enter the number of units disposed of during the reporting period in Column B.
- 3.3 Enter the refrigerant in Column C (Optional).
- 3.4 Enter the GWP of refrigerant in Column D. Table 1 has been provided as a reference.
- 3.5 Enter the original refrigerant charge (kg) for this type of equipment in Column E. Default values for various applications have been provided in Table 2.
- 3.6 Enter the annual leakage rate (%) in Column F. Default values for various applications have been provided in Table 2.
- 3.7 Enter the time (years) since last recharge in Column G.
- 3.8 Enter the percentage of refrigerant recycled of refrigeration/AC equipment in Column H. Default recycling efficiency values for various applications have been provided in Table 2.
- 3.9 Enter the amount of refrigerant destroyed (kg) during the current period in Column I.
- 3.10 Disposal Emissions (tonnes of CO₂ equivalent/yr) should be automatically calculated in Column K.
- 3.11 Repeat Steps 3.1 to 3.10 for each type of equipment and each refrigerant.

Step 4. Total Emissions

- 4.1 Assembly emissions are automatically calculated from Step 1.
- 4.2 Operation emissions are automatically calculated from Step 2.
- 4.3 Disposal emissions are automatically calculated from Step 3.

4.4 Total emissions are automatically calculated (Assembly Emissions + Operation Emissions + Disposal Emissions).

Table 2. Default Assumptions from IPCC Good Practice Guidelines*

Application	Lifetime (years)	Charge (kg)	Emission Factors (% of initial charge/yr)		
			Assembly	Annual Leakage Rate	Recycling Efficiency
Domestic Refrigeration	12 - 15	0.05 - 0.5	0.2 - 1 %	0.1 - 0.5 %	70% of remainder
Stand-Alone Commercial Applications	8 - 12	0.2 - 6	0.5 - 3 %	1 - 10 %	70 - 80% of the remainder
Medium and Large Commercial refrigeration	7 - 10	50 - 2000	0.5 - 3 %	10 - 30 %	80 - 90% of remainder
Transport Refrigeration	6 - 9	3 - 8	0.2 - 1 %	15 - 50 %	70 - 80% of remainder
Industrial Refrigeration including Food Processing and Cold Storage	10 - 20	10 - 10000	0.5 - 3 %	7 - 25 %	80 - 90% of remainder
Chillers	10 - 30	10 - 2000	0.2 - 1 %	2 - 15 %	80 - 95% of remainder
Residential and Commercial A/C, including Heat Pumps	10 - 15	0.5 - 100	0.2 - 1 %	1 - 5 %	70 - 80% of remainder
Mobile Air Conditioners	12	Not provided	0.5 %	10 - 20 %	0%
* These values are from IPCC Good Practice Guidelines and Uncertainty Management in National Greenhouse Gas Inventories (2000). These default values are provided for reference purposes only as their wide range can result in highly variable calculation outcomes. If a value is chosen from within the range, that value should be used consistently from reporting period to reporting period or year to year. They should only be used if entity-specific data are not available, but an inventory that uses these values should be considered preliminary.					

IV. Ensuring Inventory Quality

Companies should provide information on the approach used to quantify direct HFC emissions as different approaches have different levels of associated accuracy and uncertainty.

To identify calculation errors and omissions, the quality of the emissions data obtained should be controlled. Two simple and effective alternatives are recommended:

1. Emissions comparisons

Compare the emissions data obtained with emissions data calculated for the same facility in previous years. A calculation error is probable if differences between current data and data from previous years cannot be explained by changes in activity levels or changes in production technologies employed.

2. Order of magnitude checks

If you have used Approach 1 to estimate emissions, you can employ the method proposed in Approach 2 to check whether your results are in the correct range. In addition, estimates can be compared to annual HFC/PFC consumption as another check.

V. Acknowledgements

These guidelines were developed by ICF Inc, USA for the GHG Protocol Initiative. The road test draft of the guidelines was peer reviewed by Fred Keller/Carrier, Dr S Devotta/NCL, Mr R S Iyer/India, Tom Werkema/GGEEC, and Deborah Ottinger and Dave Godwin from US-EPA. Dr. Brad Upton from NCASI and Anthony Dvarskas from WRI also contributed to technical review of the guidance and tool. The intellectual property rights belong to World Resources Institute and the World Business Council for Sustainable Development. Please quote original reference when using any part of this workbook. While the guidelines are largely self explanatory, for questions or suggestions on its contents, please contact Pankaj Bhatia at pankaj@wri.org.

VI. References

HPAC Engineering (Heating/Piping/Air Conditioning Engineering) (1999), Summary Physical, Safety, and Environmental Data for Refrigerants. Monthly magazine, August edition.

IPCC (1996), Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Great Britain: Cambridge University Press

IPCC (1997), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Greenhouse Gas Inventory Reference Manual.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Available on-line at: <http://www.ipcc-nngip.iges.or.jp/gp/report.htm>

IPCC/TEAP (1999), Opportunities for the Reduction of HFC-23 Emissions from the Production of HCFC-22. Presented at the IPCC/TEAP Joint Expert Meeting, Petten, Netherlands, 26-28 May 1999.

US EPA (1999), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 1997. EPA 236-R-99-003.

Carrier (2001), Peer Review by Fred Keller of Draft Version of HFC and PFC Emissions from Refrigeration/Air-Conditioning. Available on-line at: www.ghgprotocol.org

US EPA (2001), Peer Review of Draft Version of HFC and PFC Emissions from Refrigeration/Air-Conditioning. Available on-line at: www.ghgprotocol.org

WMO (1999), Scientific Assessment of Ozone Depletion: 1998. World Meteorological Organization. Global Ozone Research and Monitoring Project, Report No. 44. Geneva, Switzerland.

USEPA (2004), Direct HFC and PFC Emissions from Use of Refrigeration and Air Conditioning Equipment: June 2004. Climate Leaders Greenhouse Gas Inventory Protocol, Core Module Guidance